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

KEONJHAR DISTRICT, ODISHA

दक्षिण पूर्वी क्षेत्र, भुवनेश्वर

South Eastern Region, Bhubaneswar

सत्यमेव जयते

MINISTRY OF JAL SHAKTI
GOVERNMENT OF INDIA

NATIONAL AQUIFER MAPPING AND MANAGEMENT PLAN

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS &

AQUIFER MANAGEMENT PLAN

KEONJHAR DISTRICT, ODISHA

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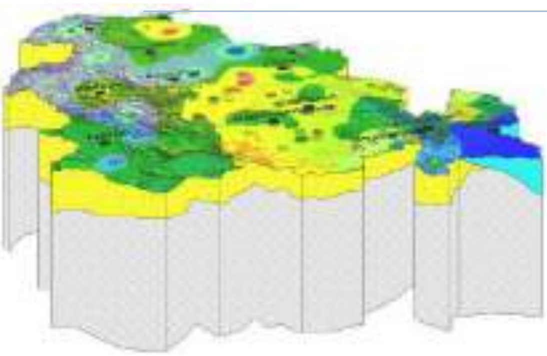







CENTRAL GROUND WATER BOARD
SOUTH EASTERN REGION
BHUJAL BHAWAN
KHANDAGIRI, BHUBANESWAR

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FOREWORD

In recent decades groundwater has emerged as a dependable resource for assured irrigation, drinking and industrial needs worldwide. In food production and boosting up the economy of India, it has played a significant role in recent decades. It has now been quite essential to know our aquifers; the source of groundwater, its yield potential and response to the increasing demand of pumping, and the ways of its sustainable management.

Keonjhar district, in the north-eastern parts of Odisha State, is quite unique in its geology. It is a premier mineral producing district in the state and in the country as well. The geological formations in Keonjhar district are diverse and predominated by Precambrian rocks. These rocks, with their inherent properties, always constitute difficult terrains as far as groundwater prospects are concern. Unless there are some structural deformations and other geological activities perturbing the country rock, it's always difficult to get sufficient water in the secondary pores of these rocks. In Keonjhar district, groundwater forms the major source of drinking and domestic needs. Though, the surface water irrigation works successfully in some parts of the district, groundwater based irrigation is yet to take up.

The present report brings forth the information available about the aquifers in the district under the ***National Aquifer Mapping*** programme of government of India. It is an excellent effort by Dr Sudarsan Sahu, Scientist-'C', Central Ground Water Board, South Eastern Region, Bhubaneswar to analyze and synthesize the data and present it in a lucid way to make it quite user friendly. I am sure, the ***Aquifer Management Plan*** suggested here, will be of immense help to the Policy Makers, Planners and Researchers alike.

P K Mohapatra
Regional Director (IC)

Author's View

The contour maps prepared in this report, taking the limited available number of aquifer parameters may vary from the real scenario in the field. Specifically, such maps for the fracture aquifers and their yield potentials have been prepared to depict their broader geographic distribution, which may bear limited practical value in the field condition.

KEONJHAR DISTRICT AT A GLANCE

I.	**GENERAL PARTICULARS**		
	(a) Location	:	21^0 01' and 22^0 10' North latitude 85^0 11' and 86^0 22' East longitude
	(b) Area	:	8326 Km^2
	(c) District Head quarters	:	Keonjhar
	(d) Subdivision	:	1.Keonjhar 2. Champua 3. Anandapur
	(e) Tehsils	:	13
	(f) Blocks	:	13 Anandapur, Jhumpura, Banspal, Joda, Champua, Keonjhar, Ghasipura, Saharpada, Ghatgaon, Patna, Harichandanpur, Telkoi, Hatadihi
	(g) Subdivisional Hqrs		Keonjhar, Champua, Anandapur
	(h) No of Gram Panchayats		286
	(i) No of villages		2123
	Inhabited		2064
	Uninhabited		59
	(j) Population (as per 2001 census)	:	18,01,733 (Male-9,06,487, Female-8,95,246) 1. Rural : 15,48,674 2. Urban : 2,53,059
	(k) Work force	:	1.Cultivators : 1,98,044 2. Agricultural labourers : 3,10,075 3. Total workers : 7,66,514
	(l) Literacy	:	68.24% (Male – 78.12%, Female – 58.28%)
II	**CLIMATOLOGY**	:	
	(a) Normal annual rainfall	:	1086 mm
	(b) Maximum temperature	:	46°C
	(c) Minimum temperature	:	11°C
III	**LAND USE**	:	
	(a) Total forest area	:	311717 Ha
	(b) Net area sown	:	272919 Ha
	(c) Irrigation potential created (Surface water) (2015-16)		
	Kharif	:	82400 Ha
	Rabi	:	38403 Ha

IV	**IRRIGATION POTENTIAL CREATED** (source wise, up to 2010-11)		Kharif	Rabi
	(a) Major/ Medium Irrigation Projects	:	27240 Ha	1739 Ha
	(b) Minor irrigation Projects (flow)	:	22475 Ha	406 Ha
	(c) Minor Irrigation Projects (lift)	:	4348 Ha	4287 Ha
	(d) Ground water structures (2006-07)	:	15690 Ha	
V	**EXPLORATORY WELLS**	:		
	Bore wells drilled by CGWB under Normal Exploration Programme	:	113 Nos. (Including 19 observation wells)	
VI	**GROUND WATER RESOURCES**			
	a) Annual groundwater resource assessed	:	83869 Ham	
	b) Annual groundwater draft (for all uses)	:	33509 Ham	
	c) Balance groundwater resource for irrigation use	:	49578 Ham	
	Stage of groundwater development	:	40.0 %	

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Figure 6.7: (a) Map of Keonjhar district showing the locations of the hydrogeological transects (A-A', B-B', C-C', D-D' and E-E') and the bore wells on them.

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HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

EXECUTIVE SUMMARY

- Keonjhar district has a total geographical area of about 8340 km^2 with 13 Community Development blocks, 13 Tehsils and 286 Gram Panchayats with 2123 villages. About 85.95% of the population lives in rural areas.
- Agriculture is the principal source of livelihood of people in the district. The net sown area is 272919 Ha. Irrigation potential created in the district (2015-16) is 82400 Ha during kharif and 38403 Ha during rabi season. Paddy is the principal crop grown in the district. About 311717 Ha (~37%) of the total geographical area constitutes forest area.
- Physiographically, the district comprises of rugged and hilly terrain with thick forest covers, intermontane valleys, and extensive tracts of buried pediments with valley fills. The alluvial plains are restricted to the eastern/south-eastern parts. A major part of ~67% of the district is covered by land slope of <5%. Only about 8% of the district area exceeds the critical slope of 20%, which is not worthy of groundwater recharge. The soils in the districts can broadly be grouped into (1) Alfisols and (2) Ultisols.
- The Baitarani River along with its tributaries forms major drainage system. The rivers flow north-easterly, easterly, southeasterly to southerly. The streams like Samakoi flow in the the south-west direction to meet the river Brahmani in the west of the district. The drainage pattern is mostly dendritic but at places it is rectangular where it is structurally controlled by joints, fractures and other lineaments.
- The south-west monsoon is the principal source of precipitation in the district. The normal annual rainfall is 1379 mm, out of which about 80-85% is received during monsoon season (mid June to mid October).
- The geological formations in Keonjhar district are widely divergent and predominated by Precambrian rocks, covering around 95% of the district area. The Quaternary and Recent unconsolidated alluvium (consisting of sand, silt and clay) occur in the Baitarani

River Basin. The Singhbhum Granites covers around 50% (in the central and eastern parts) of the geographical area of the district. The Iron Ore Group constitutes the next major rock types and covers the western and south western boundaries of the district. These are made up of low grade metasediments including phyllites, tuffaceous shales, BHJ and BHQ with iron ore, ferrugeuous quartzite and metavolcanics. Swarms of newer dolerite dykes are observed intruding the Singhbhum Granites in the eastern parts of the district.

- The weathered residuum and the fracture systems at deeper levels in the hard rock areas, and the granular porous formations in alluvium form the main groundwater repositories in the district. Iron ore group of rocks and Kolhan sedimentaries have high yield potentials within 100 m depth. The Singhbhum Granites show moderate to good yield potential. The newer dolerite dykes, though have fractures, those die out with depth and are less productive due to lack of any tectonic relationship with the Singhbhum Granite and other country rocks.
- The unconsolidated formations consist of laterite and alluvium. Unless highly consolidated, the laterites bear moderate to good groundwater potential. The alluvium, comprising an admixture of clay, silt, sand and calcareous concretions often forms prolific aquifers. The thickness of alluvium reaches up to around 100 m bgl.
- The depths to water levels (DTWs) levels during pre- and post-monsoon periods varied in the ranges of 0.95-13.8 m (ave.: 6.07 m bgl) and 0.4-9.3 m bgl (ave.: 4.0 m bgl). The major parts of the district exhibited shallow water levels (<7.5 m bgl) during both the seasons. The post-monsoon DTWs reflect good recharge of the phreatic aquifer from the rainfall.
- The pre- and post-monsoon (year 2018) water level measurements indicated fluctuations between -0.7 m (water level decline) and 8.65 m (rise in water level). The average fluctuation stood at 2.20 m. The minor declines in water levels were observed in particularly the alluvial areas.
- The groundwater flow-nets indicated the effluent character of the rivers (groundwater-fed). The gradient of the potentiometric surface (range: 1:50 - 1:600) was reasonably flat in the eastern and central parts of the district in parts indicating favorable groundwater conditions.

- The decadal (2009–2018) water level trends indicated rising trends in water level in 33% 31% of the monitoring stations during the pre- and post-monsoon periods respectively. Falling trend was observed in 20% (max.: 0.71 m) and 32% (max.: 0.71 m) of the wells during the periods.
- Similar to the phreatic aquifers, the water levels in the piezometers (fracture zones: 30-50 m bgl) ranged between 4.66 – 7.29 ml and 1.96 – 5.01 m bgl during the pre- and post-monsoon periods respectively. Similar shallow water levels (range: 0.62-10.0) were also measured in different periods of time in 85% of the exploratory wells (EWs) tapping fracture zones in the depth range of 27-203 m bgl.
- The thickness of weathered zone in the district varied between 6.5-60 m with the average value of 22.7 m. The northern half of the district is predominated with the thickness range of 40.0 – 50.0 m, whereas in the southern parts, the range 10.0 – 20.0 m predominates. A major part of the district is occupied by the thickness range of 20.0 – 30.0 m.
- Within the depth of 200 m bgl, 1-6 sets of fractures have been encountered. Within 100 m bgl, the maximum recurring of the fractures takes place in the depth ranges of 15-40m, 45-65m and 70-90m bgl. Beyond the depth of 100 m bgl, the incidences of fractures are less and also irregular.
- The northern half of the districts is enriched in fractures (2-5 sets) within 200 m depth. In south-eastern parts in some cases 2-3 sets of fractures are encountered in the bore wells. In the central, eastern and western parts, maximum up to 2 sets of fractures are encountered in the bore wells.
- If depth-wise assessed, maximum numbers of fracture sets are located within the depth of 100 m bgl only. The fractures deplete to only 0-1 sets in the south-central parts. Within the depth of 100-200 m bgl, a major part of the district is covered by the area with only 0-1 sets of fractures.
- Based on the fractures zones analysis, the aquifers have been put into two categories: 1st aquifer system extending from ground surface up to depth of 100 m bgl, and 2nd aquifer system extending between the depth ranges of 100-200 m bgl. The former aquifer system possesses fractures zones up to 5 sets (more commonly 2-3 sets), while the later one is predominantly characterized by 0-1 sets of fractures.

- The yield potential of the fracture aquifers within ~27.0-200.0 m bgl varied from negligible at several places to the maximum of ~20 lps. Except a few wells, major number of wells yielded more than 1.0 lps of discharge. Common yields of 2.5–5.0 lps were found in the central, southern, northwestern and northern parts, and yields of 1.0 – 2.5 lps in the north-eastern and south-central parts. The bore wells with more than 5.0 lps discharge largely fall in the south-eastern parts of districts in the blocks of Anandapur, Ghasipura and Hatadihi.
- The 1st aquifer system is more potential with the average yield of 4.2 lps (range: 0 – 20 lps) in comparison to the 2nd aquifer system with the average yield of 3.2 lps only (range: 0.12 – 8.0 lps).
- The alluvial aquifer in Keonjhar district is considerably more potential than the fracture aquifers. The yield of tube wells in alluvium has been reported in the range of 15-31 lps with the average value of 23 lps.
- In spite of higher incidence of fractures, the wells in the north-eastern parts yield less, which is due to the dry fractures within the dolerite dykes. The area is traversed by number of sub-surface dolerite dykes which cross-cut the Singhbhum Granite. The fractures in the dykes do not possess any tectonic perturbation relation with the country rock.
- The bore wells in the district showed drawdowns in the range of 1.0-39.0 m for pumping rates varying between 0-20 lps and pumping duration between 100-300 minutes. The discharge per unit drawdown (m^3/hour/m) in the well, defined as specific capacity, varied between 0.6-31 m^3/hour/m. It also indicates poor aquifer potential in the north/north-eastern parts of the district, where the specific capacity of wells remain low at <1.5 m^3/hour/m. In the southern parts of the district, except a patch covering parts of Harichandanpur and Ghatgaon blocks, major parts exhibit higher values of specific capacity in the range of 1.5-31 m^3/hour/m.
- The transmissivity (T) of the fracture aquifers ranged between 0.18-361.5 m^2/day (ave.: 32.3 m^2/day). The aquifers with relatively high T (>40 m^2/day) are clustered more towards central and south-eastern parts. The northern and north-eastern parts of the district are rich in fracture zones due to existence of several sets of sub-surface dolerite dykes. However, the wells in these areas are less transmissive as well as less

productive. The 1st aquifer system is more transmissive with the T values varying between 0.27-361.5 m^2/day and average of 39 m^2/day. The storativity (S) values (range: $3.6X10^{-2}$ - $2.4X10^{-5}$) indicated unconfined to confined character of the aquifers.

- Based on the overlay analysis of several input parameters (i.e., geomorphology, geology, slope, soil, drainage density, lineament density, land use/land cover, rainfall, and thickness of weathered residuum) indicated that around 34.6 % and 37.3% of the district areas are occupied by moderate (Champua, Saharpada and Ghatgaon blocks) and good (Jhumpura, Keonjhar and Patna blocks) groundwater potential zones respectively. Around 13.6% of the district area is covered by very good groundwater potential zones, falling in the blocks of Anandapur, Ghasipura, Hatadihi, Banspal, Keonjhar and Jhumpura.
- The groundwater quality in the phreatic as well as deeper fracture aquifers is marginally alkaline in nature. The average EC values fall within the permissible limits with exceptions in a few patches. Nitrate (NO_3) and fluoride values are well within the permissible limit except minor patches. Groundwater fluoride contamination in patches has been observed in the Naranpur Gram Panchayat in Keonjhar block. The quality of groundwater from the shallows as well as deeper aquifers is generally good and is suitable for drinking and irrigation purposes.
- In the shallow phreatic aquifer, the water types were predominantly Ca-HCO_3. In the alluvium, water types like Na-HCO_3 and some mixed varieties are also observed. In the deeper fracture aquifers the water types were predominantly Ca-HCO_3 followed by Mg-HCO_3.
- The total annual dynamic groundwater resource of Keonjhar district is assessed to be 83868.9 hectare meter (Ham). The existing gross groundwater draft is 33508.7 Ham including an irrigation draft of 27433.5 Ham (~82% of total draft). The annual utilizable resource which remains for irrigation use has been estimated at 49577.5 Ham (after drinking allocation). The stage of groundwater development varied between 20.3-68.3% with the average of 40.0%.
- Total static/in-storage groundwater resources of 90659.4 Ham and 137.1 Ham have been estimated for the 1st and 2nd aquifer systems. The total available groundwater

resource (including the dynamic component) in the district has been estimated as 174665.4 Ha.

- At 40% as average stage of groundwater development, there exists ample scope to enhance the groundwater utilization up to 60% to meet the challenges during the drought situations and in areas withount the scope of canal water irrigation. The number of additional DWs, and dug-cum-bore wells/bore wells which are feasible in the district stood at 32960 and 3878 respectively.
- The district has a net sown area of 272919 Ha and the gross sown area of 383437 Ha with 140.5% of cropping intensity. Irrigation potential of an additional area of 29321.6 Ha can be created to utilize the available surplus groundwater. It can help in increasing the existing irrigation facility of 31.1% to ~39%.
- In the water scarcity areas, where the bore wells either fail to yield or yield meagre volume of water, large diameter dug wells (5-10 m wide) tapping the entire weathered residuum can give ample water for the needs of irrigation and drinking.
- The groundwater source points (hand pumps, dug wells) which yield water with fluoride concentration > 1.5 mg/L should be stopped immediately from use. Any alternate safe aquifer or pipe water supply for drinking and domestic use should be explored. In many cases, the dug wells yield less groundwater fluoride. However, their use should be preceded with groundwater testing for fluoride content.
- The areas showing depth to water levels >5.0 m bgl can be adopted for artificial recharge to groundwater. Total such area suitable for artificial recharge has been assessed at 1547.99 km2. Total volume of water required has been worked out to be 17874 Ham or 178.74 MCM.
- The total number of recharge structures has been estimated as 357, 179, 179 and 357 for suitable structures like percolation ponds, sub-surface dykes, nala/contour bunding and check dams/weirs respectively. Total cost of executing such projects will be around 116.18 crore with the maximum share for the percolation ponds at 71.49 crores.

CONTENTS

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

1.0 INTRODUCTION

1.1 Objective

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

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

With these aims, Aquifer Mapping study was carried out in Keonjhar district, which is situated in the northern part of the Odisha State. The district with an area of 8326 Km^2 (~5.33% of the total geographical area of the state) comes under tribal sub-plan. The distrcit is divided into 3 subdivisions and 13 community development blocks, namely, Anandapur, Banspal, Champua, Ghasipura, Ghatgaon, Hatadihi, Harichandanpur, Jhumpura, Joda, Keonjhar, Patna, Saharpada and Telkoi. About 85% of the population of the district lives in rural areas. Agriculture and related activities is the main livelihood of people. Due to lack of proper irrigation facilities in the district, the agriculture is virtually left to the vagaries of monsoon. Rainfall in the district has been erratic and unevenly distributed. Mild to normal droughts are common in the district.

1.2 Scope of the study

Aquifer mapping is a multidisciplinary exercise wherein a combination of geological, geophysical, hydrological, hydrogeological, meteorological and hydro-chemical information

Is integrated to characterize the spatial and temporal variation of quantity and quality of the aquifer system. The Keonjhar district, underlain by Precambrian hard-rocks in major parts of its area, possesses challenges in both the availability of groundwater (quantity) as well as its quality, specifically groundwater fluoride in certain pockets. The net sown area is about 32.27% of the geographical area with around 32% of irrigation facilities from various sources. Though vast groundwater resources are available in the district, its exploitation in the district is not satisfactory, being only 40%. Hence there is a large scope for groundwater development in the district which can cater to the need of irrigation, drinking water and industries and thus can play a pivotal role in the overall development of the district. The work under NAQUIM was carried out with the following broad objectives: to define the aquifer geometry with precise lateral and vertical demarcation down to the depth of 200 m below ground level (m bgl), to define the behavior of groundwater regime in time and space, to study the hydraulic characteristics of both shallow and deeper aquifers including their yield potential, to study the hydrochemistry of aquifer systems, to prepare Aquifer Maps indicating dispositions of aquifers along with their characterization and to formulate the Aquifer Management Plans for sustainable development and management of groundwater resources.

1.3 Methodology

A multi-disciplinary approach was followed during the study. The studies involving geological, geophysical, hydrological, hydrogeological, hydro-geomorphological and hydro-geochemical survey were carried out in 1:50,000 scale to meet the aim and objectives of the aquifer mapping. For doing so, in the preliminary phase, all the available data pertaining to various study elements were collected and compiled. This involved the compilation of all existing data of CGWB and State agencies (concerning lithology, aquifers, groundwater quality, yield of aquifers etc) gathered through groundwater exploration activities, water well drilling, hydrogeological studies, district reports, groundwater management studies etc. Data related to climate, population, agriculture, industries etc were collected from the concerned agencies like Directorate of Agriculture, local administration, India Meteorological Department, Directorate of Statistics and Economics etc.

Field plans for collection of temporal data like depth to water level and groundwater samples for chemical analysis of groundwater were executed during the pre- and post-monsoon seasons of the year 2018. For the purpose, the existing National Hydrograph

Network Stations (NHNS) of CGWB in the district (pre-monsoon, n=62; post-monsoon, n=57) were taken into account and monitored (Annexure 2 & 3). Besides, additional key wells (n=130 during the pre-monsoon and n=149 during the post-monsoon period), representing various hydrogeological and geomorphological units were established and monitored (Annexure 4 & 5). The water samples (n=171) were analyzed for quality in the regional chemical laboratory of CGWB at Bhubaneswar (Annexure 6). The major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and the major anions (HCO_3^{-}, Cl^{-}, SO_4^{2-}, CO_3^{2-}) were analyzed using the standard protocols adopted by the American Public Health Association (APHA, 1995). Other than the major parameters, the samples were also analyzed for hydrogen potential (pH), electrical conductance (EC), total hardness (TH) and alkalinity of groundwater. The TDS values have been worked out from the EC values by taking a factor of 0.65 of EC. The fluoride (F^{-}) levels in the groundwater have been determined through Ion-Selective Electrode Method (Thermo scientific). Besides, the historical data pertaining to the groundwater quality in the deeper aquifer has been analyzed (Annexure 7).

Various thematic maps pertaining to the location and extent of the study area, rainfall, land use/ land cover, geomorphology, drainage, drainage density, distribution of lineaments, lineament density, lithology, soil types, ground surface elevation, ground slope, hydrogeology, depth to water levels (annual and decadal), distribution of chemical parameters (e.g., pH, EC, TDS, Ca^{2+}, HCO_3^{-}, Cl^{-}, F etc), thickness of weathered zone, spatial distribution of fracture zones, yield of bore wells, specific capacity of wells, transmissivity of aquifers, demarcation of areas suitable for groundwater recharge etc were prepared in ArcMap 10.3. Most of the maps, thus, generated were again clipped for every 13 blocks in the district. Area distributions of various characteristic elements in different maps were also worked out using the Arc GIS platform.

Ground water potential map of the district was prepared using 9 input parameters that control the groundwater occurrence, such as geomorphology, geology, land use/ land cover, drainage density, lineament density, soil types, weathered zone thickness, land surface slope and rainfall. The ranks and weightage of the parameters were taken as per the standard adopted by various researchers in hard rock areas. The map characters were reclassified into four categories; 1- low groundwater potential, 2- moderate potential, 3- good potential, and 4- very good potential. The reclassified maps were analysed through the methodology of sum overlay analysis in the spatial analysis tools.

Spatial analysis tools were used for preparation of the maps. Contour maps of various parameters have been prepared using the Inverse Distance Weighted (IDW) method. The interpolation technique estimates the missing values based on the values at nearby locations weighted only by distance from the interpolation location. The IDW method is based on the assumption that the value of an attribute z at any unvisited point is a distance weighted average of data points occurring within a neighbourhood or window surrounding the unvisited point.

Most of the data pertaining to the climate, population, land use, agriculture, and those pertaining to the aquifer (e.g., distribution of fractures, aquifer yields, water levels of different aquifers in different seasons, groundwater quality, transmissivity, storativity etc) were compiled in Excel sheets (Annexure 8). Analysis was carried out through various graphs, diagrams and statistical approach.

From the generated maps pertaining to the aquifers, synthesis of the fracture zones were carried out in relation to their depth and area of occurrence. Spatial distributions in the aquifer properties were studied. Based on such studies, the aquifer 3D models and various hydrogeological cross-sections (transects) were prepared using Surfer and Mapinfo Professional.

The Dynamic (annually replenishable) Ground water Resources (as on 31st March 2017) for the shallow phreatic aquifer, estimated jointly by CGWB, Bhubaneswar and GWD, Govt. of Odisha has been taken as the resource component in the district. The static/ in-storage groundwater resources for the unconfined fracture and alluvial aquifers (1st aquifer system within 100 m below ground) underlying the phreatic aquifer, and confined deeper fracture zone aquifers (2nd aquifer system within 100-200 m below ground) have been estimated based the available borehole lithology.

Based on the total available groundwater resources in the district, the stage of groundwater development in the district and its different blocks, the trend in the post-monsoon depth to water levels, decadal water level trends, and the groundwater quality, aquifer management plans for the district and all the blocks in the district were prepared.

1.4 Study area

1.4.1 Location, Extent and Accessibility

Geographically, Keonjhar district, with an area of 8326 Km^2, is located in the northern part of Orissa State (Plate 1.1) with the district headquarters at Keonjhar. The district is situated between 21^0 01' and 22^0 10' North latitudes and 85^0 11' and 86^0 22' East longitudes (Plate 1.2) covered under Survey of India degree sheets nos. 73 F, G, and K. It is bounded on the north by Singhbhum districts of Jharkhand state, on the east by Mayurbhanj district, on the south by Dhenkanal and Jajpur districts and on the west by Angul and Sundargarh districts of Orissa.

The district Keonjhar, also spelled as Kendujhar bears a special significance in the state of Odisha. Geologically and anthropogenically the district is unique in the state. Keonjhar has the distinction of having one of the oldest rocks in the world covering an area of 100 squre kms at Asanpat. The rock is said to be 38,000 million years old. Its mineral resources are varied and rich. Its iron-ore, manganese and chrome ores are opulent as well as extensive. Anthropologically, it has two main tribes, the Juangs and the Bhuyans who have unique ethnic life style. Around 40% of area of the district is covered by forests.

The district is well connected by roads. The district headquarter is connected to the state capital by national high way-6 (NH-6) and NH-215 that pass through the district from east to west and north to south directions respectively. The Block headquarters are well connected by road. Interior villages are also connected with the nearby towns by all weather, fair weather and other roads. Trains have recently started running on the rail network connecting it with the East Coast Railway.

1.4.2 Administrative divisions, demographic particulars, population

For the administrative convenience and keeping the development perspective in view the district has been divided into 3 Sub-divisions, namely, Anandapur, Champua and Keonjhar. There are 13 Community Development blocks (Plate 1.2), 13 Tehsils and 286 Gram Panchayats (GPs) with 2123 inhabited villages. Sub-division wise distribution of blocks and GPs are produced in **Table 1.1**. There are four Municipalities viz. Barbil, Joda, Kendujhar and Anandapur and 1 NAC functioning in the District. Besides, there are five non-statutory towns i.e. Census towns viz. Balagoda (Bolani), Jajanga, Champua, Jhumpura and Daitari within the district. For maintenance of law and order there are 24 Police Stations in the district.

As per 2011 census, the total population of Keonjhar district is 1,801,733 (Male: 9,06,487; Female: 8,95,246), constituting about 4.3 percent of the total population of Orissa. The rural and urban populations are 1,548,674 and 253,059 respectively. The rural population constitutes about 85.95% of the total population. The sub-division and block-wise population is given in Table 1.2. The decennial growth rate (2001-2011) of the district is 15.35%. Total Scheduled Castes and Scheduled Tribes in the district constitute 11.61% and

45.45% respectively of the total population of the district. The density of population of the district is 217 against the state figure of 269 persons per sq. km. Average literacy in the district is 68.24% against the state average of 72.87%. Total work force of the district is about 7,66,514 out of which 1,98,044 are cultivators and 3,10,075 are agricultural labourers.

Table 1.1: The sub-divisions, blocks and the number of Gram Panchayats, Keonjhar district.

Name of the sub-division	*Name of the block*	*No. of Gram Panchayats*
1. Keonjhar Sadar sub-division	1. Keonjhar Sadar	24
	2. Saharpada	20
	3. Patna	20
	4. Ghatgaon	26
	5. Telkoi	22
	6. Banspal	21
	7. Harichandanpur	25
2. Anandapur sub-division	8. Hatadihi	31
	9. Anandapur	16
	10. Ghasipura	22
3. Champua sub-division	11. Jhumpura	22
	12. Champua	22
	13. Joda	15
	Total	**286**

Table 1.2: Sub-division and block-wise population, Keonjhar district, Odisha.

Sub-division/CD Block	**Population (Census 2011)**
1. Keonjhar sub-division	**871927**
Keonjhar Sadar	161931
Saharpada	102527
Patna	96590
Ghatgaon	142150
Telkoi	118307
Banspal	101518
Harichandanpur	88314
2. Anandapur sub-division	**462437**
Hatadihi	148554
Anandapur	109669
Ghasipura	164629
3. Champua sub-division	**467369**
Jhumpura	125728
Champua	115321
Joda	113149

1.4.3 Land use, Agriculture and Irrigation

1.4.3.1 Land Use

The land use pattern is closely related to the geomorphological and climatic condition of the area. The block-wise land use pattern of Keonjhar district is presented in Table 1.3. The generalized categories of land use pattern as extracted from the satellite maps with limited fields checks have been given in Fig 1.1. The same land use map of the district has been produced as Plate 1.3.

Table 1.3: Land use pattern of Keonjhar district (2015-16) (Source: DDA, Keonjhar; District Irrigation Plan, Keonjhar)

Sl No.	Name of the Block	Area in Ha						
		Area under agriculture				Area under forest	Area under Wasteland	Area under other uases
		Gross cropped area (1)	Net sown area (2)	Area sown more than once (1-2)	Cropping intensity (%)			
1	Anandapur	26765	16094	10671	166.3	6338	1699	12693
2	Banspal	20668	14687	5981	140.7	83589	2494	63014
3	Champua	30955	21714	9241	142.6	5862	2439	7367
4	Ghasipura	29323	19215	10108	152.6	5742	3231	12750
5	Ghatagaon	27522	18686	8836	147.3	36600	1276	17536
6	Harichandanpur	33794	24114	9680	140.1	45402	1852	18403
7	Hatadihi	37788	27098	10690	139.5	8600	47	8743
8	Jhumpura	32441	24012	8429	135.1	16706	619	15320
9	Joda	19524	14351	5173	136.1	14872	1718	20959
10	Keonjhar	43331	30474	12857	142.2	13069	487	12043
11	Patna	31270	23799	7471	131.4	9721	1235	11453
12	Saharpada	28649	23365	5284	122.6	6098	857	11051
13	Telkoi	21407	15310	6097	139.8	59118	2142	14936
	Total	**383437**	**272919**	**110518**	**140.5**	**311717**	**20096**	**226268**

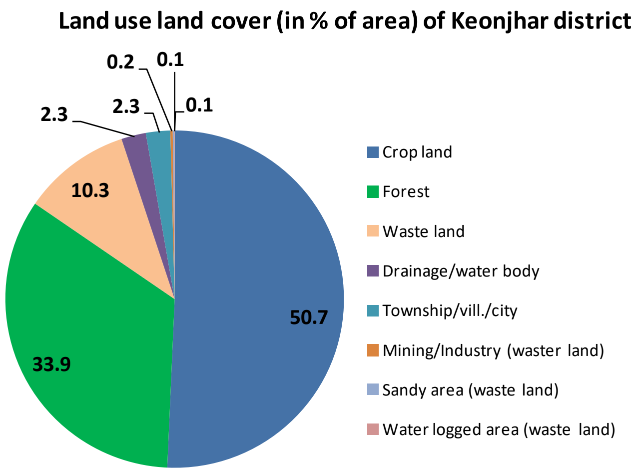


Figure 1.1: Generalized land use land cover area in percentage in the district of Keonjhar, Odisha.

1.4.3.2 Agriculture

The Keonjhar district has varied agro-climatic conditions. Rainfall in the district is moderately high but the irrigation facilities, though improved over years, are still inadequate. Paddy is the major crop. Other crops grown in the district during autumn, winter and summer seasons are Pulses, Oilseeds, maize, wheat, Vegetables and sugarcane etc. Net sown area in the district stands at 272919 Ha and the gross sown area at 383437 Ha. Thus, the area sown more than once is estimated as 110518 Ha. The cropping intensity varies between 122.6% in Saharpada block and 166.3% in Anandapur block with the average at 140.5%. Year-wise (2009-10 to 2014-15) area coverage of different major crops in the district is produced in Table 1.4.

Table 1.4: Area covered under important crops grown in the district during 2009-10 to 2014-15 (Source: District Gazetteer, Keonjhar).

Crop type	Year-wise area (Ha)					
	2009-10	**10-11**	**11-12**	**12-13**	**13-14**	**14-15**
Paddy	195510	181570	171460	170650	167036	168641
Maize	27250	27800	24570	26650	24541	28110
Wheat	1270	1460	1450	1130	1318	1140
Pulses	75020	77820	71530	76350	79079	78806
Oilseeds	34690	36340	36000	34340	36712	36920
Vegetable	56190	52240	52320	51200	54126	51685
Spices	9680	9360	9160	9150	9020	9015
Fibre crops	4860	4300	4510	4370	3615	3149

1.4.3.3 Irrigation

The Salandi irrigation project and the Kanupur irrigation project are the major irrigation projects in the district benefiting the blocks Hatadihi, Champua, Joda, Jhumpura and keonjhar. Kanjhari and Remal irrigation projects are the medium irrigation projects benefiting the blocks like Patna, Keonjhar, Ghatagaon, Ghasipura and Harichandanpur. There are number of Minor Irrigation Projects (Flow) and Lift Irrigation Projects working in the district. Ground water contributes about 24% during *kharif* and 44% during *rabi* of the total irrigation potential created so far for the two crop seasons respectively in the district. However there is a vast scope of creating additional irrigation potential through groundwater in the district, as most part of the groundwater resource remains unutilized.

The area wise, crop wise irrigation status of thirteen blocks for Keonjhar district are given in Table 1.5. The *Kharif* is the important season in the district, producing bulk of the crops. During this, irrigation caters to only 64720 Ha cereal crops (mainly paddy), whereas, the major 108720 Ha remains unstable and rain-fed. The pulses are largely produced during *rabi* season which covers 46090 Ha (with irrigation facility to only 2750 Ha). The total crop area of Keonjhar district is 370598 Ha out of which the rain-fed covers a major of 249795 Ha and irrigated area covers 120803 Ha.

The block-wise and season-wise irrigation status in Keonjhar district has been produced in Table 1.6. Irrigation percentage for the *Kharif* and *rabi* crops in the blocks varies between 10.5 – 54.1% of the total cropped area. The the average irrigation facility stands at 31%. It is the Hatadihi block, where the irrigated cropping exceeds the rain-fed cropping (Fig 1.2).

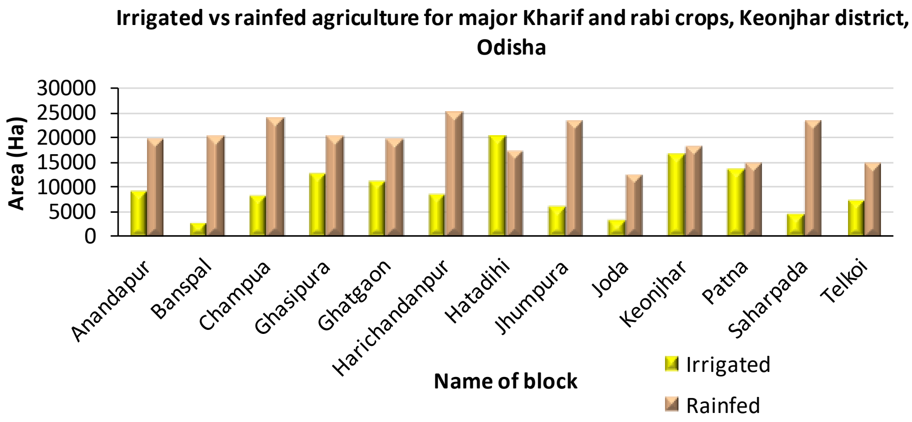


Figure 1.2: Irrigated vs rainfed agriculture for major Kharif and rabi crops, Keonjhar district, Odisha.

Table 1.5: Area and crop-wise irrigation status in Keonjhar district (2015-16) (Source: Source: DDA & DDH, Keonjhar; District Irrigation Plan, Keonjhar 2016)

Crop type	Kharif (Area in Ha)			Rabi (Area in Ha)			Summer Crop (Area in Ha)			Total Area (Area in Ha)			Horticulture & Plantation Crops (Area in Ha)		
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
A) Cereals	64720	108720	173440	3070	0	3070	0	0	0	67790	108720	176510	0	0	0
B) Coarse cereals	3900	20970	24870	233	0	233	0	0	0	4133	20970	25103	0	0	0
C) Pulses	0	27900	27900	2750	43340	46090	0	0	0	2750	71240	73990	0	0	0
D) Oil seeds	0	14950	14950	3980	12840	16820	0	0	0	3980	27790	31770	0	0	0
E) Fibre	1420	2195	3615	0	0	0	0	0	0	1420	2195	3615	0	0	0
F) Any other															
i) Vegetables	11180	16178	27220	23030	0	23030	0	0	0	34210	16178	50388	0	0	0
ii) Condiments/spices	1180	2702	3882	5290	0	5290	0	0	0	6470	2702	9172	0	0	0
iii) Sugarcane	0	0	0	50	0	50	0	0	0	50	0	50	0	0	0
iv) Plantation	0	0	0	0	0	0	0	0	0	0	0	0	3.45035	18.05365	21.504
v) Floriculture	0	0	0	0	0	0	0	0	0	0	0	0	0.06325	0.33275	0.396
TOTAL	**82400**	**193615**	**275877**	**38403**	**56180**	**94583**	**0**	**0**	**0**	**120803**	**249795**	**370598**	**3.5136**	**18.3864**	**21.9**

Table 1.6: Block-wise and season-wise irrigation status in Keonjhar district (2015-16) (source: DDA & DDH, Keonjhar, District Irrigation Plan, Keonjhar 2016)

Sl No	Name of Block	Kharif (Area in Ha)			Rabi (Area in Ha)			Summer Crop (Area in Ha)			Total Area (Area in Ha)			Horticulture & Plantation Crops (Area in Ha)		
		Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
1	**Anandapur**	5549	13684	19233	3241	5767	9008	0	0	0	8790	19451	28241	0.33855	1.91845	2.257
2	**Banspal**	1502	15372	16874	855	4705	5560	0	0	0	2357	20077	22434	0.2835	1.6065	1.89
3	**Champua**	4308	19394	23702	3655	4278	7933	0	0	0	7963	23672	31635	0.20265	1.14835	1.351
4	**Ghasipura**	10448	13349	23797	2014	6665	8679	0	0	0	12462	20014	32476	0.4528	1.8112	2.264
5	**Ghatgaon**	6785	15718	22503	4273	3595	7868	0	0	0	11058	19313	30371	0.2232	1.2648	1.488
6	**Harichandanpur**	5475	19650	25125	2866	5290	8156	0	0	0	8341	24940	33281	0.2232	1.2648	1.488
7	**Hatadihi**	15841	12048	27889	4189	4977	9166	0	0	0	20030	17025	37055	0.2885	0.8655	1.154
8	**Jhumpura**	3464	18195	21659	2245	4983	7228	0	0	0	5709	23178	28887	0.20235	1.14665	1.349
9	**Joda**	1471	9146	10617	1471	2969	4440	0	0	0	2942	12115	15057	0.1017	0.5763	0.678
10	**Keonjhar**	10325	13795	24120	6073	4137	10210	0	0	0	16398	17932	34330	0.34515	1.95585	2.301
11	**Patna**	9785	11674	21321	3644	2938	6582	0	0	0	13429	14612	28041	0.3045	1.7255	2.03
12	**Saharpada**	2460	20607	23067	1829	2348	4177	0	0	0	4289	22955	27244	0.345	1.955	2.3
13	**Telkoi**	4987	10983	15970	2048	3528	5576	0	0	0	7035	14511	21546	0.2025	1.1475	1.35
	District total	**82400**	**193615**	**275877**	**38403**	**56180**	**94583**	**0**	**0**	**0**	**120803**	**249795**	**370598**	**3.5136**	**18.3864**	**21.9**

1.4.4 Industries, Mining Activities

Keonjhar is one of the premier mineral producing districts in Orissa. The district occupies a prominent place in the mineral map of the Country. Mining activities for variety of minerals go on in the district (Table 1.7).

Table 1.7: Working Mines, Area Covered, Output and Value of Minerals in parts of Keonjhar District.

Name of the Ore	No. of Working Mines	Area Covered (in Hect)	Output (in 000'MT)	Value of output (Rs. In Lakhs)	Quantity export abroad (in 000'MT)
Iron ores and Manganese	61	23274	8328	20525	8022
Pyrophyllite	8	552	33	53	27
Quartzite	2	82	9	7	9
Manganese	8	2684	393	3749	348
Iron ores	32	9389	17683	49512	-
Pyroplyllite & quartzite	4	255	-	-	-
Quartz & quartzite	2	82	5	10	-
Serpentine	-	-	6	NA	-
Total	**117**	**36318**	**26457**	**73856**	**8406**

Iron ore formations occupy most part of the district which can be traced from the Bihar boarder in the north to the Jajpur boarder in the South. Extensive deposits of Manganese ore are found in Thakurani and Joda East hills of Barbil. Good deposits of Chromite**,** an important and strategic mineral are found in Boula area near village Nuasahi of Anandapur sub-division. There are also some other mineral deposits in the district such as Quartzite, Bauxite, Gold, Pyrophillite and Limestone**.** The two important mineral based industries in the district are the "Kalinga Iron Works" Barbil and the "Ferro-Manganese Plant", Joda.

1.4.5 Previous Work

The entire Keonjhar district has been geologically mapped by the Geological Survey of India and C.G.W.B on 1:50,000 scale. Hydrogeological surveys have been conducted in different parts of the district by Shri S. Chaklada, A.D. Rao, S.C.Behera and S.V Chougule (1980-86) of CGWB, SER. So far 94 exploratory wells and 19 observation wells were drilled under Normal Ground Water Exploration programme of CGWB to delineate groundwater potential of deeper aquifers. The reappraisal hydrogeological surveys in parts of the district covering nearly 3200 Sq Km was carried out by Shri A. Kar, Sc-B during 1888-89 and 1991-92 and subsequently by Shri P.K Naik, Sc-B in 4600 Sq. Km area during 2003-04. Ground water monitoring is being done through 57 numbers of National Hydrograph Network Stations four times in a year and water samples are collected once in a year during pre-monsoon for chemical analysis. In the year, Smt. Chirashree Mohanty, Sc-B, carried out the reappraisal study in the entire district. Ground water management studies in the districts were also carried out by R. K Nayak, Sc-C and A. K Biswal, Sc-C during the year 2010-11 for the northern blocks (Patna, Saharpada, Keonjhar, Jhumpura, Champua & Joda) and the southern blocks (Banspal, Telkoi, Ghasipura, Anandapur, Harichandanpur, Hatadihi and Ghatgaon) respectively.

Geophysical resistivity surveys were carried out in parts of the districts by Shri P. Narendra, R.A. Yadav and S.Guha, during the period 1988-91. Hydrogeomorphological mapping was conducted in parts of the district by Shri S. C. Behera with the aid of satellite imageries on 1: 2, 50, 000 scale in the year 1989.

2.0 CLIMATE

The climate of the district is characterized by an oppressively hot summer with high humidity. Summer generally commences in the month of March. Temperature begins to rise rapidly attaining the maximum in the month of May. During the summer maximum temperature is 38.20 C. The weather becomes more pleasant with the advent of the monsoon in June and remains as such up to the end of October. The temperature in the month of December is lowest i.e. 11.70 C. Sometimes it even drops down to 70 C. The average annual rainfall is 1431 mm.

2.1 Rainfall

Southwest monsoon is the principal source of precipitation in the district. The monsoon generally breaks in middle of June and continues till end of September or middle of October. The rainfall in the district varies between 1200-1600 mm per year (Plate 2.1). The normal annual rainfall of the district is 1379 mm, out of which about 80% to 85% is received during monsoon season (mid June to mid October). In general, the rainfall increases towards the central, northern and western parts of the district covered by hilly tracts. The normal annual rainfall and normal monsoon rainfall in each block in the district have been produced in Fig 2.1.

The average rainfall in the district depicts an increasing trend (Fig 2.2) as evident from the last 24 years (1995–2018) rainfall data (**Annexure**). The Fig 2.2 shows the lows; in the years 2002 and 2015 when the rainfalls were 861.2 and 1009.5 mm respective. The maximum rainfall of 2128.5 mm has been recorded during the year 2005. In the last 10 years, the rainfalls varied between 1009.5-1910.1 mm (average: 1381 mm). The rainfall is highly erratic both in space and time. If the deviations from the normal rainfall in the district are studied (Fig 2.3), it is noticed that, the rainfall in excess to the normal have occurred during 2011 (33.5% excess of normal) and 2018 (16.4% excess of normal) only. In the rest of the years, there have been deficits in the rainfall below normal (-7.6% to -29.5%). Based on the average annual rainfall data of rain gauge stations at the block head quarters the isohyetal map has been prepared (Plate 2.1). Summarized station wise data is presented in Appendix-I.

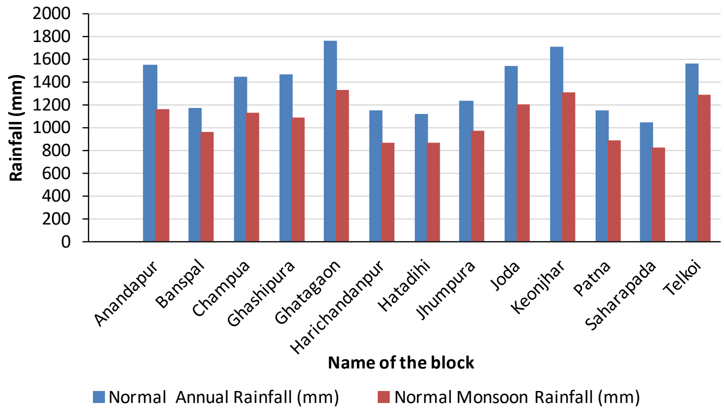


Figure 2.1: Annual normal and monsoon rainfalls in the blocks of Keonjhar district, Odisha.

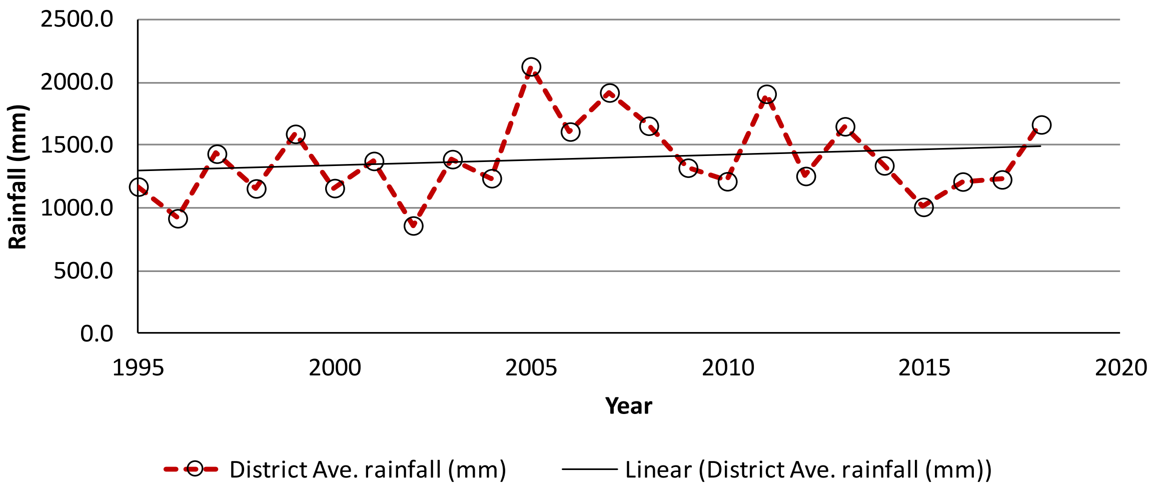


Figure 2.2: Long term trend in the annual average rainfall, Keonjhar district, Odisha. It shows a slightly increasing trend in the rainfall in the district.

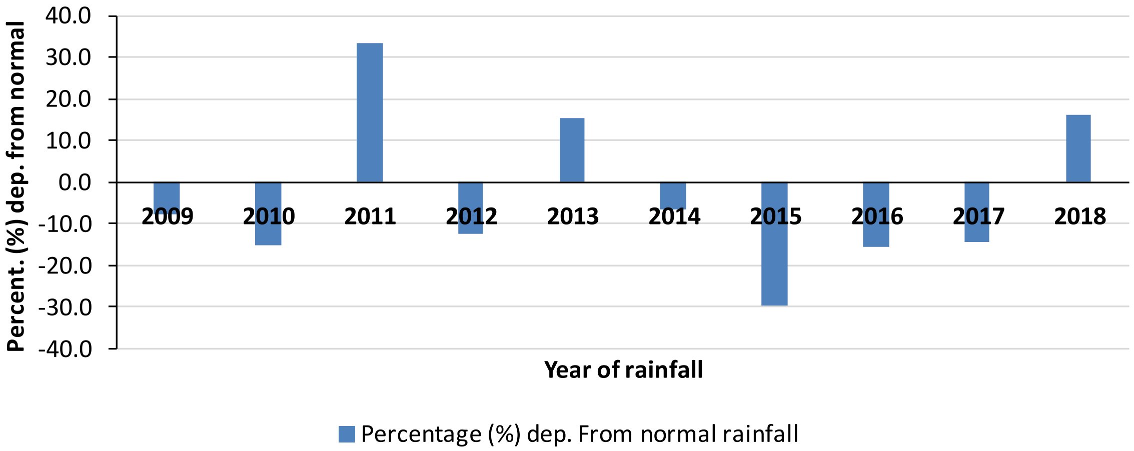


Figure 2.3: Annual percentage departure in the rainfall, Keonjhar district, Odisha. Highest negative departtures were during the years 2011 and 2015. During the study year of 2018, there was more rain than the normal.

2.2 Temperature, Humidity and wind

The winter season is felt between November to February when mean daily temperature drops down up to 6^0 C. The winter is followed by summer (March-Mid June) and the month of May is usually the hottest month when the maximum temperature in day time is about 43^0 C. Monsoon season lasts between June and September. Relative humidity is around 60 to 70 % throughout the year. South-West monsoon is the principal source of rainfall in the study area and wind is active in this period.

PLATE – 1.1

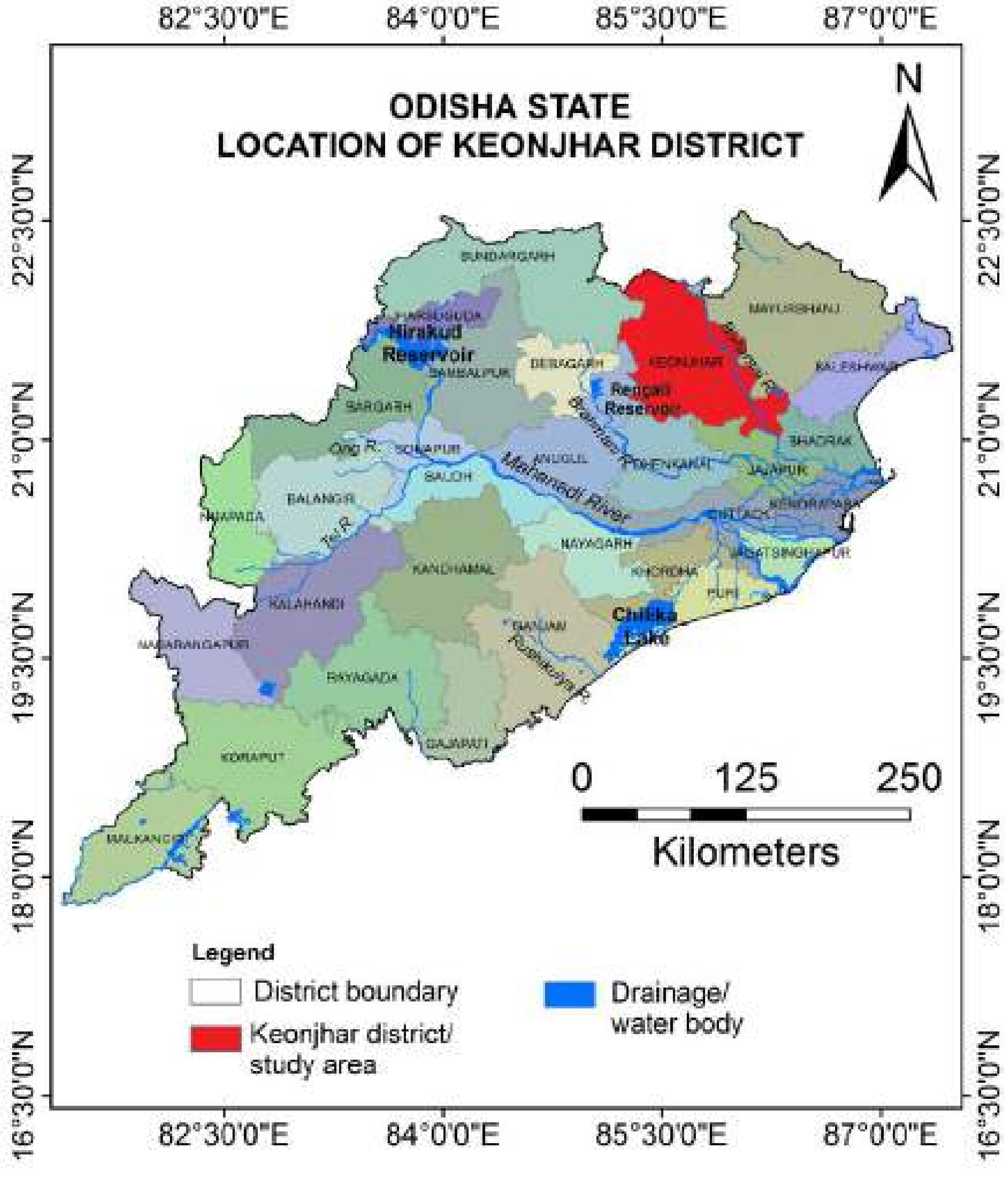

ODISHA STATE
LOCATION OF KEONJHAR DISTRICT
N
82°30'0"E
84°0'0"E
85°30'0"E
87°0'0"E
22°30'0"N
21°0'0"N
19°30'0"N
18°0'0"N
16°30'0"N
SUNDARGARH
MAYURBHANJ
KEONJHAR
Hirakud Reservoir
SAMBALPUR
DEBAGARH
Rengali Reservoir
BARGARH
BALESHWAR
BHADRAK
SONAPUR
ANUGUL
JAJAPUR
BALANGIR
Mahanadi River
KENDRAPARA
NUAPADA
NAYAGARH
KANDHAMAL
KHORDHA
PURI
KALAHANDI
Chilika Lake
GANJAM
NABARANGAPUR
RAYAGADA
GAJAPATI
KORAPUT
MALKANGIRI
0
125
250
Kilometers
Legend
District boundary
Keonjhar district/ study area
Drainage/ water body

PLATE – 1.2

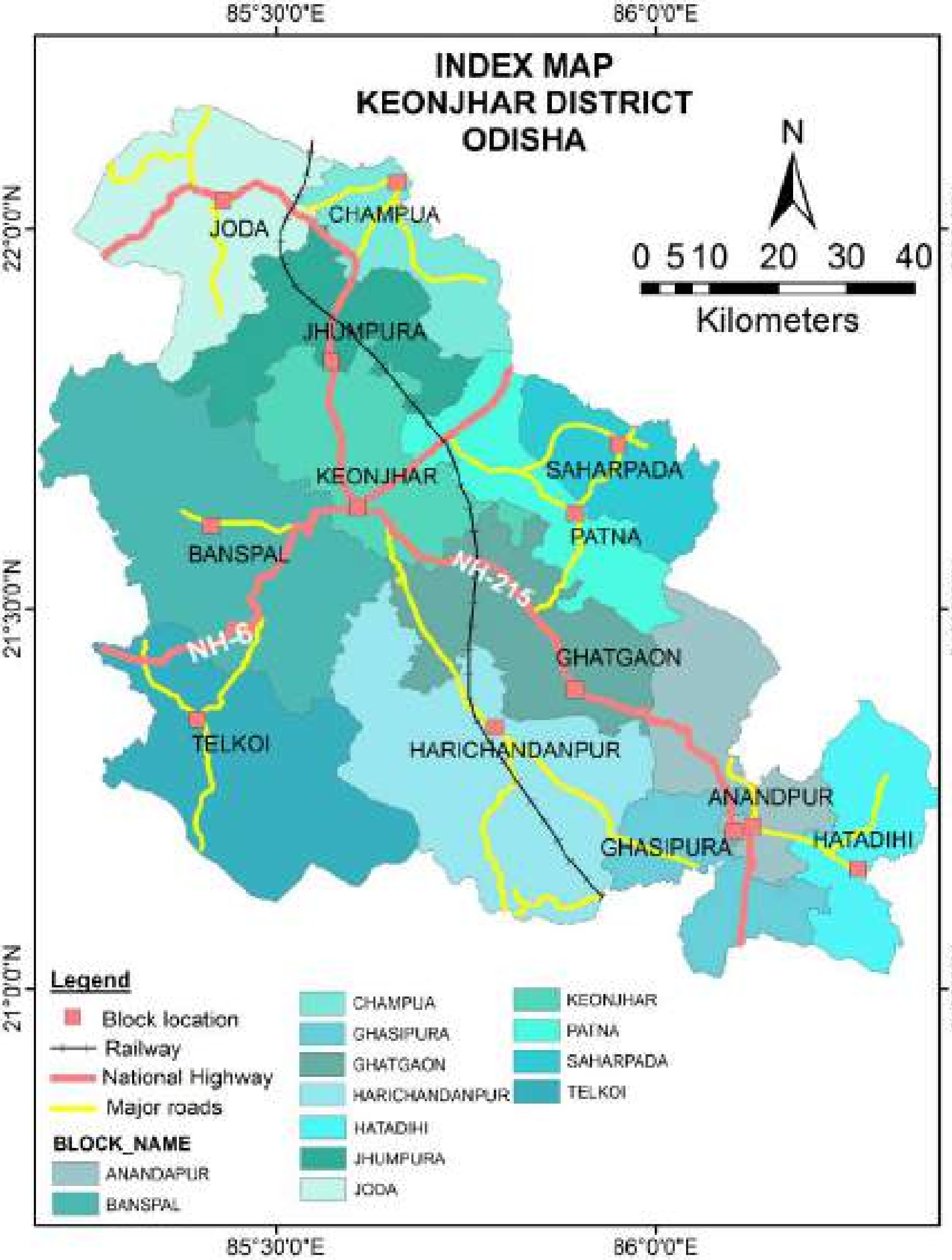

85°30'0"E
86°0'0"E
INDEX MAP
KEONJHAR DISTRICT
ODISHA
N
0 5 10 20 30 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
JODA
CHAMPUA
JHUMPURA
KEONJHAR
SAHARPADA
PATNA
BANSPAL
NH-215
NH-6
GHATGAON
TELKOI
HARICHANDANPUR
ANANDPUR
GHASIPURA
HATADIHI
Legend
Block location
Railway
National Highway
Major roads
BLOCK_NAME
ANANDAPUR
BANSPAL
CHAMPUA
GHASIPURA
GHATGAON
HARICHANDANPUR
HATADIHI
JHUMPURA
JODA
KEONJHAR
PATNA
SAHARPADA
TELKOI

PLATE – 1.3

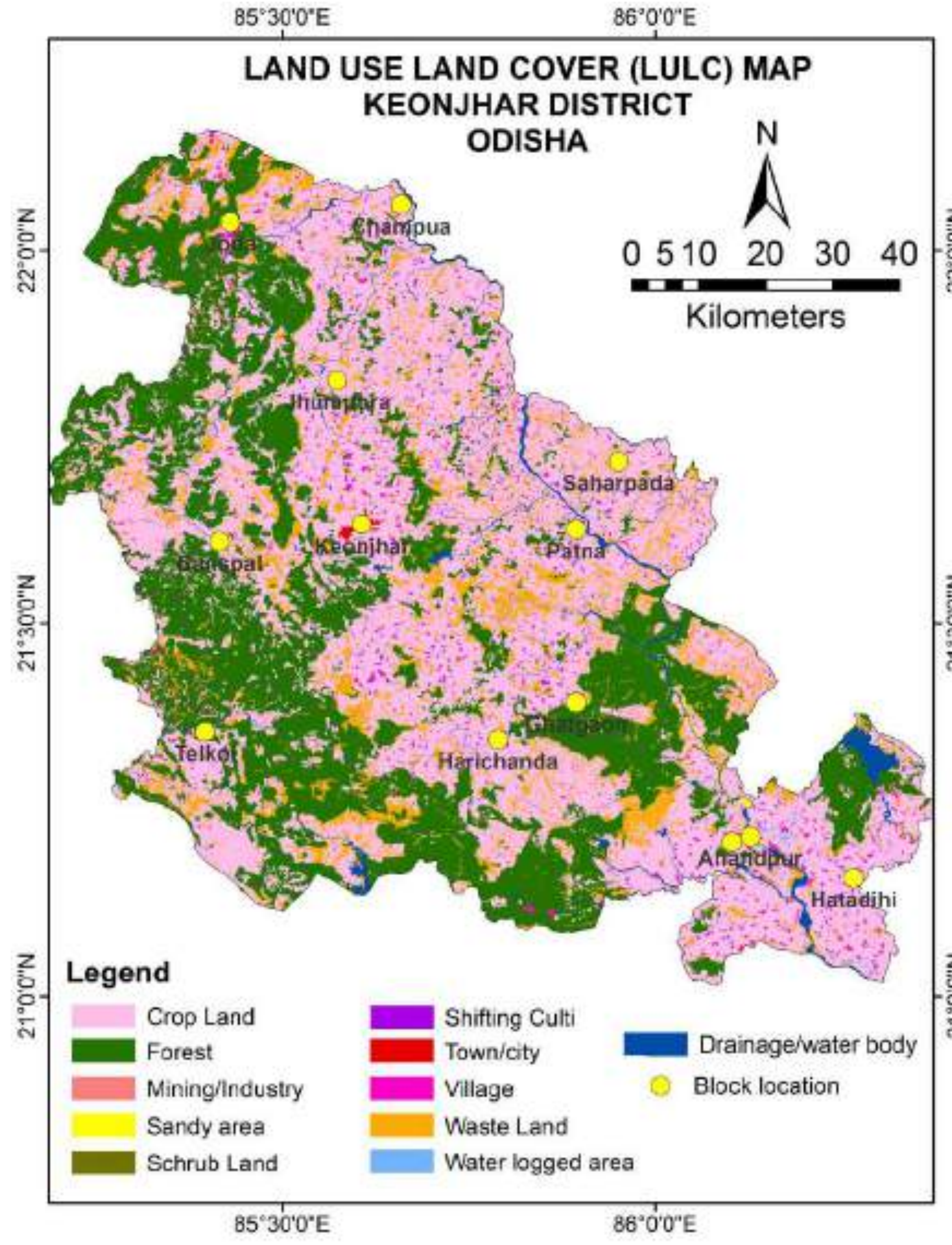
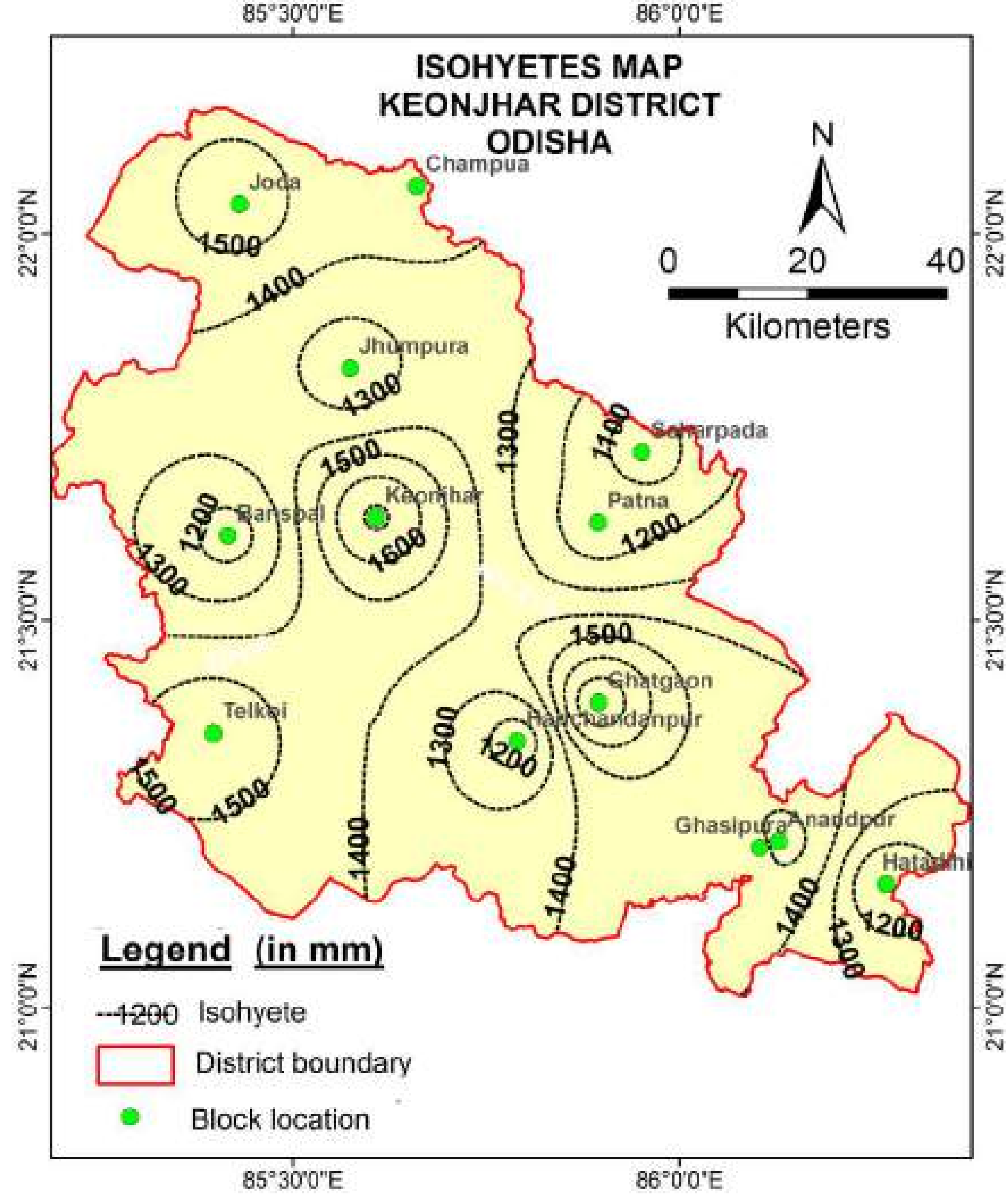

LAND USE LAND COVER (LULC) MAP
KEONJHAR DISTRICT
ODISHA
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
N
0 5 10 20 30 40
Kilometers
Champua
Joda
Jhumpura
Saharpada
Keonjhar
Patna
Banspal
Ghatgaon
Telkoi
Harichanda
Anandpur
Hatadihi
Legend
Crop Land
Forest
Mining/Industry
Sandy area
Schrub Land
Shifting Culti
Town/city
Village
Waste Land
Water logged area
Drainage/water body
Block location

PLATE – 2.1



85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
ISOHYETES MAP
KEONJHAR DISTRICT
ODISHA
N
0
20
40
Kilometers
Joda
Champua
Jhumpura
Keonjhar
Telkoi
Patna
Ghatgaon
Ghasipura
Anandpur
1500
1400
1300
1200
1600
Legend (in mm)
1200 Isohyete
District boundary
Block location

3.0 GEOMORPHOLOGICAL SET UP

3.1 Physiography

Physiographically the district comprises diverse landforms consisting of rugged hill ranges, plateaus, undulating plains dotted with residual hills and mounds and fertile erosional plains and valleys. The Plate 3.1 cropped from the SRTM Digital Elevation Model (SRTM DEM) shows the topographic variation in the Keonjhar district. The Keonjhar can distinctly be divided into two parts which are highly dissimilar in nature, namely, (1) Lower Keonjhar and (2) Upper Keonjhar. The former one consists of Keonjhar valley and low lands of Anandapur civil Sub-division whereas the Upper Keonjhar comprising the Keonjhar and Champua civil Sub-division is mountainous and undulating in nature.

The elevation of the ground surface in the district varies from the minimum of ~19 m above sea level (m asl) in the south-east end around Anandapur and Hatadihi to the maximum of 1062 m asl in the western parts around Suakati and Banspal sector (Plate 3.2). The highly resistant rocks like quartzites, BHJ and BHQ bearing iron ore group of rocks, Proterozoic volcanics and Kolhan sedimentaries constitute the high hill ranges in Suakati, Banspal Sector. This range constitute along the western boundary of the district to the Joda, Barbil and Bolani sector. The Tamka-Daitary Iron ore range exposed in the south western part of the district encompasses high hills of Maghananda Parbat which rises to a height of 1055m a msl. The undulating terrain stretching from north to the south-east is reversed by numerous isolated hillocks and granite domes, the height of which varies from 100m to 602 m. Flat alluvial track made up of late Pleistocene to recent sediments occurs in the flood plain of the Baitarani River in the south eastern part of the district and is located at a height of ~20-50 m amsl.

3.2 Land surface slope

The land surface slopes north-east to eastward in the northern parts of the district, which gradually turns south-east to southward in the southern parts of the districts (Plate 3.3). In the south-western parts of the district in Telkoi block, the ground surface slopes south-west to westward. In a regional scale in the district, the surface slope is more flat in the north-eastern and eastern parts than in the southern and western parts.

Slope of land surface plays an important role in retention of water, generating run-off, infiltration rainfall and soil erosion etc. It is a significant factor in rainfall infiltration and groundwater storage. The ground surface slopes greater than 20% are not considered as reahrge worthy, even if a good thiness of weathered zone exists. During the rainfall, most of the water gets wasted as run-off on higher slopes. For groundwater the land needs to absorb water and it requires lower and gentler slope. The lower slopes ofetn help in delineating good groundwater potential zones.

Figure 3.1 with bar diagram depicts the area percent (%) of the Keonjhar district falling under different land surface slope ranges. In Keonjhar district, a major part of around 67% of the area is covered by land slope of <5% (Plate 3.3). Such areas fall in the southern (alluvial areas) and east-central parts (mostly areas with Singhbhum Granites).

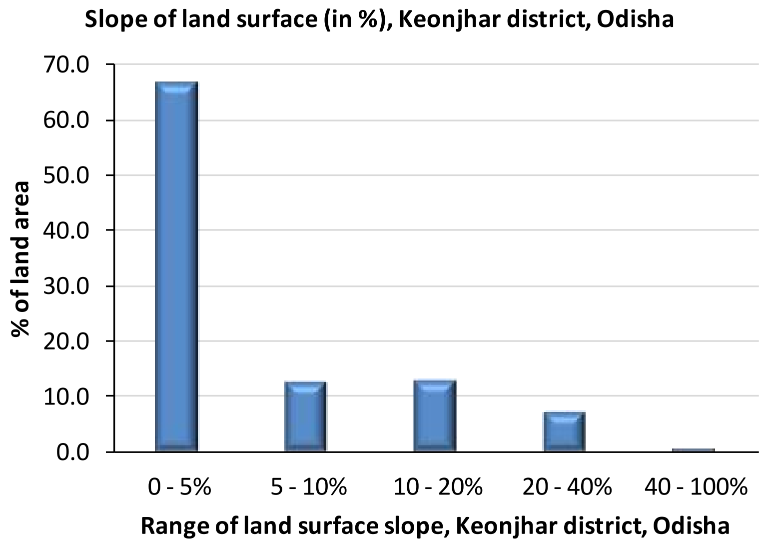


Figure 3.1: Bar diagram depicting the area percent (%) of the Keonjhar district falling under different land surface slope ranges.

Table 3.1: Percentage (%) of area of blocks and the district Keonjhar falling under different land surface slope range.

Sl No	Name of block	% of dist. Area under diff. land surface slope range				
		0 - 5%	5 - 10%	10 - 20%	20 - 40%	40 - 100%
1	Anandapur	70.4	15.6	10.6	3.2	0.1
2	Banspal	29.2	18.4	33.4	17.8	1.1
3	Champua	96.9	2.5	0.6	0.0	0.0
4	Ghasipura	91.4	4.7	3.0	0.8	0.0
5	Ghatgaon	81.5	12.4	4.8	1.3	0.0
6	Hatadihi	75.8	5.8	7.7	9.3	1.4
7	Harichandanpur	63.3	13.8	12.5	9.3	1.1
8	Jhumpura	77.6	11.9	8.1	2.4	0.0
9	Joda	41.0	27.6	22.6	8.3	0.5
10	Keonjhar	85.7	6.9	5.3	2.0	0.0
11	Patna	90.4	6.7	2.0	0.8	0.0
12	Saharpada	96.7	3.1	0.2	0.0	0.0
13	Telkoi	57.3	13.0	15.8	12.7	1.3
District total		**66.6**	**12.7**	**12.9**	**7.2**	**0.6**

The block wise area percent coverage of various slope patteren is produced in Table 3.1. The blocks with maximum area (>70% of block area) in the lower slope category include Anandapur, Patna, Champua, Ghasipura, Keonjhar, Saharpada, Ghatgaon, Hatadihi and Jhumpura. Only about 8% of the district area exceeds the critical slope of 20%. Such areas in a major way fall in the blocks of Telkoi, Joda, Banspal, Hatadihi, Harichandanpur.

3.3 Hydrogeomorphology

The district has been classified in to different hydrogeomorphic units based on the visual mapping of Landsat Thematic Mapper data with some limited field checks. The different geomorphic units that are identified from satellite imageries are described below and are depicted in Plate 3.4. Distribution of different hydrogeomorphic units in the district in area percent has been given in Fig 3.2. The units are briefed in the following lines.

Alluvial Plain: It is the youngest geomorphic units comprising the plains of Baitarani River. It consists of sand, silt and clay. Other geomorphic features like point bars, channel bars, natural levies, palaeochannels, back-swamps, meander scars etc fall in flood plains. The alluvial plains, owing to availability of granular zones in the sediment profile, bear good prospect for forming potential aquifers.

Lateritic upland: Lateritic uplands are mostly confined to the hill slopes in Iron ore group of rocks and other crystalline rocks in parts of the blocks of Anandapur, Harichandanpur, Ghasipura and Hatadihi. They form on the top of the crystalline rocks by certain unique selective weathering processes. The laterites are highly porous and permeable. But those very limited in vertical extent. Though, they bear a good water bearing prospect, the water reharged in them gets discharged in short times.

Buried Pediment: The thse are gently undulating surfaces with moderate to thick soil profiles that vary in thickness in the range of 10-30 m.. The buried pediments area formed when the sloping surfaces of the pediments get gradually covered with thick mantles of of soil and colluvial materials. This unit covers a major part of the district, especially in its eastern and central parts covering the blocks of hampua, Jhumpura, Joda, Keonjhar, Patna, Saharpada, Harichandanpur, Ghatgaon, Ghasipura and Anandapur. A significant part of Telkoi block in the western part is also covered by the buried pediment. The unit generally possesses greater moisture content and denser vegetation than pediments. The water table fluctuation is relatively less and recharge to groundwater is large. Hence, they form potential zones for groundwater development by dug wells and bore wells.

Valley fills: These are the deposits restricted to the linear depressions which are mostly joint / fractured controlled. These are types of hannel deposits developed by the proesses of deeper pedimentation in an erosional environemnt in hard rock terrains. Sand, silt, clay, kankar nodules with gravels constitute the valley fills. The slope remains low and the moisture content and vegetation cover remains more in this geomorphic unit. Thus, they form important units for groundwater development in hard rock terrains.

Pediments: This is a gently undulating rocky surface with a thin veneer of soil cover. These are mostly restricted to mountain front and act as run off zones. They are often chracterized by topographies with a number of gullies. They bear very poor to limited groundwater potential.

Denudational hills: These are the hills which have undergone through processes of weathering and denudation and are still under the process of active wearthering and denudation. These are mostly restricted to granitic terrain with low to moderate relief and criss-cross by fractures and lineaments (dykes). In the district of Keonjhar, they are mostly found in the blocks of Ghatgaon, Harichandanpur, Ghasipura, Anandapur and in some parts of Champua. The groundwater prospects in such units are believed to be poor.

Residual hills: These are hillocks of low relief rising to a height of 10-15 m above ground levels. These are the residual masses left out after weathering and denudation. These are widely distributed in the district in dispersed and isolated patches. These are characteirized by rugged topography with high run-off and less infiltration. The infiltrations, however, takes place along the joints and fractures. Flowing along the joints/fractures, often the infiltrated water finally comes out as springs at the topographic cut-offs. The groundwater prospects in these units are considered to be very low.

Structural hill: These are the structures of moderate to high relief with complex folding developed mainly in Iron ore group of rocks. These types of land forms cover a major part of the district in its western parts and the south-eastern parts in Hatadihi blcok. The units are often traversed by prominent lineaments. The groundwater prospect in these units remains low.

Linear ridges/dykes: These are long linear ridges consisting of basic dolerite dykes. The width of these dykes varies to a great extent. These are exposed through out the district in a cross-cross way. Though, the dykes themselves are characterized by poor groundwater prospect, but often they help in creating suitable groundwater zones in their contact zones with the country rocks, especially in their upstream side of groundwater flow. They act as impermeable boundaries, thus obstructing the groundwater flow and creating groundwater reservoirs. The lee sides remain poor in groundwater.

Intermontane valleys: These are small to large valleys developed between the hills and mountains. They develop owing to rapid weathering of structurally weaker linear zones, in particularly the rocks such as sandstones, shales etc. These units are specifically filled with alluvium of different extents. The intermontane valleys in the Keonjhar district are widely observed in westerns parts in areas covered by rocks pertaining to Iron Ore Group. These units possess good to moderate groundwater potential owing to accumulation and storage of valley run-offs in the available pore spaces in the alluvial overburden.

Inselbergs: These small isolated residual hillocks left out as remnants of weathering and denudation. This type of landforms is mostly in the granitic terrain and act as runoff zones.

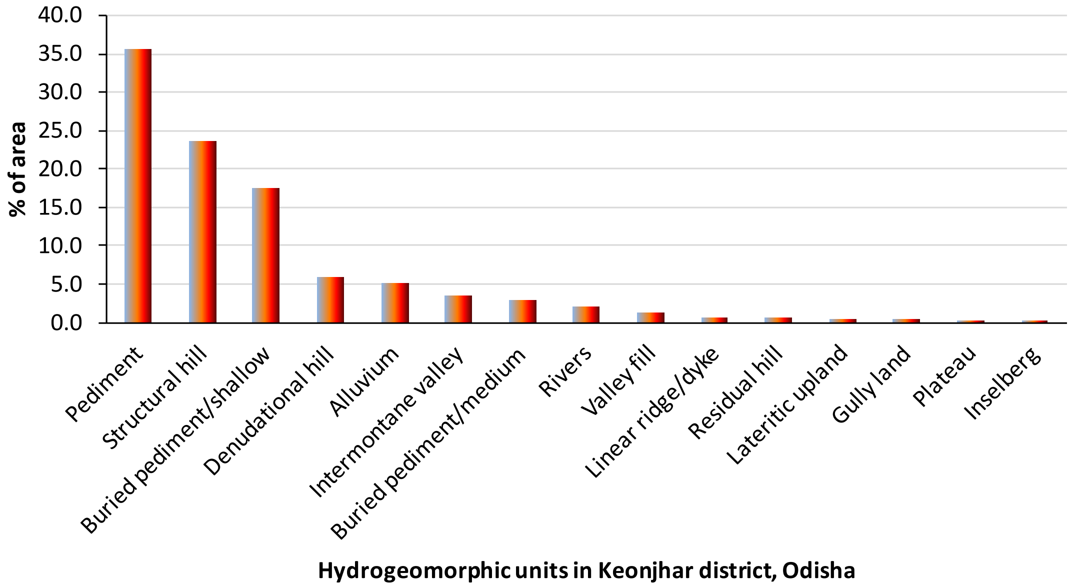


Figure 3.2: Area percent (%) distribution of various hydro=geomorphic units in Keonjhar district.

3.4 Drainage/water bodies

The district possesses a good network of drainages (Plate 3.5). The most important among them is the Baitarani River, which forms the largest river system in the district and is the third longest river in the state of Odisha. It originates from the Guptaganga hills about 2 km from Gonasika Village at an elevation of 900 m in the Banspal block. The river travels a total length of about 360 km (traversing through into 8 districts of the state namely Keonjhar, Bhadrak, Mayurbhanj, Jajpur, Kendrapara, Sundargarh, Balasore & Anugul) before it joins the Bay of Bengal. At the origin, the river flows in a northerly direction as a hill stream up to the Chaibasa border where it abruptly turns to the south. After about 80 km from the origin it takes a 90 degree turn and flows eastwards. It forms during part of its course, the boundary between Keonjhar and Singbhum district of Jharakhand State and also as a boundary between Keonjhar and Mayurbhanj districts (Plate 3.5). After traversing mountainous tracts, the river enters the plains of Anandapur. During dry spell, the river is navigable with difficulty in plain regions near Anandapur, Batto and Habaleswar.

Other rivers in the district include Kanjhari, Ardei, Musal, Kusei, Sita, Mohalda, Bamri, Neorojol, Nermeda, Salandi, Karo, Samakoi, etc. Except the last two rivers (Karo and Samakoi), all others form the tributaries of Baitarani. The river Samakoi (with tributary Hanumattia) flows towards west to join with the Brahmani River in Dhenkanal district. All the rivers in the district are seasonal in nature and remain almost dry during the summer. Their beds are usually rocky, which render them unfit for navigation. A number of irrigation projects (i.e., Kanjhari, Remal, Salandi, Anandapur barrage, Kanpur) on the Baitarani and others exist in the districts.

The drainage pattern is mostly dendritic but at places it is rectangular and sub-trellis where it is structurally controlled by joints, fractures and other lineaments. The drainage density is moderately high in the western part of the area representing high hill ranges constituted mostly by Iron Ore Group of rocks and volcanics which suggests high run-off and low infiltration. Hyrdrogeological surveys and remote sensing studies have revealed that the drainage pattern in the district is controlled by the fracture system and several linear dykes which were emplaced during the several phases of tectonic deformations.

A total of 2560 water bodies of various dimensions (0.000094 – 29.2 km^2), including the irrigation related reservoirs, are found in the Keonjhar district. Such water bodies are largely concentrated in the central, eastern and southern parts of the district (Plate 3.5). The western parts (hill dominated), except the parts in Telkoi block in the Samakoi river basin, ared are in a bigger way devoid of such water bodies. The water bodies are dotted on the both sides of the drainage line of the Baitarani River and its tributaries.

3.5 Soil Characteristics

Based on the physical and chemical characteristics, mode of origin and occurrence, soils of the district can broadly be grouped into two types such as Alfisols and Ultisols (Plate 3.6). Soils of the district are generally having average to good fertility status. All common types of crops can be grown in the district. The distribution of different soil types in the district is presented in Plate 3.6 and briefly described below.

Alfisols: The Alfisols include red sandy soils, red loamy soils mixed red and black soils. The soils predominantly occur in Harichandanpur, Hatadihi, Anandapur, Ghatagaon and Telkoi blocks. This group of soil can be subdivided in to sand soil, red loamy soil and older alluvial soil. These soils are neutral to slightly alkaline in nature (pH varies from 5.5 to 8.5). The characteristic features of red soils are (i) light texture, porous and friable structure, (ii) absence of lime kankar and free carbonates and (iii) soluble salts in small quantity usually not exceeding 0.05%. These are usually deficient in nitrogen, phosphate, organic matter and lime. These soils are suitable for cultivation of paddy and other crops.

Ultisols: These soils predominatly occur in Champua, Patna, Jhumpura, Keonjhar and Saharpara blocks. Essentially these are lateritic, red and yellow soil and red gravelly soil. These soils are poor in nitrogen, phosphate, potassium and organic matter. The pH values ranges between 4.5 - 6.0. As per the agroclimatic classification, the district falls in the north central plateau and north eastern coastal plain.

PLATE – 3.1

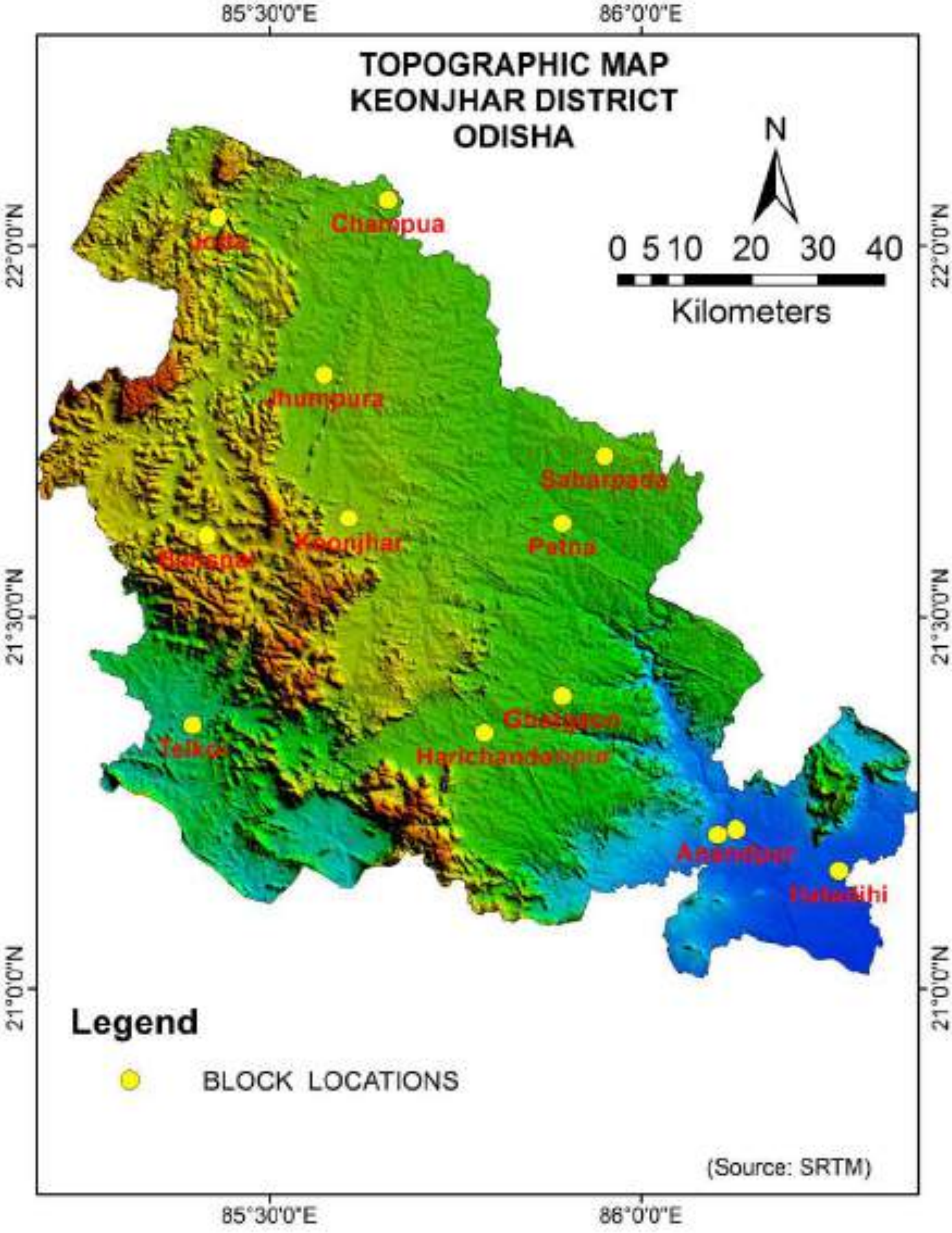

85°30'0"E
86°0'0"E
TOPOGRAPHIC MAP
KEONJHAR DISTRICT
ODISHA
N
0 5 10 20 30 40
Kilometers
Champua
Jhumpura
Keonjhar
Patna
22°0'0"N
21°30'0"N
21°0'0"N
Legend
BLOCK LOCATIONS
(Source: SRTM)

PLATE – 3.2

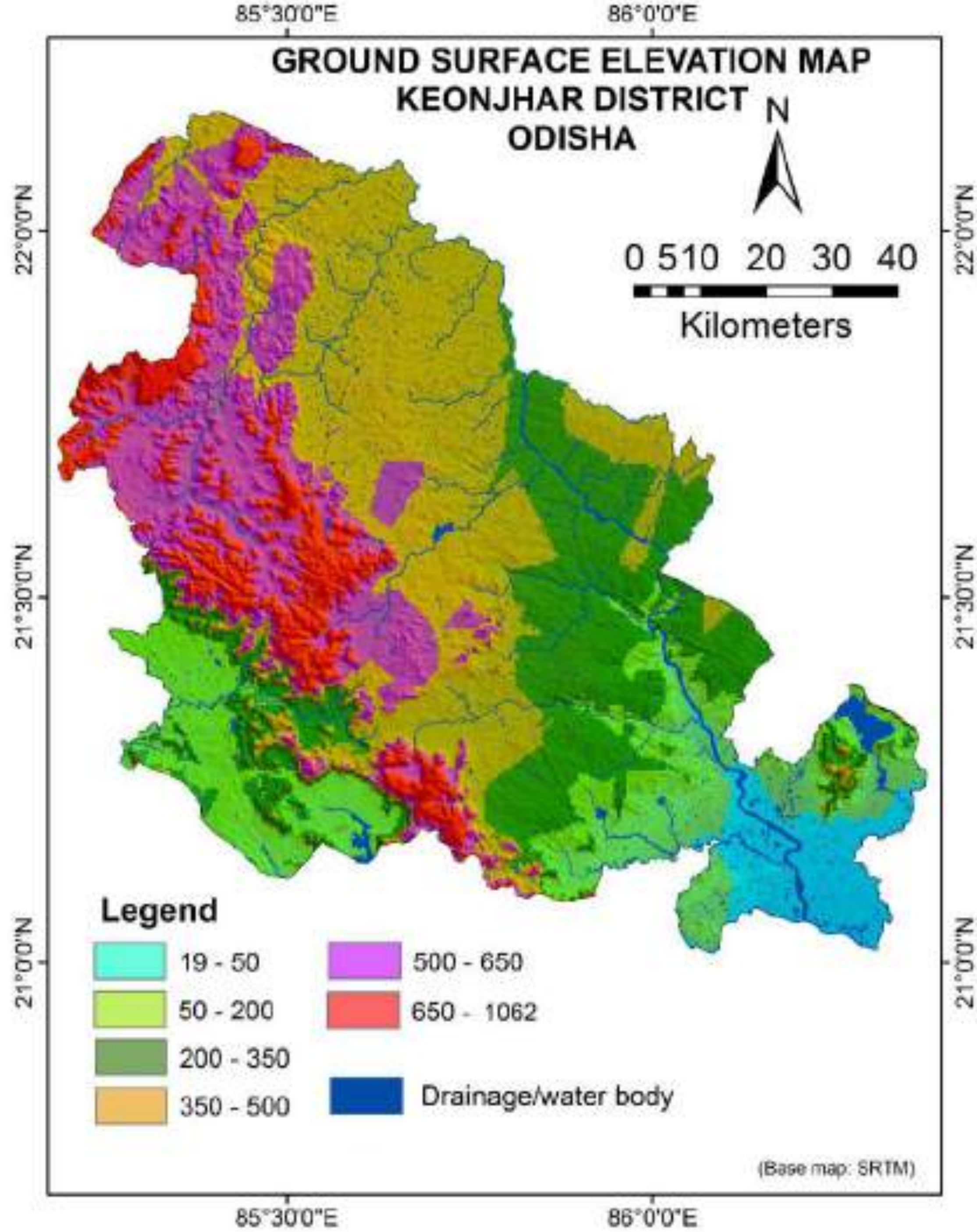

85°30'0"E
86°0'0"E
GROUND SURFACE ELEVATION MAP
KEONJHAR DISTRICT
ODISHA
N
0 5 10 20 30 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Legend
19 - 50
50 - 200
200 - 350
350 - 500
500 - 650
650 - 1062
Drainage/water body
(Base map: SRTM)

PLATE – 3.3

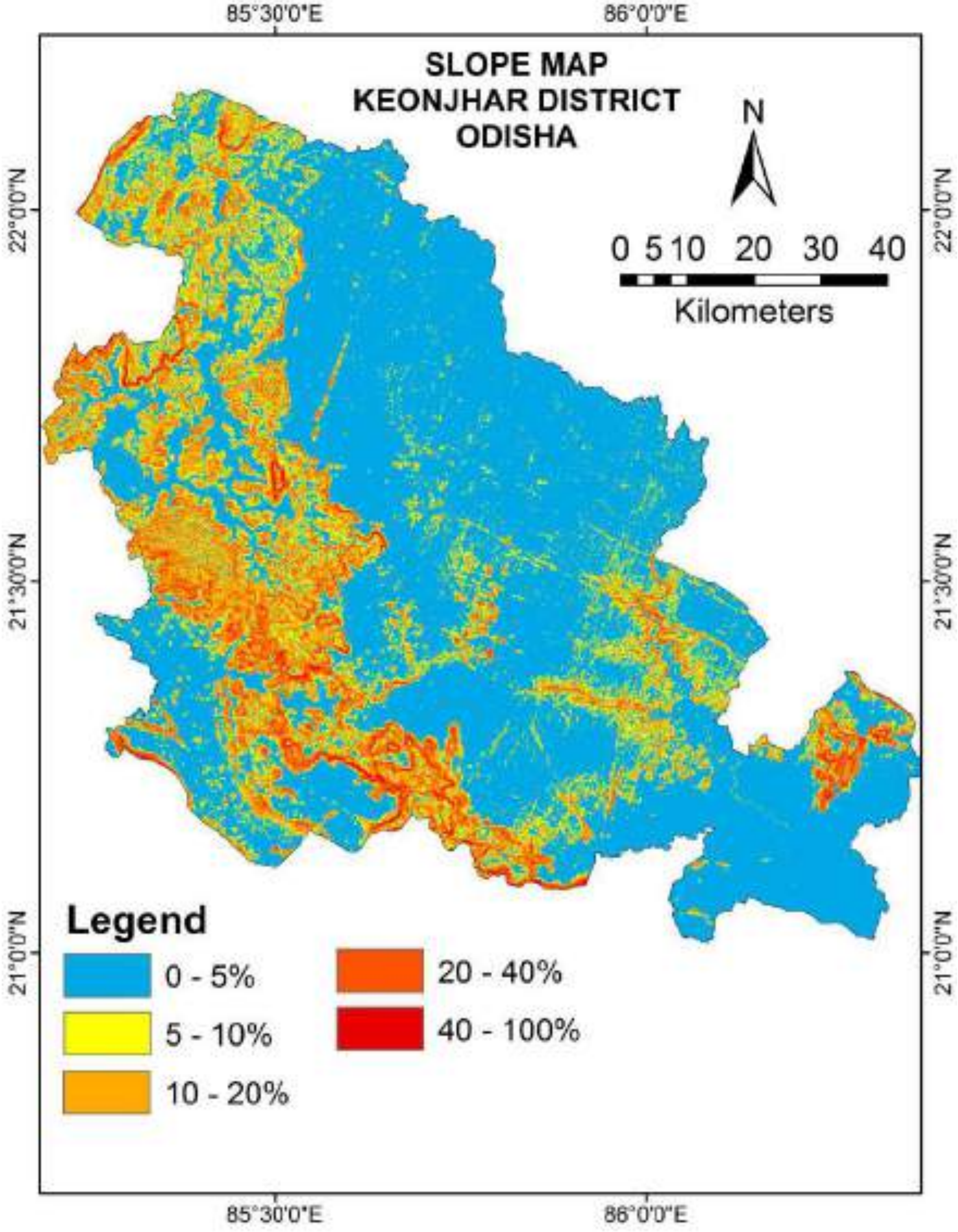

SLOPE MAP
KEONJHAR DISTRICT
ODISHA
N
0 5 10 20 30 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%

PLATE – 3.4

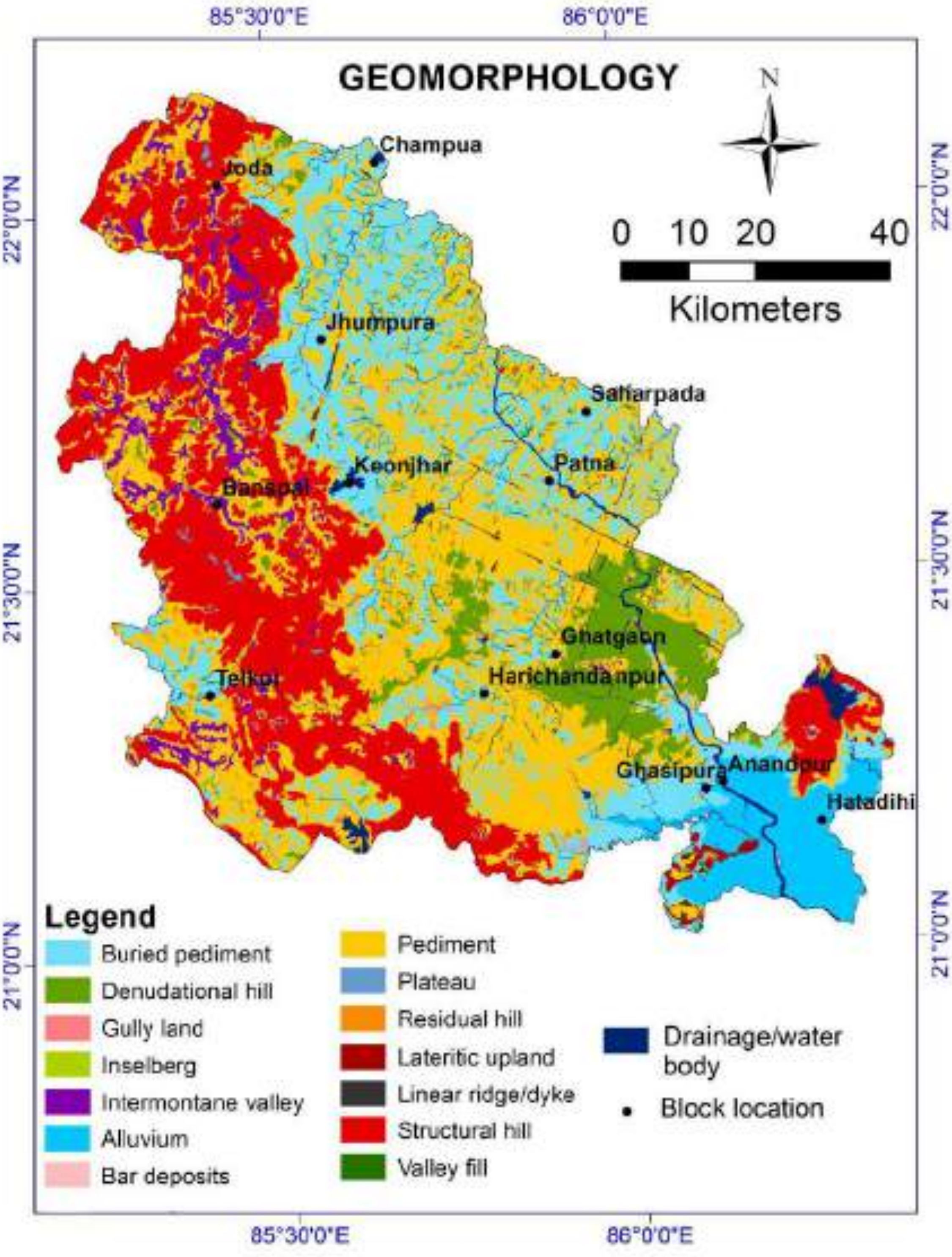

GEOMORPHOLOGY
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
N
0 10 20 40
Kilometers
Champua
Joda
Jhumpura
Saharpada
Keonjhar
Patna
Banspal
Ghatgaon
Harichandanpur
Telkoi
Ghasipura
Anandpur
Hatadihi
Legend
Buried pediment
Denudational hill
Gully land
Inselberg
Intermontane valley
Alluvium
Bar deposits
Pediment
Plateau
Residual hill
Lateritic upland
Linear ridge/dyke
Structural hill
Valley fill
Drainage/water body
Block location

PLATE – 3.5

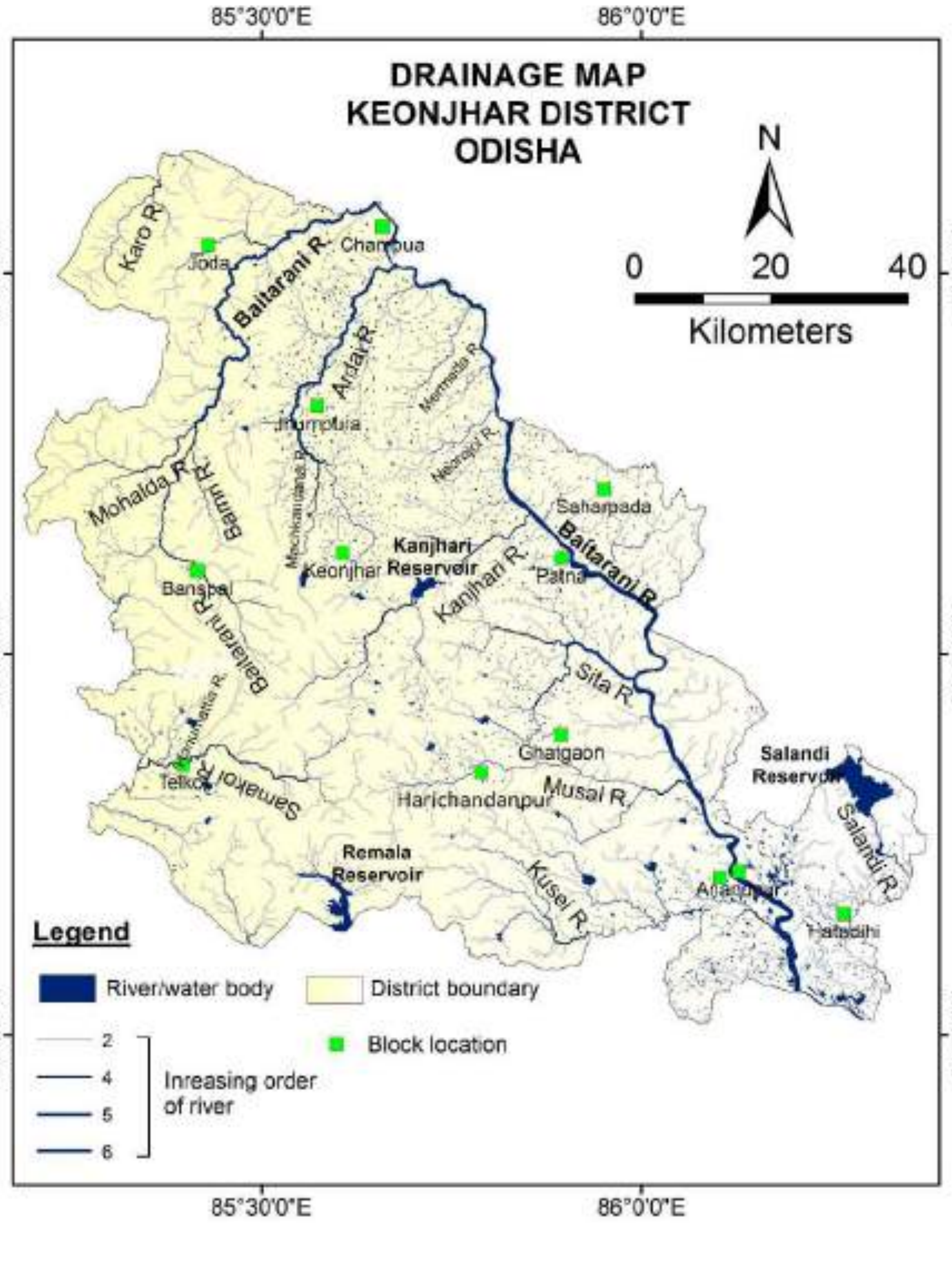
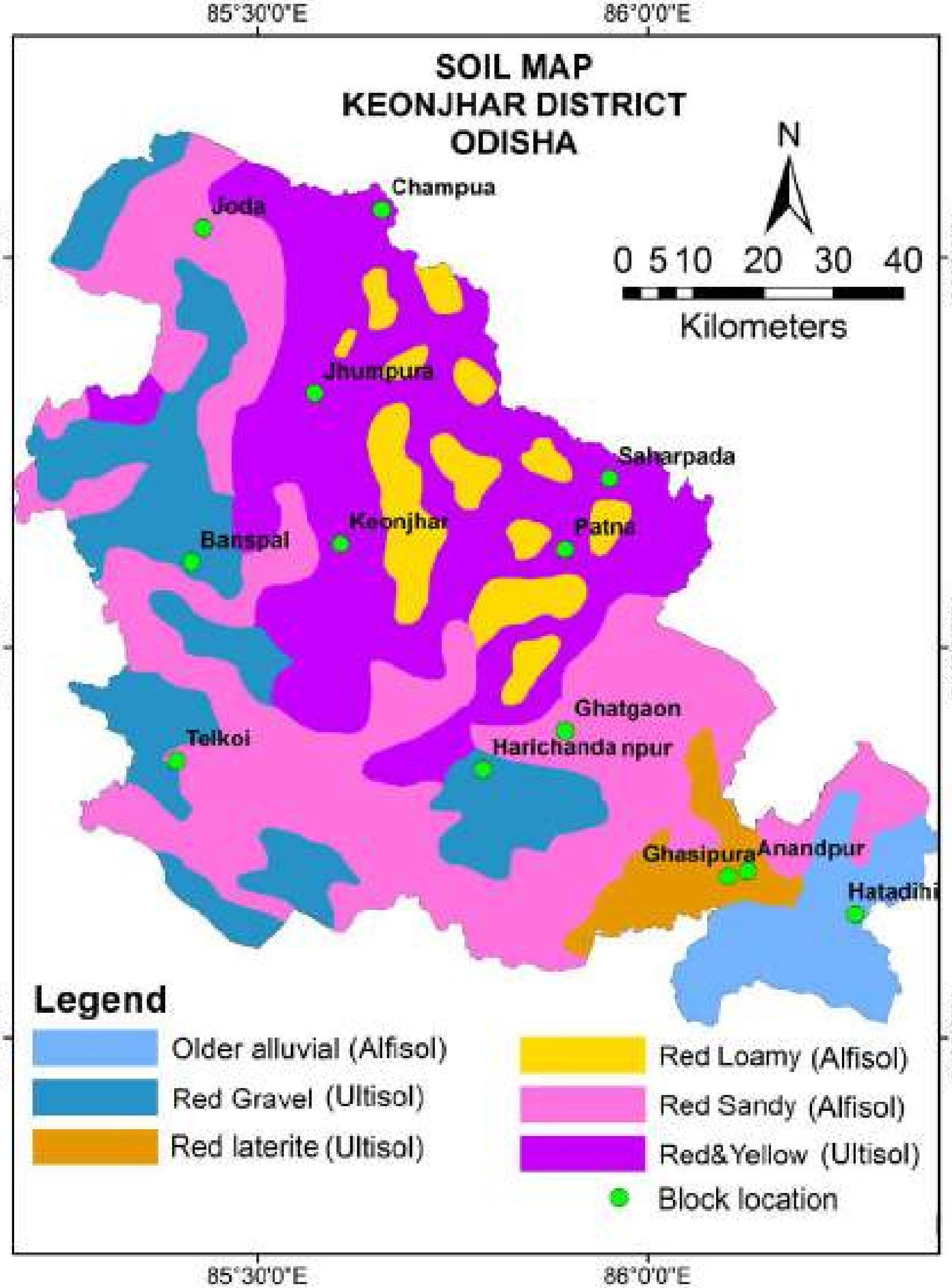

DRAINAGE MAP
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Karo R.
Joda
Baitarani R.
Champua
Ardai R.
Jhumpura
Mohalda R.
Baitarani R.
Saharpada
Kanjhari Reservoir
Keonjhar
Banspal
Kanjhari R.
Patna
Sita R.
Ghatgaon
Telkoi
Samakoi R.
Harichandanpur
Musal R.
Salandi Reservoir
Salandi R.
Remala Reservoir
Kusei R.
Hatadihi
Legend
River/water body
District boundary
Block location
Inreasing order of river
2
4
5
6

PLATE – 3.6



85°30'0"E
86°0'0"E
SOIL MAP
KEONJHAR DISTRICT
ODISHA
N
0 5 10 20 30 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Champua
Joda
Jhumpura
Saharpada
Keonjhar
Banspal
Patna
Ghatgaon
Telkoi
Harichanda npur
Ghasipura
Anandpur
Hatadihi
Legend
Older alluvial (Alfisol)
Red Gravel (Ultisol)
Red laterite (Ultisol)
Red Loamy (Alfisol)
Red Sandy (Alfisol)
Red&Yellow (Ultisol)
Block location

4.0 GEOLOGY

4.1 Major geologic formations

Geologically, Keonjhar district is rich and is a tresure house of rock types and mineral resources. The geological formations in Keonjhar district are widely divergent and predominated by Precambrian rocks. The Quaternary and Recent unconsolidated alluvium occur in the Baitarani River Basin. Broadly the district can be divided into eight geological Units viz: i) the patchy occurrence of metamorphites belonging to older metamorphics group (OMG) of Archaean age, ii) huge batholiths of Singhbhum Granite (massive granites and plutonic ignesous rocks) with swarms of newer dolerite dykes in the eastern part of the district, iii) Metasedimentaries of Banded Haematite Jasper (BHJ) and Banded Haematite Quartzite (BHQ) belonging to Banded Iron Formations (BIF) of Iron Ore Super Group (IOSG) of rocks of Archaean age in the south eastern part of the district, iv) (meta) volcano-sedimentary sequence (Volcanics/Lava Quartzite/Volcanics) intruded by Bonai granite (granite/younger granites) belonging to lower Bonai group of age ranging between Archaean to Palaeo Proterozoic age in the southwest and on the northwest, v) Intrusives like chromiferous ultramafics, gabbro-anorthosites, dolerite & quartz vein of Archaean to Proterozoic age, vi) Sedimentaries and metasedimentaries (Quartzite/shale/sandstone) belonging to Kolhan group ranging in age from lower to middle proterozoic, vii) Laterites of cenozoic age and viii) Quarternaries ocnsisting of sand, silt an clay are represented by Kaimundi formation & unclassified alluvium in the plains of Baitarani River. The area has been studied in details by different workers like Dunn and Dey, Krishnan, Jones (1934), Sarkar and Saha (1988) etc.

4.2 Stratigraphic succession

The broader stratigraphic succession of the area as modified after Saha et al. 1988 is given in Table 4.1.

Table 4.1: The Stratigraphic succession of Keonjhar district, Odisha

	Geologial time	**Formation**	**Age in Ma**
QUATERNARY	Recent	Alluvium – sand, silt, clay with calcareous concretions, gravel etc.	
	Early Pliestocene	Laterite	

	(up. Cenozoic)		
PRECAMBRIAN	Proterozoic	Newer dolerite dykes & sills	950-1600 Ma
		Gabbro- anorthosite- ultrafamics	2100 Ma
		Kolhan Group	2100-2200 Ma
		Unconformity	
		Dhanjori Group: Malangtoli Lava, Jagannathpur lava Equivalent to Dhanjori & Simlipal lavas	2300Ma
		Unconformity	
	Archaean	Singhbhum granite(Phase - III)	3.1Ga
		Iron Ore Group: Mafic lava, tuff, acid volcanics, tuffaceous shale, Banded Hematite Quartzite with iron ores, ferruginous chert, local dolomite and quartzitic sandstone.	
		Singhbhum Granite (Phase I & II)	3.3 Ga
		Pallahara gneiss	
		Folding and metamorphism of OMG and OMTG	3.4-3.5 Ga
		Older metamorphic tonalite gneiss (OMTG)	3.775 Ga
		Older Metamorphic Group (OMG), Pelitic schist, quartzite, Paramphibolites, Orthoamphibolites	4.0 Ga

The salient features of the various lithounits are discussed below:

Older Metamorphic Group (OMG) and the Older Metamorphic Tonalite Gneiss *(OMTG):* The oldest rocks of the Singhbhum - Orissa iron ore craton are designated as older metamorphic group which consists of pelitic schist, amphibolite and micaceous quartzite etc. These rocks are exposed in an area around Champua (22° 04’:85° 40’) which is considered to be the type area of OMG. The OMG rocks are intruded by a group of biotite hornblende – tonalite-gneiss (OMTG) grading to granodiorite, occupying an area to the east and south of champua (Sahu et al. 1988). The OMG is considered to be the oldest recognizable lithologic component of Eastern Indian Craton. The geochronological data have indicated that the OMTG was emplaced at least 3.4 Ga ago.

Singhbhum Granite: *The* huge Singhbhum Granite batholithic complex occupies an extensive area of the district. Geochronologic and field data suggest that this vast batholithic mass was emplaced at least in two stages namely Singhbhum Granite phase-I & II, and III around 2700 million years ago. Of these, phase I & II are emplaced simultaneously, where as phase III had been emplaced at a later stage. The lower granitic mass forms the basement of Iron Ore Group of rocks where as the upper one (i. e. phase III) has intruded the Iron Ore Group of rocks at various places. Petrographically, Singhbhum granites are biotite granodiorite grading to adamellite granite. The rock is medium to coarse grained. In addition to the Singhbhum Granites the granitic gneisses occurring in the south western part of the district has been termed by Sarkar et al. (1990) as Pallahara Gneiss. These are foliated migmatitic granites. Field relation suggests that this granitic mass is synchronous with the phase I and II of the Singhbhum Granite as the Iron Ore Group metamorphites unconformably overlie the Pallahara gneiss.

Iron Ore Super Group: *The* Iron Ore Super Group constitutes the major supra-crustal unit in the Singhbhum Orissa craton and covers the western and south-western boundaries of the district. These are made up of low grade metasediments including phyllites, tuffaceous shales, BHJ and BHQ with iron ore, ferrugeuous quartzite and metavolcanics. In the district they were deposited in two major basins, namely (i) Jamda-Koira basin (ii) Pallahara–Daitari basin. The first basin encompasses the type area of iron ore group of rocks in the area around Bolani–Joda and Barbil. On the basis of tectonic analysis Saha & Sarkar (1962-63) have confirmed that the regional structure of the iron ore basin is a low NNE plunging synclinorium overtuned towards south east.

Lower Bonai Group and the Proterozoic volcanics: The lower Bonai group, in the Bonai-Keonjhar region bears a volcano-sedimentary package which commenced with platformal package represented by basic volcanic-quartzite association. This is an asymmetric synclinal structure described as Horseshoe Synclinorium. It also exposes BIF horizons comprising BHQ, BHJ, BMQ and BCQ. The banded iron silica rocks gave rise to rich and extensive Iron and Manganese deposits of the district. Proterozoic volcanics suh as Bonai range volanics, Malangtoli lavas (around Banspal – Kanjipani) and Jagannathpur lavas (around Joda) occur in the west and northern part of the district The lavas are vesicular at most places and the vesicles are filled up mostly by quartz and chlorite and locally calcite. The lavas are slightly metamorphosed and consist of chlorite, saussuritised feldspar, pyroxene and epidotes.

***Early Proterozoic Gabbro-Anorthosite Suite (Ultramafic Complex)*:** These Gabbro-anorthosite bodies having chromite ore bodies as lenses, stringers and veins, which were intruded in the metasedimentary basement rocks of Iron Ore Group. Such mafic-ultramafic complexes are located in the Boula-Nuasahi belt in the Hatadihi block. In Baula-Nausahi area of Keonjhar district, an ultramafic-mafic suite, comprising dunite – peridotite - pyroxenite and gabbro / anorthosite, intrude metasupracrustals. Dolerite dyke swarms in turn, intrude the ultramafic-mafic suite.

Kolhan Group of sedimentaries: This consists of a gently westerly dipping 5°-15° monotonous sequence of grey orthoquartzite (locally arkosic) with several thin bands of grayish yellow shales. These rocks overlie Singhbhum granite, OMTG & OMG rocks unconformably. The Kolhan Group comprising of sandstone, siltstone, shale and conglomerate were deposited by the side of Baitarani River in the Joda-Bansapani sector.

Newer Dolerite: A spectacular set of reticulating basic dyke swarms, the Newer Dolerite suite with a dominant NNE to NE and a subsidiary NW trend, traverses the Singhbhum granitic complex and other older suite of rocks in the district. They constitute an important lithologic component in the Keonjhar district. Dunn and Dey (1942) coined the term Newer Dolerite, to the youngest stratigraphic unit in the terrain. The dykes range in width from less than 5 metres to over 30 metres in width and from 50 metres to over 20 kms in length. The dykes are represented mainly by dolerites and gabbros, though minor ultramafic, noritic and granophyric dykes are also reported.

Laterite: *The* Singhbhum Granite and Iron Ore Group metasedimentaries have been extensively lateritised in the upper portion and form duricrust on the top. The area around Saharpara underlain by Singhbhum Granite, have been lateritized. The metasedimentaries in and around Barpada in Anandapur block are highly lateritized. In general the Singhbhum Granites are lateritized to some extent throughout the district.

Alluvium (Kaimundi Formation): *This* is the youngest geologic unit of Pleistocene to Recent age. It consists of sand silt and clay with calcareous concretion. It is present along the Baitarani River courses.

The major generalized lithologies in the district are prodiced in the Plate 4.1. The percent (%) area coverage of different rock types have been given in Fig 4.1. Singhbhum Granite covers around 50% of the geographical area of the district.

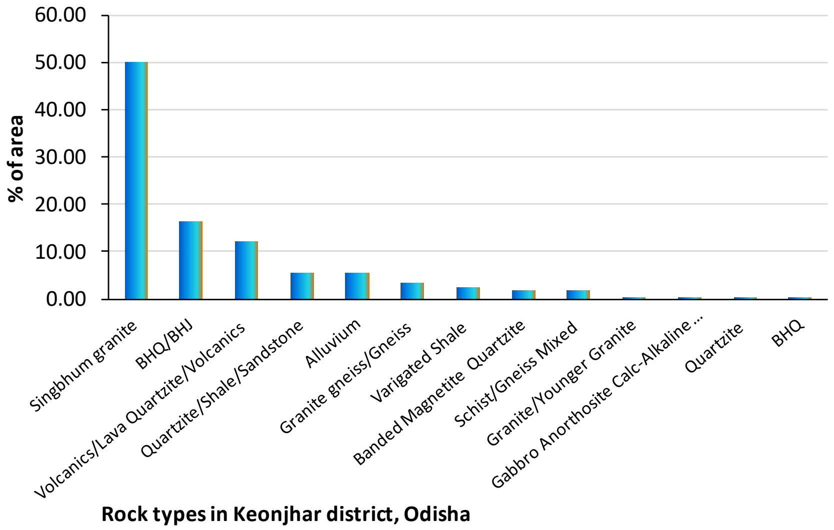
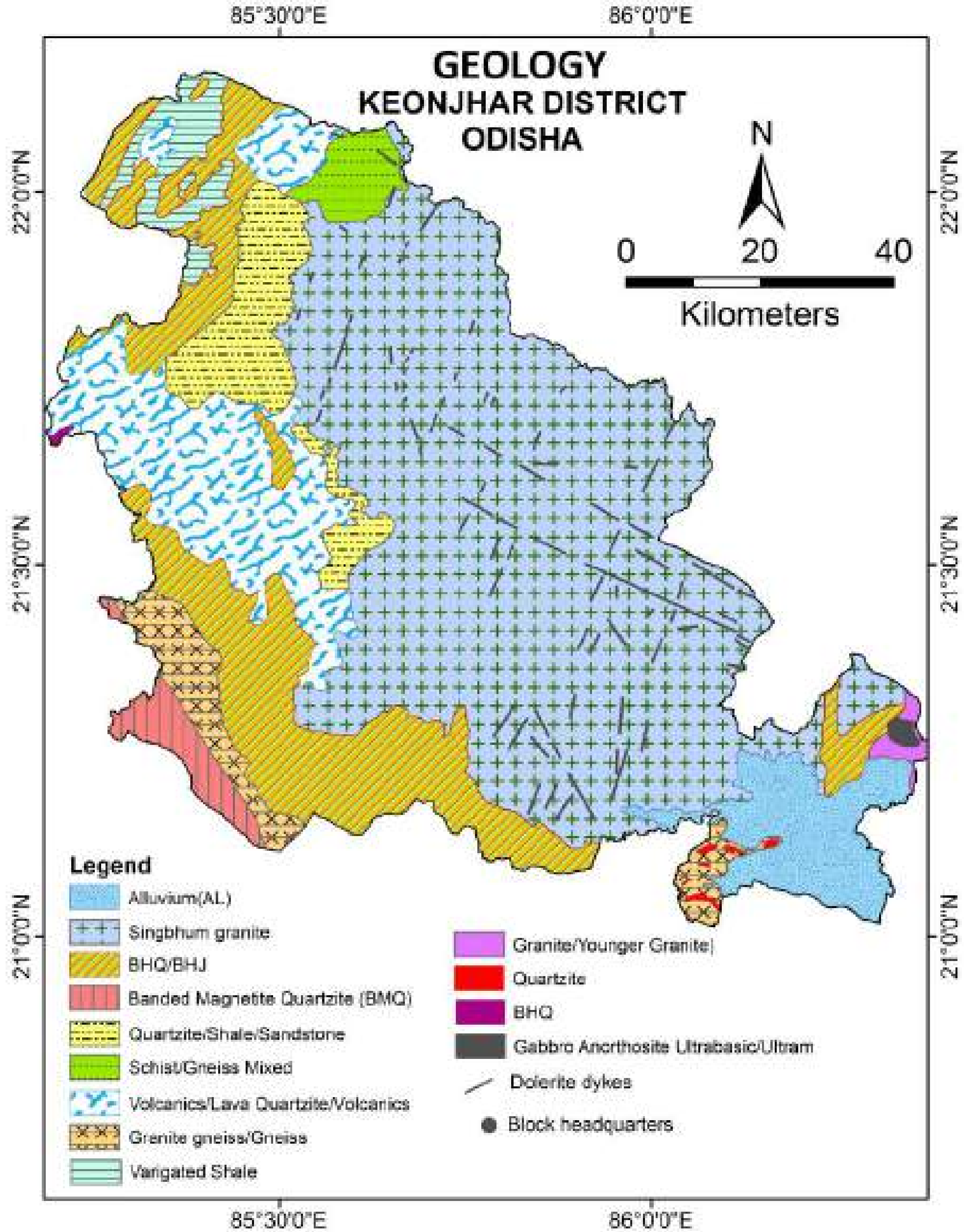


Figure 4.1: Bar diagram depicting the percent (%) area coverage of different rock types in Keonjhar district, Odisha.

4.3 Structure

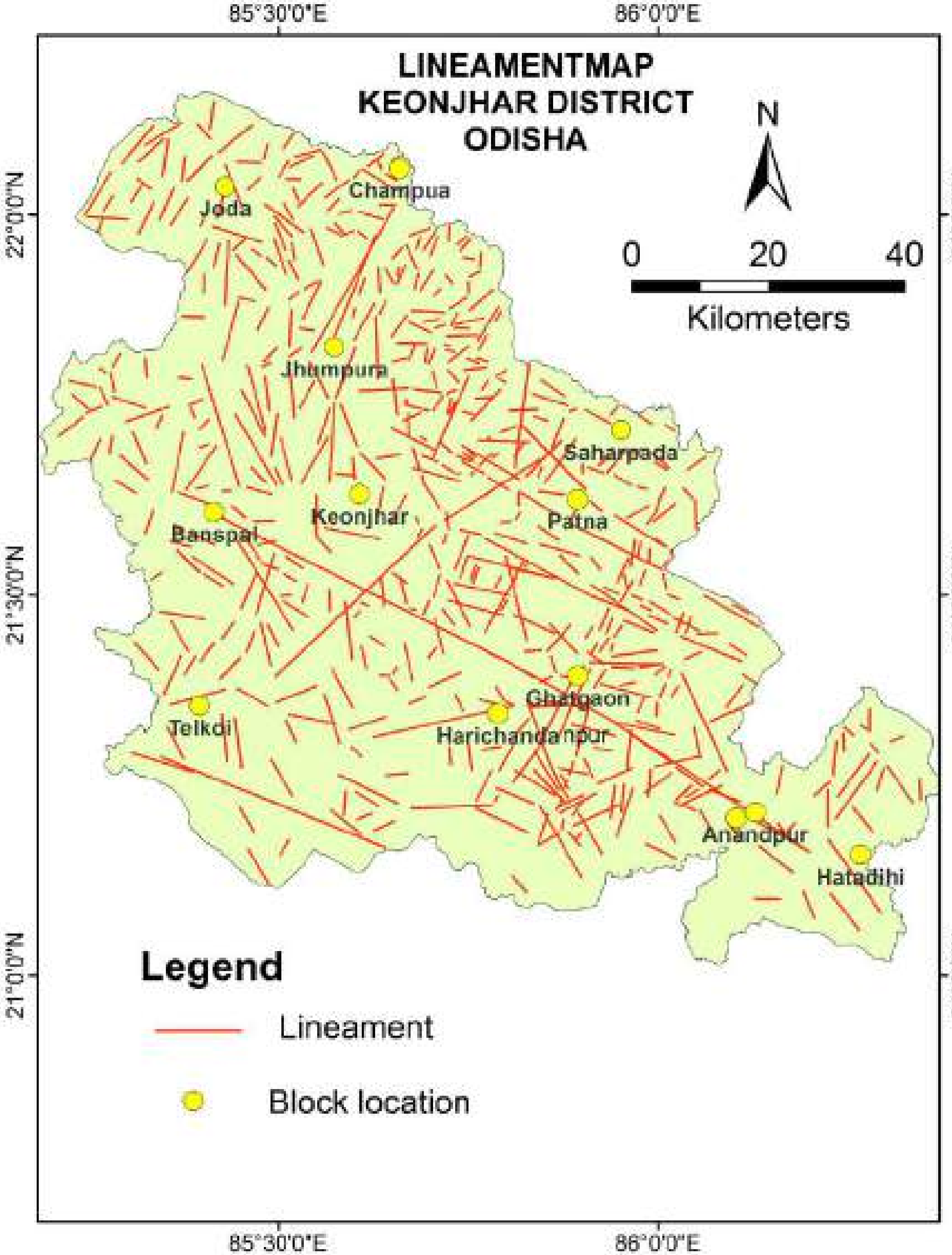
Major lineaments are picked up from satellite data interpretation. Most of them are trending in NW-SE, NE-SW and EW direction (Plate 4.2). Two major dykes are traceable for long distances in NW-SE direction in the central part of the district, and another in the NE-SW direction.

PLATE – 4.1



GEOLOGY
KEONJHAR DISTRICT
ODISHA
N
0
20
40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Legend
Alluvium(AL)
Singbhum granite
BHQ/BHJ
Banded Magnetite Quartzite (BMQ)
Quartzite/Shale/Sandstone
Schist/Gneiss Mixed
Volcanics/Lava Quartzite/Volcanics
Granite gneiss/Gneiss
Varigated Shale
Granite/Younger Granite
Quartzite
BHQ
Gabbro Anorthosite Ultrabasic/Ultram
Dolerite dykes
Block headquarters

PLATE – 4.2


85°30'0"E
86°0'0"E
LINEAMENTMAP
KEONJHAR DISTRICT
ODISHA
N
0
20
40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Joda
Champua
Jhumpura
Saharpada
Keonjhar
Patna
Banspal
Ghatgaon
Telkoi
Harichandanpur
Anandpur
Hatadihi
Legend
Lineament
Block location

5.0 HYDROGEOLOGY

5.1 Major hydrogeological units

The varied geological and structural set up primarily controls the Hydrogeological condition of the district. The geological formations of the district have diverse lithological composition and structure. Hence the hydrogeological condition too shows wide variations. Depending upon geology, water bearing and water yielding properties, two major Hydrogeological units have been identified in the district. These are:

1. Consolidated formations and
2. Unconsolidated formations.

In the former, comprising mostly the crystalline rocks devoid of primary porosity, groundwater occurs mainly in the weathered zones at shallow depths as also in the weaker zones such as joints, shears, foliation planes and fractures at deeper depths. In the latter groundwater occurs in the inter-granular pore spaces.

Rainfall and climate, topography, soil conditions and land use are the other factors controlling groundwater potentials of the area. The hydrogeological map of the district is presented in Plate 5.1.

5.1.1 Consolidated Formations

The hydrogeological framework of the district is mainly controlled by the geological set up, rainfall distribution and the degree of secondary and primary porosities in the geological formations for storage and movement of groundwater. Since major part of the district is underlain by the hard rocks of diverse lithological composition and structure, the water bearing properties of the formations also vary. The area has undergone several phases of intense tectonic deformations, which are responsible for the development of deep seated fracture systems. Hydrogeological surveys in the district bring out the bearing of lithology and tectonic deformation on the occurrence and distribution of groundwater reservoirs and their water bearing and water yielding properties. The occurrence of long linear dykes and other structural elements i.e. Lineaments forms due to tensile deformations were picked up from remote sensing studies followed by field checks. These structural elements chiefly control the occurrence and movement of groundwater in the typically fractured crystalline terrain. Studies bring out two major sets of lineaments and dykes developed due to tensile deformation. The NW-SE trending set is relatively younger and constitutes prominent conduits for groundwater occurrence and movement to the wells located in the vicinity and records copious yields. In contrast, the bore well yield in the vicinity to the NE-SW dykes and lineament is relatively poor and inconsistent due to clogging of older fractured horizon by clayey material or filling up by later intrusives.

Water bearing properties of the consolidated formations: Major parts of the area are occupied by hard crystalline rocks belonging to Precambrian age. Of these the older metamorphics, Singhbhum granites, Iron Ore Group of rocks and Proterozoic metavolcanics are extensively developed to offer scope for exploitation of groundwater, and hence the hydrogeologic properties of these litho units are fairly well known. The Kolhans and meta-volcanics of Iron Ore Group of rocks are having localized occurrence in relatively inaccessible pockets, and hence hydrogeological potentials are not much known except in valley areas. Newer dolerite dykes are fractured which were mostly developed during the cooling period. These fractures die out with depth and have no tectonic relationship with Singhbhum Granite and other country rocks. Hence although these linear intrusives are indicators of the direction of tensile deformation, the intrusive themselves appear to be less productive.

Aquifer characteristics of consolidated formations: In the hard crystalline rock, recharge of water from precipitation or seepage from surface water bodies percolate into the weathered zone. In case the underlying basement rocks are incised by open fractures, the downward movement of the water from the upper regolith zone is facilitated. In the weathered zone groundwater generally occurs under unconfined condition where as in the fractured bed rock aquifers it occurs under semi-confined to confined conditions. At places confined conditions have given rise to the formation of auto-flowing well in the basement rock aquifers as seen near Pacheri (Joda block) .The groundwater potential of the weathered zones (tapped by dug wells), weathered basement rock and shallow fractured fresh basement rock horizon (tapped by the hand pumps) and deep fractured basement rock (tapped by the deep boreholes of CGWB) vary considerably depending upon their lithological characteristics and age.

The deeper rock horizons were studied from exploratory borewells of CGWB. The results reveals that the younger Proterozoic volcanics do not form potentials aquifers both in saprolite, weathered basement and fractured fresh basement rock horizons although in the limited areas of good recharge and in proximity to potential lineaments high yielding borewells have also been drilled. Kolhan sedimentaries too occurring in valley areas (e.g. near Suakati) have good potentials up to 60 m depth wherever truncated by dolerite dykes. Iron ore group of rocks have high yield potentials in the upper 75 m depth. The granitic rocks (both Older Metamorphic Tonalite Gneiss and Singhbhum Granite) show moderate to good yield in the saprolite horizon. However, the performance of weathered basement rock and shallow fracture horizon and deeper horizons of OMG & OMTG is better than comparatively younger Singhbhum Granites. The reasons being perhaps the intense ruptural deformation in the successive tectonic cycles renders the older basement aquifers porous and transmissive.

5.1.2 Unconsolidated Formations

The unconsolidated formations consist of laterite and alluvium. Laterites at places are highly consolidated and used as building stones. The laterites have high degree of effective porosity and form potential aquifers commonly tapped in dug wells. The alluvium comprises an admixture of clay, silt, sand and calcareous concretions in varying proportions. The fan type deposits dominated by boulders, gravels and pebble occur in parts of Telkoi block. Qauternary alluvium comprising sand (fine to coarse), gravels, silt and clay cover significant parts in the blocks of Anandapur, Ghasipura and Hatadihi in the southeastern parts of the district. The coarse sediments like sand and gravel form the main repository of groundwater. Ground water occurs under phreatic condition at shallow depth. The thickness of the alluvium varies from 15 to the maximum of 95 m bgl with the average of around 40 m. The thickness of granular zones varies from 12 m to 25 m. Inference from lithologs of the tube wells drilled by OLIC shows that towards Salandi there is remarkable change from sand to silt. The aquifer characteristics of the lateritic aquifers indicate high development potentials.

5.2 Depth to water level in phreatic aquifer

The phreatic zone constitutes the most potential groundwater reservoir in the district. This zone has been mapped in course of hydrogeological surveys and groundwater exploration activities. The depths to water levels (DTWs) in aquifers depend on several factors like rainfall, topography, drainage characteristics, and proximity to drainage channels, lithology, water bearing and water yielding properties of the rocks, as also land use. With a view to ascertain the changes in the groundwater regime and make an overal assessment of the groundwater resources CGWB has, so far, established 69 National

Hydrograph Network Stations (NHNS) throughout the district which are monitored manually 4 times a year, during the months of January, April, August and November.

Besides the monitoring of NHS dug wells, 130 key wells during the pre-monsoon and 149 key wells during the post monsoon were established to monitor the DTWs in the Keonjhar district. Based on the monitoring data pertaining to the year 2018, the DTWs contour zonation maps for pre- and post-monsoon periods and the annual water level fluctuation map were prepared and presented in Plate 5.2, 5.3 and 5.4 respectively. Reduced levels for the water level monitoring locations were extracted from the SRTM Digital Elevation Model (SRTM DEM), and subsequently water table contours for the phreatic aquifer were also prepared, which are produced in Plates 5.5 and 5.6 respectively for the periods of pre- and post-monsoon 2018.

5.2.1 Pre-monsoon (April)

The DTWs levels during the pre-monsoon period (year 2018) varied between the minimum of 0.95 m below ground level (m bgl) at Childa (Patna block) and the maximum of 13.8 m bgl at Khajurimundi (Banspal block). The average water level stood at 6.07 m bgl. About 8% and 38% of the wells exhibted water levels less than 2.0 m and 5.0 m bgl respetively in the district. Only ~6% of the measurements showed water levels exeeding 10 m bgl. The shallower water levels were observed in the southern (including the alluvial area) and the east-entral parts, whereas the deeper ones remained predominant in the northern and the western parts of the district covering parts of the blocks Joda, Banspal, Harichandanpur and Telkoi (Plate 5.2). The shallower DTWs seemed to clustered in some low lying river valley segments (i.e., Ardel, Mermeda, Kusei and the river Baitarani), other than the alluvial area in the south of the district. The deeper DTWs areas are primarily hilly tracts. Based on the depth to water level contour zonation map (Plate 5.2), areas overed by different water level ranges were calculated, which are produced in Fig 5.1, and their block-wise distribution are produced in Table 5.1. As per the calculations, the DTWs in the range of 5.0-7.5 m bgl covered maximum area of 54.1% of the district area, which was followed by 2.5 – 5.0 m bgl with the area overage of 25.2% (Fig 5.1). Water levels exceeding 10.0 m bgl covered only 1.5% of the district area. The Hatadihi block showed maximum of 12.1% of its area possessing pre-monsoon DTWs <2.5 m bgl (Table 5.1). Similarly, in the range of 2.5 – 5.0 m bgl water levels, the blocks Anandapur, Ghasipura and Hatadihi exhibited 67.2, 66.5 and 86.9% of their area coverage respectively. The blocks Ghatgaon, Harichandanpur, Joda, Keonjhar, Patna, Saharpada and Telkoi depicted DTWs in the range of 5.0-7.5 m bgl in more than 50% of their geographial areas. In Banspal block around 57% of the area was characterized by DTWs in the range of 7.5 – 10.0 m bgl.

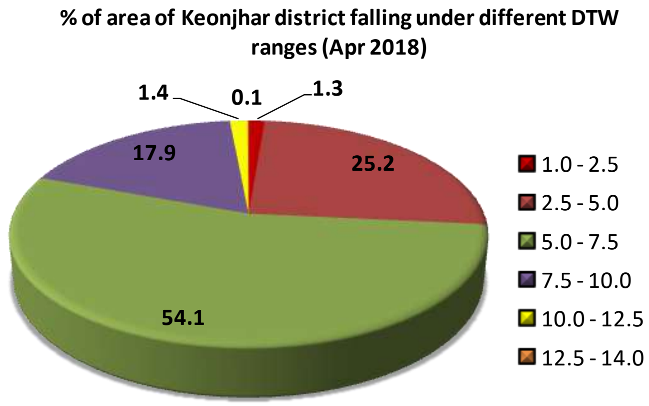


Figure 5.1: Pie diagram depicting the percentage (%) of area of Keonjhar district falling under different DTW (in m) ranges during pre-monsoon (April 2018) period.

5.2.2 Post-monsoon (November)

The post-monsoon DTWs reflect good recharge of the phreatic aquifer from the rainfall. The water levels varied between 0.4 – 9.3 m bgl; the minimum at Rimuli in Champua block and the maximum at Goudasahi in Keonjhar block. The shallower DTWs existed in the same discontinuous of patches in the valleys of the rivers Ardel, Mermeda, Kusei and the Baitarani (Plate 5.3). The average DTW was estimated at 4.0 m bgl only in contrast to the 6.07 m bgl during the pre-monsoon period.

Table 5.1: Percentage (%) of area of Keonjhar district and its blocks falling under different DTW (in m) ranges during pre-monsoon (April 2018) period.

Sl No	Name of block	% of area falling under different DTW (in m) ranges					
		1.0 - 2.5	2.5 - 5.0	5.0 - 7.5	7.5 - 10.0	10.0 - 12.5	12.5 - 14.0
1	Anandapur	2.1	67.2	29.4	1.3	0.0	0.0
2	Banspal	0.0	0.8	36.4	56.8	5.5	0.5
3	Champua	0.7	10.6	48.4	39.7	0.6	0.0
4	Ghasipura	1.8	66.5	30.5	1.3	0.0	0.0
5	Ghatgaon	0.4	19.2	75.1	5.2	0.1	0.0
6	Hatadihi	12.3	86.9	0.8	0.0	0.0	0.0
7	Harichandanpur	1.0	27.2	60.7	9.1	2.0	0.0
8	Jhumpura	0.8	20.4	21.9	1.5	0.0	0.0
9	Joda	0.0	5.7	71.3	21.0	1.9	0.1
10	Keonjhar	0.2	10.1	69.5	19.7	0.5	0.0
11	Patna	1.8	27.7	67.5	3.0	0.0	0.0
12	Saharpada	0.0	29.7	65.9	4.4	0.0	0.0
13	Telkoi	0.0	6.1	74.5	18.7	0.8	0.0
District total		**1.3**	**25.2**	**54.1**	**17.9**	**1.4**	**0.1**

A perusal of the Plates 5.2 & 5.3 indicates that major parts of the areas which showed DTWs in the ranges of 2.5 – 5.0 and 5.0 – 7.5 m bgl during pre-monsoon period, have elevated their water levels to the ranges of 0.43 – 2.5 and 2.5 – 5.0 m bgl respectively. The areas which were earlier in pre-monsoon exhibited the water level range of 7.5 – 10.0 m bgl, have been transformed to the water level range of 5.0 – 7.5 m bgl. Alternately saying, areas covered by water levels <2.5 m and 2.5-5.0 m bgl expanded, while those of 5.0-7.5 m and 7.5-10.0 m shrinked during post-monsoon period (Table 5.2).

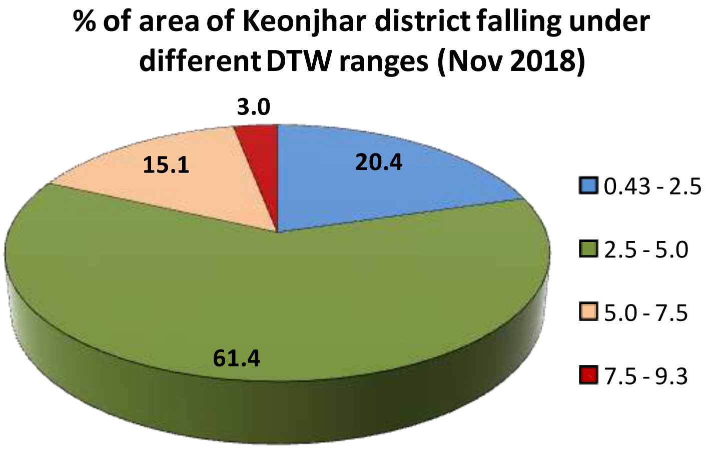


Figure 5.2: Pie diagram depicting the percentage (%) of area of Keonjhar district and its blocks falling under different DTW (in m) ranges during post-monsoon (Nov 2018) period.

Based on the post-monsson depth to water level contour zonation map (Plate 5.3), areas overed by different water level ranges were also calculated for the post-monsoon measurements, which are produced in Fig 5.2, and their block-wise distributions in Table 5.3. As per the calculations, around 61% of the district area was characterized by DTWs in the range of 2.5 – 5.0 m bgl (Fig 5.2), which was followed by 0.43 – 2.5 m bgl covering ~20% of the district area. The water levels in the range of 7.5 – 9.3 m bgl covered only a negligible area of 3% of the district, which were in a major way concentrated in the blocks of Banspal, Joda and Harichandanpur. If looked into the status of blocks, the Hatadihi block depicted water levels <2.5 m bgl in 68.6% of its geographical area (Table 5.3). Except the Banspal block, all other blocks in the district, showed DTWs less than 5.0 m bgl in more than 50% of their geagraphical areas.

Table 5.2: A comparison of area percent covered by different DTW ranges during the pre- and post-monsoon seasons in Keonjhar district.

DTW range (m bgl)	Area % covered in diff. seasons	
	Pre-monsoon	Post-monsoon
<2.5 m	1.3	20.4
2.5 - 5.0 m	25.2	61.4
5.0 - 7.5 m	54.1	15.1
7.5 - 10.0 m	17.9	3
10.0 - 12.5 m	1.4	nil
12.5 - 14.0 m	0.1	nil

Table 5.3: Percentage (%) of area of Keonjhar district and its blocks falling under different DTW (in m) ranges during post-monsoon (Nov 2018) period.

Sl No	Name of block	% of area falling under different DTW ranges			
		0.43 – 2.5	2.5 – 5.0	5.0 - 7.5	7.5 - 9.3
1	Anandapur	10.4	84.5	3.7	1.3
2	Banspal	2.3	42.8	40.2	14.7
3	Champua	22.6	70.2	6.9	0.3
4	Ghasipura	40.5	52.3	6.9	0.3
5	Ghatgaon	8.8	78.9	11.4	0.8
6	Hatadihi	68.6	31.4	0.0	0.0
7	Harichandanpur	24.1	61.1	12.0	2.8
8	Jhumpura	46.0	49.0	4.6	0.4
9	Joda	10.1	55.8	32.0	2.0
10	Keonjhar	22.4	67.0	9.8	0.8
11	Patna	46.8	52.9	0.2	0.0
12	Saharpada	12.6	71.1	16.4	0.0
13	Telkoi	4.4	84.2	11.2	0.2
	District total	**20.4**	**61.4**	**15.1**	**3.0**

5.2.3 Annual water level fluctuation

The water level fluctuations between the pre- and post-monsoon (year 2018) water level measurements varied between the minimum -0.7 m (water level decline) at Belabahali (Hatadihi block) to the maximum of 8.65 m at Katalaposhi (Telkoi block) (Plate 5.4). The average fluctuation stood at 2.20 m. Based on the water level fluctuation contours, different area percentage of the district falling in different ranges of fluctuations were worked out. It was seen that the DTW fluctuations in the ranges of 0.0 – 2.0 m and 2.0 – 4.0 m covered maximum areas of the district; 41.4 and 53.4% respectively (Fig 5.3). Similar estimations for every block are given in Table 5.4. Water level declines (negative trend) were observed in patches (1.1% of district area), particularly in the alluvial areas of Anandapur, Ghasipura and Hatadihi blocks. It may be attributed to the groudwater extraction for irrigation. The blocks where the annual DTW fluctuations were restricted within 0.0 – 2.0 m in more than 50% of their geographical areas include Anandapur, Ghasipura, Hatadihi, Saharpada and Telkoi. Major parts of the Telkoi block constitute a large depressed valley like feature, which might have been the reason behind lower DTW fluctuations. The blocks such as Banspal, Champua, Ghatgaon, Harichandanpur, Jhumpura, Joda and Keonjhar registered DTW fluctuations in the range of 2.0 – 4.0 m beyond 50% (up to max. 93.1% in Joda) of their geographical areas. The DTW fluctuations in the range of 4.0 – 6.0 m were significantly observed in the blocks of Champua (22.3% of its area) and Keonjhar (12.1% of its area).

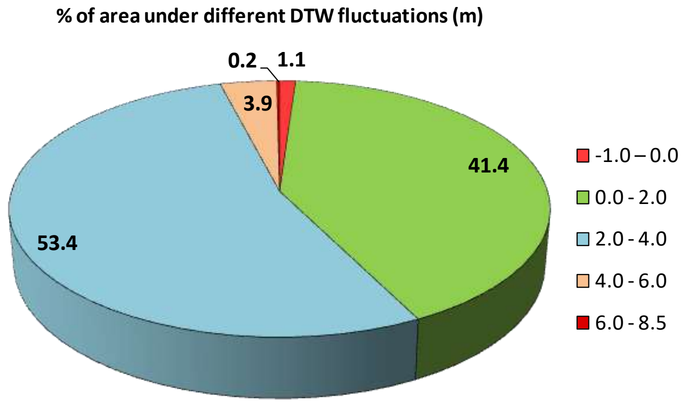


Figure 5.3: Pie diagram depicting the percentage (%) of area of blocks and the district falling under different annual water level fluctuation levels.

Table 5.4: Area percent (%) of the blocks and the district Keonjhar falling under different annual water level fluctuations.

Sl No	Name of block	% of area under different DTW fluctuations in m				
		-1.0 – 0.0	0.0 - 2.0	2.0 - 4.0	4.0 - 6.0	6.0 - 8.5
1	Anandapur	3.4	96.5	0.1	0.0	0.0
2	Banspal	0.0	18.7	75.5	5.7	0.2
3	Champua	0.0	7.1	70.6	22.3	0.0
4	Ghasipura	4.4	91.3	4.3	0.0	0.0
5	Ghatgaon	0.0	44.5	51.8	3.3	0.4
6	Hatadihi	6.7	93.3	0.0	0.0	0.0
7	Harichandanpur	1.0	30.0	68.3	0.7	0.0
8	Jhumpura	0.8	40.3	58.7	0.2	0.0
9	Joda	0.0	6.5	93.1	0.3	0.0
10	Keonjhar	0.2	14.1	73.2	12.1	0.3
11	Patna	0.0	29.8	63.3	6.9	0.0
12	Saharpada	0.1	66.3	33.5	0.0	0.0
13	Telkoi	1.1	63.3	31.3	3.4	1.0
District total		**1.1**	**41.4**	**53.4**	**3.9**	**0.2**

5.3 Water table and groundwater flow

During pre-monsoon period, the water table in the Keonjhar district lied in the heights ranging between ~50-600 m asl (Plate 5.5); the minimum being in the south-eastern (Hatadihi and Anandapur block) part to the maximum in the western parts around Telkoi block. The equipotential lines have been drawn joining the points of equal head in the potentiometric surface. The slope of the potentiometric surface largely follows the ground surface slope. In the northern parts, the groundwater flows easterly to south-easterly, which turns southern to south-easterly in the southern parts of the district. In the western parts of the district in Banspal and Telkoi blocks, falling in the Samakoi river basin, the groundwater flows westerly to south-westerly. Most of the equipotential lines, while passing across the rivers, turn concave downstream, indicating the effluent character of most of the rivers in the district.

The gradient of the potentiometric surface varied roughly between 1:50 and 1:500. It was reasonably flat in the eastern and central parts of the district in parts of the blocks Champua, Jhumpura, Patna, Keonjhar, Telkoi and in the alluvial parts of Anandapur and Hatadihi. The flat water table might be indicating favorable groundwater conditions in such parts. The water table becomes steep near the hills in the western side and at the transit from weathered zone to alluvium in the south-east of the district.

As per the post-monsoon water level measurements in the Keonjhar district, though the water table varied between the same 50 and 600 m asl (Plate 5.6). The slope of the potentiometric surface and the groundwater flow patterns remain the same as during the pre-monsoon period. The gradient of the water table however, becames more flat (up to 1:600) owing to rising of the water levels after rains. The corresponding patches which showed flat slope during the pre-monsoon period became even more flat. The trend of the water table remained the same to the pre-monsoon period. The lower slope of water table became more conspicous in parts of the blocks of Champua, Jhumpura, Saharpada, Patna, Ghatgaon, Hatadihi and Anandapur.

5.4 Long term trend in water level in phreatic aquifer

The decadal (2009–2018) water level trends (monitored from the district NHS wells) during pre-monsoon period (n=114) indicated rising trend in water level in 33% (n=38) of the monitoring stations with the maximum being at 0.71 m/yr (Plate 5.7). The falling trend of water level was shown by about 20% (n=23) of the stations and maximum fall recorded is 0.52 m/yr. In about 70% of the stations (n=16) where falling trend was observed, the fall exceeded the critical limit of 0.1 m/yr. In these areas, intervention is required to restore the water level.

The decadal water level trend analysis data (n=114) of post-monsoon period (2009–2018) indicated rising trend of water level in 31% cases (n=35) and falling trend in about 32% cases (n=36) (Plate 5.8). At rest of the monitoring stations no trend was observed. The maximum rise recorded is 0.79 m/yr including the 63% of them where the values exceeded 0.10 m/yr. The maximum fall was around 0.71 m/yr with around 44% of them showing water level decline at rates exceeding 0.1 m/yr. The data of rise and fall in water level of hydrograph stations during pre- and post-monsoon periods are presented in Tables 5.5 and 5.6.

Table 5.5: Decadal trend in the pre-monsoon depth to water levels in the Keonjhar district

SL No	***Name of Blok***	***Loation of well***	***No. of data points***	***Rise (m/yr)***	***Fall (m/yr)***	***Intercept***
1	Anandapur	Anandapur	1	-	-	0
		Balduan-I	7	-	0.4242	3.1009
		Belbahali	4	-	-	0
		Bhagomunda	10	0.3232	-	8.1416
		Dhokuta	5	-	-	0
		Nuagaon	5	-	-	0
2	Banspal	Banspal	3	-	-	0
		Banspal-Ii	5	-	-	0
		Baradevata	5	-	-	0
		Baraguda	1	-	-	0
		Kanjipani	10	-	0.1122	5.5434
		Suakati	10	-	0.0244	6.2794
		Tarmakant	0	-	-	0
3	Champua	Belaipada	4	-	-	0
		Champua 1	9	0.3537	-	10.7264
		Jaymangalpur	10	0.0754	-	5.7931
		Jodipada	4	-	-	0
		Karanjia	2	-	-	0
		Parsora	9	-	0.1239	6.9382
		Sasang	5	-	-	0
4	Ghasipura	Balarampur	6		0.0273	4.8483
		Barpada	9	0.6994	-	9.6704
		Ghasipur	10	0.0539	-	8.1878
		Ghasipura	0	-		0
		Birgovindpur	9	0.1341	-	7.5306
		Deogan1	10	-	0.1443	3.6194
		Ghasipura pz	6	-	0.3722	4.3145
		Kesudapal-Ii	4	-	-	0
		Kesurdapal	10	0.0658	-	4.4283
		Ramchandrapur	5	-	-	0
		Sainkula	5	-	-	0
5	Ghatgaon	Baxibarigan	9	0.2781	-	7.58
		Dhangadiha	10	0.341	-	10.1287
		Dhenkikot	3	-	-	0
		Dhenkikote	5	-	-	0

		Dhenkikot-Ii	2	-	-	0
		Gadadharpur	6	0.2805	-	7.9068
		Ghatgaon	10	0.5599	-	9.0563
		Ghatgaon-I	4	-	-	0
		Ghatgaon-Ii	1	-	-	0
		Janghira	9	0.5988	-	10.2735
		Melana	4	-	-	0
		Patilo	6	-	0.1459	5.9577
		Pipilia	0	-	-	0
		Pipilia1	4	-	-	0
		Rajpat	3	-	-	0
6	Harichandanpur	Baxibargaon	4	-	-	0
		Harichandanpur	10	-	0.0176	4.7007
		Harichandanpur-Ii	6	0.1514	-	6.8429
		Jhangira	6	0.3258	-	8.4224
		Sonapent	9	-	0.5204	0.9749
7	Hatadihi	Anandapur	6	0.626	-	12.8941
		Bidyadharpur	7	-	0.3404	3.7021
		Mathadai	9	-	0.1213	3.3364
		Mathadai-Ii	3	-		0
		Nuasahi	8	-	0.1942	2.4604
8	Jhumpura	Badaposhi	6	-	0.4238	2.7568
		Jhumpura	10	-	0.2655	4.795
		Jhumpura-Ii	5	-	-	0
		Karanjia 1	9	0.6328	-	9.9861
		Katalaposhi	5	-	-	0
		Ukhunda	0	-	-	0
		Ukunta	9	0.0027	-	4.1982
9	Joda	Barbil	9	-	0.1278	5.1835
		Bhadrasahi	10	-	0.303	4.2846
		Bolani	0	-	-	0
		Guali	5	-	-	0
		Joda	10	-	0.0333	5.7801
		Nalda2	2	-	-	0
		Rugudi	8	0.2692	-	9.0773
		Rugudi 1	3	-	-	0
10	Keonjhar	Brahmandgram	3	-	-	0
		Gopalpur2	10	0.4723	-	8.4556
		Haridagot	10	0.5709	-	8.9862
		Jhadbelda 1	2	-	-	0
		Keonjhar	0	-	-	0
		Keonjhar Sadar	1	-	-	0
		Keonjhargarh	10	0.1172	-	7.1518
		Keonjhar-Ii Old Town	3	-	-	0
		Muktapur	3	-	-	0
		Naranpur	5	-	-	0
		Padampur2	8	0.1638	-	11.4057
		Padampur-Ii	5	-	-	0
		Palasponga	8	0.5311	-	8.7139
11	Patna	Balaniposi	5	-	-	0
		Burikapuri	10	0.0122	-	6.545
		Kendeiposhi	8	0.4563	-	8.3368

		Khiritangiri	10	0.0851	-	9.0758
		Khiritangiri-Ii	2	-	-	0
		Kothaghar	8	0.0881	-	4.7553
		Malliposi	9	0.5221	-	8.969
		Swampatna-Ii	5	-	-	0
		Tangarpada	6	0.0822	-	4.4954
		Turmunga	10	-	0.0606	5.3041
12	Saharpada	Badbil	6	-	0.3278	3.646
		Gajitangri	6	0.7077	-	11.3134
		Saharapada	0	-	-	0
		Saharpara	8	0.519	-	10.3076
		Swampatna	9	0.1271	-	4.8925
		Udaipur	9	0.3805	-	7.9329
		Udaipur-Ii	6	0.6502	-	9.5001
13	Telkoi	Akul	6	0.1487	-	6.3027
		Balijhodi	5	-	-	0
		Benamunda	4	-	-	0
		Bimala	9	-	0.0842	5.0732
		Gonasika	4	-	-	0
		Jagmohanpur	9	0.0468	-	7.1963
		Jagmohanpur-Ii	6	0.1647	-	8.431
		Kaliahata	10	-	0.121	4.5395
		Khuntapada	5	-	-	0
		Padang	10	-	0.0575	5.1546
		Patakhali	2	-	-	0
		Pitanali	5		-	0
		Telkoi	**10**	**0.1014**		**7.4993**

Table 5.6: Decadal trend in the post-monsoon depth to water levels in the Keonjhar district

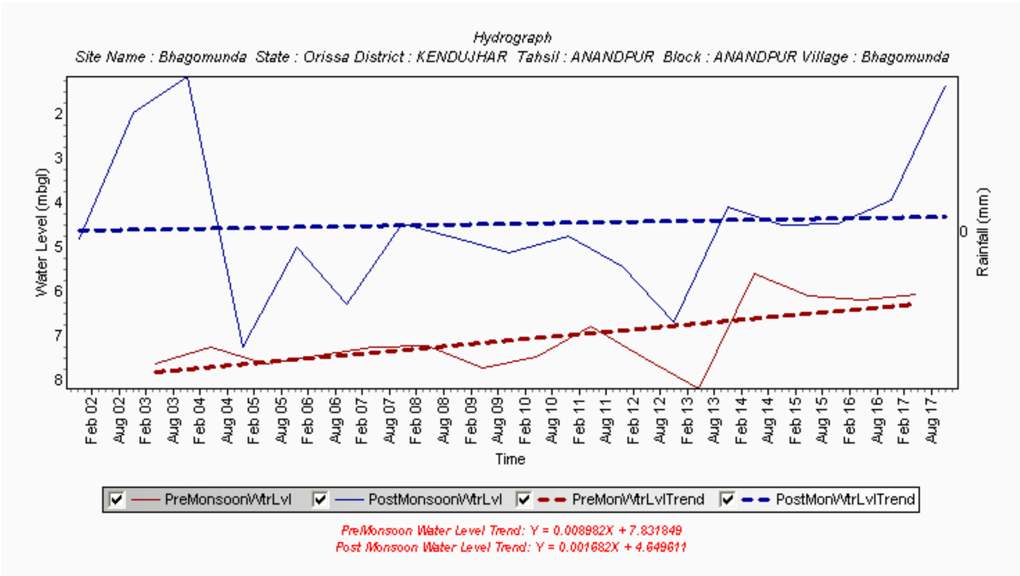
SL No	***Name of Blok***	***Loation of well***	***No. of data points***	***Rise (m/yr)***	***Fall (m/yr)***	***Intercept***
1	Anandapur	Anandapur	2	-	-	0
		Balduan-I	6	0.0896	-	3.7452
		Belbahali	3	-	-	0
		Bhagomunda	10	0.3624	-	6.2739
		Dhokuta	5	-	-	0
		Nuagaon	5	-	-	0
2	Banspal	Banspal	4	-	-	0
		Banspal-Ii	7	0.3909	-	8.6703
		Baradevata	6	-	0.7141	-0.2044
		Baraguda	0	-	-	0
		Kanjipani	9	0.143	-	4.1546
		Suakati	10	0.0692	-	3.8867
		Tarmakant	1	-	-	0
3	Champua	Belaipada	5	-	-	0
		Champua 1	10	0.1772	-	5.4977
		Jaymangalpur	10	-	0.0344	2.2861
		Jodipada	6	0.0391	-	3.1231
		Karanjia	1	-	-	0
		Parsora	9	0.3745	-	4.5547

		Sasang	6	-	0.1346	1.3812
4	Ghasipura	Balarampur	6	-	0.0451	2.2425
		Barpada	10	-	0.0058	1.7995
		Ghasipur	10	0.0552	-	7.189
		Ghasipura	1	-	-	0
		Birgovindpur	10	0.0823	-	4.9932
		Deogan1	10	-	0.0746	2.8298
		Ghasipura pz	5	-	-	0
		Kesudapal-Ii	3	-	-	0
		Kesurdapal	10	-	0.0675	1.3331
		Ramchandrapur	5	-	-	0
		Sainkula	6	0.7035	-	8.2255
5	Ghatgaon	Baxibarigan	10	-	0.0145	3.3793
		Dhangadiha	10	0.0477	-	4.2021
		Dhenkikot	4	-	-	0
		Dhenkikote	5	-	-	0
		Dhenkikot-Ii	2	-	-	0
		Gadadharpur	6	0.1166	-	4.328
		Ghatgaon	9	-	0.1	2.374
		Ghatgaon-I	4	-	-	0
		Ghatgaon-Ii	2	-	-	0
		Janghira	9	0.3137	-	5.2874
		Melana	5	-	-	0
		Patilo	6	-	0.1524	2.3708
		Pipilia	0	-	-	0
		Pipilia1	4	-	-	0
		Rajpat	3	-	-	0
6	Harichandanpur	Baxibargaon	7	0.0336	-	3.3707
		Harichandanpur	9	-	0.1636	1.0273
		Harichandanpur-Ii	5	-	-	0
		Jhangira	6	-	0.0943	2.2843
		Sonapent	8	-	0.4833	0.1348
7	Hatadihi	Anandapur	7	0.7899	-	9.7362
		Bidyadharpur	5	-	-	0
		Mathadai	10	0.0402	-	1.4811
		Mathadai-Ii	6	-	0.0664	0.5365
		Nuasahi	9	-	0.0683	1.1391
8	Jhumpura	Badaposhi	6	-	0.0712	1.5613
		Jhumpura	10	-	0.1752	0.473
		Jhumpura-Ii	7	0.0152	-	2.5458
		Karanjia 1	7	0.2998	-	4.5789
		Katalaposhi	6	0.0991	-	2.9613
		Ukhunda	0	-	-	0
		Ukunta	10	-	0.095	2.066
9	Joda	Barbil	8	-	0.0055	4.078
		Bhadrasahi	10	-	0.2955	2.3675
		Bolani	0	-	-	0
		Guali	4	-	-	0
		Joda	9	0.2193	-	5.833
		Nalda2	3	-	-	0
		Rugudi	9	0.1302	-	5.1258
		Rugudi 1	3	-	-	0

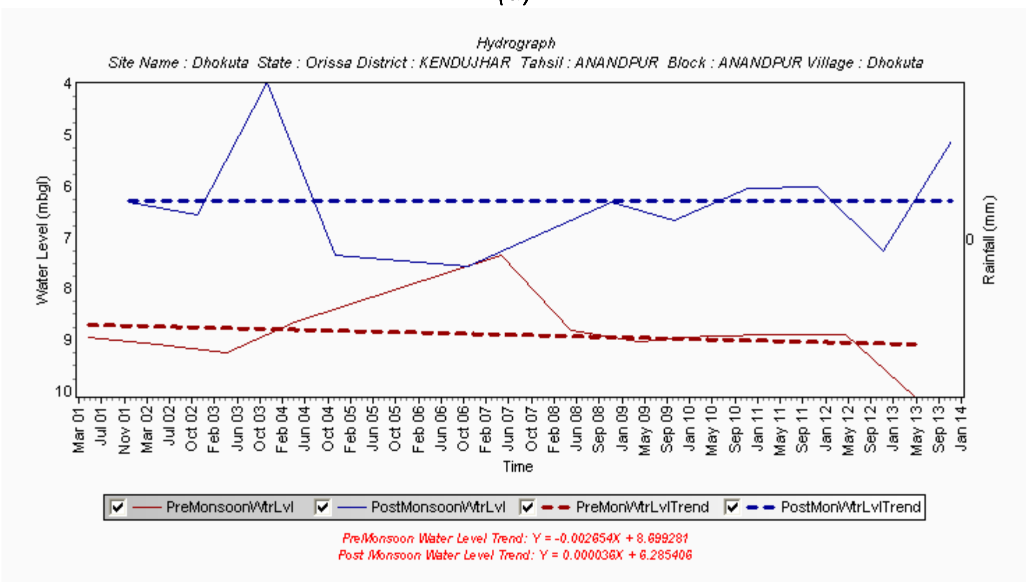
10	Keonjhar	Brahmandgram	3	-	-	0
		Gopalpur2	10	-	0.047	1.9405
		Haridagot	10	-	0.1657	1.4358
		Jhadbelda 1	3	-	-	0
		Keonjhar	0	-	-	0
		Keonjhar Sadar	4	-	-	0
		Keonjhargarh	10	0.1344	-	4.9713
		Keonjhar-Ii Old Town	2	-	-	0
		Muktapur	4	-	-	0
		Naranpur	5	-	-	0
		Padampur2	10	0.3503	-	7.4173
		Padampur-Ii	7	0.561	-	7.4376
		Palasponga	8	0.3441	-	4.6896
11	Patna	Balaniposi	6	0.2208	-	4.4537
		Burikapuri	9	0.0277	-	3.5653
		Kendeiposhi	10	-	0.0741	2.5073
		Khiritangiri	10	0.1638	-	4.5437
		Khiritangiri-Ii	3	-	-	0
		Kothaghar	10	-	0.2035	0.7516
		Malliposi	10	-	0.034	2.4511
		Swampatna-Ii	6	-	0.0974	3.0013
		Tangarpada	6	-	0.0969	1.4555
		Turmunga	10	-	0.0041	2.4716
12	Saharpada	Badbil	6	-	0.2399	1.7904
		Gajitangri	6	0.0876	-	4.1537
		Saharapada	0	-	-	0
		Saharpara	8	0.4585	-	6.1628
		Swampatna	10	-	0.0927	2.1792
		Udaipur	7	0.0757	-	3.8557
		Udaipur-Ii	7	0.1541	-	4.9682
13	Telkoi	Akul	6	-	0.3413	-0.8453
		Balijhodi	4	-	-	0
		Benamunda	4	-	-	0
		Bimala	10	-	0.077	2.9949
		Gonasika	4	-	-	0
		Jagmohanpur	7	0.3633	-	5.729
		Jagmohanpur-Ii	6	0.4035	-	6.5071
		Kaliahata	9	-	0.1372	2.5853
		Khuntapada	5	-	-	0
		Padang	10	-	0.0779	2.9707
		Patakhali	6	-	0.0442	2.0899
		Pitanali	5	-	-	0
		Telkoi	**10**	**-**	**0.0119**	**4.3045**

5.5 Hydrograph analysis

The hydrographs of 38 groundwater monitoring stations from the 13 blocks under NAQUIM in Keonjhar district were analysed for the period from 2001 to 2018 (Fig 5.4-5.16). In short term and long term, the water levels vary depending on the rate of natural recharge from rainfall and the groundwater withdrawal to meet the requirements in domestic, agriculture and industry. The analysis of hydrographs shows that the annual rising limbs in hydrographs indicate the natural recharge of groundwater regime due to monsoon rainfall, as the monsoon rainfall is the only source of water. The recession limbs indicate the combined effect of baseflow and the groundwater draft for various uses. Though, the hydrographs a few locations during either/or both the pre- and post-monsoon periods exhibit rising trends in water levels, at several locations they show downward declining trend. It indicates that the groundwater resources are not replenished or recharged fully and the groundwater levels are under continuous stress and depleting at several locations. It has also been observed that there were few years when the recharge exceeded draft for a particular period or year but in the next successive year, the draft again exceeded recharge.

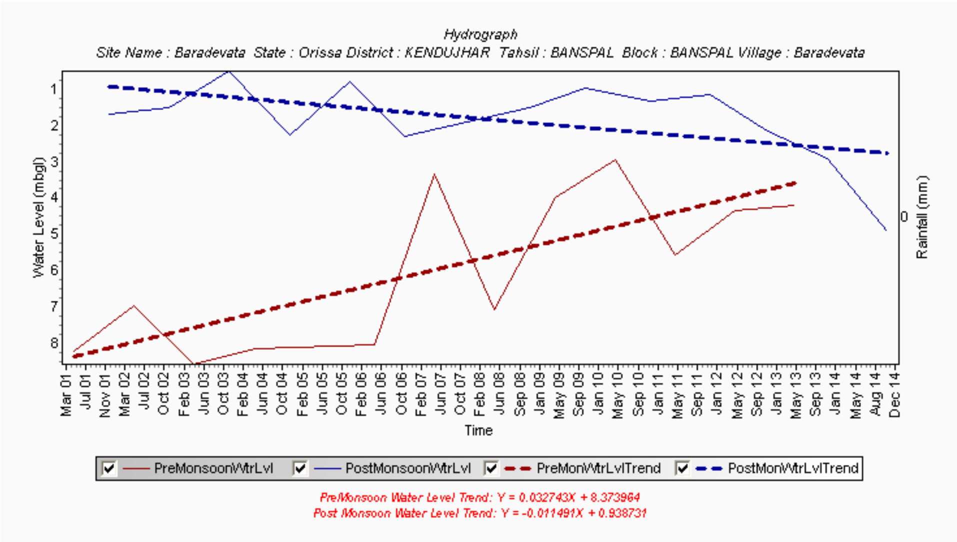


(a)

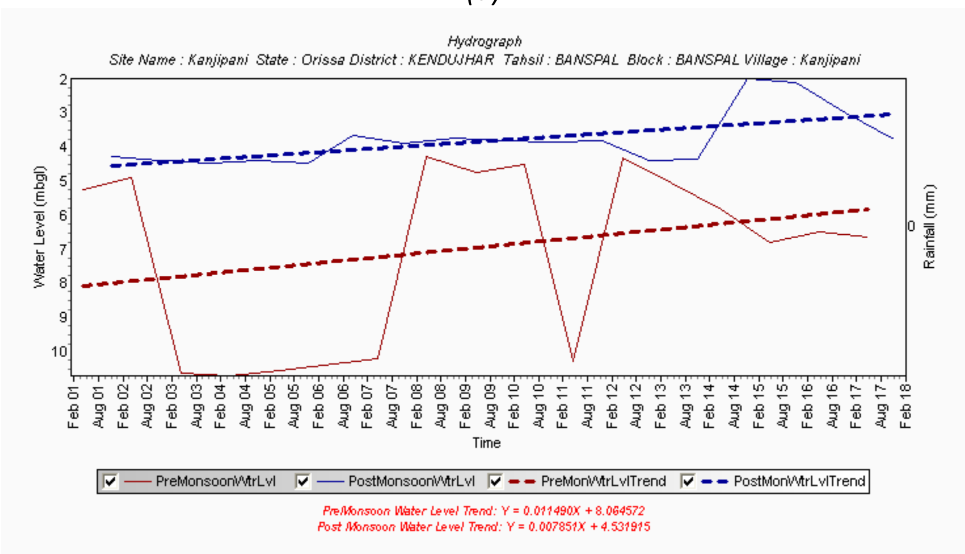


(b)

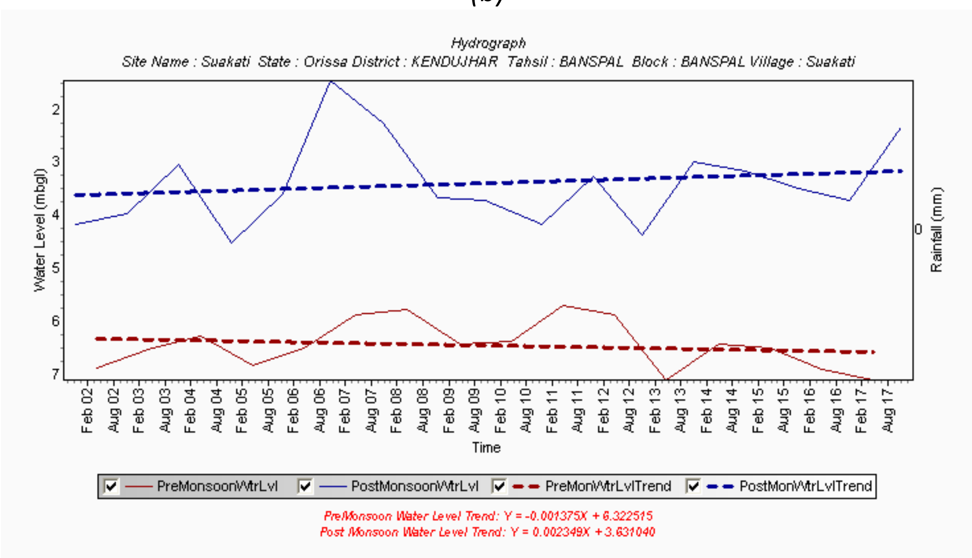
Figure 5.4: Hydrographs of (a) Bhogamunda, and (b) Dhakota, Anandapur block, Keonjhar district



(a)



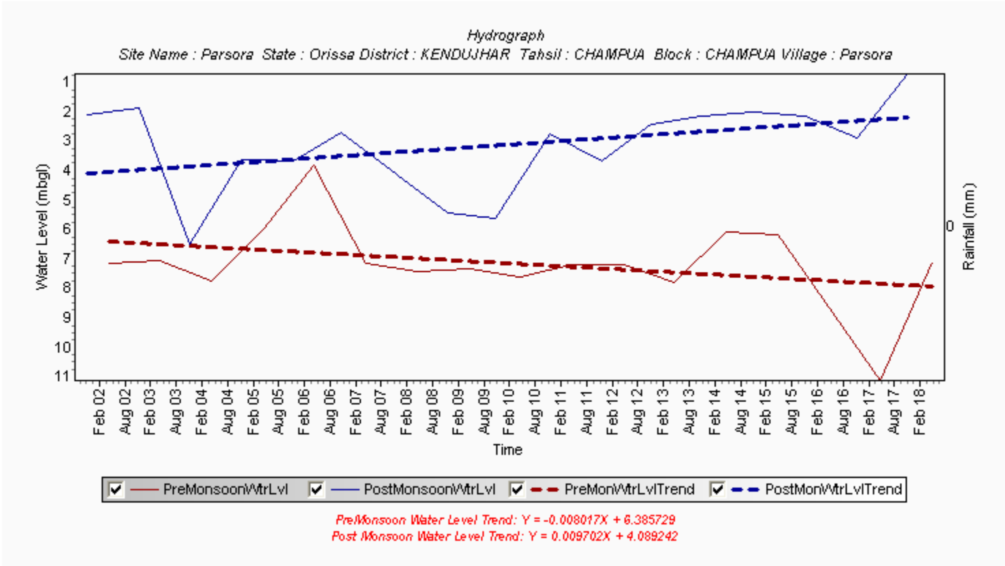
(b)



(c)

Figure 5.5: Hydrographs of (a) Baradevata, (b) Kanjipani, and (c) Suakati, Banspal block

(a)



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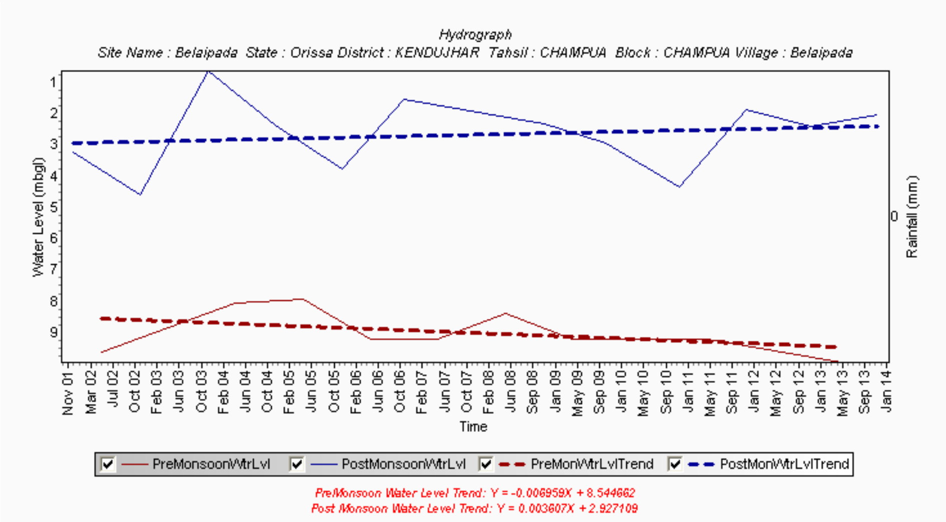


(c)

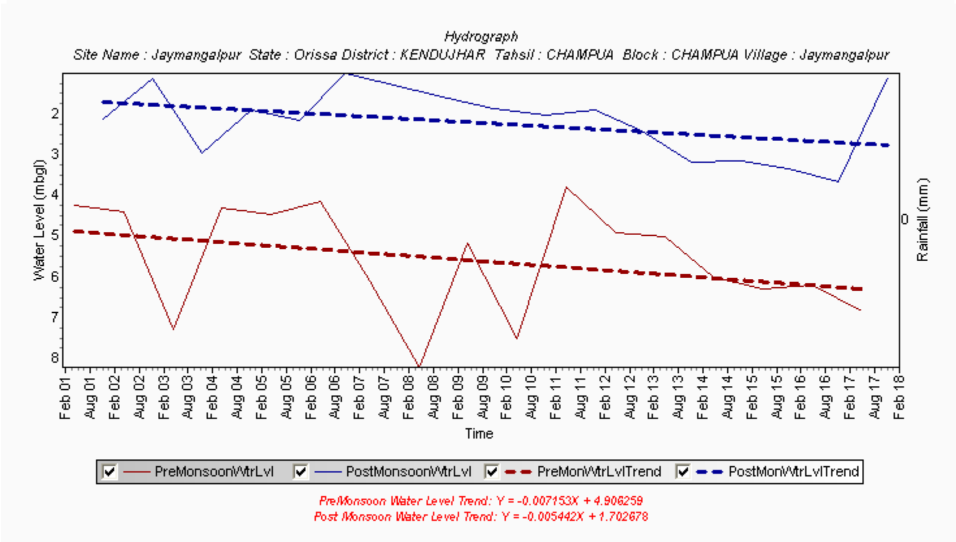
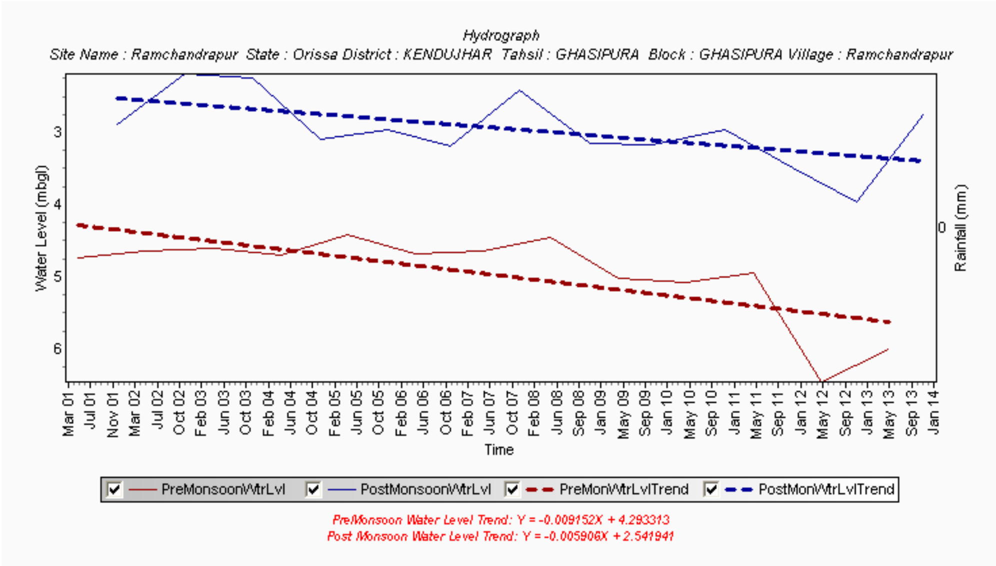


Figure 5.6: Hydrographs of (a) Parsora, (b)Beleipada, and (c) Jaymangalpur, Champua block

(a)



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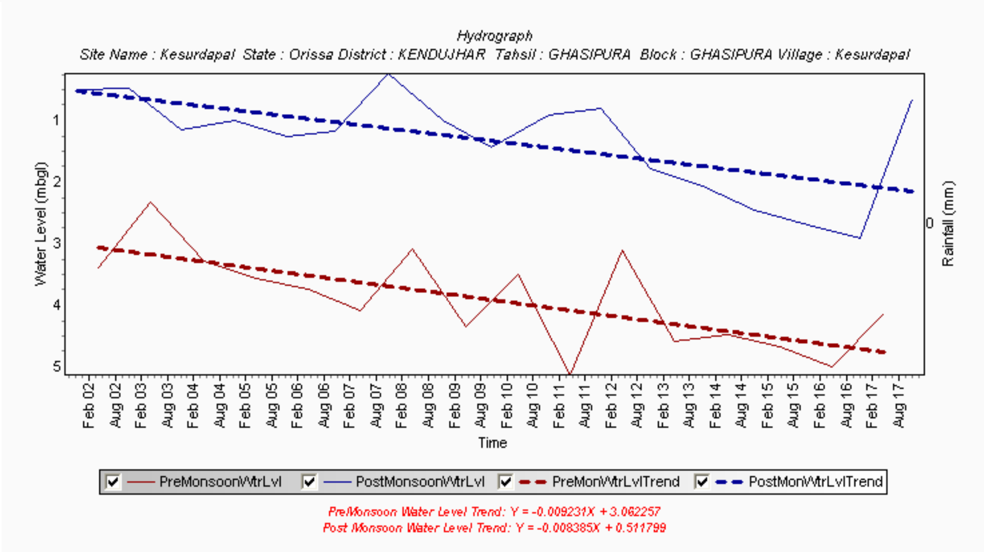

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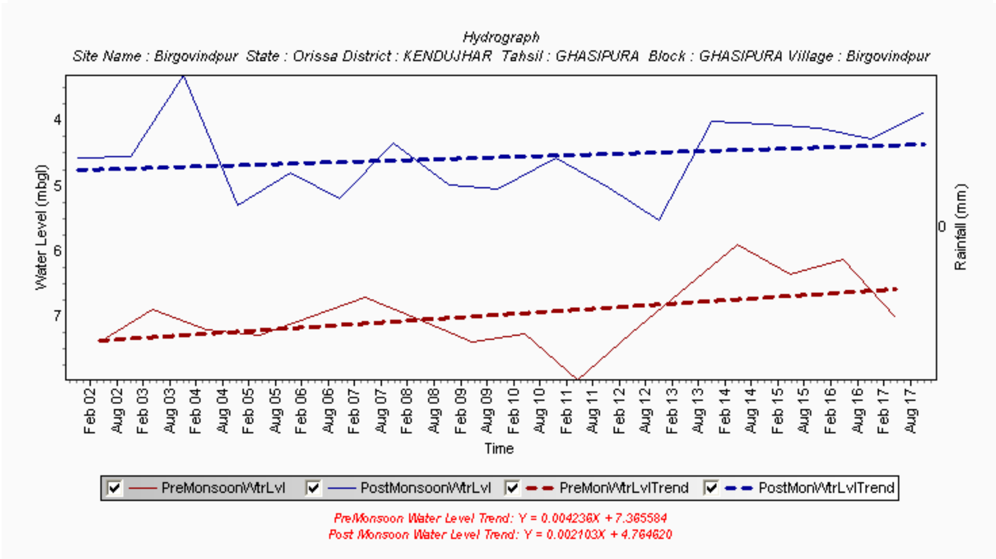
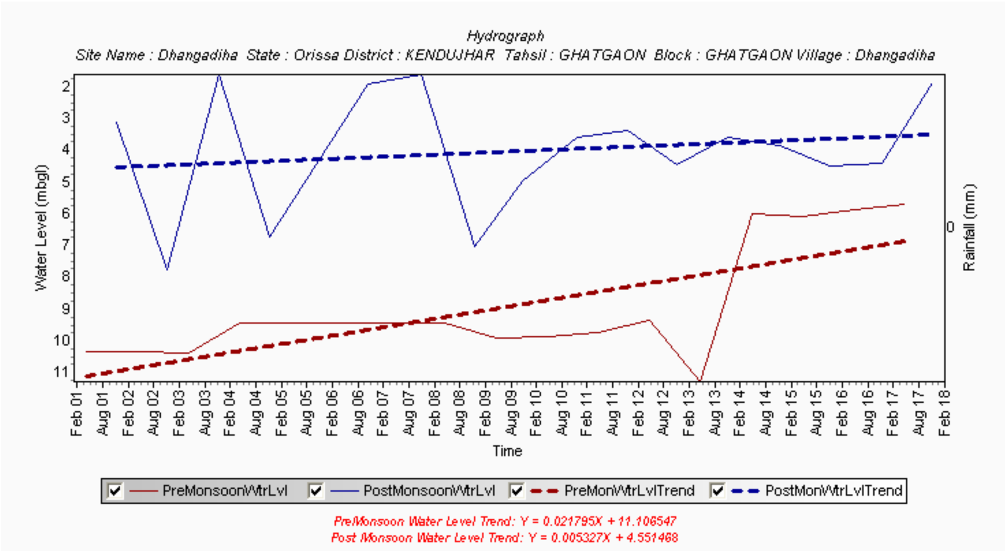


Figure 5.7: Hydrographs of (a) Ramachndrapur, (b)Kesdurapal, and (c) Birgovindpur, Ghasipura block

(a)



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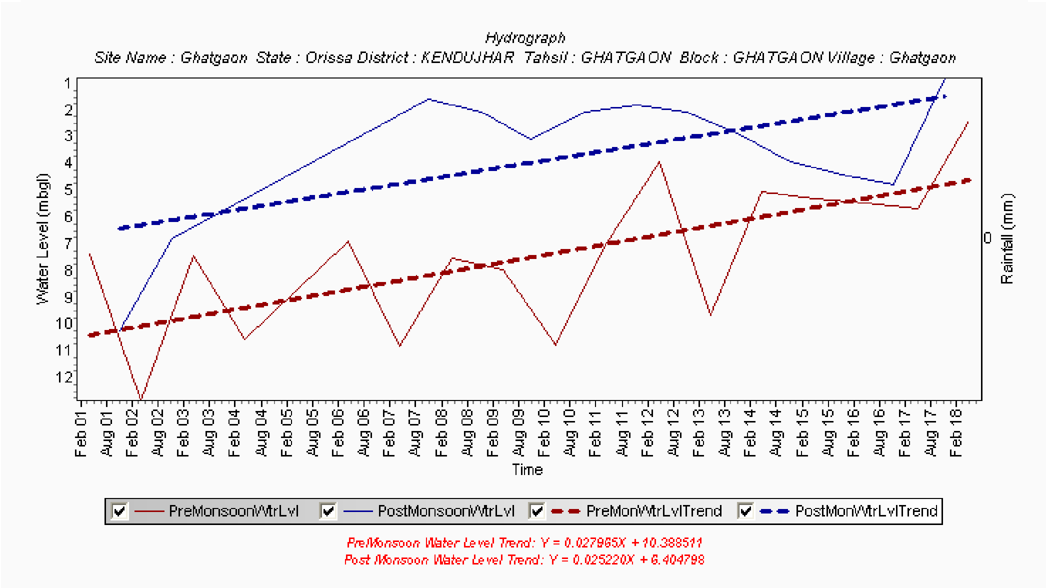

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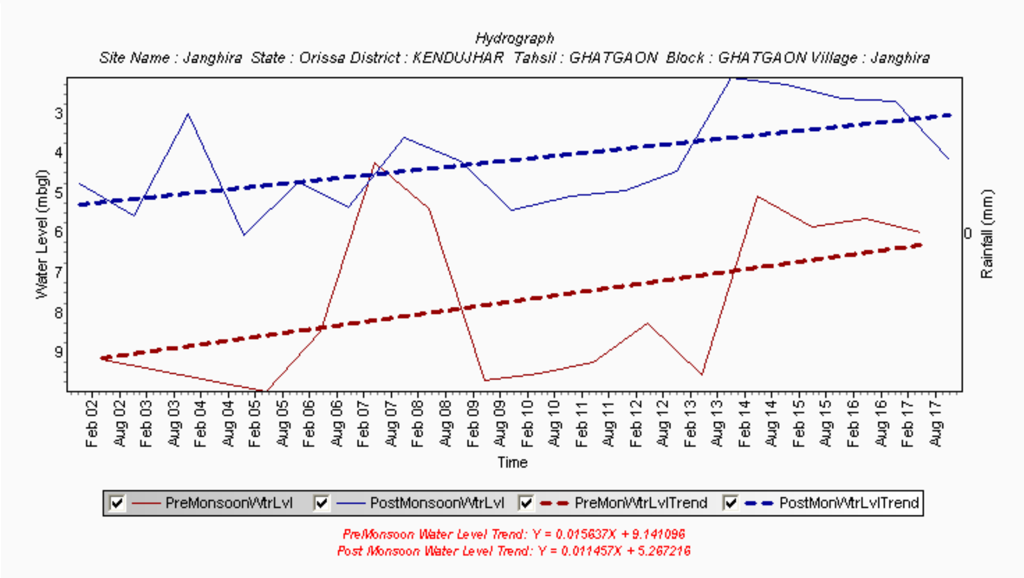
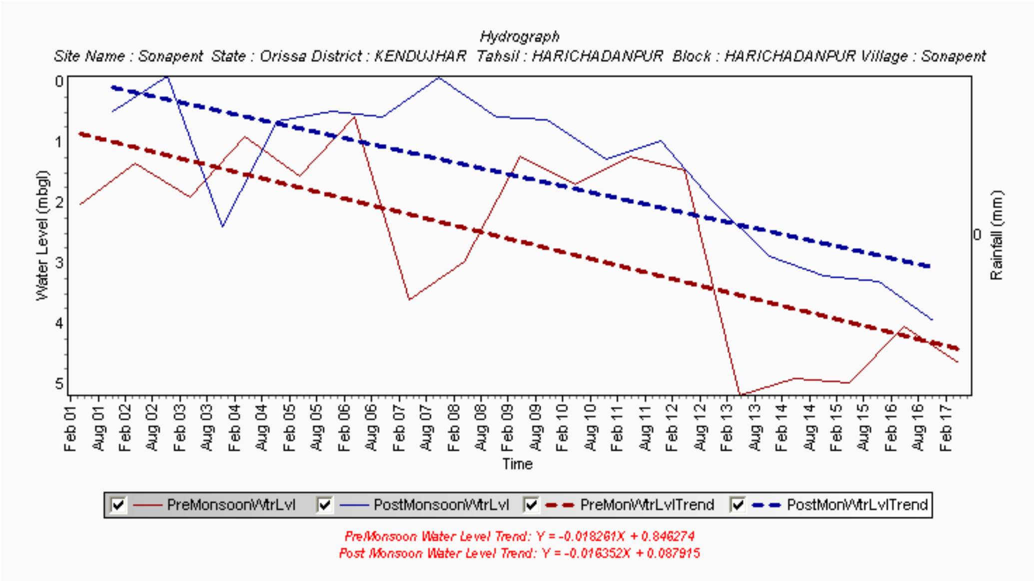
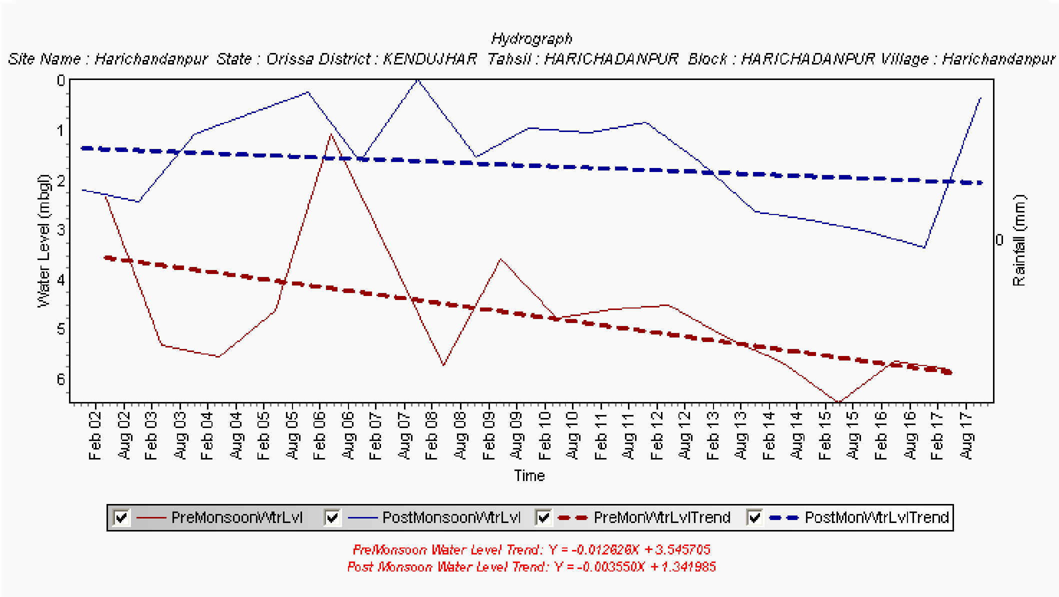


Figure 5.8: Hydrographs of (a) Dhangadiha, (b)Ghatgaon, and (c) Janghira, Ghatgaon block

(a)



(b)



(c)

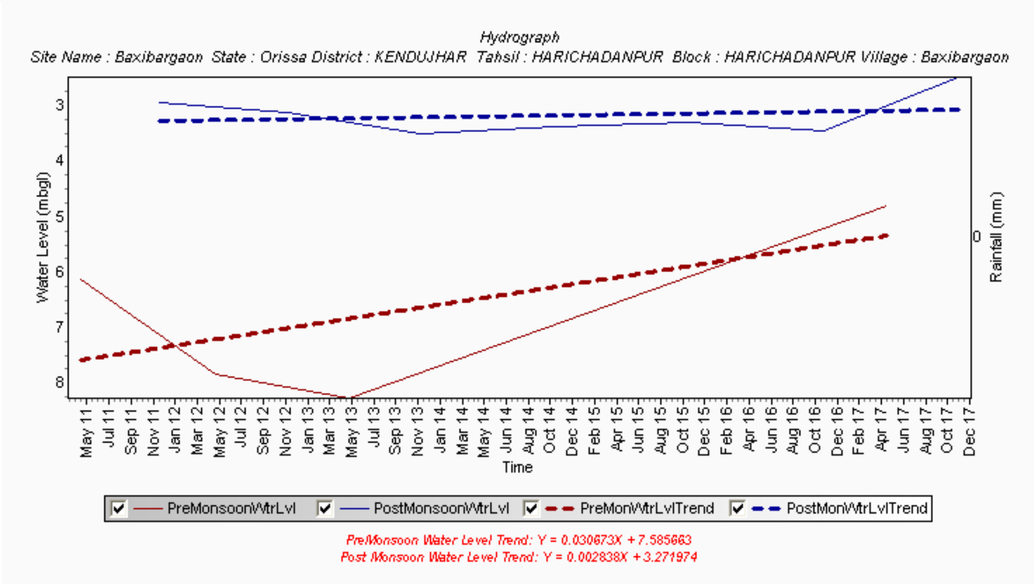
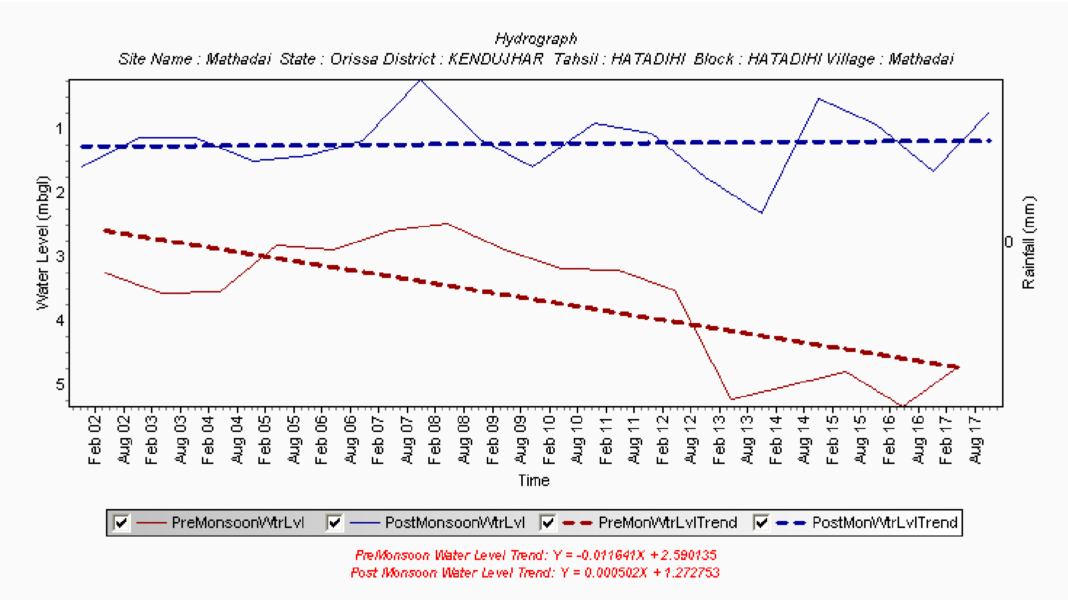
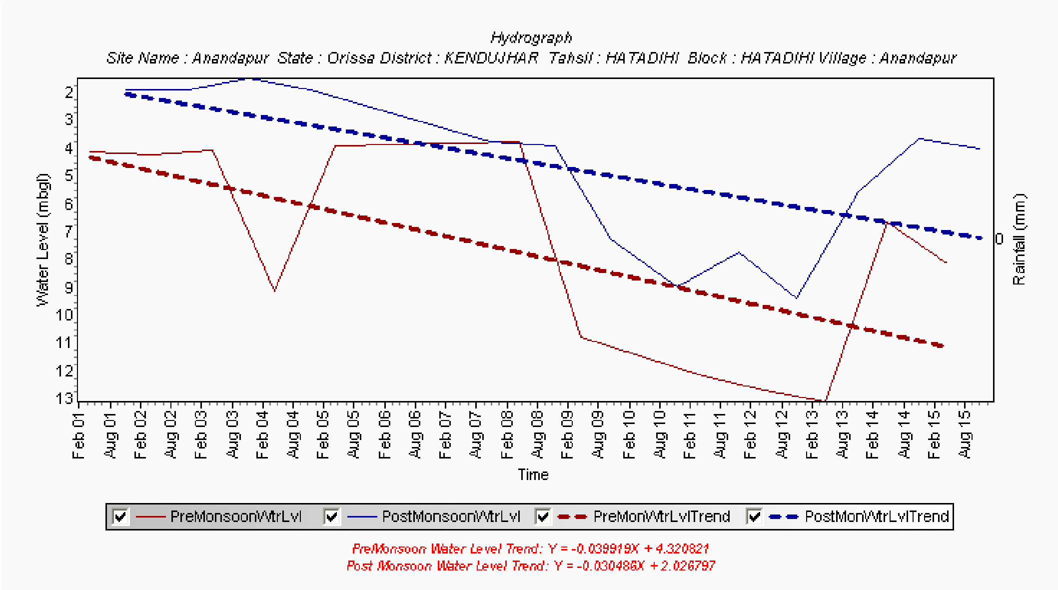


Figure 5.9: Hydrographs of (a) Sonapent, (b)Harichandanpur, and (c) Baxibarigaon, Harichndanpur block

(a)



(b)



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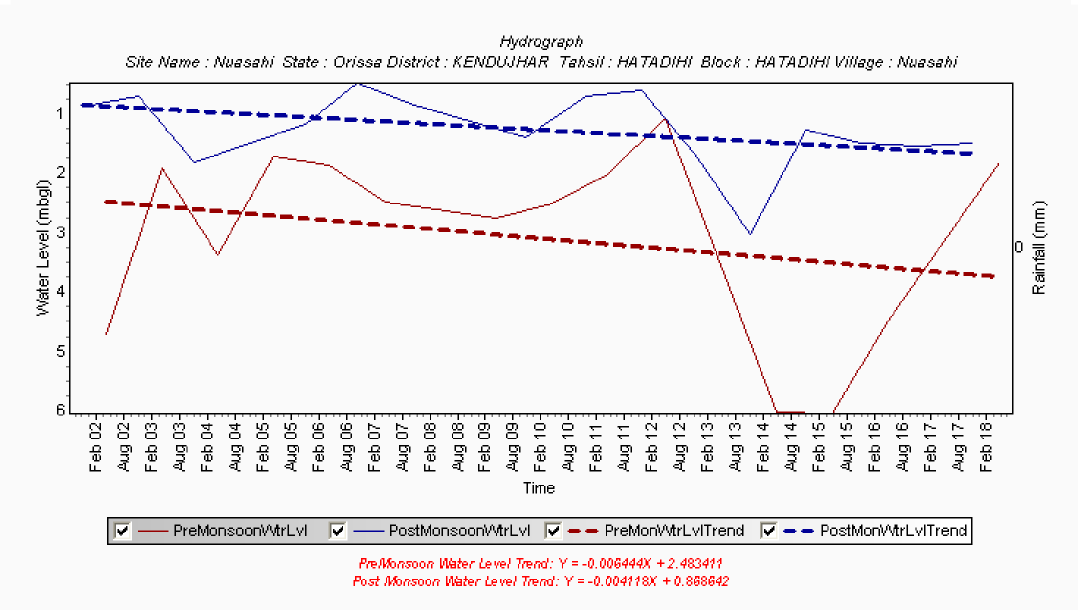
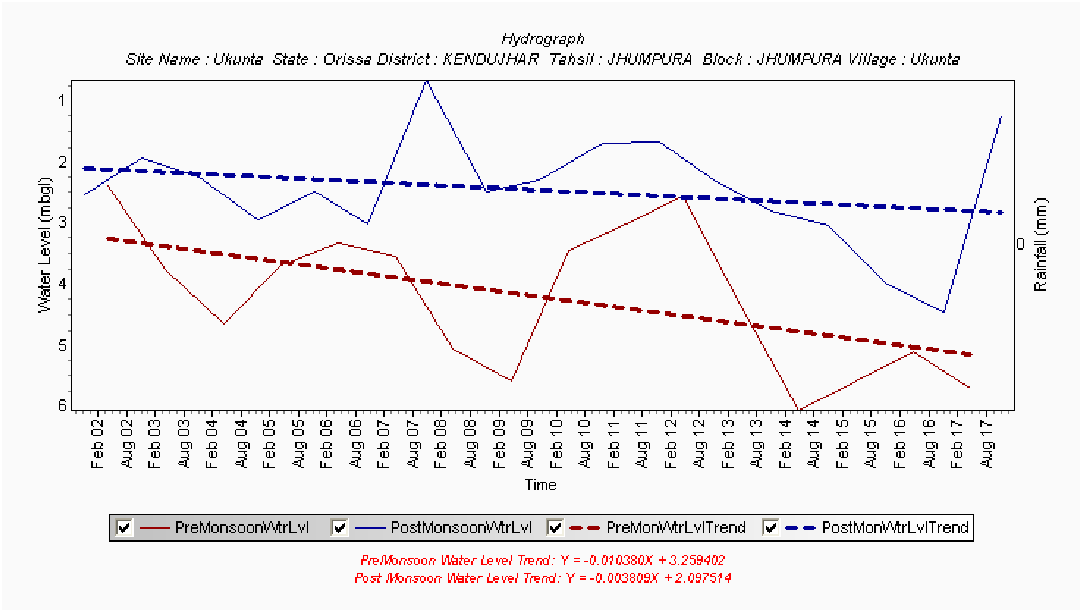


Figure 5.10: Hydrographs of (a) Mathadai, (b) Anandapur, and (c) Nuasahi, Hatadihi block

(a)



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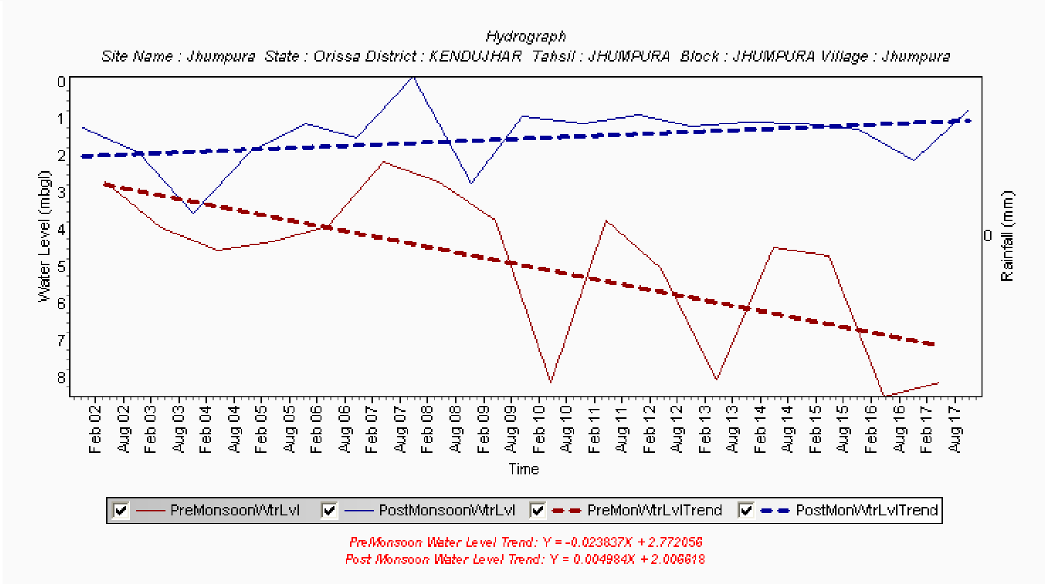

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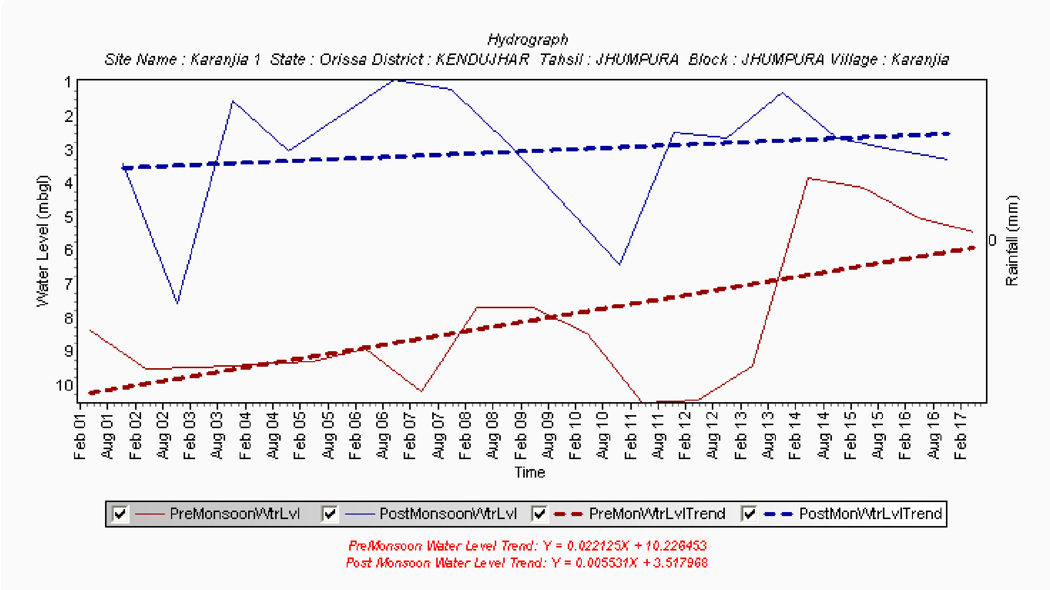
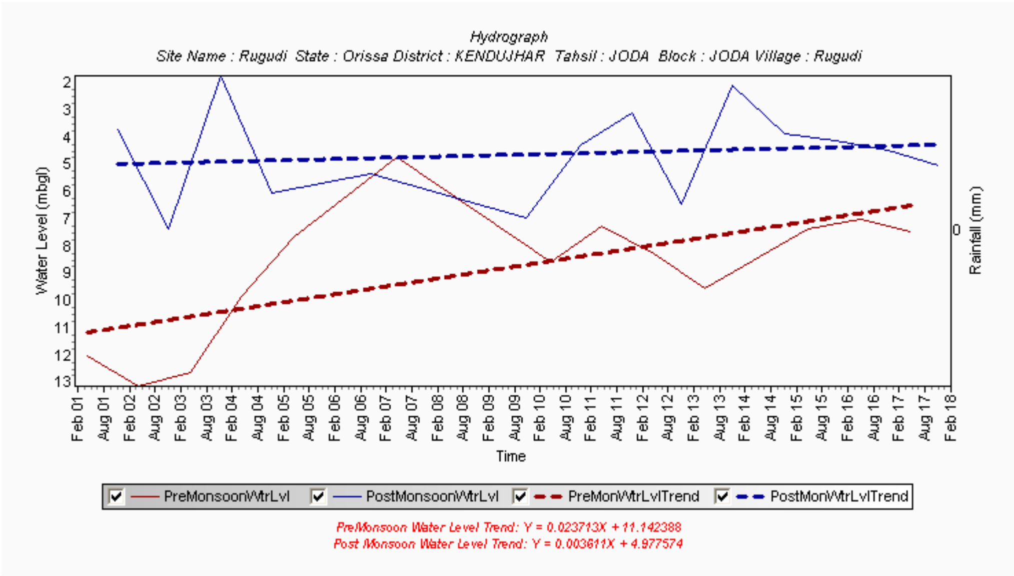


Figure 5.11: Hydrographs of (a) Ukhunda, (b)Jhumpura, and (c) Karanjia, Jhumpura block

(a)



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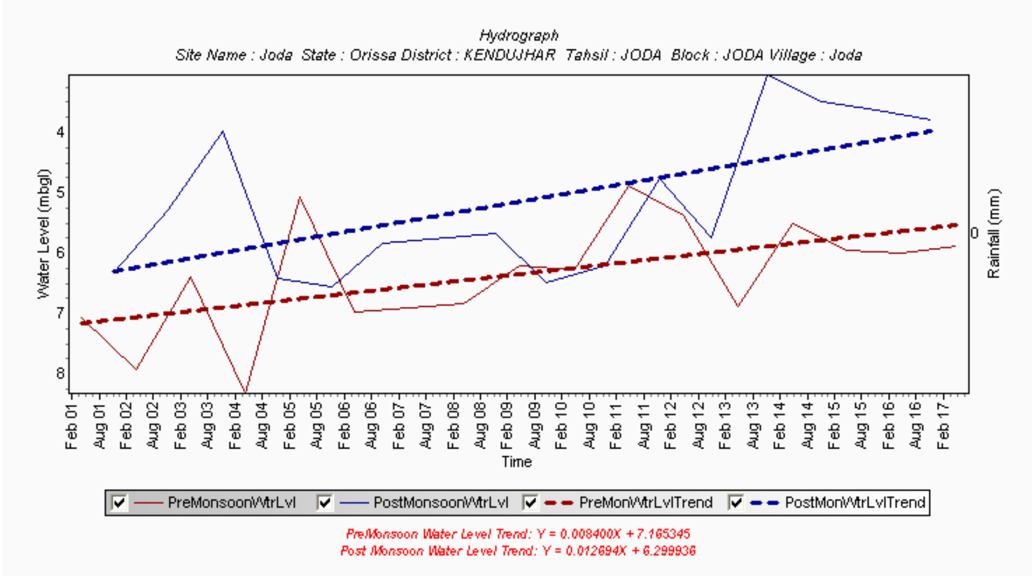

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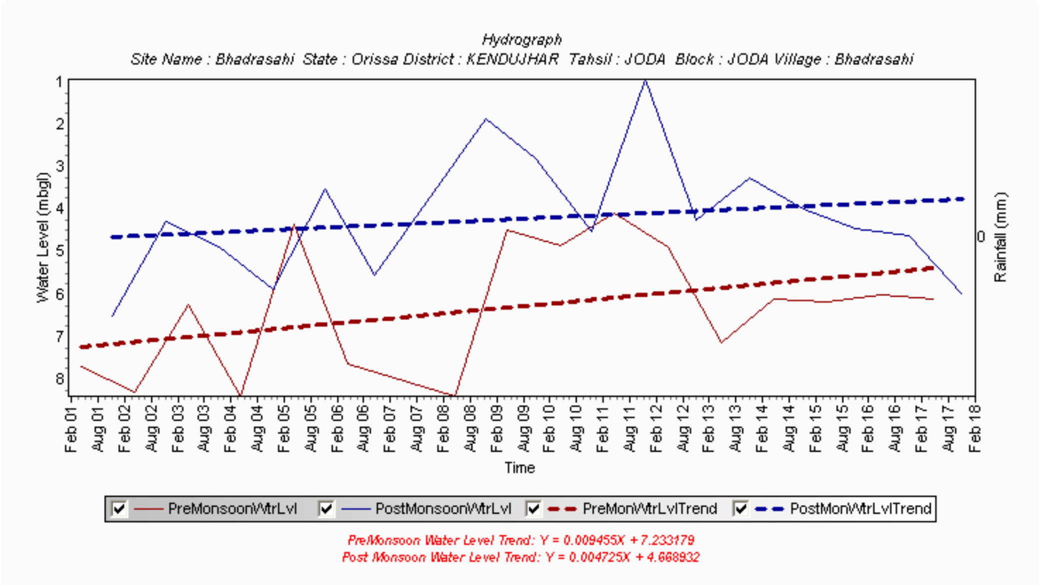


Figure 5.12: Hydrographs of (a) Rugudi, (b) Joda, and (c) Bhadrasahi, Joda block

(a)

(b)

(c)

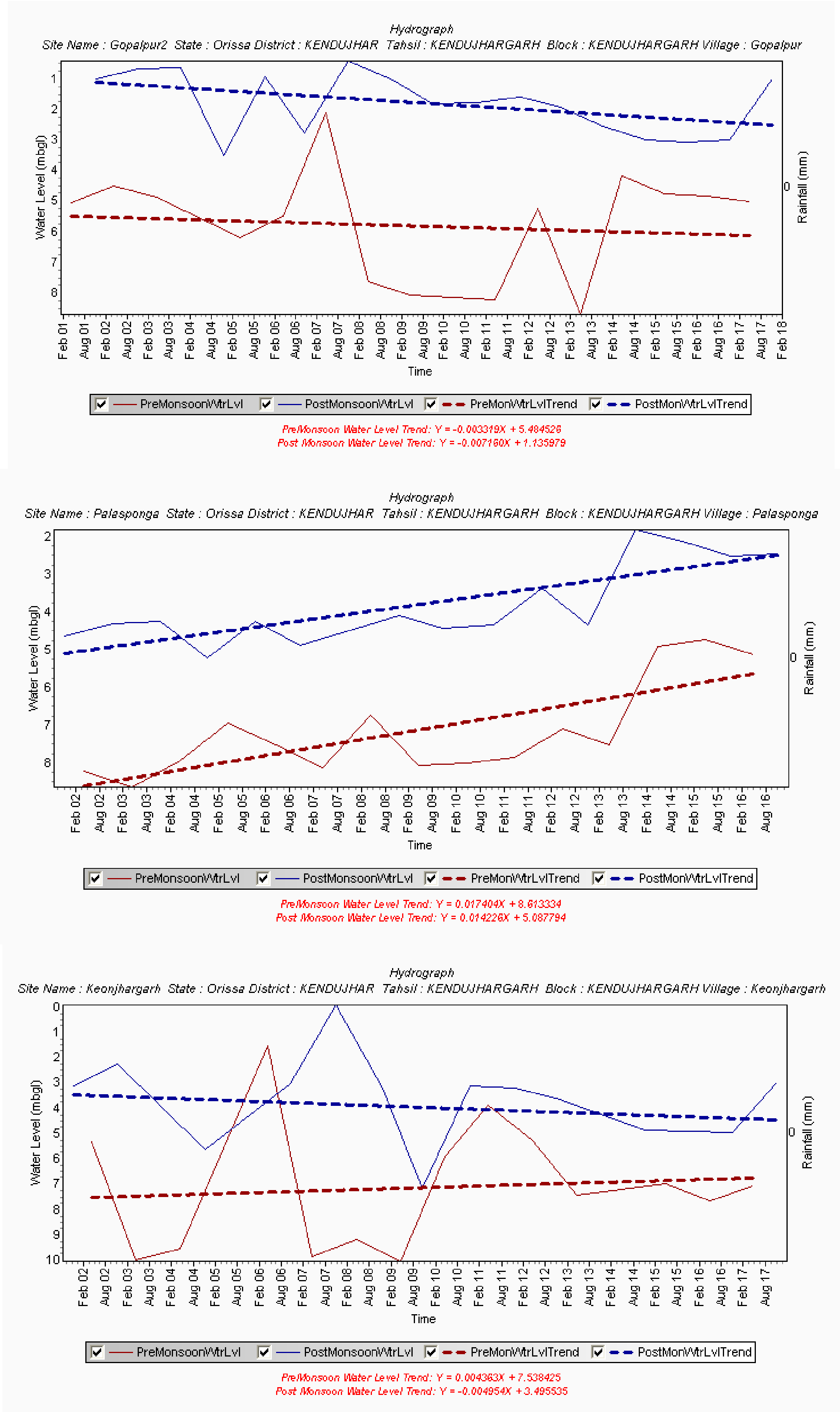


Figure 5.13: Hydrographs of (a) Gopalpur, (b) Polasponga, and (c) Keonjhargarh, Keonjhar block

(a)

(b)

(c)

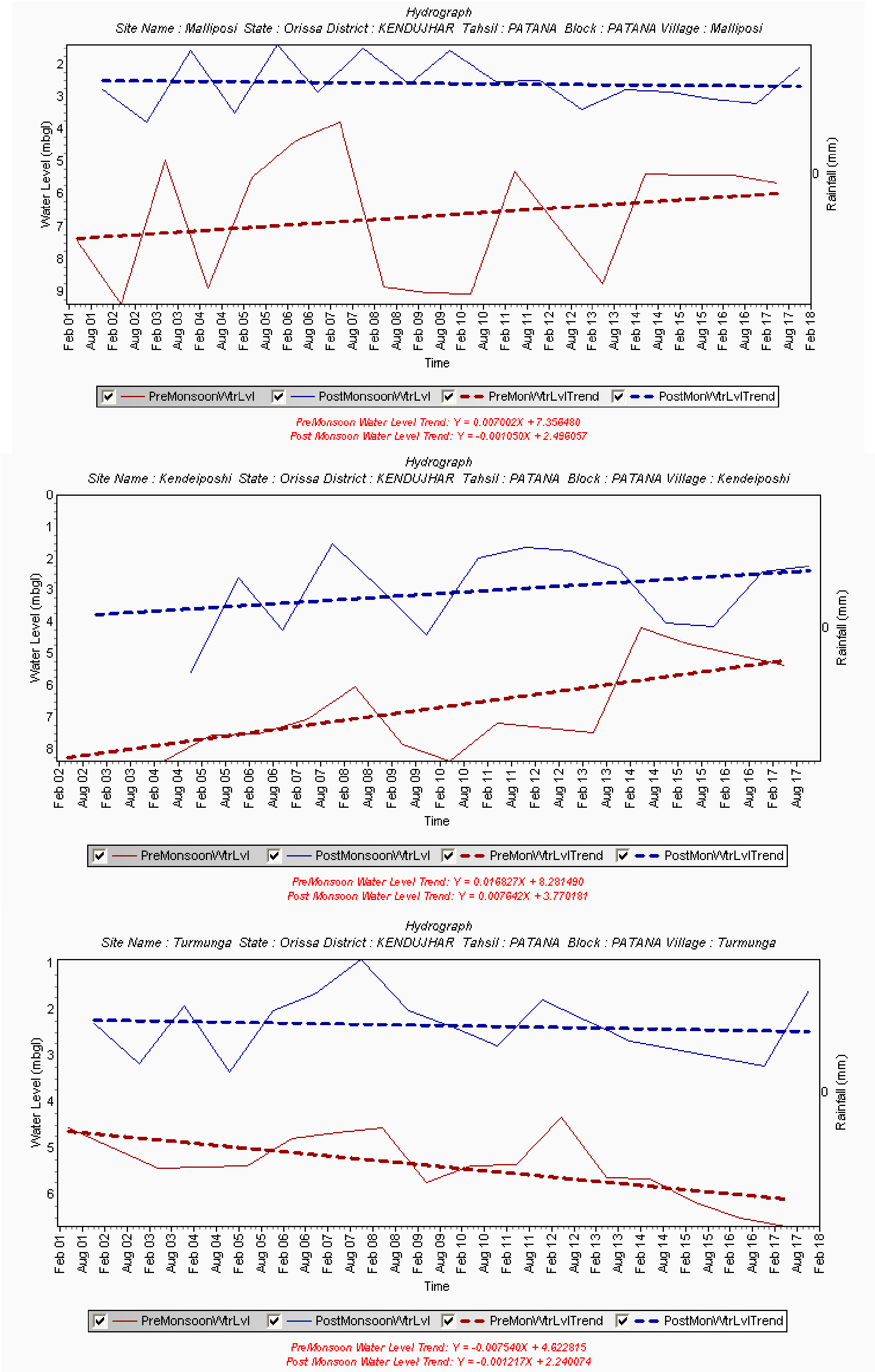


Figure 5.14: Hydrographs of (a) Mallioposi, (b) Kendeiposi, and (c) Turumunga, Patna block

(a)

(b)

(c)

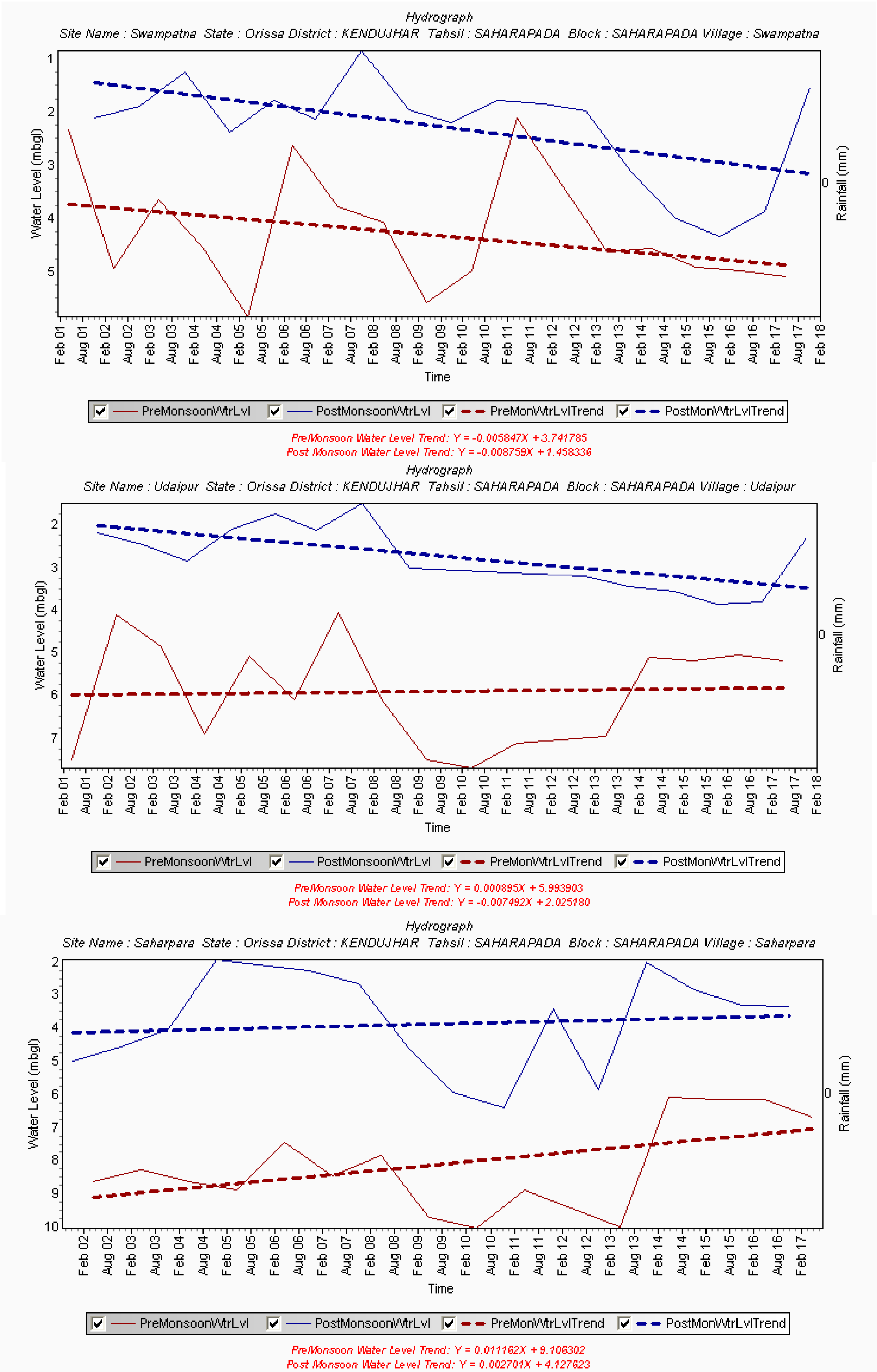


Figure 5.15: Hydrographs of (a) Swampatna, (b) Udaipur, and (c) Saharpada, Saharpada block

(a) *(b)* *(c)*

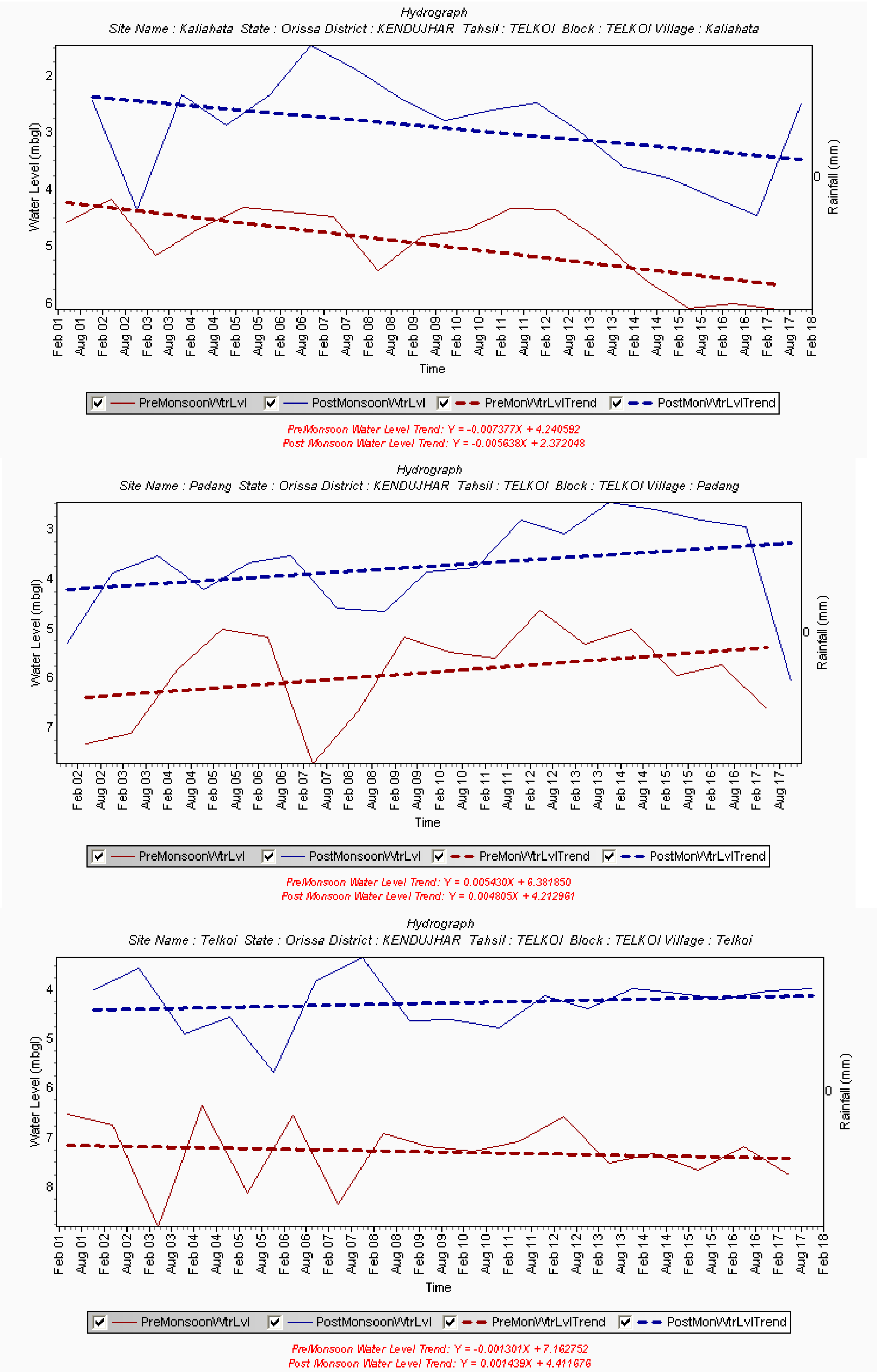


Figure 5.16: Hydrographs of (a) Kaliahatta, (b) Padang, and (c) Telkoi, Telkoi block

5.6 Depth to water levels in deeper aquifer

There are 14 piezometers in the Keonjhar district which are also measured during the monitoring of hydrograph stations. The piezometers tap the fractures within the depth range of 30-50 m bgl. The depths to water levels measured in the piezometers are given in Table 5.7. The water during the both the seasons of pre- and post-monsoon are very much similar to those observed in the shallow dug wells. During the pre-monsoon period the water levels varied in the range of 4.66 – 7.29 m bgl, whereas those in the post-monsoon period ranged between 1.96 – 5.01 m bgl.

Table 5.7: Depth to water levels in the piezometers tapping the deeper fracture aquifers in Keonjhar district.

Sl. No	Block name	Village name	Long.	Lat.	DTW_Pre (m bgl)	DTW_Post (m bgl)
1	Ghasipura	Balduan-	86.188	21.209	5.93	2.1
2	Hatadihi	Banspal	85.418	21.619	7.29	3.75
3	Harichadanpur	Baxibargaon	85.650	21.500	5.22	1.96
4	Harichadanpur	Bidyadharpur	86.279	21.250	6.09	3.15
5	Harichadanpur	Ghatgaon	85.982	21.394	5.05	3.45
6	Telkoi	Harichandanpur	85.790	21.346	5.82	2.18
7	Anandapur	Jagmohanpur	85.335	21.435	7.00	2.58
8	Ghatgaon	Jhangira	85.626	21.435	6.08	2.01
9	Saharapada	Jhumpura	85.567	21.828	7.29	2.36
10	Banspal	Padampur	85.588	21.764	7.13	3.90
11	Patana	Sainkula	86.131	21.119	7.00	2.42
12	Kendujhargarh	Swampatna	85.653	21.505	4.66	2.48
13	Jhumpura	Udaipur	85.858	21.703	4.85	2.64
14	Ghasipura	Ghasipura	86.108	21.211	6.88	5.01

Other than the regularly monitored piezometers in the district as described above, the water levels in the exploratory wells (EWs) also tell about the hydraulic regimes in the deeper fracture aquifers. It is to be noted that the EWs aree constructed at different periods of time of the year and as such different water levels are recorded. Still, their range of water levels data can indicate a general scenario for comparison with the shallow aquifer water levels. The depth of the bore wells (n=87) varies between 27-203 m bgl with 87% of them exceeding the depth of 100 m bgl. The water levels are recorded between 0.62-18.37 m bgl with the average value of 6.6 m bgl. About 42% and 85% of the bore wells register water levels of <5.0 m and <10.0 m bgl respectively. At a single place (Alati, Ghasipura block) it has been recorded at 0.28 m above ground level (m agl) depicting the auto-flow condition in the well. Thus, the water levels in the deeper fracture aquifers in the district are very similar to those observed in the shallow phreatic aquifer.

PLATE – 5.1

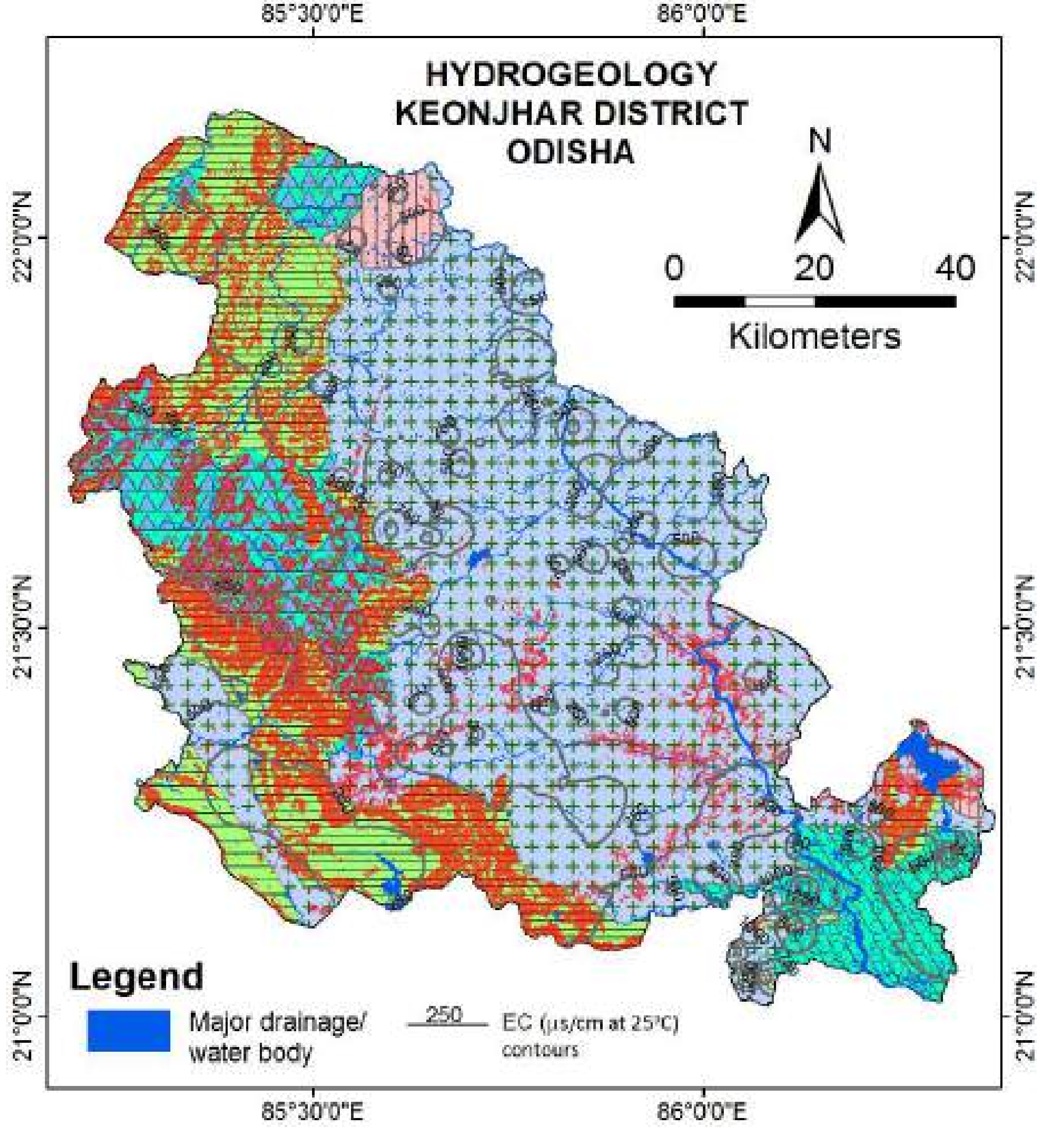

85°30'0"E
86°0'0"E
HYDROGEOLOGY
KEONJHAR DISTRICT
ODISHA
N
0
20
40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Legend
Major drainage/
water body
250
EC (μs/cm at 25°C)
contours

PLATE – 5.1 Contd…

INDEX

	AGE GROUP	LITHOLOGY		HYDROGEOLOGICAL CONDITION		GROUNDWATER POTENTIAL
UNCONSOLIDATED FORMATION	Quaternary	Older Alluvium and Laterite, Silt, Sand, Ferrugenous/Calcareous Concretions, Lithomargic Clay		POROUS FORMATION	Moderately thick and regionally extensive confined/unconfined aquifer down to 50-100m depth	Moderate yield prospects 15-40 lps
CONSOLIDATED FORMATION	Pre-Cambrian	Volcanics, Epidiorites etc.				10-15 or more lps
		Quartzite, Shale, Sandstone, BIF, Limestone & Dolomite		FISSURED FORMATION	Groundwater restricted to weathered residuum fracture zones having secondary porosity	Low to moderate yield 3-10 lps
		Slate, Phyllite, Schist, Gneiss, Marble, intrusive(acid/basic/ultrabasic/ultramafic)				Low Yield 1-5 lps
	Archaean	Granite and Granite Gneiss			Groundwater restricted to weathered residuum fracture zones	Low to moderate yield 3-10 lps

Hilly areas without productive aquifers, yield <1.0 lps

PLATE – 5.2

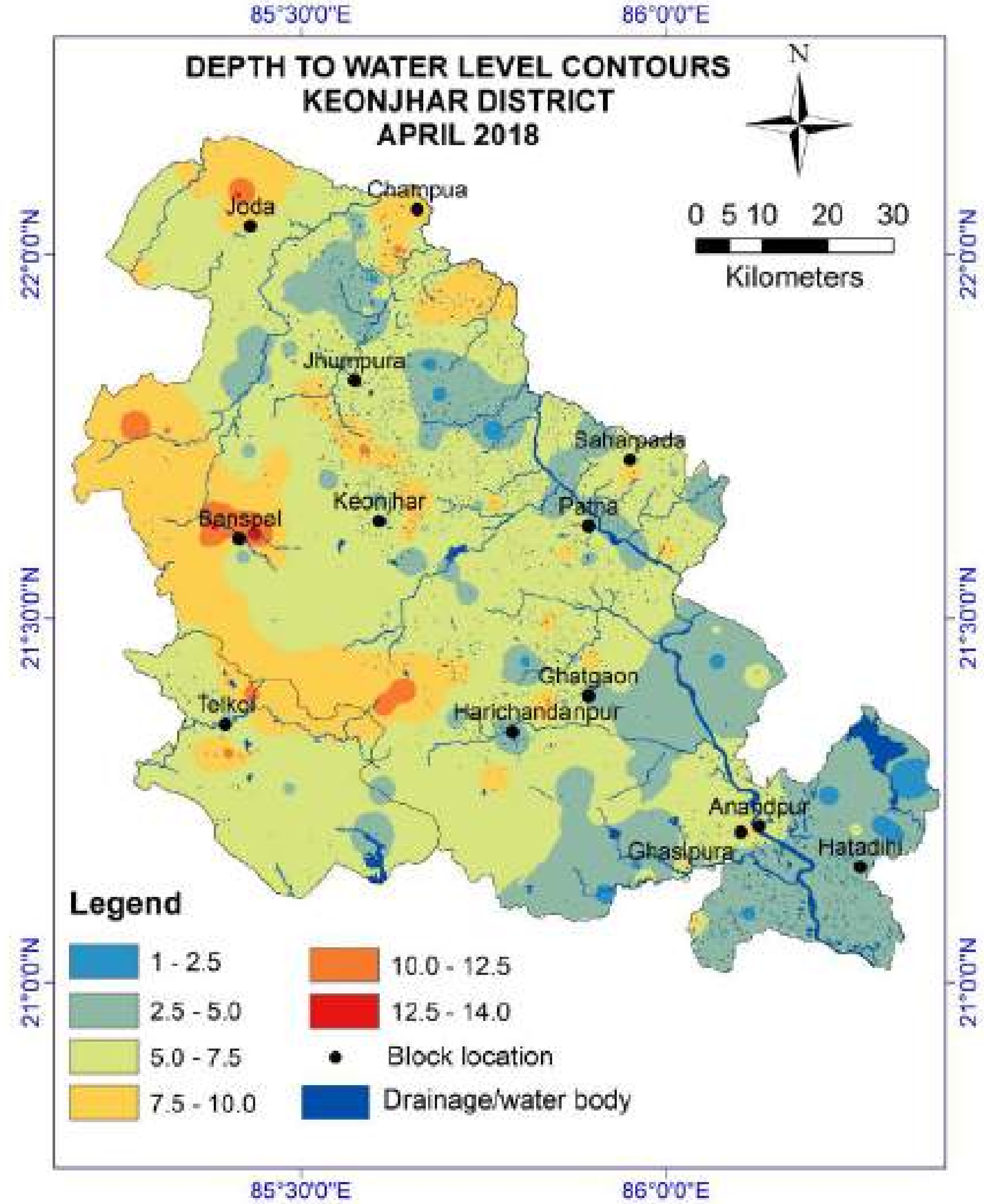
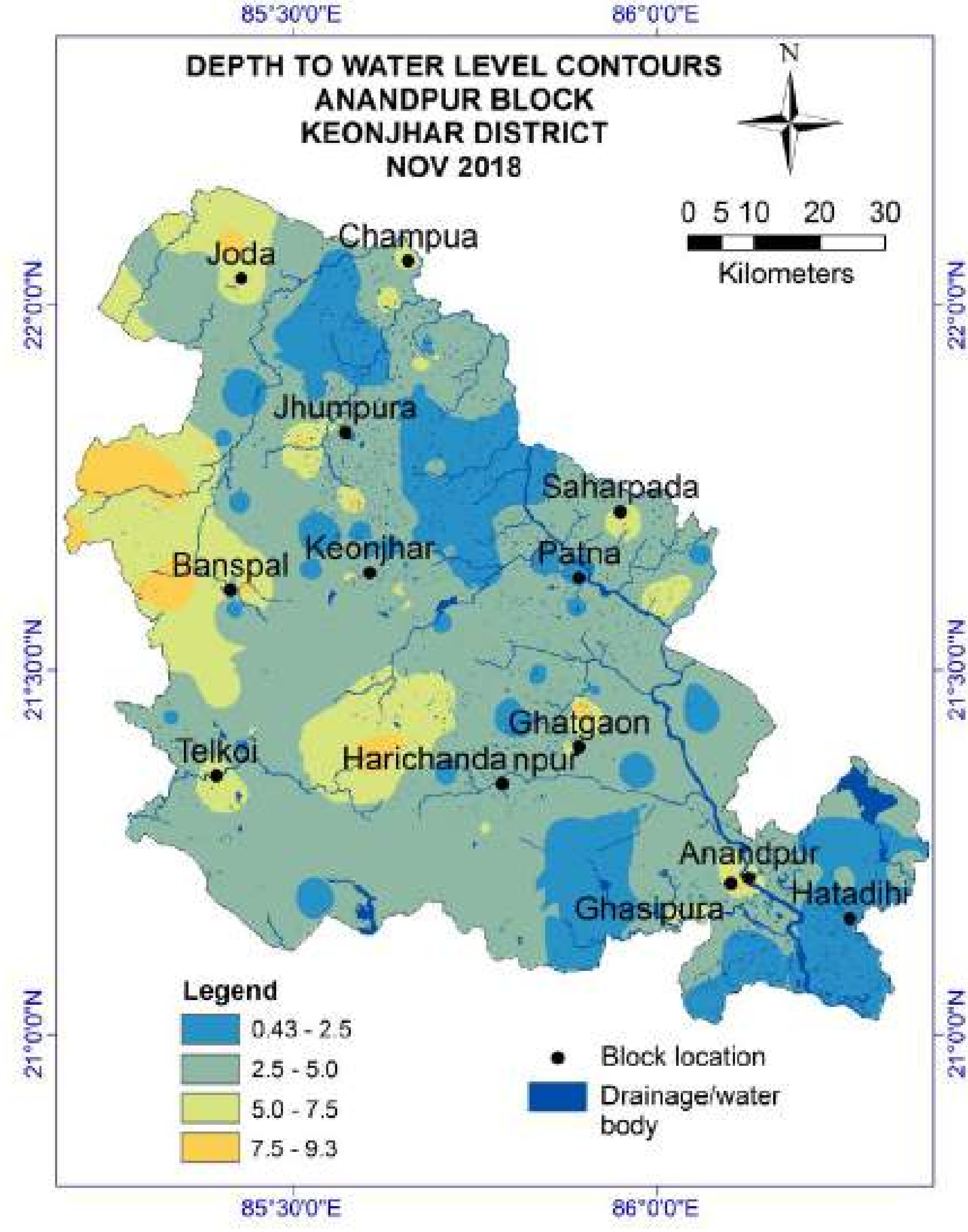
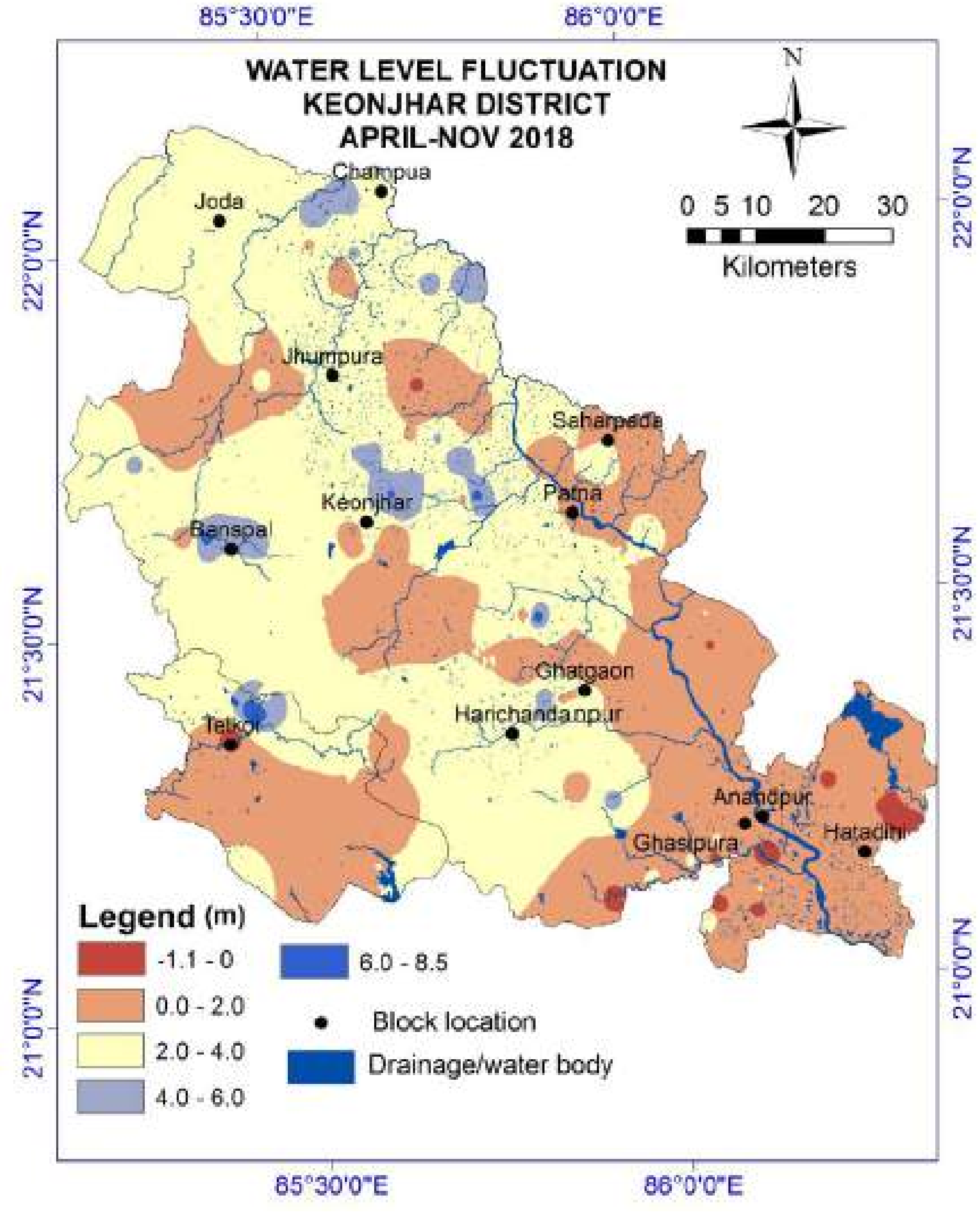

DEPTH TO WATER LEVEL CONTOURS
KEONJHAR DISTRICT
APRIL 2018
N
0 5 10 20 30
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Joda
Champua
Jhumpura
Saharpada
Keonjhar
Patna
Banspal
Ghatgaon
Telkoi
Harichandanpur
Anandpur
Ghasipura
Hatadihi
Legend
1 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
12.5 - 14.0
Block location
Drainage/water body

PLATE – 5.3



DEPTH TO WATER LEVEL CONTOURS
ANANDPUR BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 5 10 20 30
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Joda
Champua
Jhumpura
Saharpada
Keonjhar
Patna
Banspal
Ghatgaon
Telkoi
Harichandanpur
Anandpur
Ghasipura
Hatadihi
Legend
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
Drainage/water body

PLATE – 5.4



WATER LEVEL FLUCTUATION
KEONJHAR DISTRICT
APRIL-NOV 2018
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
N
0 5 10 20 30
Kilometers
Champua
Joda
Jhumpura
Saharpada
Patna
Keonjhar
Banspal
Ghatgaon
Harichandanpur
Telkoi
Anandpur
Ghasipura
Hatadihi
Legend (m)
-1.1 - 0
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
6.0 - 8.5
Block location
Drainage/water body

PLATE – 5.5

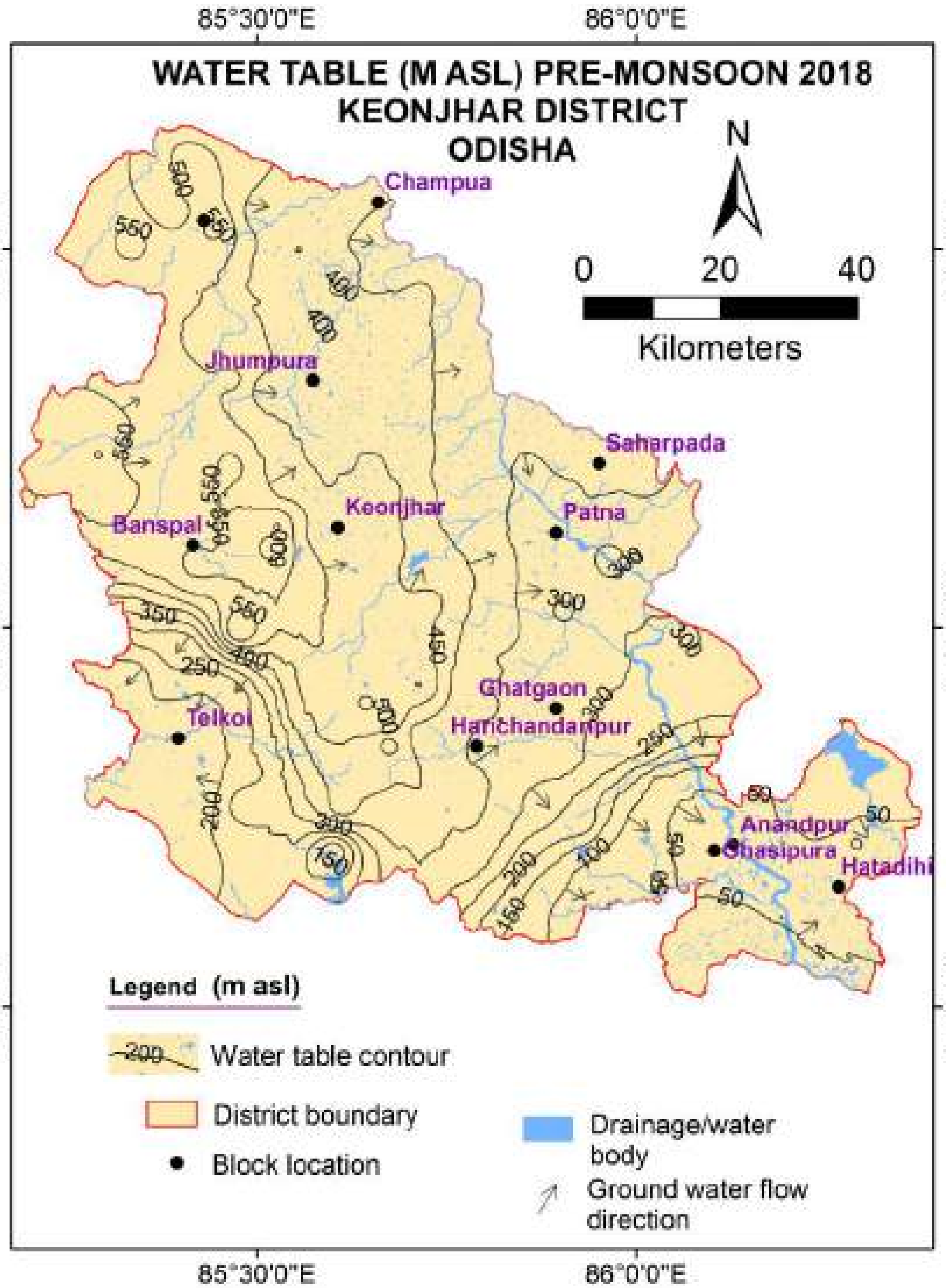

85°30'0"E
86°0'0"E
WATER TABLE (M ASL) PRE-MONSOON 2018
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Champua
Jhumpura
Saharpada
Patna
Keonjhar
Banspal
Telkoi
Ghatgaon
Harichandanpur
Anandpur
Ghasipura
Hatadihi
Legend (m asl)
200 Water table contour
District boundary
Block location
Drainage/water body
Ground water flow direction

PLATE – 5.6

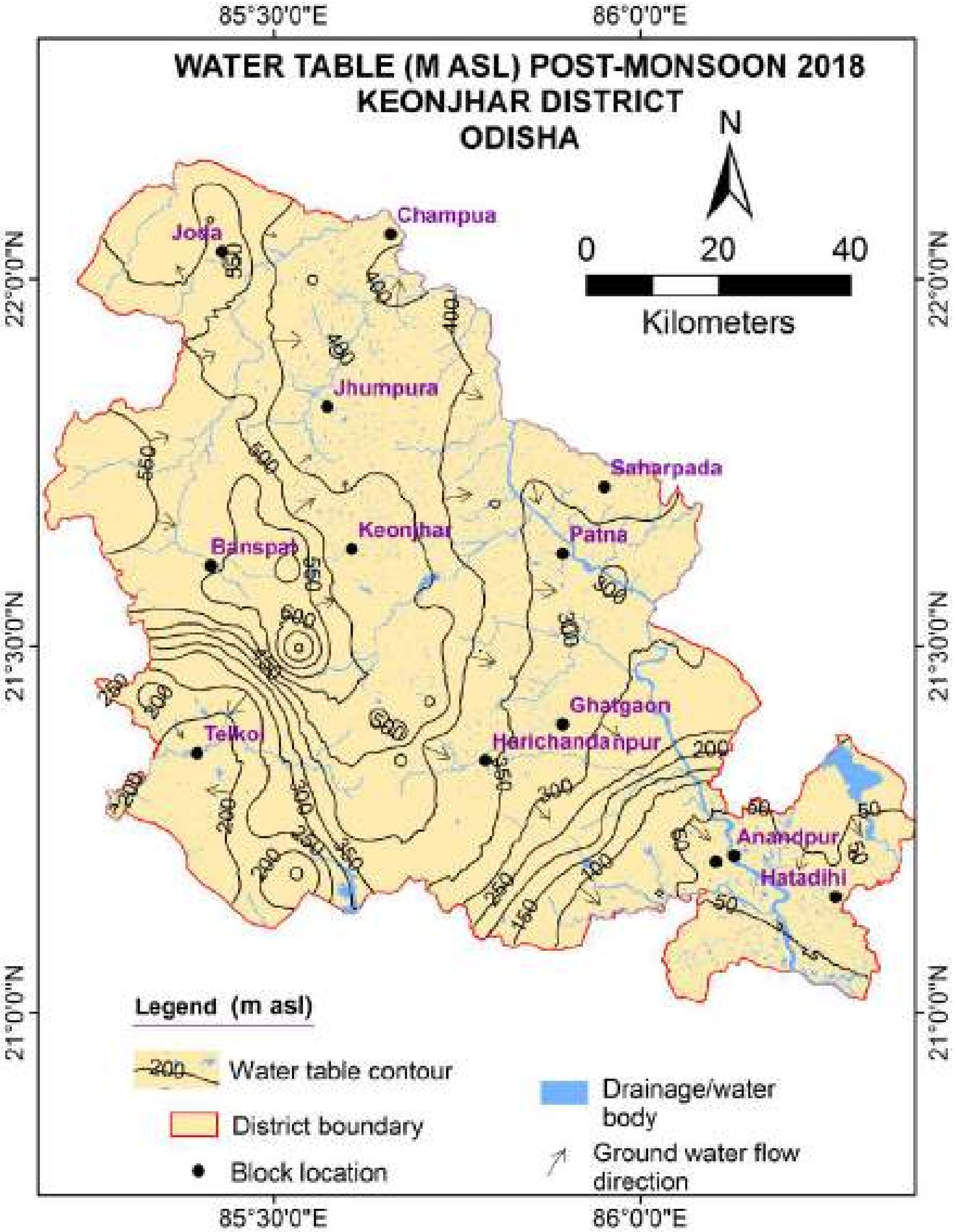

85°30'0"E
86°0'0"E
WATER TABLE (M ASL) POST-MONSOON 2018
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Joda
Champua
Jhumpura
Saharpada
Keonjhar
Banspal
Patna
Ghatgaon
Telkoi
Harichandanpur
Anandpur
Hatadihi
Legend (m asl)
Water table contour
District boundary
Block location
Drainage/water body
Ground water flow direction

PLATE – 5.7

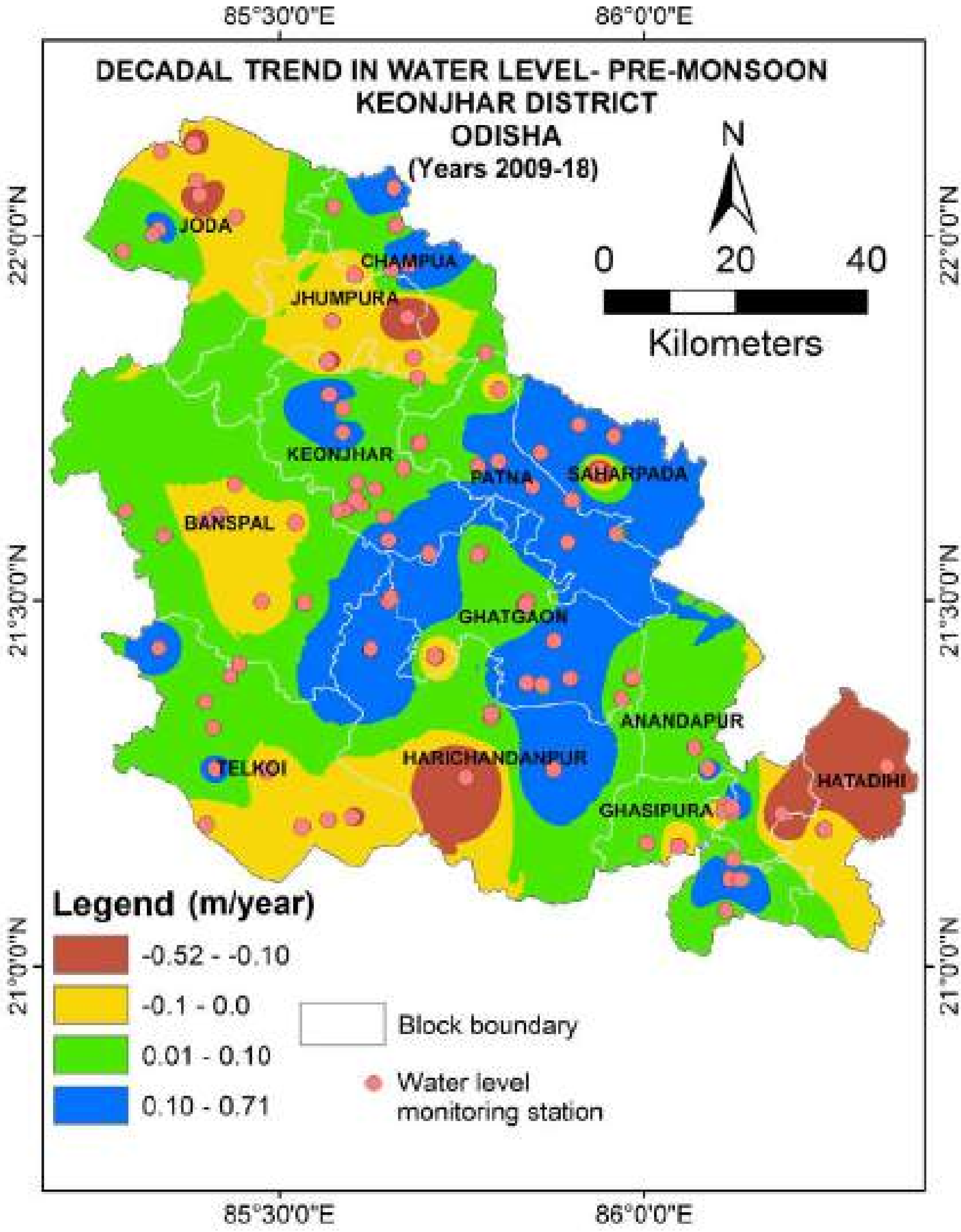
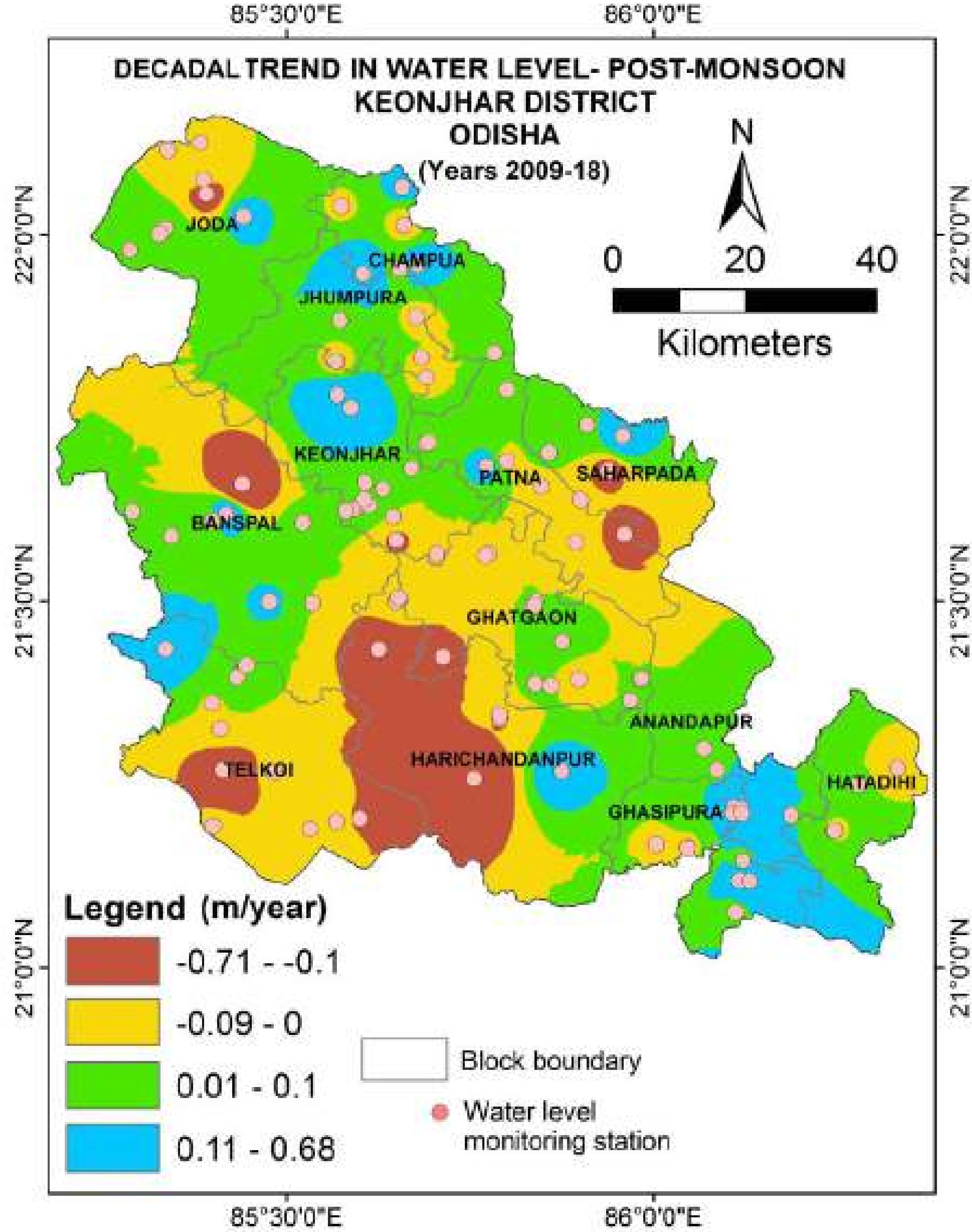

85°30'0"E
86°0'0"E
DECADAL TREND IN WATER LEVEL- PRE-MONSOON
KEONJHAR DISTRICT
ODISHA
(Years 2009-18)
N
0 20 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
TELKOI
HARICHANDANPUR
HATADIHI
GHASIPURA
Legend (m/year)
-0.52 - -0.10
-0.1 - 0.0
0.01 - 0.10
0.10 - 0.71
Block boundary
Water level monitoring station

PLATE – 5.8



DECADAL TREND IN WATER LEVEL- POST-MONSOON
KEONJHAR DISTRICT
ODISHA
(Years 2009-18)
N
0 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
HARICHANDANPUR
TELKOI
HATADIHI
GHASIPURA
Legend (m/year)
-0.71 - -0.1
-0.09 - 0
0.01 - 0.1
0.11 - 0.68
Block boundary
Water level monitoring station

6.0 AQUIFER GEOMETRY AND CHARACTERS

The information available from variuous geophysical studies and exploratory bore wells dilled in the district has been taken into account in delineating the aquifer geometry and the aquifer characters in the district. Besides, the lithologs obtained from the OLIC, Govt. of Odisha were also analysed for the aquifer framework in the alluvial parts in the district.

6.1 Geophysical studies

Electrical resistivity survey has been carried out in an area of 2,270 Sq. Km (Fig 6.1) by conducting 442 VES and 2,580 line meters wenner profiling and a few radial soundings during FSP 1988-89, 1989-90 and 1990-91. The area lies between 21^0 26’ and 22^0 (N) latitudes and 85^0 30’ and 860 (E) longitudes. The area falls under survey of India Toposheet nos 73 G/9, 10, 13 and 15. Based on comparative studies of VES results near the exploratory wells and lithology, the geoelectric parameters of the area were standardized (Table 6.1).

Figure 6.1: Map of Keonjhar district showing the geopgysical surveyed area in the north-eastern parts of the district.

Table 6.1: The geo-electric parameters in the surveyed area in Keonjhar district.

No.of Layer	Resistivity ranges in Ω.m	Lithology
I	7-360	Topsoil/Clay
II	30-150	Highly weathered zone
III	150-250	Weathered/highly fractured rocks
IV	250-700	Fractured rock
V	>700	Fresh rock

6.1.1 Geo-electric cross-sections

The top thickness varies from 1m to 18m. The weathered layer thickness varies from 1m to 40m. The fractured rock thickness ranges between 2m and 110m. Two geo-electric cross sections A-A' and B-B' have been prepared and shown in Fig 6.2.

(1) Section A-A'

The section A-A' (Fig 6.2) runs from VES 147 (Sanhundula village) to VES 31 (Baljori village) NW-SE direction. The first layer having 15 Ω meter. Resistivities indicate variable nature of top soil. The layer immediately underlying the surface layer has resistivity range between 30 to 80 Ω m. indicating water saturated sand. This layer is prominent at VES 49, 22, 63 and 44 having a maximum thickness of 20m at VES 49. The layer with higher order of resistivities between 80 Ω m and 150 Ω m indicates weathered granite, having mximum thickness of 32 m at VES 36, VES 147, 45, 49, 22, 54 and 151, a layer with resistivities between 180 Ω m and 230 Ω m indicating highly fractured granite is observed with almost uniform thickness of 15 m below the weathered layer. This layer may also be due to the fact that the VES especially VES 54, 22, 36 and 151 are located close to the lineaments. This layer is north western part of the section at VES 147, 45 and 49 might be saturated sandstone as these VES are in the vicinity of sandstone area. Below this layer granites with less to moderately fractured nature and resistivities ranging between 280 Ω m and 680 Ω m are indicated with minimum thickness of 6 m at VES 87 and a maximum thickness of 55m at VES 51. The last layer with resistivities ranging from 785 Ω m to very high indicates fresh and massive granite. Along the section, the massive rock is observed to encounter from 12m (VES 102) to 60m (VES 150/151) depth.

(2) Section B-B'

The section B-B' (Fig 6.2) runs from VES 113 (Jyotipur village) to VES 98 (Kapaspada village) in NNW-SSE direction. It is almost along the Baitarani River between VES 113 and VES 94. The resistivity of the surface layer varies from 18 Ω m to 80 Ω m correspond to sand saturated with water with thickness ranging between 15m at VES 113 and 3m at VES 101. This layer with higher order of resistivities between 95 Ω m and 143 Ω m correspond to weathered granite having maximum thickness of 13 m at VES 64 and minimum thickness of 3m at VES 84. This layer is expected to be a potential groundwater bearing zone and gets recharged from Kalinjhar Nadi. Further SSE of VES 64 the presence of this layer is not prominent and at VES 76 massive rock is encountered at shallow depth. At VES 111, 108, 102,101,100 and 94, a layer with resistivities ranging between 205 Ω m at VES108 and 274 Ω m at VES 100 indicating highly fracture granite forms the 3rd layer with a maximum thickness of 26 m at VES 101 and minimum thickness of 6m at VES 94 in which most of the VES are in close vicinity of the linements. Below this layer a layer with resistivities from 280 Ω m to 680 Ω m is indicated with a minimum thickness of 3 m at VES 76 and maximum thickness of 27m at VES 20 and 64. In indicates the granites with moderate to less degree of fracturing. The last layer with resistivities from 752 Ω m. to very high indicate fresh and massive granite and has been encountered at depths ranging from 8 m. at VES 76 to 51 m. at VES 64 along the section.

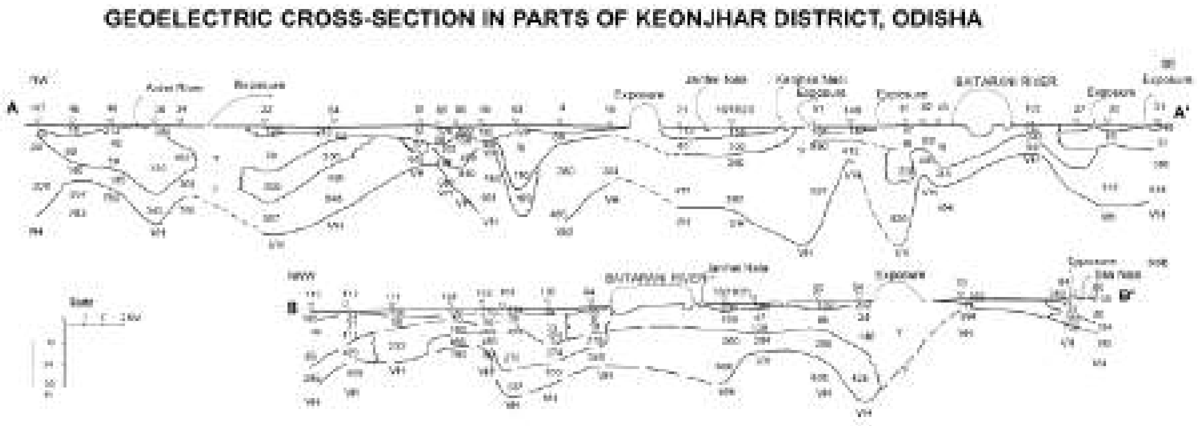


Figure 6.2: Geo-electric cross-sections A-A' and B-B' in parts of Keonjhar showing the spatial variation in the resistivity values in the earth materials.

6.1.2 Fence diagram based on VES results

The fence diagram (Fig 6.3) has also been prepared based on VES results to have a clear picture of the extension of the weathered, fractured and/or hard formation within the surface. The fence diagram depicted three to four geoelectrical sub-surface layers set up with thin surface layer followed by weathered, fractured and massive formation. In the eastern and central parts of the area (VES 132 to VES 158) a thick weathered zone of resistivity ranging from 38 Ω m to 120 Ω m within the granites and granitic gneisses revealed, having its maximum thickness of 50m (VES 145). The very high resistivities belo this weathered zone indicate hard and massive rocks except in VES 32, 60, 140 and 141 where moderately fractured nature of the formations have been encountered. In the northern part of the area almost all VES's depicted a fractured zone with resistivities from 172 Ω m (VES 159) to 640 Ω m (VES 86) having thickness ranging between 6 m to 30m. in the north-western part VES 153, 148, 47, 44 and 27 recorded lower order of resistivities for the fractured zone ranging between 200 to 300 Ω m may correspond to sandstones. In the southern and southwestern part most of the VES's revealed shallow basement underlying the weathered zone.

Based on the VES results and after the interpretations of the fence diagram, it is evident that the thickness of the weathered zone goes beyond 40 m bgl in the NW side of the area and in SE parts. In the central and SE parts, major portions are covered with weathered zone thickness in the range of 10-25 m, whereas in the NW side, the thickness range of 25-40 m covers a significant part of the area. In the central, northwestern and southeastern parts, the existence of highly fractured to moderately fractured rocks below the weathered zone up to the delth ~80 m were suggested.

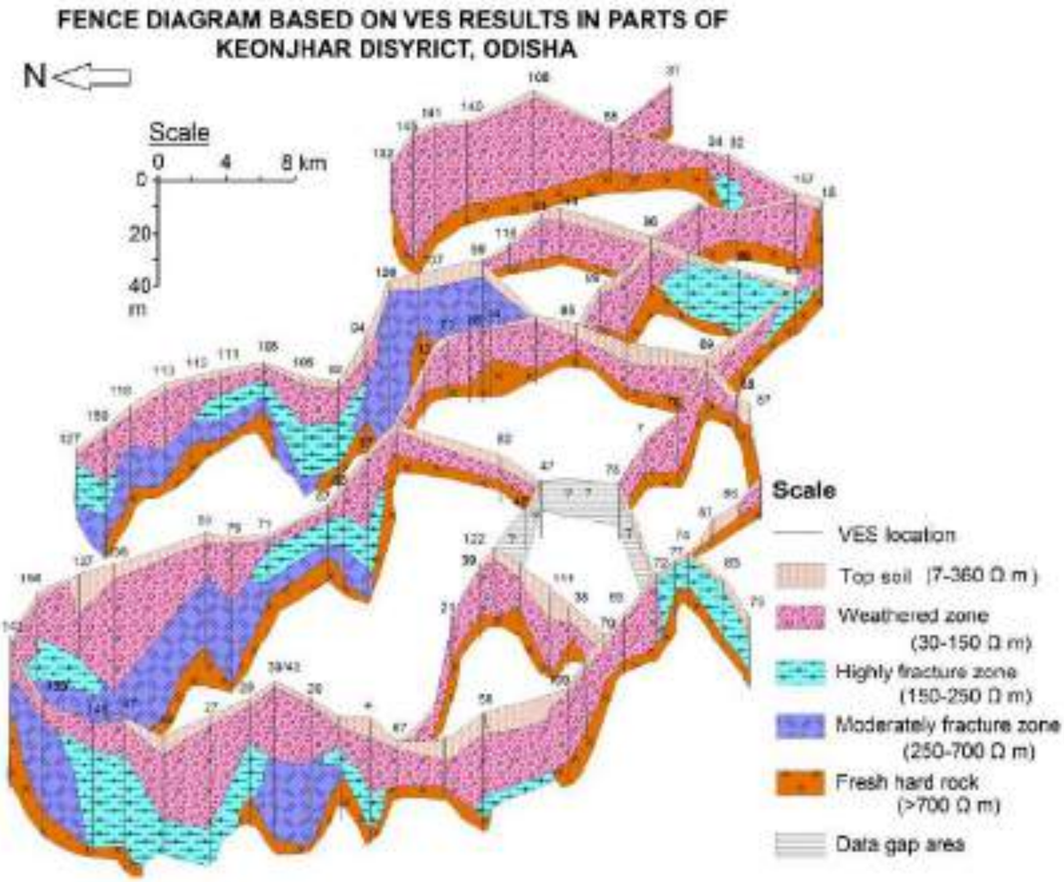


Figure 6.3: Fence diagram based on VES results in the north-eastern parts of Keonjhar district.

6.2 Exploratory drilling

Exploratory drilling was taken up by the Central Ground Water Board at different periods of time in Keonjhar district with the objective to delineate deeper water bearing fractures in the consolidated formation and their yield potential within a maximum depth of 200m. Suitable DTH (Down the hole hammer) rigs were deployed for groundwater exploration in the district at different times. The distribution of exploratory borehole locations is given in Plate 6.1. The rigs have provision for mud circulation rotary drilling to drill through the loose weathered formation. Different sizes of button bits were used during the drilling. Invariably 215 mm diameter boreholes were drilled in the weathered zone and the loose weathered zones were cased with 178 mm / 203 mm diameter blank pipe to prevent collapse of the bore and the borehole beyond that depth was kept nacked. So far 94 exploratory wells and 19 observation wells have been drilled under the groundwater exploration programme. The depth of wells varied from ~25.0 to 200.2 m.

6.2.1 Thickness of weathered zone

From the information of borehole lithology and the casing depth in constructed bore wells, the thickness of the weathered zones at locations of groundwater exploration were taken. The thickness of weathered zone varied between 6.5 m and the maximum of 60 m with the average value of 22.7 m for the district. A contour zone map for the district has been prepared taking the available information (Plate 6.1). The south-eastern part of the district is occupied by alluvium. A perusal of the plate indicates the northern half of the district is predominated with the thickness range of 40.0 – 50.0 m, whereas in the southern parts, the range 10.0 – 20.0 m predominates. A major part of the district is occupied by the thickness range of 20.0 – 30.0 m. A bar diagram has been prepared which presents the area percent of the district occupied by various thickness ranges of the weathered zone (Fig 6.4).

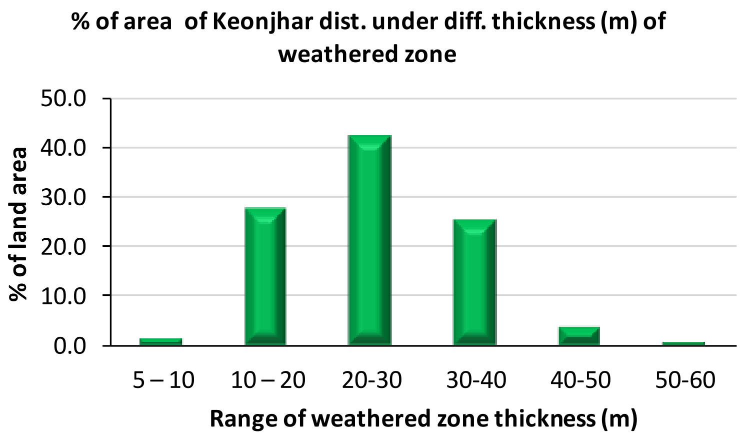


Figure 6.4: Bar diagram depicting the area percent of the Keonjhar district occupied by various thickness ranges of weathered zone.

Block-wise distribution of weathered zone (area percent) in various thickness ranges have been produced in Table 6.2. The blocks where the thickness of the weathered zone exceeds 20 m in major parts include Anandapur, Champua, Hatadihi, Saharpad, Telkoi, Jhumpura, Banspa, Joda and Keonjhar.

Table 6.2: Percentage (%) area of blocks and the district of Keonjhar falling under different weathered zone thickness (m) ranges.

Sl No	Name of block	Area (Km2) of blocks under diff. range of weathered zone thickness (in m)					
		5-10	10-20	20-30	30-40	40-50	50-60
1	Anandapur	0.0	41.5	55.8	2.7	0.0	0.0
2	Banspal	0.0	2.5	36.0	57.8	3.7	0.0
3	Champua	4.6	38.0	53.4	4.0	0.0	0.0
4	Ghasipura	0.0	37.2	31.4	25.6	5.8	0.1
5	Ghatgaon	9.7	74.4	15.7	0.2	0.0	0.0
6	Hatadihi	0.0	40.8	59.2	0.0	0.0	0.0
7	Harichandanpur	0.1	71.6	28.2	0.0	0.0	0.0
8	Jhumpura	1.6	9.1	53.0	28.5	7.9	0.0
9	Joda	0.0	0.0	22.9	64.7	11.8	0.6
10	Keonjhar	0.8	10.8	28.6	50.2	6.8	2.8
11	Patna	0.0	35.7	27.3	21.5	9.7	5.8
12	Saharpada	0.0	0.9	77.6	15.5	5.2	0.7
13	Telkoi	0.0	2.5	84.1	13.3	0.0	0.0
	District total	**1.2**	**27.5**	**42.0**	**25.0**	**3.7**	**0.6**

6.2.2 Fracture zones analysis

This analysis has been carried out taking 90 bore wells including exploratory wells and observation wells) in the district. Though, the depth of 4 bore wells remained less than 100 m bgl (50-88 m bgl), the others have been drilled between the depths of 100-202 m bgl. Among them, 68% of the wells exceed 150 m depth, while 30% reach the target depth of 200 m bgl. Within this drilled depth, 1-6 sets of fractures have been encountered with spatial variation in their occurrence and recurrence. It has been tried to synthesize the fracture depth data with the increasing depth of the bore well. Fig 6.5a shows the cumulative incidence of fractures in every meter increase in depth. Though, single fractures have been observed at various depths in many of the bore wells, It can be seen from the figure that the fractures are more frequently observed in some particular broad depth ranges like 20-30m, 35-40m, 45-48m, 52-56m, 81-83m, 85-90m, 100-105m and 116-122m bgl. The depths at which maximum recurring of fractures at different locations have been observed include 23m, 28m, 31m, 77m and 118m. In Fig 6.5b, the fractures have been clubed into various depth ranges for easy grasp. It indicates gradual diminishing in the incidence of number of fractures downward in the boreholes. Up to the depth of 95 m bgl, three cycles of fractures sustems are evident in the depth ranges of 15-45m, 45-65m and 70-95 m bgl. Within this depth, the maximum recurring of the fractures takes place in the depth ranges of 15-40m, 45-65m and 70-90m bgl. Beyond the depth of 100 m bgl, the incidence of fractures is less and also their occurrence seems to be irregular. The maximum reccurrence of fractures takes place in the depth ranges of 100-105m, 115-120m and 145-150 m bgl.

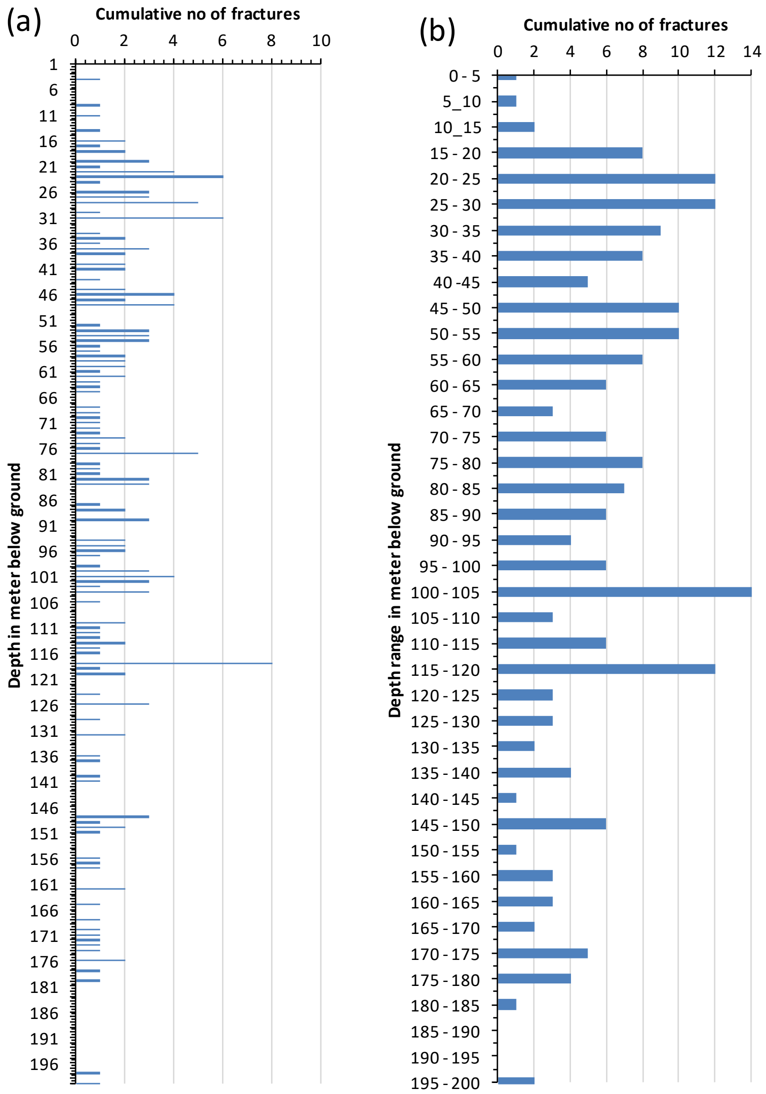


Figure 6.5: (a) Depth-wise incidence of number of fracture zones in the bore wells within 200 m bgl. (b) Cumulative number of fracture zones in each depth range as obtained in each bore well in Keonjhar district.

The total incidence of fractures in each bore well has been plotted and contoured only in order to assess their geographic distribution in the district (Plate 6.2). It is observed that maximum numbers of fractures (2-5 sets) within the depth of 200 m bgl are found in the northern half of the district. In southeastern parts in Anandapur and Ghasipura blocks in some cases 2-3 sets of fractures are encountered in the bore wells. In the central, eastern and western parts, in parts of the blocks Harichandanpur, Ghatgaon, Saharpada and Banspal, maximum up to 2 sets of fractures are encountered in the bore wells.

The total number fracture sets in each bore well has been segregated into two depth ranges, as depicted in Plates 6.3 & 6.4. The Plate 6.3 is very similar in look to the Plate 6.2, indicating the maximum numbers of fractures sets are located within the depth of 100 m bgl only. However, some differences are very clear in the north-central parts covering parts of the blocks Banspal, Keonjhar, Patna and Saharpada, and the south-central parts covering parts of the blocks Harichandanpur, Ghatgaon, Anandapur, Ghasipura and Patna. In the former one, Plate 6.2 depicts 2-3 sets of fractures within 200 m bgl, while in Plate 6.3 (within 100 m bgl depth) only 1-2 sets of fractures are depicted. Similarly, in the later area, only 0-1 sets of fractures are found within 100 m bgl depth.

The Plate 6.4 interestingly shows a major part of the district being covered by the area with only 0-1 sets of fractures within the depth of 100-200 m bgl. Only in certain pockets in the north-eastern side in the blocks of Joda, Champua, Jhumpura and Patna, in the central parts in blocks of Harichandanpur and Ghatgaon, and in the south-eastern side in the blocks of Harichandanpur and Ghasipura, more than one sets of fractures are encountered. The maximum incidence of fractures within thic depth goes up to 4 sets in the Jhumpura block in the north-eastern part.

6.2.3 Classification of aquifers

Using the weathered zone thickness map at the top, a 3D aquifer model of the district has been prepared displaying three aquifer types (Fig 6.6): (1) weathered zone aquifer; (2) Precambrain fractured aquifer and (3) alluvial aquifer. On the basis of the discussions and logic put forth in the fracture zones analysis section, the fractures systems in the district can broadly be put into two aquifer systems; (1) 1st Aquifer System within the depth of 100 m bgl, which includes the weathered zone aquifer, and (2) the 2nd Aquifer System within the depth range of 100-200 m bgl. Thus, the 1st aquifer system also includes the weathered zone aquifer at the top and the alluvial aquifer in the south-eastern parts of the district. The aquifer systems have been briefed in the following lines.

(1) 1st Aquifer System

This aquifer system extends from the ground surface up to the depth of 100 m bgl (encompassing the weathered zone aquifer), where, a definite change in the trend of occurrence of fracture zones is observed in the district. Out of the total fractures encountered in 90 bore wells in the district, 66% of the fracture zones have been got in the

1st aquifer system. Up to 5 sets of fractures (more commonly 2-3 sets) are observed in the north/north-eastern parts of the district. However, the fractures are more depleted in the aquifer system in the south-central parts (Plate 6.3).

(2) 2nd Aquifer System

This aquifer system extends between 100-200 m depth ranges. Within this depth range, often the drilling goes dry. The fractures are very limited (0-1 sets only) in major parts of the district. In the same north/north-eastern parts again, some more fractures zones are encountered in the aquifer system.

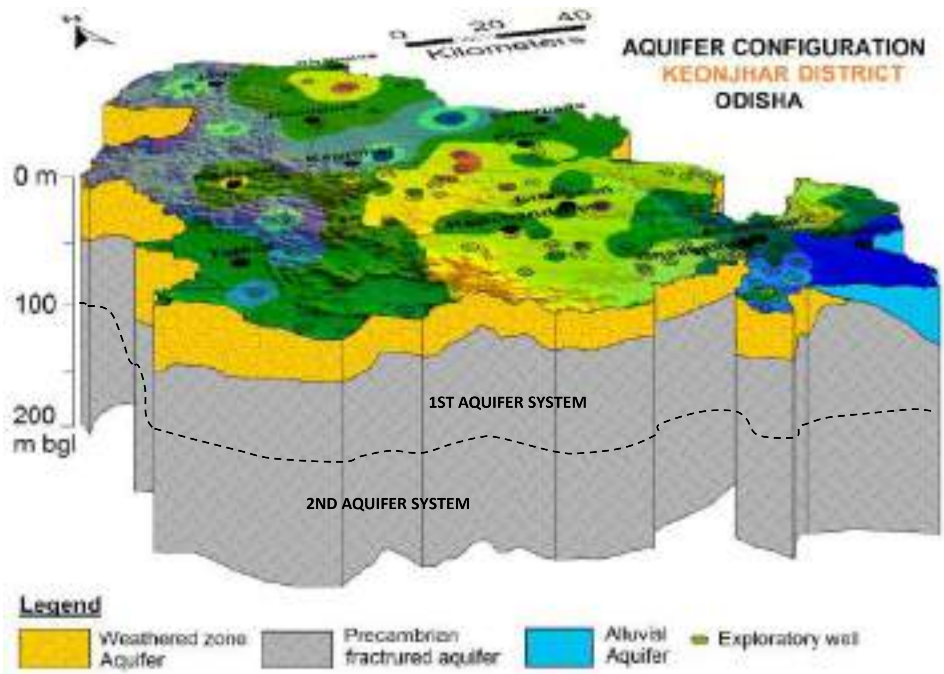


Figure 6.6: The 3D aquifer model of Keonjhar district showing the disposition of two aquifers systems. The 1st aquifer system encompasses the the top weathered zone aquifer and the alluvial aquifer in the district.

6.2.4 Hydrogeological transects in hard rock

With the available information on borehole lithology, five hydrogeologial transects have been prepared (for locations, see Fig 6.7a): (1) A-A' from Nalda in the Joda block to Saharpada in Saharpada block along the eastern boundary of the state (Fig 6.7b); (2) B-B' from Kanjipani in Banspal block to Swampatna in Patna block (Fig 6.7c); (3) C-C' from Keonjhar to Balijodi in Ghatgaon block (Fig 6.7d); (4) D-D' from Pipapiti in Harichandanpur block to Baripal in Ghasipura block (Fig 6.7e); and (5) E-E' from Kanto in Anandapur block to Jarada in Ghasipura block (Fig 6.7f). In all transects the borehole lithologies have been drawn schematically. Approximate depths of the fractures encountered in eash bore well have been provided. Yield in each of the bore well have also been indicated. Fractures in the intervenning areas have been drawn only schematically and may not bear any significance in field conditions. Brief descriptions about transects are given below:

(1) Transect A-A'

It encompasses a total of 11 bore wells (Fig 6.7b); Nalda; Joda, Basudevpur, Champua, Karanjia, Jyotipur, Ukhunda, Turumunga, Udaipur, Badbil and Saharpada. The bore well depths vary in the range of 51-200 m bgl, the minimum being at Nalda in the western parts of transect. Though, the predominating lithology remains the granite/granite gneiss, BHQ and shale was encountered in the boreholes at Nalda and Joda respectively in the western parts of transect. The thickness of weathered zone is also markedly more (~40-50 m) in the western parts. In the central and westcentral parts of transect in the boreholes at Basudevpur, Champua, Karanjia and Jyotipur, basic rocks/dolerite dykes were encountered as intrusions, predominantly in the upper parts of the boreholes. In the boreholes, one to five sets of fractures were encountered. Around 70% of the fractures were located within the depth of 100 m bgl. The yield of the bore wells varied in the range of negligible at Udaipur to the maximum of 12.3 lps at Champua, with the average transect yield of 2.0 lps. Often, the fratures were obtained at the contact zones of the intrusions and the country rock.

(2) Transect B-B'

It encompasses a total of 6 bore wells, namely Kanjipani, Suakati, Raisuan, Jharbelda, Pipani and Swampatna (Fig 6.7c). Transect is aligned in E-W direction in the district. The minimum drilled depth of 88 m bgl was at Kanjipani. However, the discharge of this well stood at maximum of 20.2 lps. At Kanjipani and Suakati, in the western parts of transect, basic dykes were encountered. In the central and eastern parts, granite/granite gneiss predominates. The thickness of the weathered zone is more in the central and western parts (~50-60 m). In this transect 1-3 sets of fractues are encountered. Around 85% of the fractures were encountered within the depth of 100 m bgl. The yield of the bore wells varied in the range of 0.5-20.2 lps with three of the bore wells (Suakati, Raisuan, Swampatna) recording yields of 1.0 lps and less.

(3) Transect C-C'

The transect C-C’ passes through eights bore wells, namely, Keonjhar, Ramachandrapur, Jharbeda, Pipilia, Dhenkikote, Dehuriposi, Ghatgaon and Balijodi (Fig 6.7d). It is located in the central parts of the districts with an alignment in NW-SE direction. The depths of the wells vary from the minimum of 111 m at Jharbeda to the maximum of 200 m bgl. The predominant lithology remains the granite/granite gneiss. The weathered zone thickness is more (~50 m) towards Keonjhar in the west of transect. In this transect, 1-2 sets of fractures area encountered. In contrast to transects A-A’ and B-B’, only about 30% of the fractures in C-C’ are observed within the depth of 100 m bgl. Yield of the bore wells in transect varies between 0.3 – 5.4 lps with 50% of the wells registering yield more than 4.0 lps.

(4) Transect D-D’

It runs through 6 bore wells, namely Pipapiti, Harichandanpur, Shuadhala, Bhogamunda, Barigaon and Baripal (Fig 6.7e). With an alignment in NW-SE direction, it represents the south-western parts of the districts (Fig 6.7a). The minimum depth drilled is 93 m bgl at Baripal in the eastern side of transect. The predominant lithology remains the granite/granite gneiss. In this transect, 1-3 sets of fractures are encountered with ~40% of them lying within the depth of 100 m bgl. Th yields in the bore wells fall in the range of 0.3 – 12.0 lps with maximum at Baripal in the eastern side of transect. However, 4 out of the total 6 bore wells in the district record yield in the range of 1.0 – 2.0 lps.

(5) Transect E-E’

A total of eight bore wells fall on transect E-E’, namely, Kanto, Bhalukuma, Sailong, Ghasipura, Belabahali, Barpada, Sainkul and Jarada (Fig 6.7f). It is to mark that, the bore wells in this transect fall on almost plain land with the ground surface elevation lying at the maximum of 50 m asl, in contrast to the other transects, where the reduced level of the wells goes up to 600 m asl. The minimum depth drilled stands at 108 m bgl. Though, the predominant lithology remains the granite/granite gneiss, numerous basic intrusions are reported at sevral depths specifically in the western half of transect. In the eastern side, metasediments like quartzite/shale/sandstone have also been reported, partiularly in the Sainkul borehole. Further, in the eastern side, extensive lateritization is observed up to the depth of ~50 m bgl, where highly porous permeable laterites/ ompat laterites and lateritic clays are enountered. The laterites in the area yield good volume of water for the sustenance of the dug wells. In the borehole at Belabahali, top clay of ~20 m thick is observed which may be the extension of the alluvial plain pertaining to the Baitarani River. In this transect, 1-5 sets of fractures are enountered and interestingly ~83% of the fractures lye within the depth of 100 m depth. Except the bore wells at Jarada in the east and that at Kanto in the west, all othet wells record yields in the range of 2.0 – 14.0 lps. Four out of the total 8 wells give discharge even more than 4.0 lps.

If the above five hydrogeological transects are analyzed, it makes a picture that the areas which are traversed by basic intrusions/dykes are harateriesed by more number of fractures and more yield in the bore wells. Again, such intrusions are observed in more inidence within the depth of 100 m bgl, where the fractures are also got in more numbers. Less basic intrusions in the country rock as depicted in transects have typically less number of fractures within 100 m bgl.

(a)

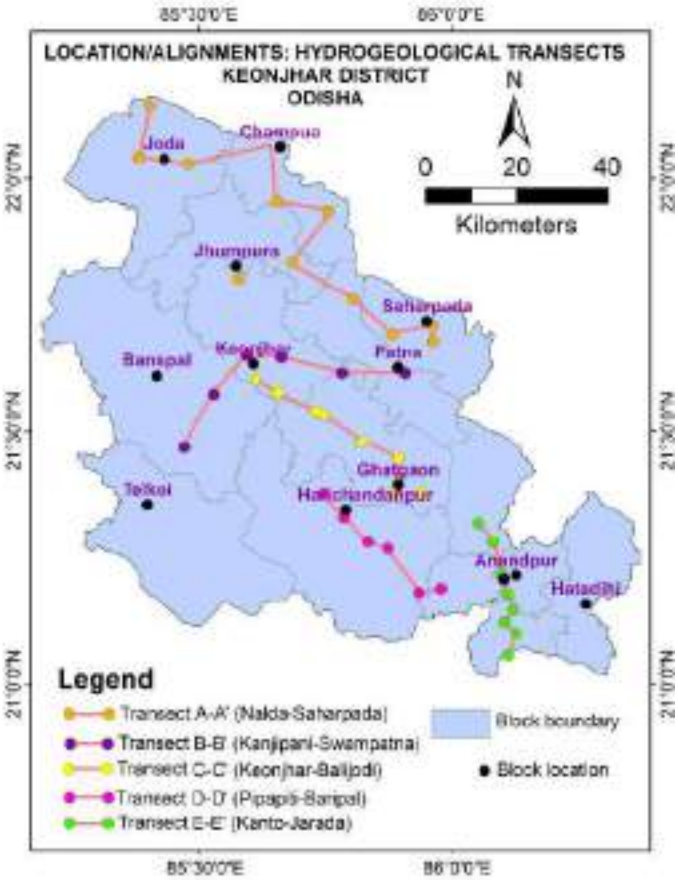
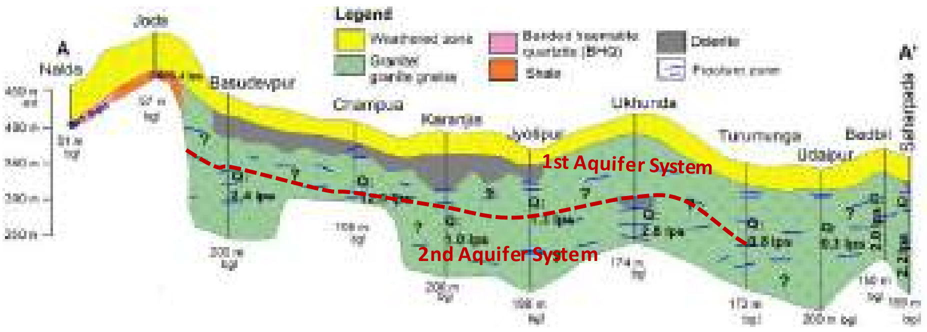
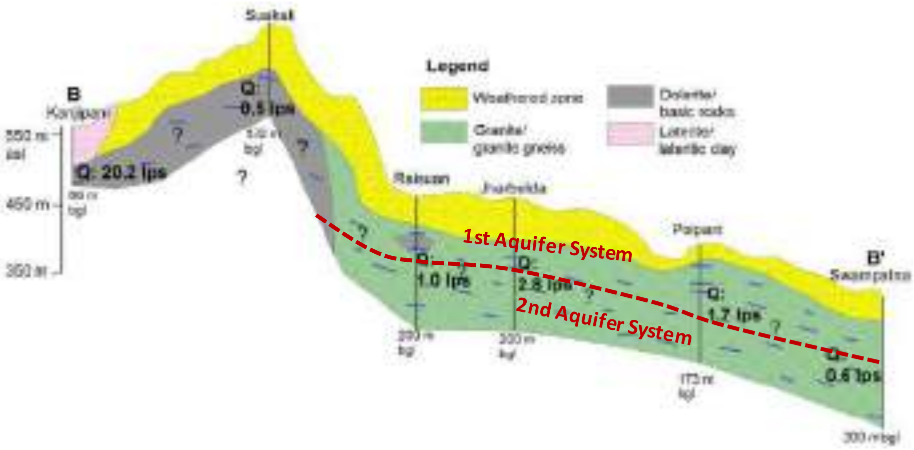


Figure 6.7: (a) Map of Keonjhar district showing the locations of the hydrogeological transects (A-A', B-B', C-C', D-D' and E-E') and the bore wells on them.

(b)



(c)



(d)

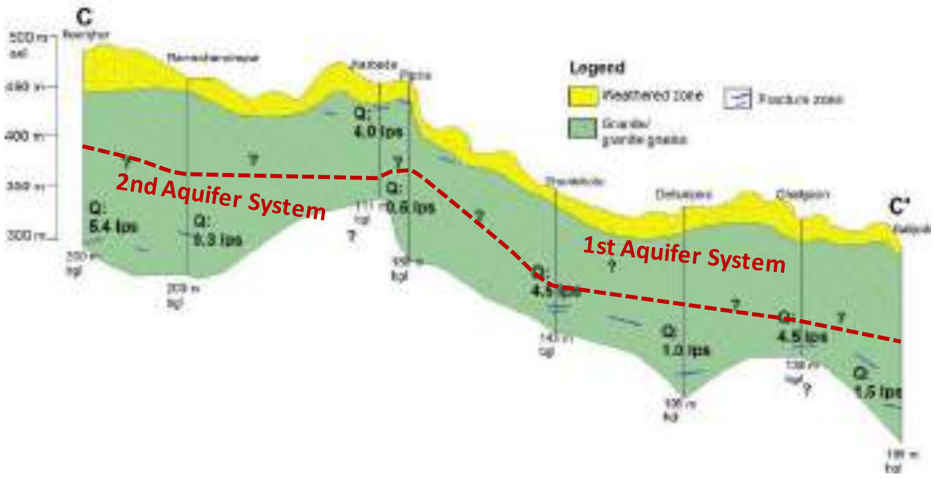
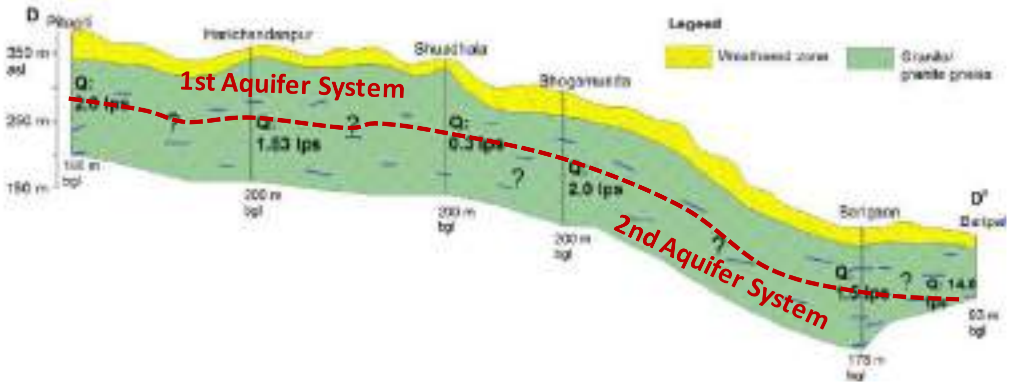


Figure 6.7 contd.: The hydrogeological transects in Keonjhar district: (b) A-A’, (c) B-B’ and (d) C-C’depicting aquifer disposition and their yield potential.

(e)



(f)

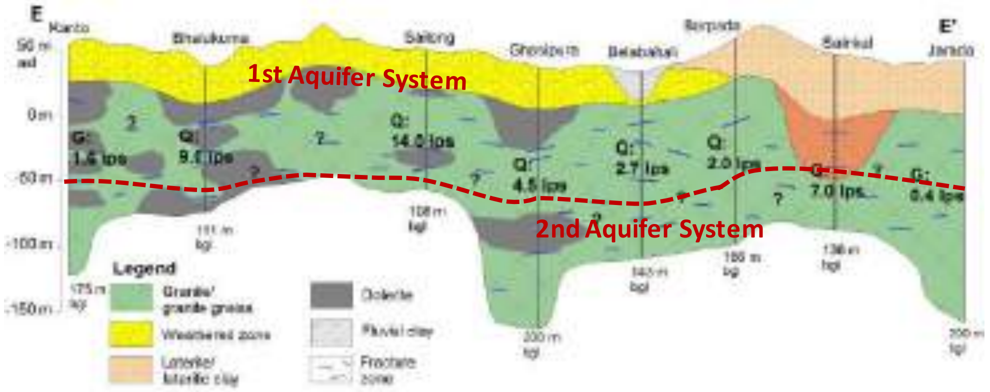
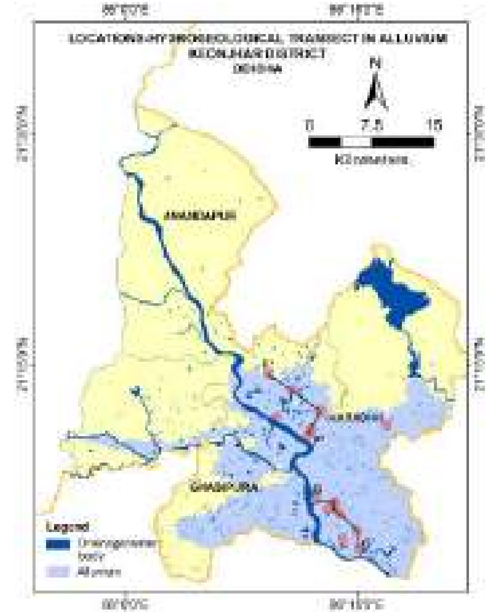


Figure 6.7 contd.: The hydrogeological transects in Keonjhar district: (e) D-D' and (f) E-E' depicting aquifer disposition and their yield potential.

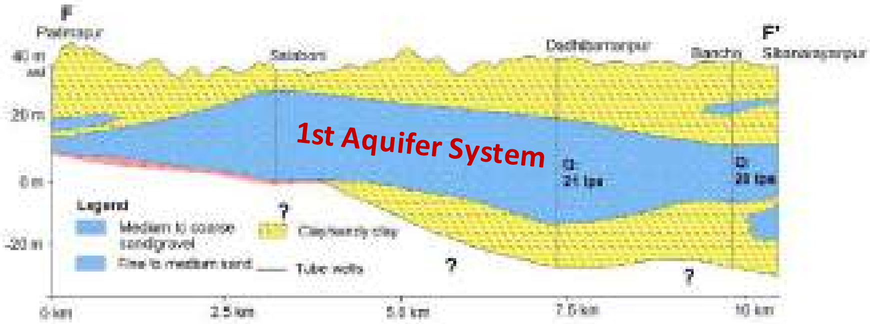
6.2.5 Hydrogeological transect in alluvium

The alluvial area belonging to the Baitarani River basin is located in the south-eastern parts of the district. It covers a combined area of ~370 km^2 in three blocks namely Ghasipura, Anandapur and Hatadihi. The alluvial depth goes up to ~100 m towards the south-eastern corner. The lithological data of a few boreholes (made for the purpose of constructing water wells) of Odisha Lift Irrigation (OLIC) departrment, Government of Odisha were obtained to study the spatial variation in litholology. Two hydrogeological transects (F-F' and G-G') have been prepared along the Baitarani River along its right bank. The boreholes are drilled between the depths of 33-101 m bgl. The locations of transects have been given in Fig 6.8a. It is discernible from the transects that in a corridor close to the existing Batarani River channel, there exists at least two sand zones of thickness between 10-20 m. At far off places, a thick sand zone (10-40 m) exists at depths between 10-30 m bgl.

(a)



(b)



(c)

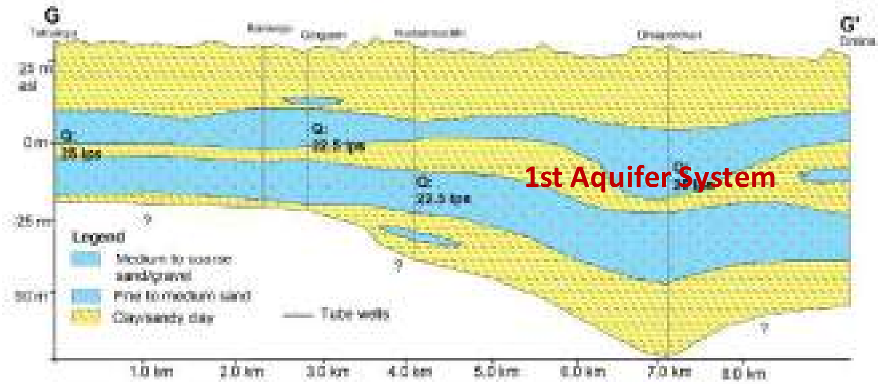


Figure 6.8: (a) Part of the Keonjhar district covering Hatadihi, Ghasipura and Anandapur blocks, showing the alluvial area and the alignment of the hydrogeological transects (F-F' and G-G') along with the location of the borehole (OLIC) on them. (b) The transect F-F' between Padmapur and Sibanarayanpur villages. (c) The transect G-G' between the villages Telisinga and Dimiria.

(1) Transect F-F'

It runs between from Padmapur village in the north of Anandapur to Sibanarayanpur in the south near the bank of Baitarani River (Fig 6.8b). The depths of boreholes vary between 33 m bgl at Padma to 88 m at Sibanarayanpur. The basement granitic rock has been encountered at shallow depth in the northern parts at Padmapur and Salaboni at 33m and 45 m bgl respectively. Though, granular zones of thickness 12 m only is found at Padmapur, it increases towards south and 20-40 m thick zones are encountered at rest of the boreholes. It forms a single aquiferf zone with wide areal extent. At shallow depth the sand is fine to medium in nature whereas the deeper sand is dominated by medium to coarse sand and gravels. At Sibanarayanpur and Bancho boreholes which lie vey close to the Baitarani River, a shallow fine to medium sand zone of 4-5 m thick is observed at depth around 10 m bgl. At Sibanarayanpur, a third granular zone also seems to start at around 50 m bgl.

(2) Transect G-G'

It runs between the villages Telisinga in the north to Dimiria in the south (Fig 6.8c). The transect location is close to the river baitarani in the central parts of the alluvial tract. The depths of the boreholes vary between 48-101 m bgl. In contrary to the transect F-F', two prominent sand zones are observed in this transect, besides other minor lenes. The thickness of these zones varies between 10-20 m, separated by a clay layer of 5-20 m thcikness. The sand is predominantly medium to coarse and gravels. The thick clay layer at top of the section is sandy clay to sticky clay in nature.

6.3 Aquifer characters

6.3.1 Yield potential of aquifers

As per the available data from 102 locations, the yield potential of the fracture aquifers encountered between the depths of ~27.0-200.0 m bgl varied in the range of negligible (0.3-0.4 lps) to the maximum of ~20 lps at Kanjipani (long: 85.4698; lat: 21.4687) in the Banspal block. Though, it is always erroneous to prepare contour maps taking the point values of discharge of bore wells in the fracture aquifers, an attempt has been made to prepare such a map here taking good intensity of data points in the area (Plate 6.5). It can just produce a good glimpse of the areal distribution of potential aquifers in the area. Owing to the non-availability of data in the Telkoi block, it has been put in the data gap area in the contour map. As per the map, except a few wells, major number of them exhibit discharge more than 1.0 lps. A major part of the district is covered by the bore wells with the yields in the range of 2.5 – 5.0 lps (central, southern, northwestern and northern parts), follwed by the wells with the yields in the range of 1.0 – 2.5 lps (northeastern and southcentral parts). There are two major corridors with yield of wells in the range of 1.0 – 2.5 lps: the 1st one is a linear patch covering parts of the blocks such as Joda, Jhumpura, Champua, Patna, Saharpada and Ghatgaon, and the 2nd one runs sothwesterly to northeasterly covering parts of the blocks of Harichandanpur and Ghatgaon. The bore wells registering yields more than 5.0 lps largely fall in the southeastern parts of districts in the blocks of Anandapur, Ghasipura and Hatadihi. These parts are covered by rocks such as Singhbhum Granite and metasediments. There are a few isolated locations in the district where the yields more than 10 lps have been obtained in the bore wells. An assessment of the all available information on fracture zones indicates that the major number of wells with yield >10 lps tap fractures largely within the depth of 100 m bgl.

The yields of the wells present quite interesting results while assessed for the 1st and 2nd aquifer systems separately. Though, some of the bore wells tap fracture zones in both the aquifer systems, there are 56 bore wells which tap the fractures zones within the 1st aquifer system. The yield of such wells varies between 0-20 lps with the average value of 4.2 lps. Major numbers of high yielding wells are located within this aquifer system. A total of 18 bore wells tap the fractures in the 2nd aquifer system. The yield of such wells range between 0.12-8.0 lps with the average of 3.2 lps only. Thus, it seems the 1st aquifer system is more potential than the 2nd aquifer system in Keonjhar district.

The alluvial aquifer in Keonjhar district is considerably more potential than the fracture aquifers. As per the data of a few OLIC tube wells, the yield varies in the range of 15-31 lps with the average value of 23 lps. The aquifers with thickness 10-40 m and medium to coarser granular materials are conspicously high potential.

6.3.2 Drawdown vs discharge

A less potential aquifer registers more drawdown during pumping in comparison to a well with the same pumping rate in a more productive aquifer. However, it also depends on pumping duration; more pumping duration yields less specific capacity. Increase in pumping rates also causes decrease in specific capacity. In Keonjhar district, during most of the hydrogeoloogical tests, the compressors/pumps have run for durations ranging between 100-300 minutes. The specific capacity values in such conditions can be compared to assess the aquifer potential in a regional scale. The bore wells in the district show drawdowns in the range of 1.0-39.0 m for pumping rates varying between 0-20 lps. The well discharge and the corresponding measured drawdowns belong to various Preliminary Yield Tests (PYTs) and pumping tests. The discharge per unit drawdown (m^3/hour/m) in the well, defined as specific capacity, has been worked out for the available 59 number of exploratory wells.

Since, yield in the well and the drawdown as well depends on the aquifer productivity, the specific capacity can be considered as one parameter which may reflect the potential of the aquifer. The worked out specific capacity of wells vary between 0.6-31 m^3/hour/m. Gepgraphic plotting of the values in the district has been carried out and presented in Plate 6.6. In congruence to the observations pertaining to yield, it also depicts poor aquifer potential in the north/north-eastern parts of the district (in parts of blocks of Joda, Jhumpura, Champua, Keonjhar, Saharpada and Patna), where the specific capacity of wells remain low at <1.5 m^3/hour/m. In the southern parts of the district, except a patch covering parts of Harichandanpur and Ghatgaon blocks, major parts exhibit higher values of specific capacity in the range of 1.5-31 m^3/hour/m. It is indicative that in the southern parts, the aquifers can yield more undergoing less drawdown. In alluvial areas, the specific capacity remains high in the range of 8-21 m^3/hour/m with drawdown varying between 4.6-8.3 m. The specific capacity of the lateritic aquifers varies from 0.0016m^3/min/m to 0.2214 m^3/min/m.

6.3.3 Transmissivity of aquifers

The transmissivity (*T*) of an aquifer can be defined as the rate of flow of water in volume per unit time per unit cross-section of the entire thickness of aquifer per unit hydraulic gradient. The *T* values estimated from the Preliminary Yield Test and pumping test data of the bore wells in Keonjhar district range between the minimum of 0.18 m^2/day at Balijodi in Ghatgaon block to the maximum of 361.5 m^2/day at Kanto in Ghasipura block. The average transmissivity stands at 32.3 m^2/day. The geographic distribution of the *T* values (Plate 6.7) indicate that the aquifers with relatively high *T* (>40 m^2/day) are clustered more towards central and south-eastern parts of the district, specifically in the blocks of Banspal, Harichandanpur, Ghatgaon, Ghasipura, Anandapur and parts of Patna. In the northern parts, the aquifers seem to be less transmissive where the major number *T* values are reported to be 20 m^2/day. Major patches in Patna, Saharpada, Jhumpura, Champua, Joda, Banspal and Keonjhar register *T* values even less than 10 m^2/day (Plate 6.7). It should be noted here that the northern, north-eastern parts of the district is rich in fracture zones. From the previous section (yield potential of aquifers) it was seen that the northern parts are also less productive as far as the potentiality of the aquifers are concerned. Thus, it can be said that the fracture aquifers in the northern/north-eastern parts of the district are less productive and less transmissive as well.

As far as the individual aquifer systems are concerned, the 1st aquifer system is more transmissive with the *T* values varying between 0.27-361.5 m^2/day. The average *T* value improves up to 39 m^2/day. The reported values of *T* for the laterite aquifers vary between 3.2 m^2/day to 506.85 m^2/day, indicating their high development potential. In the 2nd aquifer system, the *T* values range between 0.18-59.3 m^2/day with the average of only 14.2 m^2/day. This is in congruence with the availability of less number of fractures and low yield of aquifers.

6.3.4 Storativity

Storativity or coefficient of storage (S) is a measure of the volume of water yield per every unit fall in the piezometric head. In confined/semi-confined aquifers, the volume of water yield remains quite less in comparison to the volume of water yield in an unconfined aquifer with the same decline in head. In case of confined aquifers, the storativity in general ranges between 0.001-0.00001. Some of the high yielding wells, where, pumping could be carried out, the storativity (*S*) values of the aquifers have been worked. As per the reported values, the *S* varies between the maximum of $3.6X10^{-2}$ at Nalda in Joda block to minimum of $2.4X10^{-5}$ at Dhenkikote in Ghatgaon block. The average *S* stands at $4.6X10^{-3}$, which is indicative of unconfined to confined character of the aquifer.

PLATE – 6.1

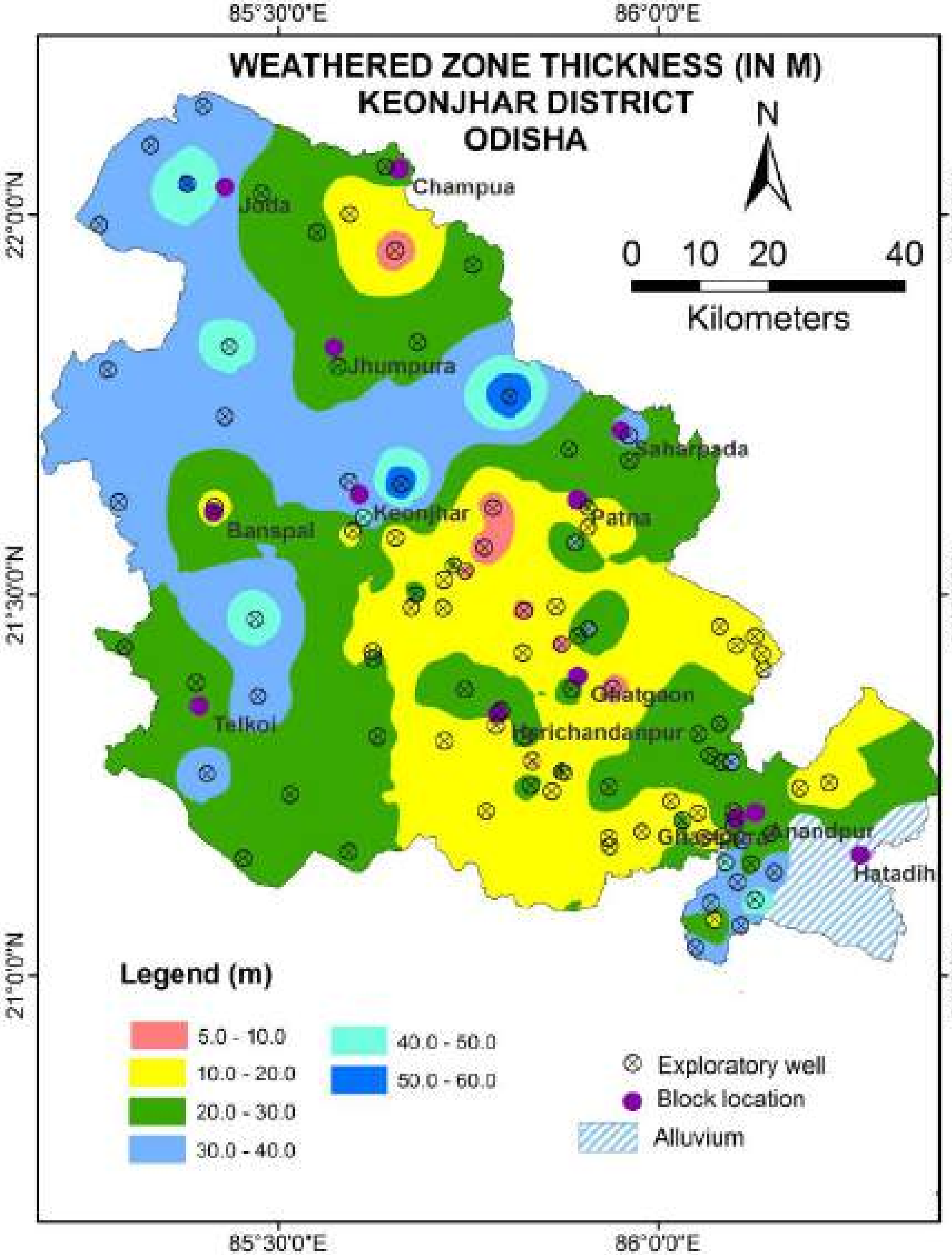

WEATHERED ZONE THICKNESS (IN M)
KEONJHAR DISTRICT
ODISHA
N
0 10 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Champua
Joda
Jhumpura
Saharpada
Banspal
Keonjhar
Patna
Ghatgaon
Telkoi
Harichandanpur
Ghasipura
Anandpur
Hatadih
Legend (m)
5.0 - 10.0
10.0 - 20.0
20.0 - 30.0
30.0 - 40.0
40.0 - 50.0
50.0 - 60.0
Exploratory well
Block location
Alluvium

PLATE – 6.2

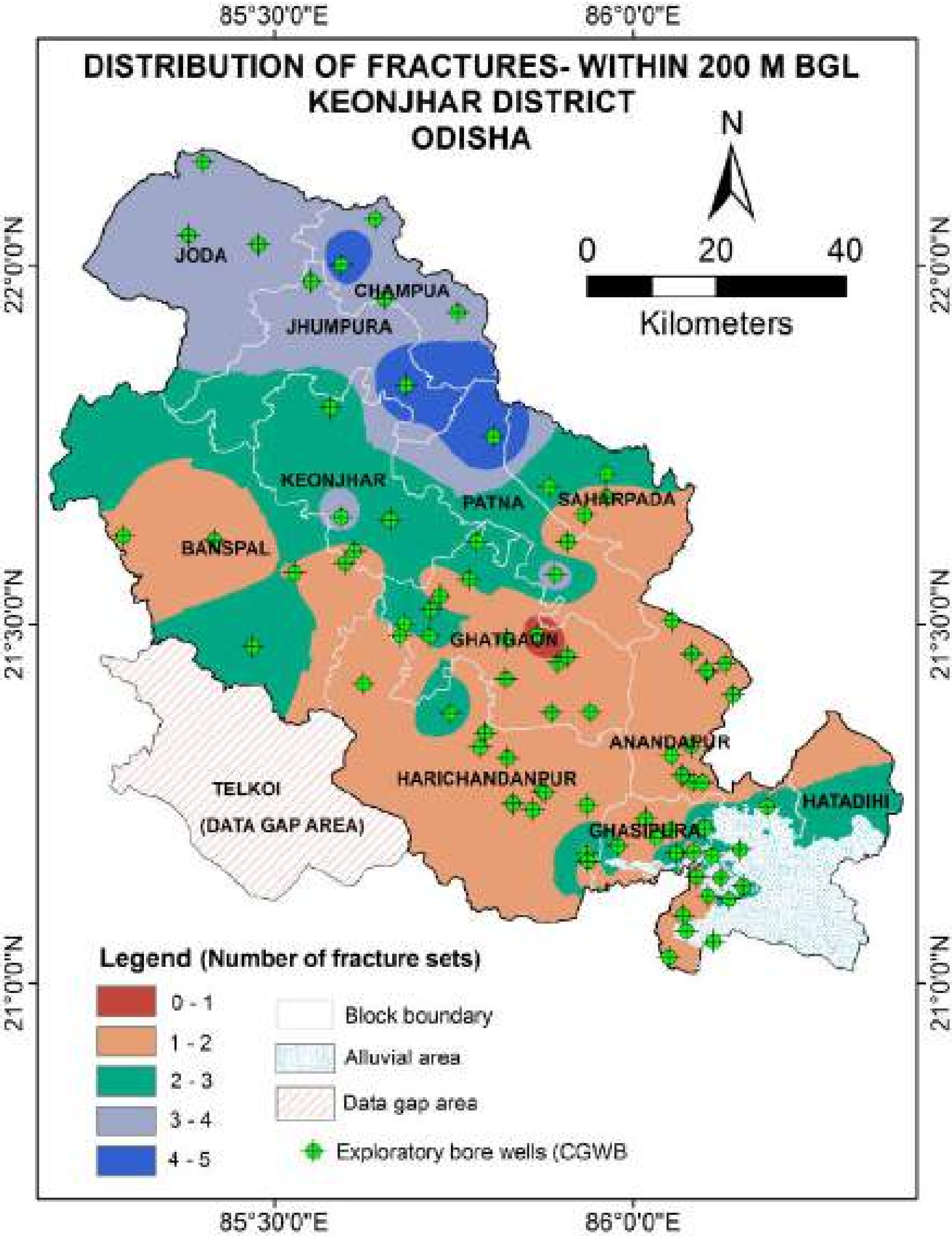
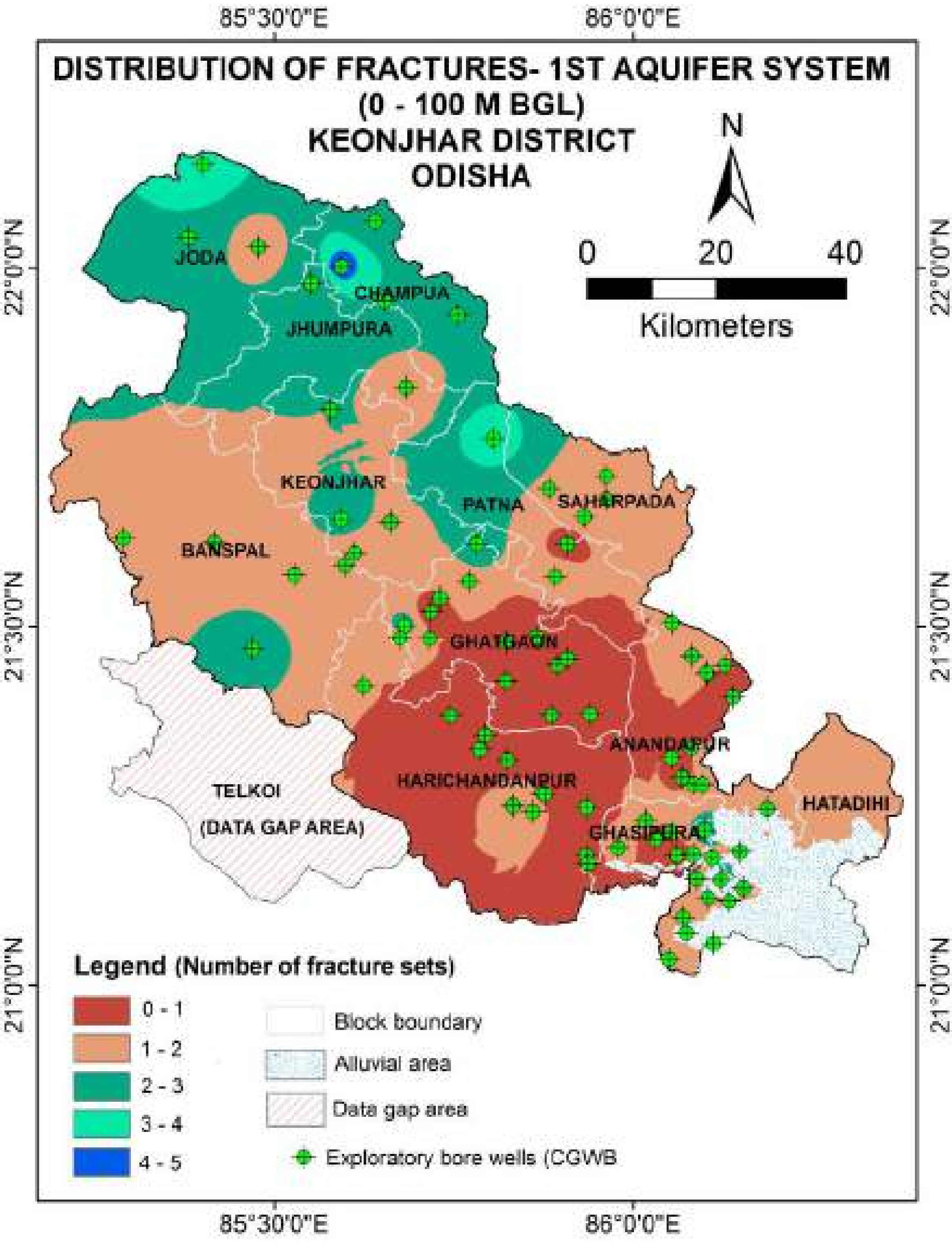

DISTRIBUTION OF FRACTURES- WITHIN 200 M BGL
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
HARICHANDANPUR
HATADIHI
GHASIPURA
TELKOI
(DATA GAP AREA)
Legend (Number of fracture sets)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
Block boundary
Alluvial area
Data gap area
Exploratory bore wells (CGWB

PLATE – 6.3



DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
HARICHANDANPUR
HATADIHI
GHASIPURA
TELKOI
(DATA GAP AREA)
Legend (Number of fracture sets)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
Block boundary
Alluvial area
Data gap area
Exploratory bore wells (CGWB

PLATE – 6.4

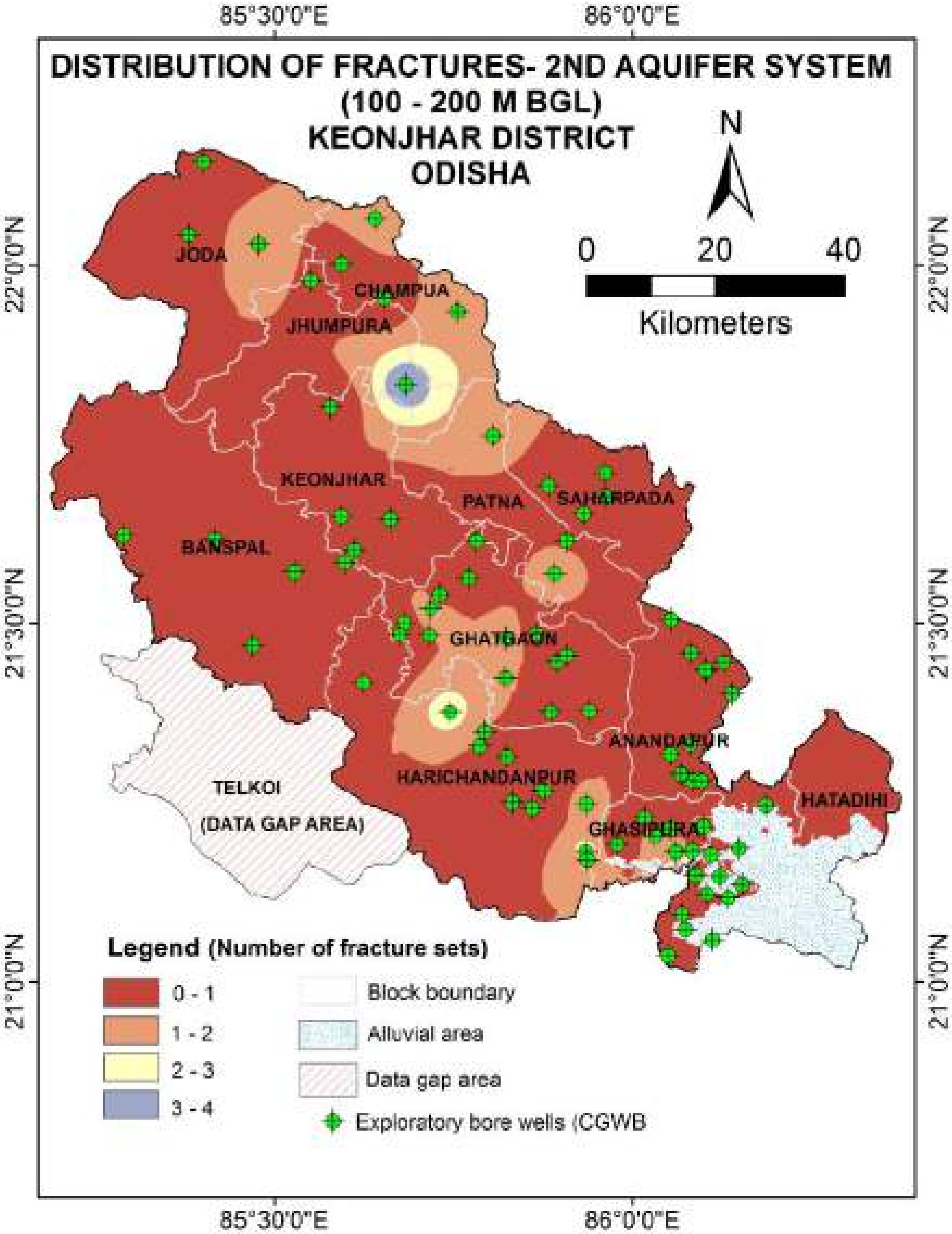
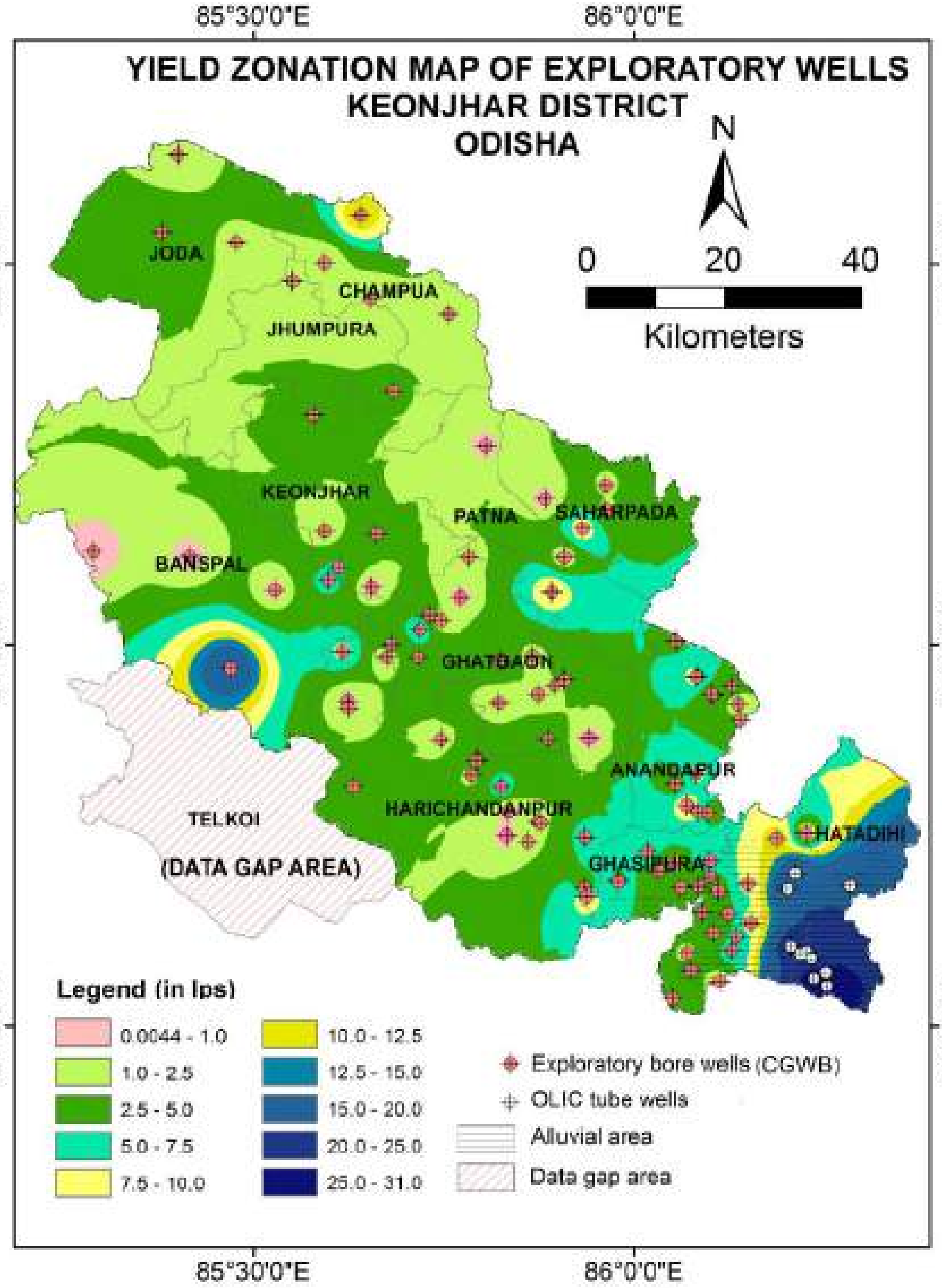
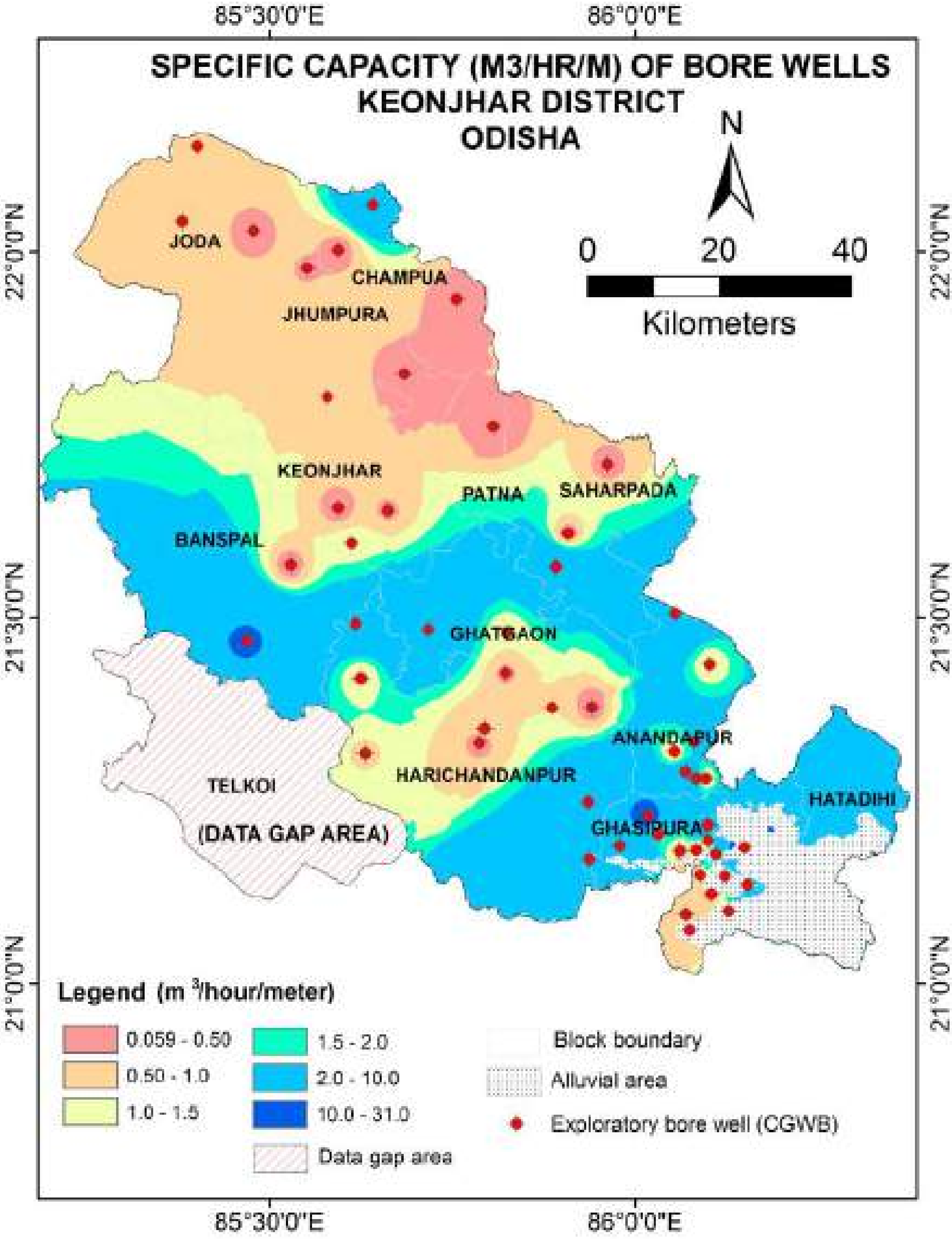

85°30'0"E
86°0'0"E
DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
KEONJHAR DISTRICT
ODISHA
N
0
20
40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
HARICHANDANPUR
HATADIHI
GHASIPURA
TELKOI
(DATA GAP AREA)
Legend (Number of fracture sets)
0 - 1
1 - 2
2 - 3
3 - 4
Block boundary
Alluvial area
Data gap area
Exploratory bore wells (CGWB

PLATE – 6.5



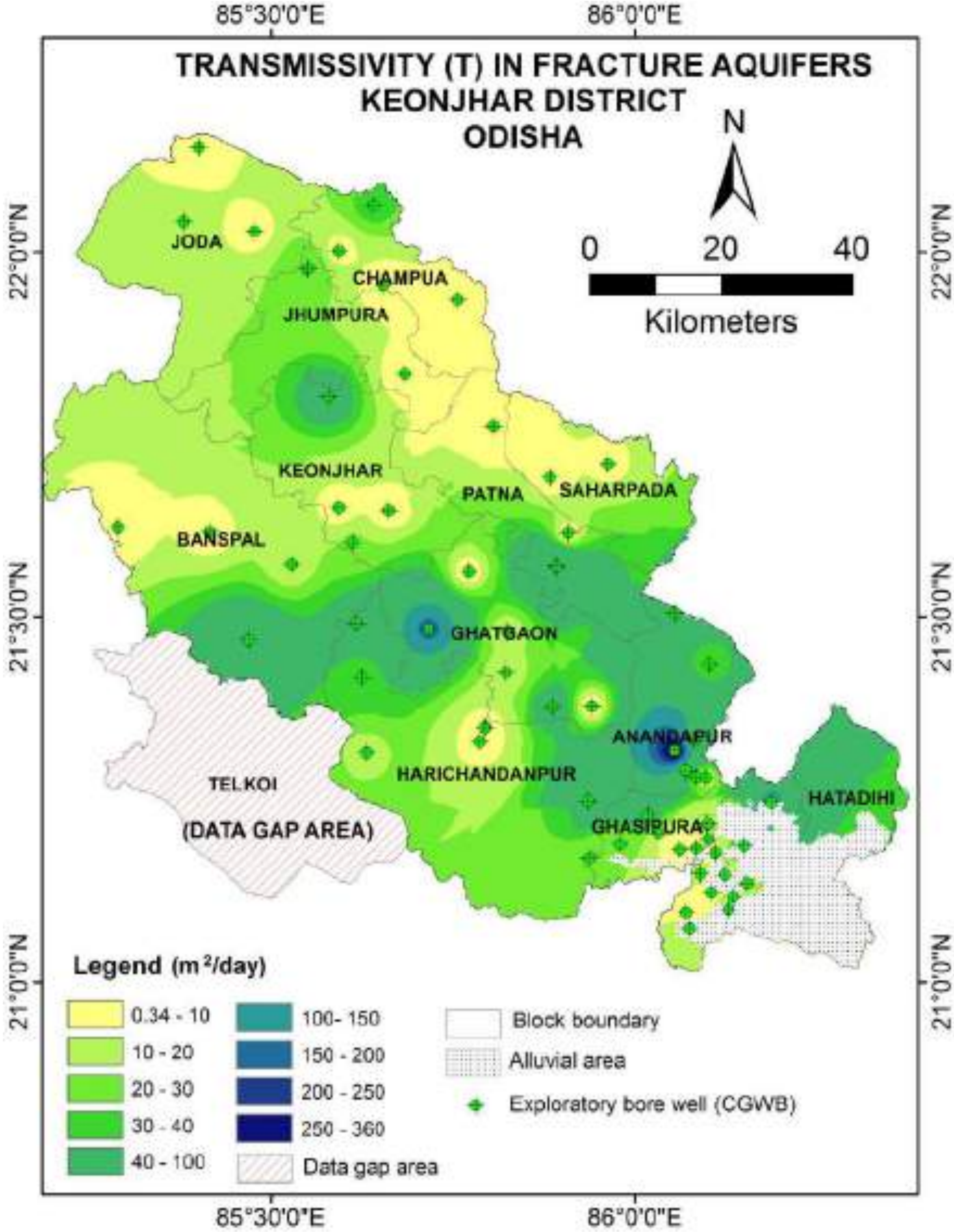
YIELD ZONATION MAP OF EXPLORATORY WELLS
KEONJHAR DISTRICT
ODISHA
N
0
20
40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
HARICHANDANPUR
HATADIHI
GHASIPURA
TELKOI
(DATA GAP AREA)
Legend (in lps)
0.0044 - 1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
12.5 - 15.0
15.0 - 20.0
20.0 - 25.0
25.0 - 31.0
Exploratory bore wells (CGWB)
OLIC tube wells
Alluvial area
Data gap area

PLATE – 6.6



SPECIFIC CAPACITY (M3/HR/M) OF BORE WELLS
KEONJHAR DISTRICT
ODISHA
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
N
0 20 40
Kilometers
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
HARICHANDANPUR
TELKOI
(DATA GAP AREA)
HATADIHI
GHASIPURA
Legend (m ³/hour/meter)
0.059 - 0.50
0.50 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 10.0
10.0 - 31.0
Data gap area
Block boundary
Alluvial area
Exploratory bore well (CGWB)

PLATE – 6.7



TRANSMISSIVITY (T) IN FRACTURE AQUIFERS
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
HARICHANDANPUR
TELKOI
(DATA GAP AREA)
GHASIPURA
HATADIHI
Legend (m²/day)
0.34 - 10
10 - 20
20 - 30
30 - 40
40 - 100
100- 150
150 - 200
200 - 250
250 - 360
Data gap area
Block boundary
Alluvial area
Exploratory bore well (CGWB)

7.0 GROUND WATER POTENTAIL ZONES, KEONJHAR DISTRICT

7.1 Overview

There has been a tremendous increase in the demand for groundwater due to increase in population, advanced irrigation practices and industrial usages in recent times. In the scenario of resultant increasing in water scarcity at different localities, it has been quite important to garner knowledge about the existence of groundwater potential zones/areas. Though, field methodologies such as geophysical and drilling techniques are more appropriate for such purpose, simple mapping techniques of Geographical Information Systems (GIS) and remote sensing can help in preliminary reonnaitory surveys. These techniques have many more avdantages over the field tehniques. Inluding the areas of poor/diffiult aessibility, the mapping tehniques can produce good results for even a greater area at a time. In recent times, inumerable workers have attempted to identify precisely the groundwater potential zones by using remote sensing and GIS techniques. GIS is an effective tool for storage, management and retrieval of spatial and non-spatial data as well as for integration and analysis of this information for meaningful solutions The GIS techniques have helped to integrate various controlling parameters on groundwater Integration of the information on the controlling parameters. The integration of GIS and remote sensing has proved to be extremely useful for groundwater studies.

Overlay analysis is a methodology used in optimal sites seletion. It is a technique for applying common scales of values to diverse and dissimilar inputs to create an integrated analysis. In this section, it has been tried to identify the probable groundwater potential zones in the Keonjhar district using the overlay analysis in the integrated platform of remote sensing and GIS techniques. The input parameters which have been used in the process for identifying groundwater potential zones are described in brief in the following lines.

7.2 Input parameters for overlay analysis

The groundwater condition in any river basin depends on various factors like climate, rainfall, geomorphi and geologi conditions in the area, soil type, landuse/land cover, drainage density, weathered zone extent and thickness, lineamnets and their density, slope of the land surface etc. All these parameters when considered with suitable ranks and weightages in overlay analysis to delineate the groundwater potential zones in any area.

7.2.1 Geology

Geology plays the major role in the occurrence and movement of groundwater. The major litho-units found in the district include the Singhbhum granite, other granites and gneisses, BHQ/BHJ, Quartzite, shale, sandstones, basic/ultra-basic intrusives, volcanic/meta-volcanic and alluvium. Among these the Singhbhum granites, BHQ/BHJ, quartzites, sandstones, volcanic/meta-volcanic and alluvium etc bear good groundwater potential. The ranks assigned to various litho-units are produced in Table 7.1.

7.2.2 Geomorphology

Geomorphology represents the surficial landforms which play the role in controlling the infiltration of water (including rain water) into the ground to augment the groundwater resources. In the district of Keonjhar, a number of geomorphic units are observed which have already been discussed in detail in previous chapters. The significant geomorphic units which help in retaining and infiltrating more water to underground include the buried pediments, intermontane valleys, valley fills, alluvial plains etc. Such features cover about 50% of the district area. The linear ridges/dykes, though, themselves often don’t host groundwater they create favorable conditions of groundwater storage in the country rock. In the present study, it has been found that the areas which are traversed by intrusives do possess more number of sub-surface fractures, often hosting groundwater. The landforms like structural / denudational / residual hills are poor as far as the groundwater conditions in them are concerned.

7.2.3 Slope

Slope is a significant factor that controls the rainfall infiltration and groundwater storage. The land surcaes with slope greater than 20% are considered as poor as far as the rainfall infiltration is considered. In Keonjhar district, around 92% (Table 3.3) of the area possesses slope less than 20%, including ~79% of the area with ground surface slope less than 10%. A detail account of the surface slope in the district has already been given in the previous chapter.

7.2.4 Weathered zone thickness

The availability of loose and permeable soil at the surface helps the water to infiltrate. Hard and compact surface only leads to run-off. The weathered zone in the hard rock areas forms by weathering and loosening of rocks. Such zones are richer in sand, gravels and clayey minerals. The loosened joints and fractures in the rocks give passage ways for water infiltration. The thickness of weathered zone in the hard rock areas plays a significant role in absorbing and storing water. Such zones in the hard rock areas often form potential aquifers for exploitation for various purposes. Thicker the zone more is the chance of groundwater storage. The weathered zone thickness between 20.0 – 30.0 m covers 42% of the area of the district (Fig 6.2).

7.2.5 Soil

Soil texture is an important factor for delineating the groundwater potential zones. Besides the slope, the infiltratioin and run-off relation depends on the soil properties and its texture. In Keonjhar district the soil types are red sandy, red gravelly, red loamy, red and yellow and alluvial soils. The red sandy, gravelly and alluvial soils bear moderate to very good potential for water infiltration. The lateritic soil is also good in water infiltration, but its vertical extent remains less.

7.2.6 Drainage density

Drainage density can be defined as the ratio of total length of the stream and river in the drainage basin and total area of the drainage basin. The study area has a dense network of streams due to the presence of mountains on its western part. The drainage density bears an inverse relation with the groundwater formation. More density of drainage indicates less infiltration avenues and more run-off and vice-versa. The drainage density map has been prepared considering the flow accumulation in range of 100 m and more (Plate 7.9). The drainage density in the district varies from 0.11 km/km^2 to 3.7 km/km^2. The entire district has been put into four zones; 0.11 – 1.0, 1.0 – 2.0, 2.0 – 3.0 and 3.0 – 3.7 km/km^2. Though, the drainage density beyond 3.0 km/km^2 is little more, they are very limited in the district and observed in certain patches only. The major parts of the district is covered with drainage density <3.0 km/km^2.

7.2.7 Lineament density

Lineaments are primarily discontinuities on the earth surface caused by geological and geomorphological process. Lineaments are formed due to various geological features like faults, shear zone, dykes and veins as well as bedding planes and stratigraphic contacts. These features can be mapped both in local and regional scales for mineral, oil, gas and groundwater studies. While, the faults, shear zones and any other avenues along the bedding planes, contacts provide passage ways for water infiltration and percolation. The fractured, jointed and disintegrated rocks provide storage space for groundwater. The satellite maps in a bigger wat help to identify such features on the ground surface. In hily and hard rock areas, the lineaments often prove to be indicators of the existence of potential groundwater reservoirs underneath. Therefore, it is very important factor in groundwater potential zone demarcation. The lineaments in the Keonjhar district were mapped and traced manually with the help of drainage and topographic maps. The district is traversed by swarms of basic linear dykes in NE-SW and NW-SE directions. The dykes also create favoravle conditions for groundwater reservoir. In previous sections of this report it has been pointed out that the existence of basic dykes in any area also warrants the availability of fractures underneath. The drainage density map of the district has been produced in Plate 7.10.

7.2.8 Land use/ land over

Land use is the description of how the land is being used by the people with respect to its suitability for particular use, whereas land cover is the description of physical material that covers the earth's surface irrespective of its suitability for specific use. Such as ofetn the cities grow on potential aquifers aquifers underneath which can help to meet the water demand. Similarly, people opt for the *rabi* crops when groundwater is available below the land in the absence of surface water irrigation. The land use pattern in any area is often guided by the availability of groundwater. The existence of water bodies like rivers, reservoirs, tanks, ponds etc in any area can also help in augmenting the groundwater resources by addional recharge. Forests and vegetal cover helps groundwater recharge and minimises surface run-off. Highly permeable land covers like forests, agricultural lands, and shrub lands favor the groundwater potential whereas low permeable lands like rocky/stony land, gullied land and eroded lands increase run-off thus limiting the percolation to subsurface.

7.2.9 Rainfall

The rainfall is the source of all water. It is an important factor for groundwater formation. The duration and intensity of rain determines the groundwater recharge, run-off and evaporation. Low rainfall, high evaporation and run-off limit recharge to the groundwater systems. Large showers in short times only increase run-off. However, higher rainfall in any area gives a possibility of groundwater potentia zones. In Keonjhar district, the rainfall remains moderate to high in the range of ~1000-1800 mm. ThusIt indicates there is no dearth of rainfall in the district for the groundwater formation in aquifers.

7.3 Ranks and weightages

All the parameters taken into account have been classified into four ranks depend ing on the characteristics of the areas; 1- low groundwater potential, 2- moderate groundwater potential, 3- good groundwater potential and 4- very good groundwater potential. The reclassified images of the parameters geology (lithology), geomorphology, slope, weathered zone, soil, drainage density, land use and rainfall have been produced in Plates 7.1 – 7.8. The other parameter, the lineament density (Plate 7.10) with its four classes such as 0.0 – 0.20, 0.20 – 0.40, 0.40 – 0.60 and 0.60 – 0.82 represent the ranks 1, 2, 3 and 4 respectively. The ranks of vaious characters of the parameters, used in the groundwater potential zone delineation, have been produced Table 7.1. The weightages of all the nine parameters have been produced in Table 7.2. The geomorphology, weathered zone thickness and geology have been given upper end weightages of 20%, 15% and 13% respectively. The drainage and lineament densities have been given 12 and 11% respectively. The slope has been given the weightage of 10%. The soil and rain fall have been given the lower end weighatges of 5 and 6% respectively.

Table 7.1: Ranks assigned to various parameter characters

Sl. No	Parameter	Character	Rank
1.	Lithology (Geology)	Singbhum granite	3
		Varigated Shale	4
		Alluvium	4
		BHQ/ BHJ	3
		Volcanics/Lava	4
		Schist/Gneiss Mixed	2
		BHQ	3

		Quartzite/Shale/Sandstone	4
		Granite/Younger Granite	1
		Granite gneiss/Gneiss	2
		Banded Magnetite Quartzite	2
		Gabbro Anorthosite	1
		Quartzite	2
2.	Geomorphology	Bar deposits	4
		Alluvial plain	4
		Buried pediment shallow	2
		Buried pediment deep	3
		Denudational hill	1
		Gully land	1
		Inselberg	1
		Intermontane valley	4
		Laterite upland	2
		Linear ridge/dye	1
		Pediment	2
		Plateau	3
		Residual hill	1
		River/water bodies	4
		Structural hill	1
		Valley fills	4
1.	Slope	0 – 5%	4
		5 – 10%	4
		10 – 15%	3
		15 – 20%	2
		>20%	1
4.	Weathered zone thickness (m)	5.0 – 10.0	1
		10.0 – 20.0	2
		20.0 – 30.0	3
		30.0 – 60.0	4
5.	Soil	Red sandy	3
		Red gravel	4
		Red and yellow	1
		Red loamy	2
		Red laterite	2
		Older alluvial soil	4
6.	Drainage density (km/km^2)	3.6 – 35.5	1
		35.5 - 50.98	2

		50.98 - 66.12	3
		66.12 - 101.52	4
7.	Lineament density (km/km^2)	0 – 0.17	1
		0.17 – 0.31	2
		0.31 – 0.47	3
		0.47 – 0.81	4
8.	Land use/land over	Crop land	4
		Fallow land	2
		Kharif land	2
		Kharif + rabi	4
		Rabi	4
		Town/cities	**3**
		Villages	2
		Shifting cultivation	1
		Gullies, ravines, eroded land	1
		Land with shrub	2
		Land without shrub	1
		Mining/industrial waste land	1
		Sandy area (river bars)	4
		Water logged area	3
		Lakes/reservoirs	4
		River/stream/creeks	4
		Decidous dense forest	4
		Decidous moist dry forest	4
		Decidous moist dry open forest	3
		Decidous moist dry shrub forest	3
9.	Rainfall	1000 – 1200	1
		1200 – 1400	2
		1400 – 1600	3
		1600 - 1800	4

7.4 Ground water potential zones

The groundwater potential zones in the Keonjhar district have been delineated following the weighted sum methodology of ArcGIS. Good to very good potential zones are largely clustered in the northern and southerns parts of the district (Plate 7.11). The parts in the central, eastern and western parts in the blocks such as Ghatgaon, harichandanpur, Telkoi, Saharpada, Patna and Anandapur fall in the low to moderate potential zones.

Area percent of different groundwater potential zones in the Keonjhar district has been produced in Fig 7.1. Around 34.6 and 37.3% of the district area are occupied by moderate and good groundwater potential zones respectively. Around 13.6% of the district area is covered by very good groundwater potential zones. Only 14.3% area of the district falls in the low potential zones.

Table 7.2: Weightage assigned to various parameters used

Sl. No	Parameter	Weightage
1	Geology	13
2	Geomorphology	20
3	Slope	10
4	Weathered zone thickness	15
5	Soil	5
6	Drainage density	12
7	Lineament density	11
8	Land use/land cover	8
9	Rainfall	6

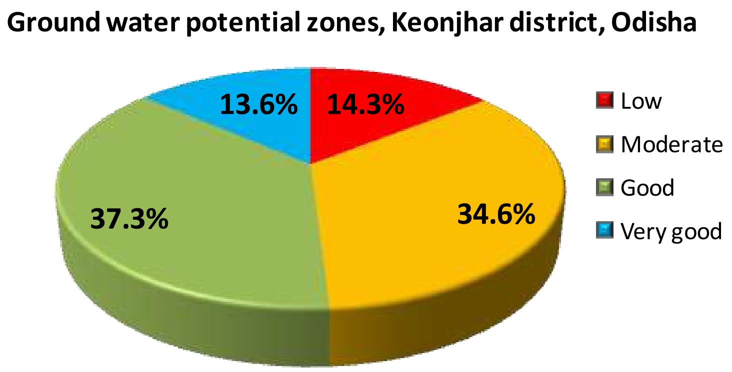


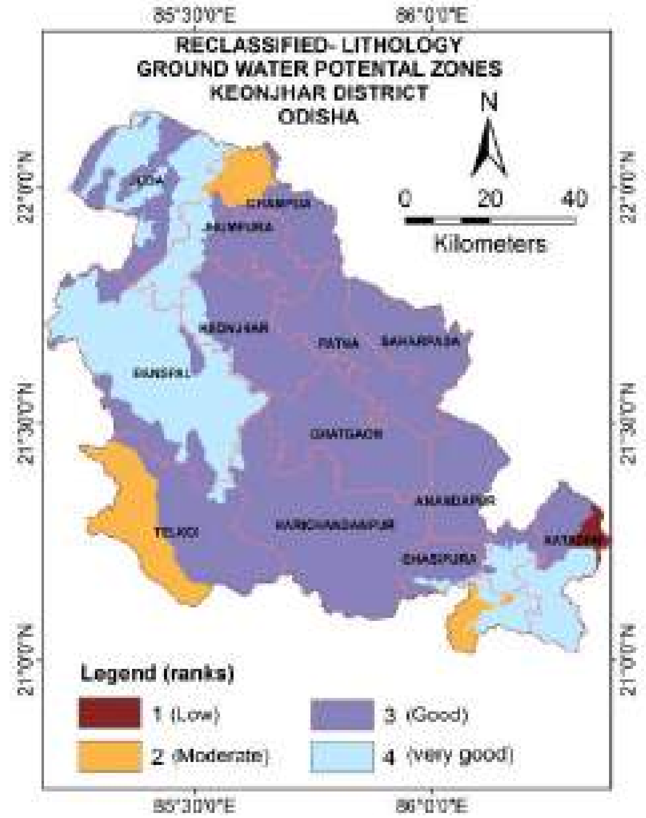
Figure 7.1: Pie diagram depicting the perentage (%) of area of Keonjhar district, Odisha, falling under different groundwater potential zones.

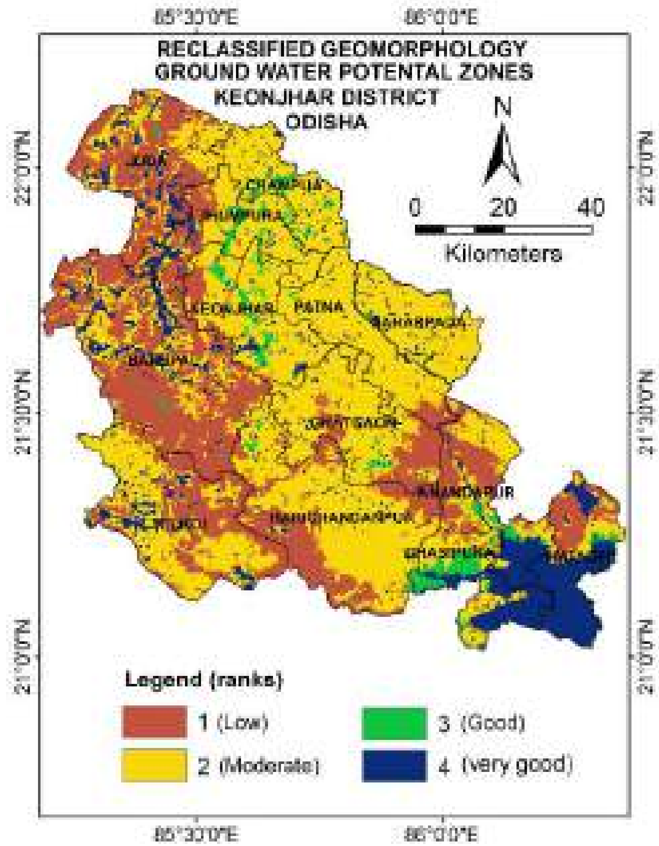
The groundwater potential zones for each block in the Keonjhar district have been worked out as area percent (Table 7.3). A perusal of the table indicates that the moderate potential zones predominate in the Champua, Saharpada and Ghatgaon blocks, while the good potential zones remain predominant in Jhumpura, Keonjhar and Patna blocks. Very good potential zones are found to occupy around 48% of the area of Hatadihi block. The low groundwater potential zones largely fall in the blocks of Harichandanpur, Hatadihi, Saharpada, Telkoi, Anandapur, Chgampua and Banspal.

Table 7.3: Perentage (%) area of blocks and Keonjhar district falling under different groundwater potential zones.

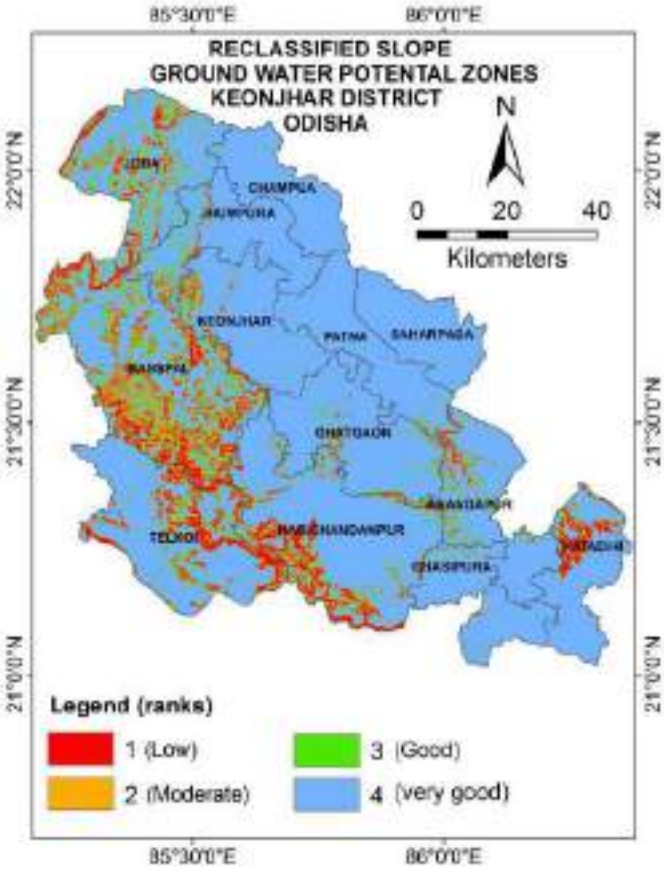
Sl No	Name of block	Area (Km^2) of blocks with different groundwater potential			
		Low	**Moderate**	**Good**	**Very good**
1	Anandapur	16.8	32.5	30.4	20.3
2	Banspal	17.7	34.7	32.8	14.8
3	Champua	10.8	53.5	31.7	3.9
4	Ghasipura	3.8	31.9	31.3	32.9
5	Ghatgaon	9.7	51.2	35.6	3.4
6	Hatadihi	23.3	13.5	15.1	48.1
7	Harichandanpur	25.9	32.7	39.4	2.0
8	Jhumpura	1.8	32.3	49.6	16.4
9	Joda	9.7	26.7	42.5	21.1
10	Keonjhar	2.0	28.3	51.6	18.0
11	Patna	2.8	30.1	60.1	7.1
12	Saharpada	22.1	45.4	26.0	6.6
13	Telkoi	19.9	39.2	34.5	6.3
	District total	**14.3**	**34.7**	**37.4**	**13.6**

PLATES – 7.1 & 7.2

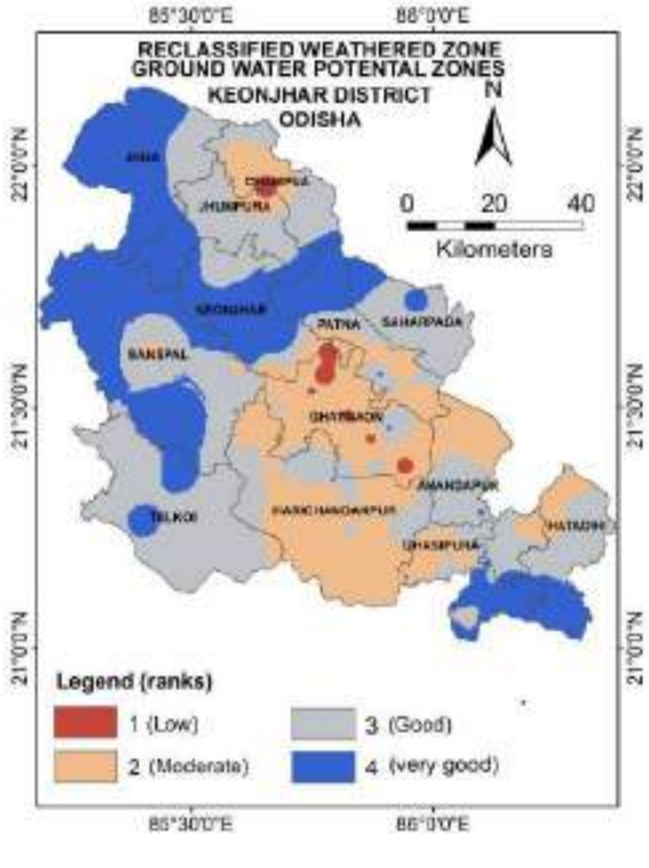

85°30'0"E
86°0'0"E
RECLASSIFIED- LITHOLOGY
GROUND WATER POTENTAL ZONES
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
KEONJHAR
PATNA
SAHARPADA
GHATGAON
ANANDAPUR
TELKOI
GHASIPURA
Legend (ranks)
1 (Low)
2 (Moderate)
3 (Good)
4 (very good)


85°30'0"E
86°0'0"E
RECLASSIFIED GEOMORPHOLOGY
GROUND WATER POTENTAL ZONES
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
TELKOI
HARICHANDANPUR
GHASIPURA
Legend (ranks)
1 (Low)
2 (Moderate)
3 (Good)
4 (very good)

PLATES – 7.3 & 7.4

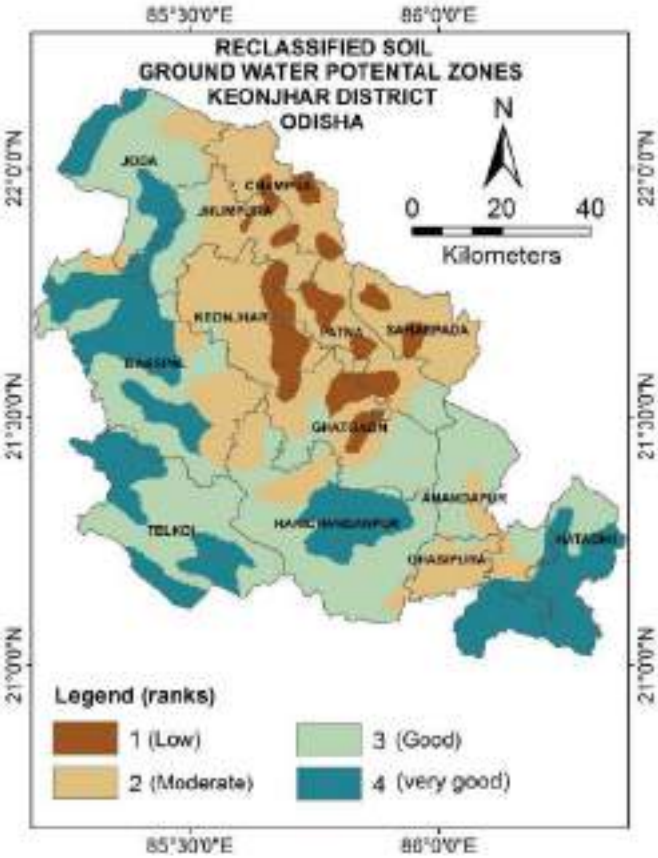


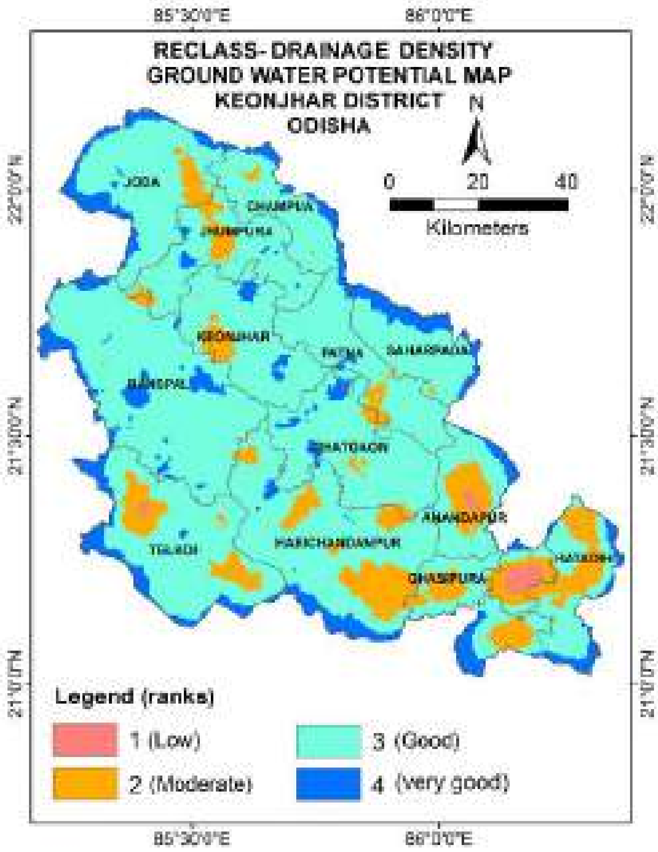
RECLASSIFIED SLOPE
GROUND WATER POTENTAL ZONES
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
TELKOI
HARICHANDANPUR
GHASIPURA
HATADIHI
Legend (ranks)
1 (Low)
2 (Moderate)
3 (Good)
4 (very good)



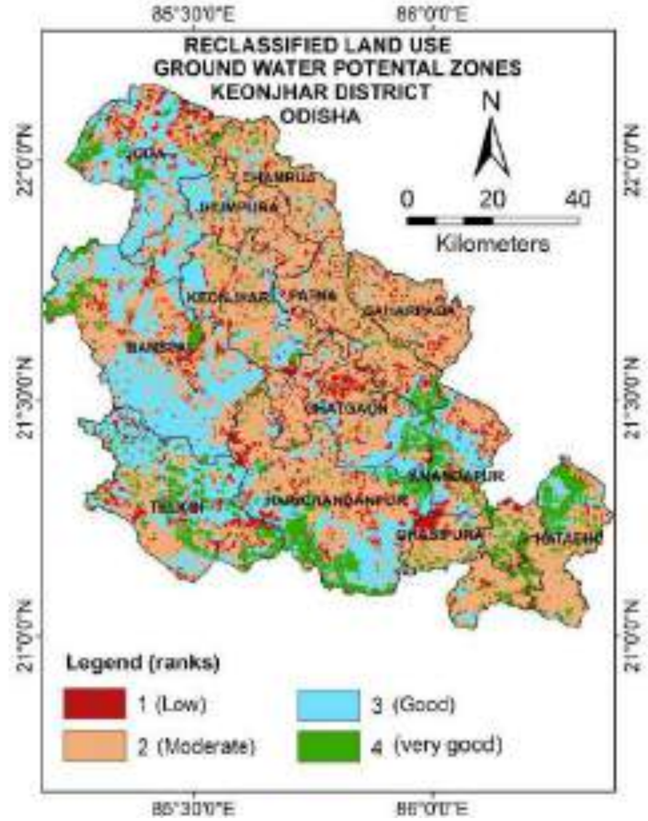
RECLASSIFIED WEATHERED ZONE
GROUND WATER POTENTAL ZONES
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
TELKOI
HARICHANDANPUR
GHASIPURA
HATADIHI
Legend (ranks)
1 (Low)
2 (Moderate)
3 (Good)
4 (very good)

PLATES – 7.5 & 7.6


RECLASSIFIED SOIL
GROUND WATER POTENTAL ZONES
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Legend (ranks)
1 (Low)
2 (Moderate)
3 (Good)
4 (very good)


RECLASS- DRAINAGE DENSITY
GROUND WATER POTENTIAL MAP
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Legend (ranks)
1 (Low)
2 (Moderate)
3 (Good)
4 (very good)

PLATES – 7.7 & 7.8


RECLASSIFIED LAND USE
GROUND WATER POTENTAL ZONES
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
Legend (ranks)
1 (Low)
2 (Moderate)
3 (Good)
4 (very good)
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N

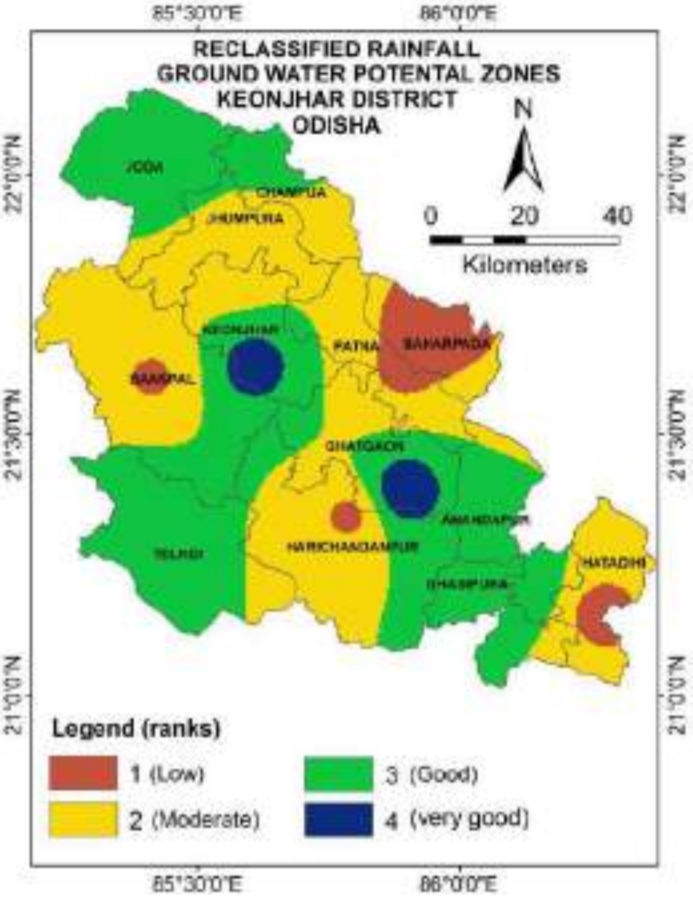
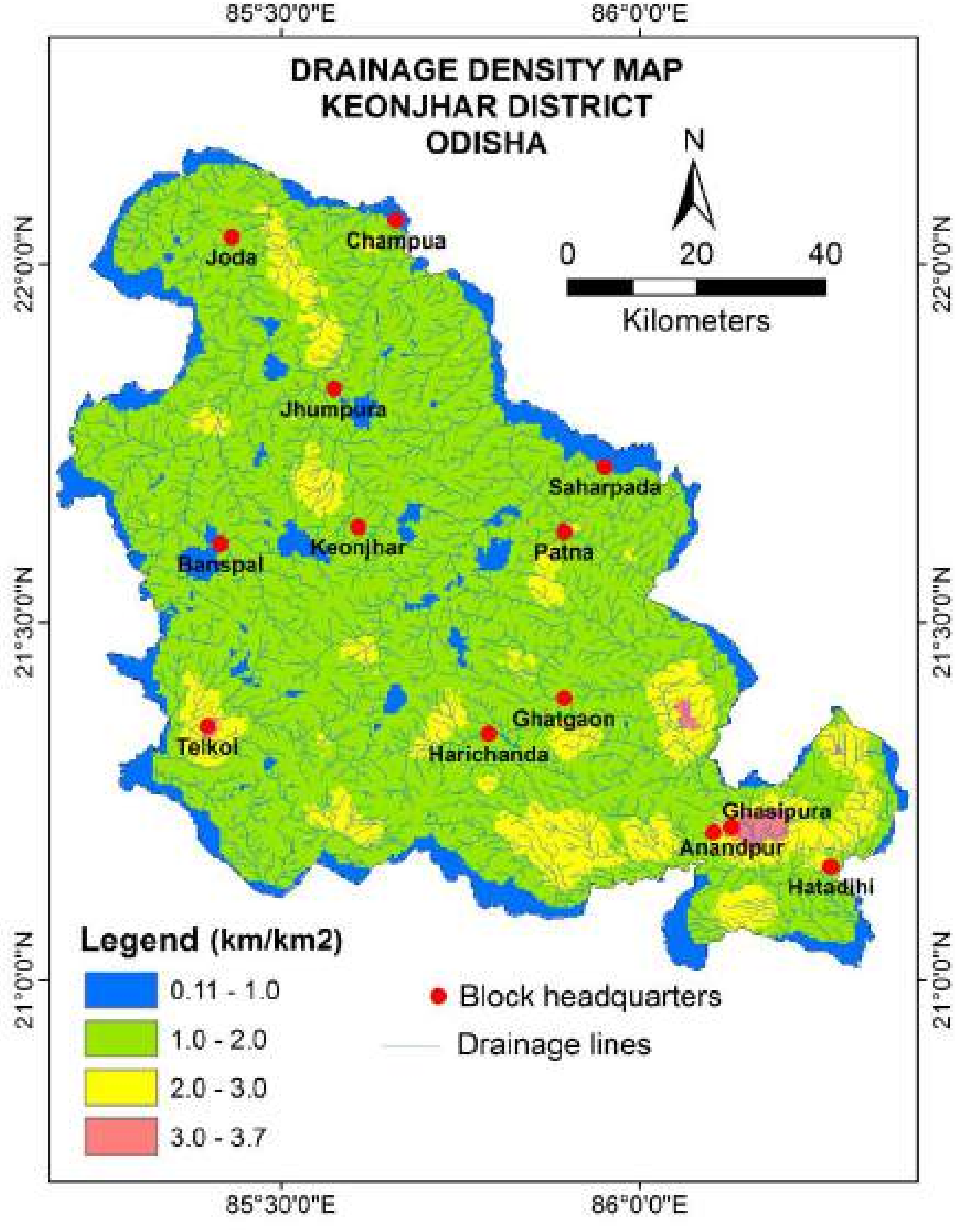
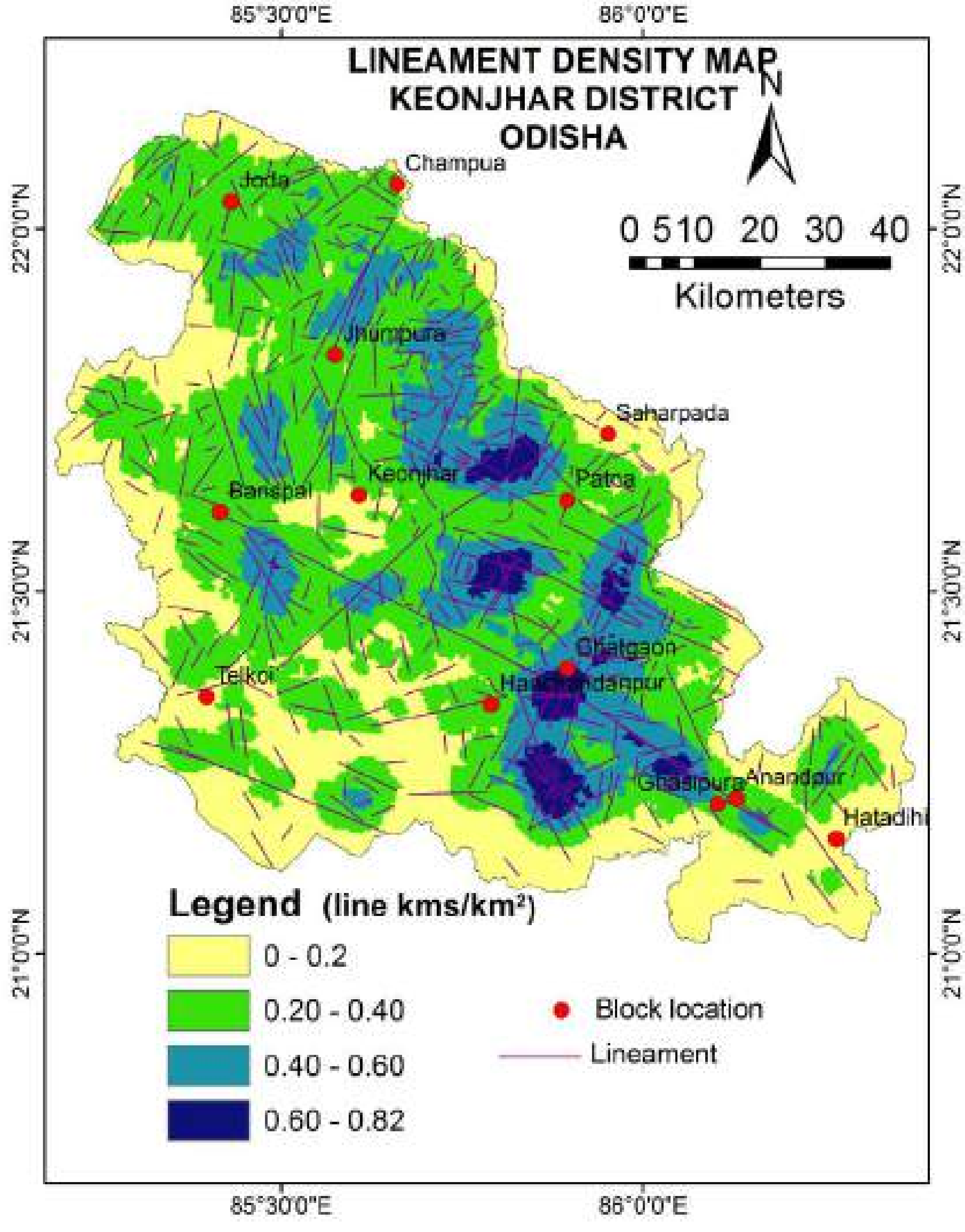

RECLASSIFIED RAINFALL
GROUND WATER POTENTAL ZONES
KEONJHAR DISTRICT
ODISHA
N
0 20 40
Kilometers
Legend (ranks)
1 (Low)
2 (Moderate)
3 (Good)
4 (very good)
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N

PLATE – 7.9



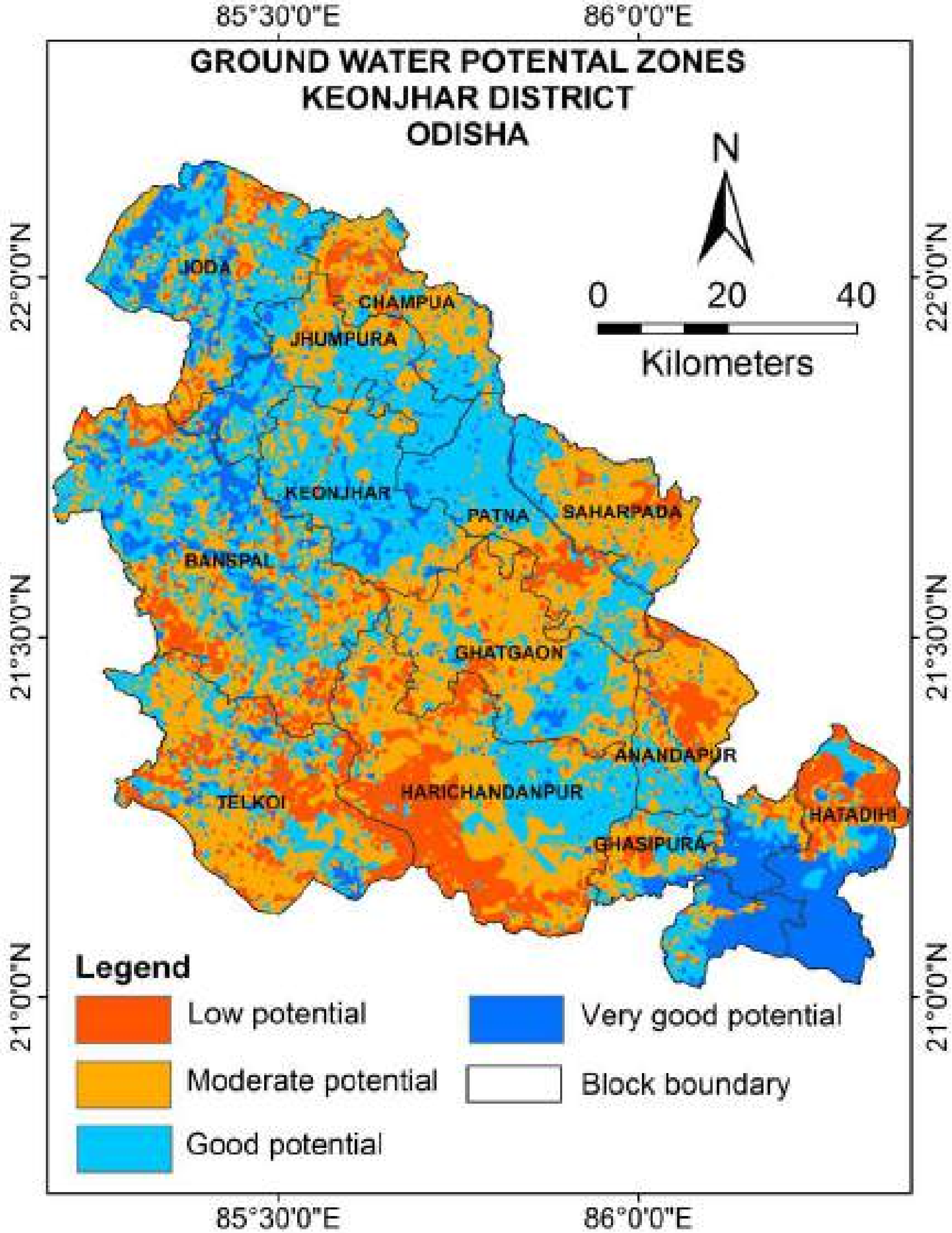
DRAINAGE DENSITY MAP
KEONJHAR DISTRICT
ODISHA
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
N
0
20
40
Kilometers
Joda
Champua
Jhumpura
Saharpada
Keonjhar
Banspal
Patna
Ghatgaon
Telkoi
Harichanda
Ghasipura
Anandpur
Hatadihi
Legend (km/km2)
0.11 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 3.7
Block headquarters
Drainage lines

PLATE – 7.10



LINEAMENT DENSITY MAP
KEONJHAR DISTRICT
ODISHA
N
0 5 10 20 30 40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Champua
Joda
Jhumpura
Saharpada
Keonjhar
Banspal
Patna
Ghatgaon
Telkoi
Harichandanpur
Ghasipura
Anandpur
Hatadihi
Legend (line kms/km²)
0 - 0.2
0.20 - 0.40
0.40 - 0.60
0.60 - 0.82
Block location
Lineament

PLATE – 7.11


GROUND WATER POTENTAL ZONES
KEONJHAR DISTRICT
ODISHA
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
N
0
20
40
Kilometers
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
TELKOI
HARICHANDANPUR
GHASIPURA
HATADIHI
Legend
Low potential
Moderate potential
Good potential
Very good potential
Block boundary

8.0 CHEMICAL QUALITY OF GROUND WATER

Quality of groundwater is an important factor for assessing its suitability for various uses in drinking, irrigation and industry. Ground water quality depends upon the lithological and chemical composition of the aquifer, climatic conditions, quantum of recharge and its movement through the aquifer, rock-water interactions, and activities of microorganisms, temperature and presence of contaminants in the environment. The groundwater quality in the aquifer systems in the Keonjhar district are discussed below.

8.1 Shallow phreatic/1st Aquifer System

Chemical analysis of 170 groundwater samples collected from the key wells and the NHNS wells were done. The groundwater samples were collected the pre-monsoon p[eriod of the year 2018. These monitoring stations basically dug wells within the depth range of 5 – 15 m bgl. The details of the analytical results of the groundwater samples are given in **annexure**.

8.1.1 Ground water quality and suitability for drinking

The range of the different chemical parameters along with their suitability for drinking (as WHO, 2012 and BIS, 2012) is presented in **Table 8.1**. The water in the shallow phreatic aquifer is largely suitable for drinking except in certain minor pockets.

Table 8.1: Range of chemical constituents in shallow phreatic aquifers of Keonjhar district.

Parameters (Major ions in mg/L)	Min.	Max.	Ave.	WHO (2012)	BIS (2012)		No. of groundwater samples exceeding BIS (2012) limit	
					Highest desirable	Max. permissible	Highest desirable	Max. permissible
pH	6.7	8.7	7.9	7.0-8.5	6.5-8.5	8.5-9.2	*n* = 2	nil
EC (µs/cm at 25^{0}C)	55.0	1720.0	420.8	750.0	-	-	-	-
TDS	36.4	882.0	219.7	500.0	500.0	2000.0	*n* = 13	nil
TH	20.0	662.0	143.0	500.0	300.0	600.0	*n* = 10	*n* = 1
Alkalinity	5.0	501.0	128.3	-	-	-		
Ca^{2+}	4.0	120.0	34.4	75.0	75.0	200.0	*n* = 5	nil
Mg^{2+}	0.0	138.0	13.8	30.0	30.0	100.0	*n* = 16	*n* = 1
Na^+	1.0	226.0	23.7	200.0	-	-	-	-
K^+	0.3	176.2	8.8	-	-	-	-	-
CO_3^{2-}	0.0	18.0	0.7	-	-	-	-	-
HCO_3^-	6.0	612.0	148.3	200.0	200.0	600.0	*n* = 41	*n* = 1
Cl^-	3.0	282.0	49.7	250.0	250.0	1000.0	*n* = 2	nil
SO_4^{2-}	0.0	569.0	14.5	200.0	200.0	400.0	nil	nil
F^-	0.1	2.2	0.3	0.6-1.5	1.0	1.5	*n* = 11	*n* = 2

Hydrogen ion concentration (pH): The pH values vary from 6.7 - 8.7 indicating the alkaline nature of groundwater in the shallow phreatic aquifer. The geographic distribution of pH values in the form of contour zones are given in Plate 8.1.

Electrical conductivity: It is the measure of mineralisation and is directly proportional to the salinity of groundwater. A perusal of the data shows that the specific conductivity of groundwater ranges between 55.0 to 1720.0 μS per cm at 25^{0}C. In major parts of Keonjhar district the groundwater is moderately mineralized and fit for domestic and irrigation purposes except for a few patches where very high EC values have been recorded. The EC values of upper range (>1000 μS per cm at 25^{0}C) are observed more in the alluvial patches in the Anandapur, Ghasipura and Hatadihi blocks (Plate 8.2).

Total Dissolved Solids (TDS): As per the TDS values deduced from the EC values, the TDS range between 36.4 – 882.0 mg/L (ave.: 219.7 mg/L). Though, the overal mineralization is low in the district, the load of solids at 10 locations exceed the BIS desirable limit of 500 mg/L. The TDS distribution in the district has been produced in Plate 8.3.

Total hardness (TH): Hardness in groundwater results from the presence of divalent metallic cations, of which Ca^{2+} and Mg^{2+} are the most important. The groundwater samples register TH values varying between 20.0 and 662.0 mg/L (ave.: 143 mg/L). Water containing calcium/magnesium carbonates at concentrations below 60 mg/L is generally considered as soft; 60–120 mg/L, moderately hard; 120–180 mg/L, hard; and more than 180 mg/L, very hard (McGowan, 2000). Among the groundwater samples collected from the Keonjhar district, 18% belong to the soft category, while the rest belong to moderately hard (30%), hard (25%) and very hard (27%) categories. At 10 locations, the TH even exceeds the BIS desirable limit of 300 mg/L, whereas at one place, it even crosses the maximum permissible limit of 600 mg/L (at Puruna Bandhogoda, Ghasipura block).

Calcium: The concentration of calcium ion in shallow groundwater ranges from 4.0 to 120.0 mg/L. However, the calcium concentration is generally within the desirable limit of 75 mg/L except five locations in the district where it exceeds the BIS disirable limit of drinking. The geographic distribution of Ca^{2+} has been produced as a contour zone map in the Plate 8.4.

Magnesium: The magnesium content in water is responsible for its hardness. The desirable limit is 30 mg/L. Though the lower concentration is not harmful, the higher concentrations are laxative. Its concentrations in the groundwater samples from Keonjhar district range between 0.0 – 138.0 mg/L with the average level of 13.8 mg/L. In most of the water samples, Mg^{2+} ion is well within the desirable limit and only in a few cases (n=16) where its concentration is more than the desirable limit of 30 mg/l. At a single location it even exceeds the BIS maximum permissible limit of 100 mg/L (Puruna Bandhogoda, Ghasipura block).

Sodium: The Na^{+} ion concentration varies from 1.0 to 226.0 mg/L with the average concentration of 23.7 mg/L. The lower concentration of Na^{+} is not harmful but higher concentration beyond 200 mg/L is laxative. Sodium ion concentration in the groundwater throughout the district is well within the permissible limit.

Bicarbonate: Bicarbonate is the principal anion of shallow groundwater of the district and the concentration of the ion ranges from 6.0 to 612.0 mg/L. The alkalinity of the water i.e. its capability to neutralize acid is mainly contributed by the anions like bicarbonate and carbonate. The bicarbonate concentrations in groundwater exceed the BIS desirable limit of drinking at 24% of the sampling locations. However, such locations are more clustered in the alluvial patch in the southeastern part of the district (**Plate 8.5**).

Chloride: The chloride concentration in the shallow aquifers in the district varies from 30 – 282.0 mg/L. In general the groundwater in the shallow aquifer is characterized by low chloride concentration i.e. less than 100 mg/l. However, at places the chloride concentration is considerably high. The locations with upper range of chloride concentrations are found to be clustered in Ghasipura, Anandapur and Keonjhar blocks in the district (Plate 8.6).

Nitrate: The NO_3 concentration ranges from 0.1 to 55 mg/l. In most of the cases it is well within the maximum permissible limit and in a few samples (Jhumpura – 53 mg/l, Barbil – 86 mg/l, Joda – 204 mg/l, and Narla – 120 mg/l) NO_3 concentration crosses the maximum permissible limit of 45 mg/l. The higher concentration of NO_3 in water may be due to the contamination of ground water from human and animal wastes or manure and fertilizers.

Fluoride: The fluoride (F^{-}) concentration in major parts of the district ranges from 0.1 to - 2.20 mg/L (ave.: 0.3 mg/L). It exceeds the BIS standard of highest desirable limit of 1.0 mg/L at 11 locations and the maximum permissible limit of 1.5 mg/L at 2 locations. The locations fall in four blocks, namely, Keonjhar, Patna, Harichandanpur and Ghasipura (Table 8.2a). However, the major numbers of such data points are located in Keonjhar block only including both the locations where it exceeds the limit of 1.5 mg/L. Most of the location with F^- > 1.0 mg/L were specifically found in the Naranpur Gram Panchayat (villages: Ghatkeswari, Tulasichoura, Saharposi etc), close to the Keonjhar town (Plate 8.7). Some symptoms in a few number of people like bending of spine, abnormal growth in children, abnormal child, born with deformities like four fingers in hand, polio like thinned and bent legs were observed in these villages in Naranpur GP. Some of the photographs are given in annexure. Most of these people depend on the shallow hand pumps for their water needs for domestic and drinkinmg use. The host rock is porphyritic granite exposed at several points in the locality.

Table 8.2a: Locations with fluoride levels > 1.0 mg/L in shallow groundwater in Keonjhar district (Pre-monsoon).

NAME OF BLOCK	LOCATIONS	LONG	LAT	Fluoride (mg/L)
Patna	Kendeipasi	85.80	21.68	1.06
Keonjhar	Saharposi 2	85.65	21.60	1.19
	Tulasichoura 1	85.64	21.86	1.05
	Tulasichoura 2	85.64	21.59	1.28
	Ghutkeswari 2	85.65	21.61	1.58
	Ghutkeswari 3	86.65	21.61	1.01
	Ghutkeswari 4	86.65	21.61	1.22
Harichandanpur	Baxibarigaon	85.65	21.50	1.05
Ghasipura	Hathisila	86.06	21.17	1.04
	Balipala	85.99	21.16	1.13

For confirmation of results the locations were resampled for specifically groundwater fluoride analysis. A total of 13 samples were collected from the villages in Naranpur GP during the post-monsoon period. However, the concentrations in all the samples were found to be less than even 1.0 mg/L (Table 8.2b). This might have happened owing to dilution of groundwater after the monsoonal rain.

Table 8.2b: Ground water fluoride levels in the affected source points during post-monsoon period (year 2018), Keonjhar district

Sl no.	Block	Gram Panchayat	Village	Source	F (mg/L)
1	Keonjhar	Naranpur	Ghutkeswari	HP	0.94
2	Keonjhar	Naranpur	Ghutkeswari	DW	0.67
3	Keonjhar	Naranpur	Ghutkeswari	DW	0.11
4	Keonjhar	Naranpur	Ghutkeswari	DW	0.65
5	Keonjhar	Naranpur	Ghutkeswari	HP	0.3
6	Keonjhar	Naranpur	Ghutkeswari	DW	0.54
7	Keonjhar	Naranpur	Tulasichoura	HP	0.14
8	Keonjhar	Naranpur	Tulasichoura	HP	0.12
9	Keonjhar	Naranpur	Tulasichoura	HP	0.81
10	Keonjhar	Naranpur	Saharposi	HP	0.61
11	Keonjhar	Naranpur	Saharposi	DW	0.15
12	Keonjhar	Naranpur	Saharposi	DW	0.15
13	Keonjhar	Naranpur	Saharposi Chowk	DW	0.22

8.1.2 Suitability for irrigation

The total concentration of soluble salts in irrigation water can be expressed as low (EC = <250 µS per cm), medium (250-750 µS per cm), high (750-2250 µS per cm) and very high (>2250 µS per cm) and defined as C-1, C-2, C-3 and C-4 salinity zone respectively (USSL 1954). A high salt concentration in water leads to formation of saline soil and high sodium concentration may cause the development of an alkaline soil. The sodium or alkali hazard in the irrigation water is expressed in terms of sodium adsorption ratio (SAR) has been estimated by the following relation:

$$\text{Sodium adsorption ratio}\,(SAR) = \frac{Na^{+}}{\sqrt{\dfrac{Mg^{+2} + Ca^{+2}}{2}}}$$

The sodium alkali hazard has been classified into four categories as S-1 (SAR<10), S-2 (10-18), S-3 (18-26) and S-4 (>26).

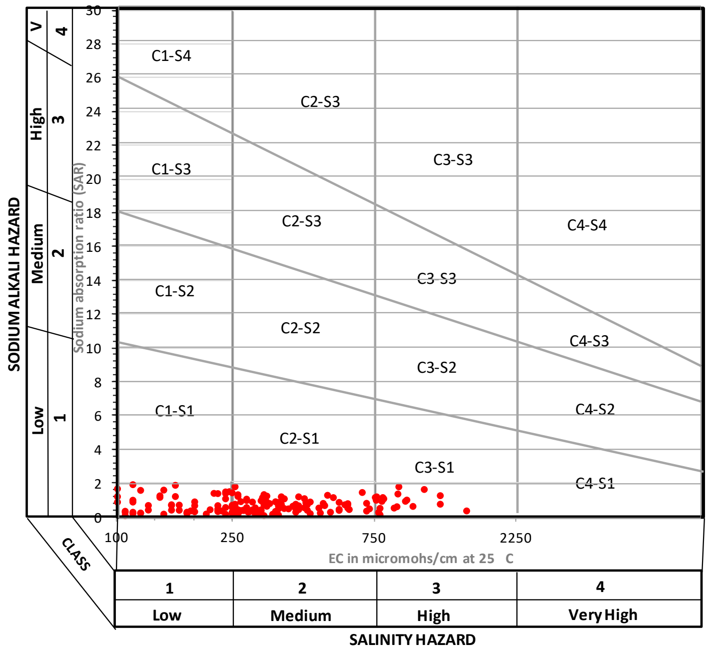


Figure 8.1: USSL salinity diagram for the shallow phreatic aquifer (1st Aquifer System), Keonjhar district, Odisha.

The plot of analytical data of water quality of the shallow aquifer on the USSL (1954) diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that 33% and 56% of the water samples fall in the C1S1 and C2S1 categories indicating the good quality of water for irrigation (Fig 8.1). The rest 13% of the groundwater samples fall in the C3S1 category which represent the moderate quality of water for irrigation. This water can be used in irrigation for salt tolerant crops under favorable drainage conditions.

8.2 Ground water quality- deeper/ 2nd Aquifer System

The exploratory wells drilled by CGWB tap all the available fractures within the depth of 200 m bgl. The range of chemical constutuents in groundwater obtained from the historical data available concerning the exploratory wells is presented in Table 8.3. The groundwater in the fracture aquifers is also alkaline in nature. The water is suitable for drinking purposes as almost all the constituents are well within the permissible limit except some sporadic locations. The quality of groundwater for irrigation use is also good.

Table 8.3: Range of Chemical constituents in deeper aquifers of Keonjhar district

Parameters (Major ions in mg/L)	Min.	Max.	Ave.	WHO (2012)	BIS (2012)		No. of groundwater samples exceeding BIS (2012) limit	
					Highest desirable	Max. permissible	Highest desirable	Max. permissible
pH	6.7	8.3	7.8	7.0-8.5	6.5-8.5	8.5-9.2	nil	nil
EC (µS/cm at 25°C)	46.0	730.0	373.1	750.0	-	-	-	-
TDS	29.9	474.5	242.5	500.0	500.0	2000.0	nil	nil
TH	15.0	335.0	131.8	500.0	300.0	600.0	*n* = 1	nil
Ca^{2+}	4.0	62.0	32.1	75.0	75.0	200.0	nil	nil
Mg^{2+}	1.2	94.0	21.4	30.0	30.0	100.0	*n* = 6	nil
Na^{+}	0.6	43.0	13.7	200.0	-	-	-	-
K^{+}	0.2	75.0	6.2	-	-	-	-	-
CO_3^{2-}	0.0	0.0	0.0	-	-	-	-	-
HCO_3^{-}	24.0	402.0	179.0	200.0	200.0	600.0	*n* = 16	nil
Cl^{-}	3.5	103.0	21.1	250.0	250.0	1000.0	nil	nil
SO_4^{2-}	0.0	33.0	5.4	200.0	200.0	400.0	nil	nil
F^{-}	0.0	4.7	0.8	0.6-1.5	1.0	1.5	*n* = 6	*n* = 4
NO_3	0.0	21.0	3.9				nil	nil

At 6 locations in the exploratory wells, the groundwater fluoride concentration exceeded the BIS highest desirable limit of 1.0 mg/L including the four locations (in Harichandanpur, Champua, Jhumpura blocks) where it even exceeded the maximum permissible limit of 1.5 mg/L (Table 8.4).

Table 8.4: Locations of exploratory wells with fluoride levels > 1.0 mg/L in groundwater, Keonjhar district.

Name of block	Location	Long	Lat	Fluoride (mg/L
Ghatgaon	Barhatpura	85.82	21.42	1.3
Ghatgaon	Dhenkikote O/W	85.82	21.48	1.07
Harichandanpur	Pandpada	85.72	21.48	2.4
Harichandanpur	Janghira	85.62	21.43	2.1
Jhumpura	Ukhunda-1	85.68	21.83	4.7
Champua	Champua	85.64	22.06	4.7

8.2.1 Suitability for irrigation

The plot of the water quality data of the deeper fracture aquifers in USSL salinity diagram shows the major number of water samples falling in the C1S1 and C2S2 category (Fig 8.2), indicating the good quality of groundwater for irrigation use. A few only fall in the C3S1 category, indicating their moderate quality for irrigation use.

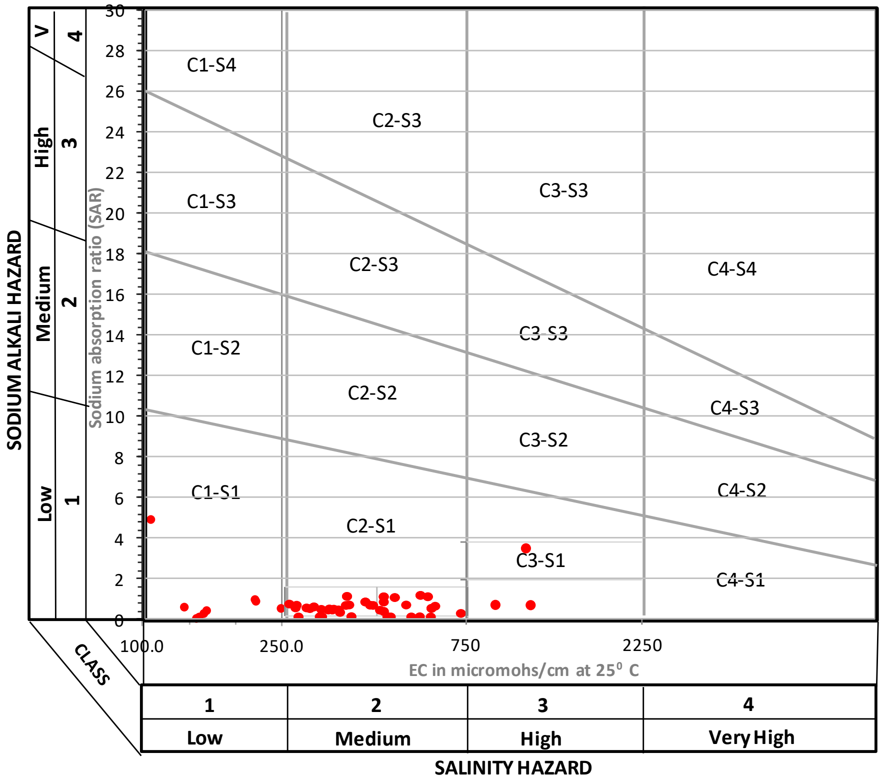


Figure 8.2: USSL salinity diagram for the deeper fracture aquifer (2^{st} Aquifer System), Keonjhar district, Odisha.

8.3 Hydrochemical facies

8.3.1 1st Aquifer System- weathered zone aquifer

The analytical results of 170 groundwater samples have been plotted in the Piper diagram (Fig 8.3). It shows that the groungwater in the Keonjhar district is more Ca-Mg-HCO_3 type, though some of them trend as Ca-Mg-HCO_3-Cl type. The detail analysis of the constituents indicated the general predominance of Ca^{2+} over the other cations except at 7 locations where Mg^{2+} loading remains more than Ca^{2+}. The loading of Ca^{2+} varied in the range of 11.2-84.4% (ave.: 46.5%). Similarly, HCO_3^- remained predominant in 89% of the groundwater samples (range of loading: 9.1-91.1%; ave.: 59.8%) and in the rest of 11%, Cl^- was the predominant anion (range of loading: 6.3-65.1%; ave.: 32.3%) (Fig 8.4). Thus, the groundwater types were predominantly Ca-HCO_3 type followed by some Ca-HCO_3-Cl types.

The general predominance of cations and anions in the shallow groundwater were found in the orders of Ca^{2+}>Mg^{2+}>Na^{+}>K^{+} and HCO_3^{-}>Cl^{-}>SO_4^{2-}>CO_3^{2-} respectively.

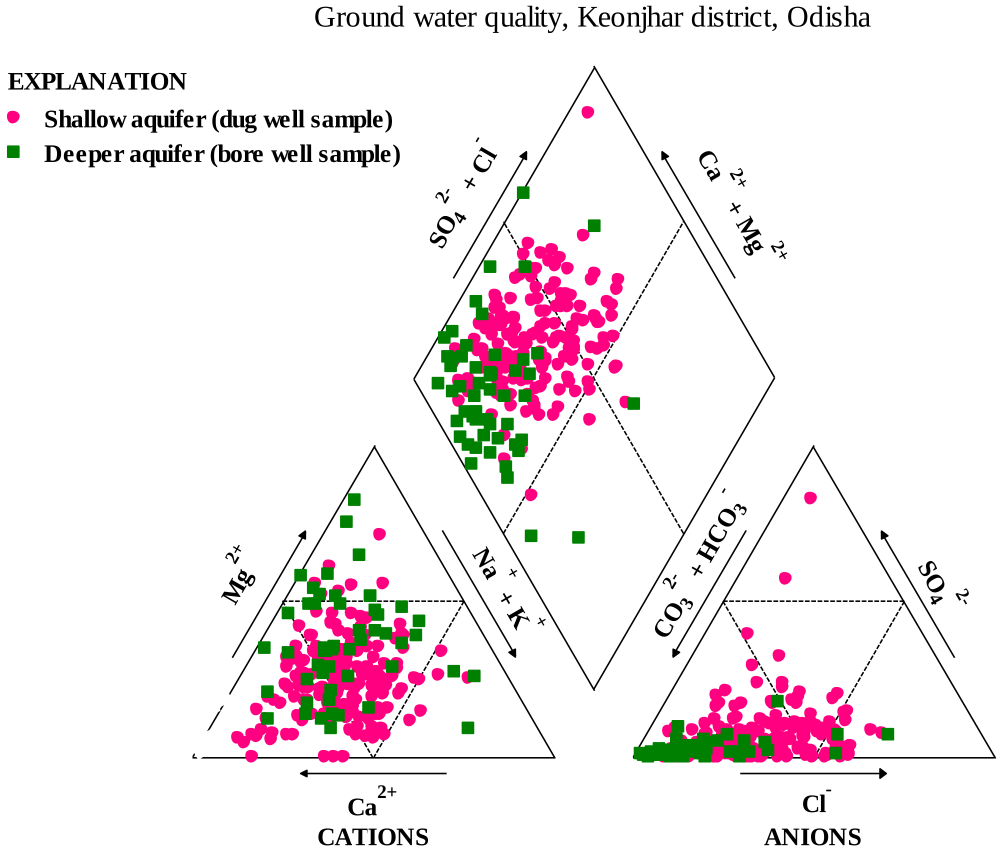


Figure 8.3: Piper (1940) trilinear diagram illustrating the chemical composition of the groundwater and the major hydrochemical water types in the shallow and deeper aquifer systems in Keonjhar district.

From the alluvial areas of Baitarani basin in the blocks of Hatadihi, Ghasipura and Anandapur, a total of 20 groundwater samples were collected. These samples, however, told a different story. The average loading of Ca^{2+} remained at 36.7%, followed by Mg^{2+} (31.7%), Na^{+} (25.4%) and K^{+} (6.2%). However, around 30% of the groundwater samples were found with significant contributions with Na^{+} cation. In some, Mg^{2+} ion also contributed significantly. The contribution from bicarbonate varies between 39-88% of the anions with the average loading of 62%. The chloride contribution is quite significant in the range of 6-55% (ave.: 31.2%). Thus, besides the Ca-HCO_3 (4 nos), Na-HCO_3 (3 nos) types, many of the hydrochemical facies types in the alluvium were to extent mixed kinds like Ca-Mg-HCO_3, Na-Cl-HCO_3, Ca-HCO_3-Cl, Mg-HCO_3-Cl, Mg-Na-HCO_3 etc.

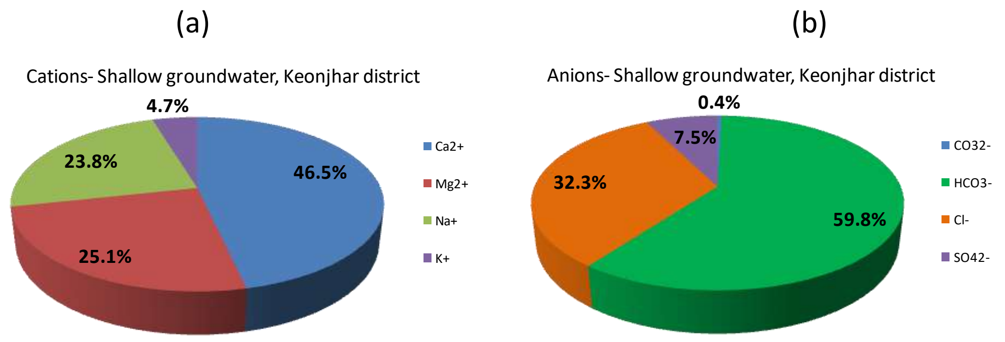


Figure 8.4: Pie diagram showing the contribution of cations (a) and anions (b) in tnhe groundwater samples collected from the shallow phreatic aquifer, Keonjhar district, Odisha.

8.3.2 Deeper fracture aquifers

The groundwater in the deeper fracture aquifers is predominated by the cation Ca^{2+} and to some extent Mg^{2+}. Both these ions make ~80% of the cation chemistry in the groundwater (Fig 8.3 & 8.5a). Among the anions, it is the bicarbonate ion (HCO_3^-) only, that predominate in most of the groundwater samples with an average loading of 80% of the anions (Fig 8.3 & 8.5b). Thus, hydrochemically, the water in the fracture aquifers are mostly Ca-HCO_3 types followed by Mg-HCO_3 types. Such kinds of facies types generally represent the local kinds of water getting fresh meteoritic recharge. It might be indicating the semi-confined to unconfined character of the deeper fracture aquifers in the Keonjhar district.

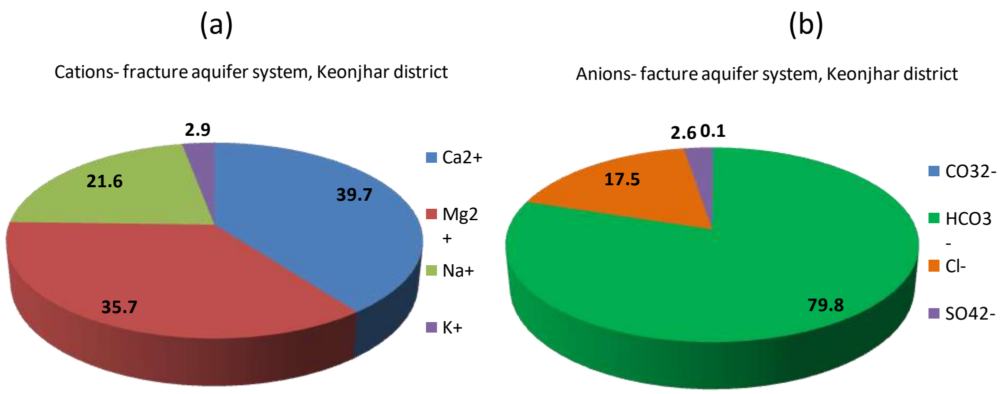


Figure 8.5: Pie diagram showing the contribution of cations (a) and anions (b) in the groundwater samples collected from the Exploratory wells tapping the deeper fracture aquifers, Keonjhar district, Odisha.

If the groundwater quality in the two aquifer systems (1st and 2nd) is considered separately, it is observed that in the 1st aquifer system, the Ca^{2+} ion becomes more predominant and the contribution from Mg^{2+} decreases further (Fig 8.6a). The anion HCO_3^- remains the single most predominant ion in the groundwater chemistry (Fig 8.6b). It indicates the 1st aquifer system comprising the fracture zones have direct meteoritic relation for its recharge and behaves purely as an unconfined aquifer.

In the 2nd aquifer system, comprising the fractures zone within the depth range of 100-200 m bgl, the groundwater quality slightly changes (Fig 8.7). The cation Mg^{2+} becomes the predominant ion with the average loading at 37.7%, higher than the level of 29.5% of Ca^{2+} (Fig 8.7a). The level of sodium (Na^+) also attains significant at 27.4% of the anions, higher than 22.1% in the 1st aquifer system. Among the anions, though, it is still the bicarbonate (HCO_3 that remains predominant, its contribution decreases to the average level of 73.3% (Fig 8.7b). In contrast, the contribution of chloride (Cl^-) increases from 17.2% in the 1st aquifer system to the average level of 22.8% (range: 4.5-67.6%). Such type of groundwater quality in the 2nd aquifer system indicates its unconfined to semi-confined character.

(a) (b)

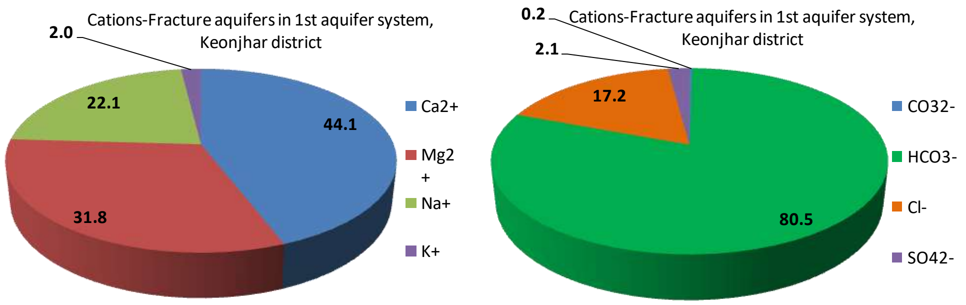


Figure 8.6: Pie diagram showing the contribution of cations (a) and anions (b) in the groundwater samples collected from the Exploratory wells tapping the fracture zones in 1st aquifer system, Keonjhar district, Odisha.

(a) (b)

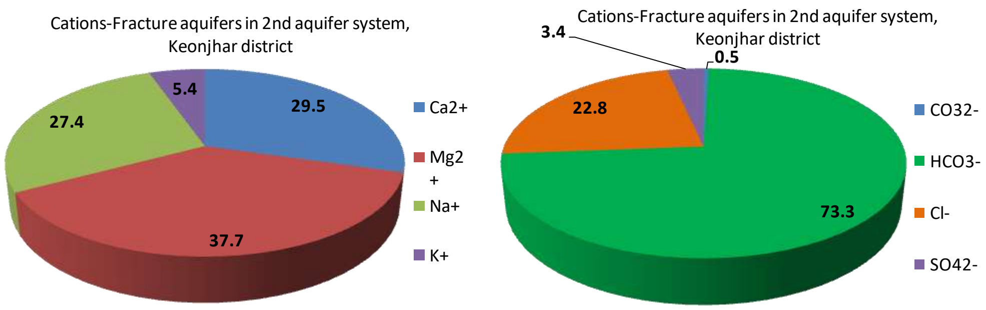
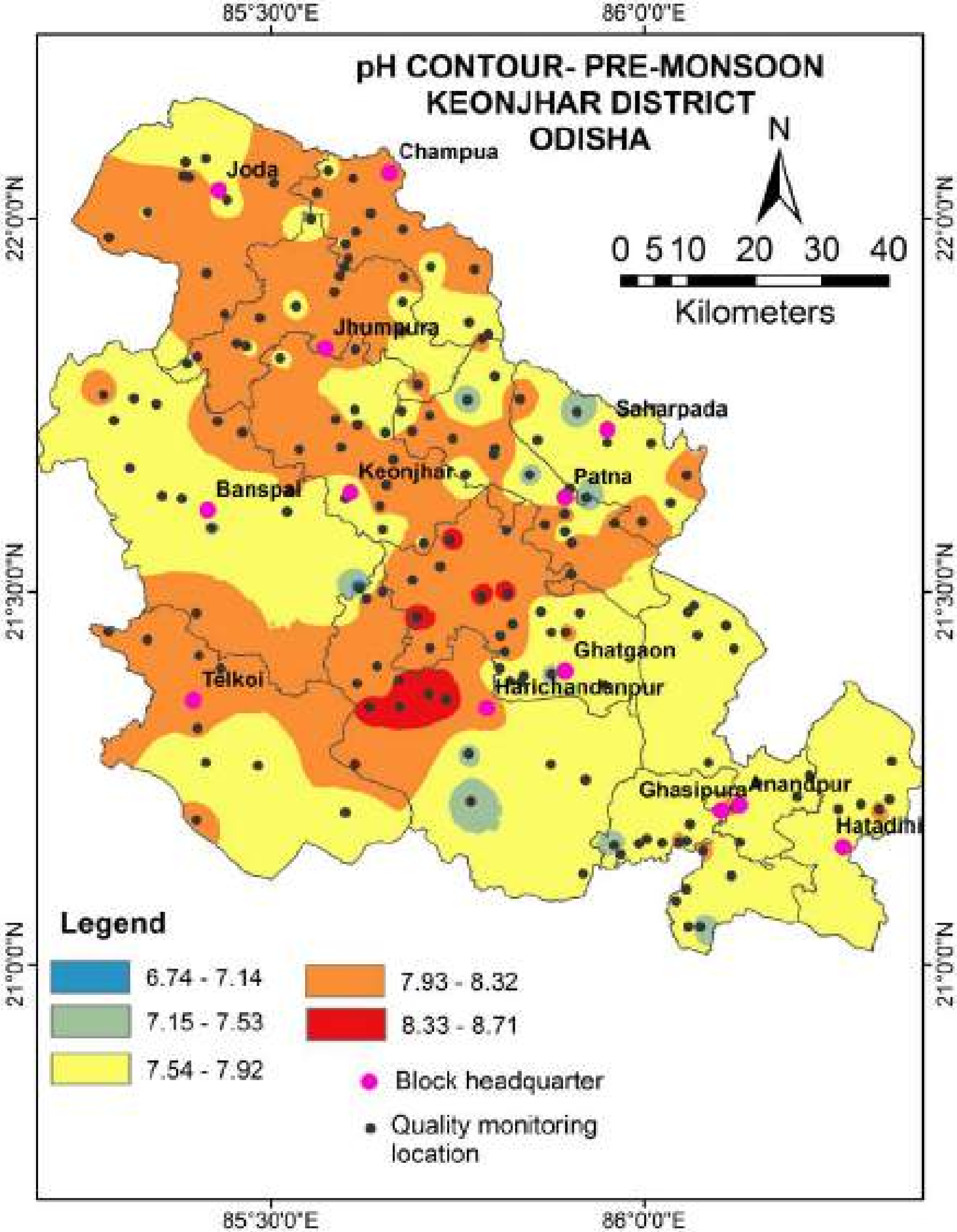


Figure 8.7: Pie diagram showing the contribution of cations (a) and anions (b) in the groundwater samples collected from the Exploratory wells tapping the fracture zones in 2nd aquifer system, Keonjhar district, Odisha.

PLATE – 8.1



pH CONTOUR- PRE-MONSOON
KEONJHAR DISTRICT
ODISHA
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
N
0 5 10 20 30 40
Kilometers
Champua
Joda
Jhumpura
Saharpada
Patna
Keonjhar
Banspal
Ghatgaon
Harichandanpur
Telkoi
Ghasipura
Anandpur
Hatadihi
Legend
6.74 - 7.14
7.15 - 7.53
7.54 - 7.92
7.93 - 8.32
8.33 - 8.71
Block headquarter
Quality monitoring location

PLATE – 8.2

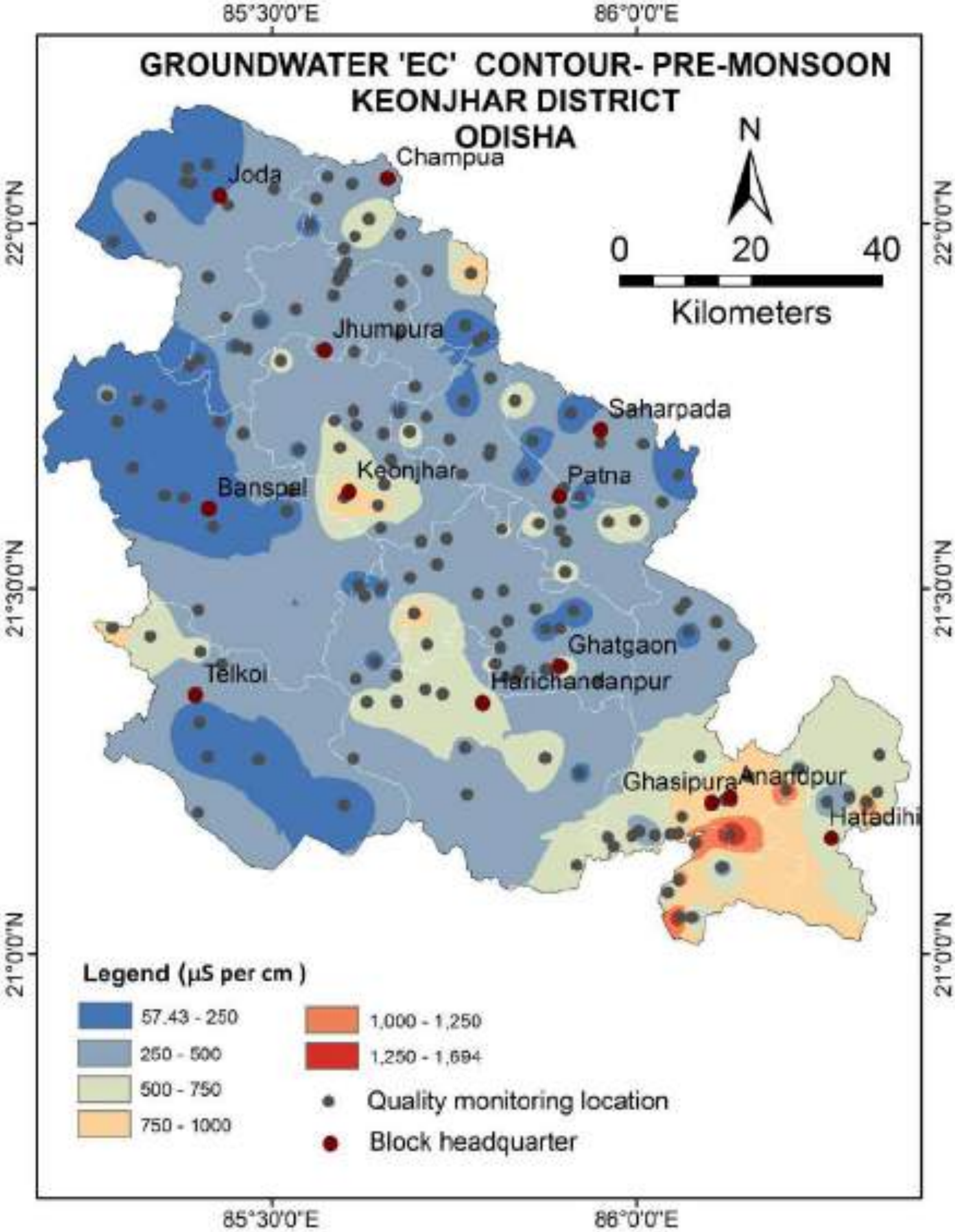

GROUNDWATER 'EC' CONTOUR- PRE-MONSOON
KEONJHAR DISTRICT
ODISHA
N
0
20
40
Kilometers
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
Joda
Champua
Jhumpura
Saharpada
Keonjhar
Banspal
Patna
Ghatgaon
Telkoi
Harichandanpur
Ghasipura
Anandpur
Hatadihi
Legend (µS per cm)
57.43 - 250
250 - 500
500 - 750
750 - 1000
1,000 - 1,250
1,250 - 1,694
Quality monitoring location
Block headquarter

PLATE – 8.3

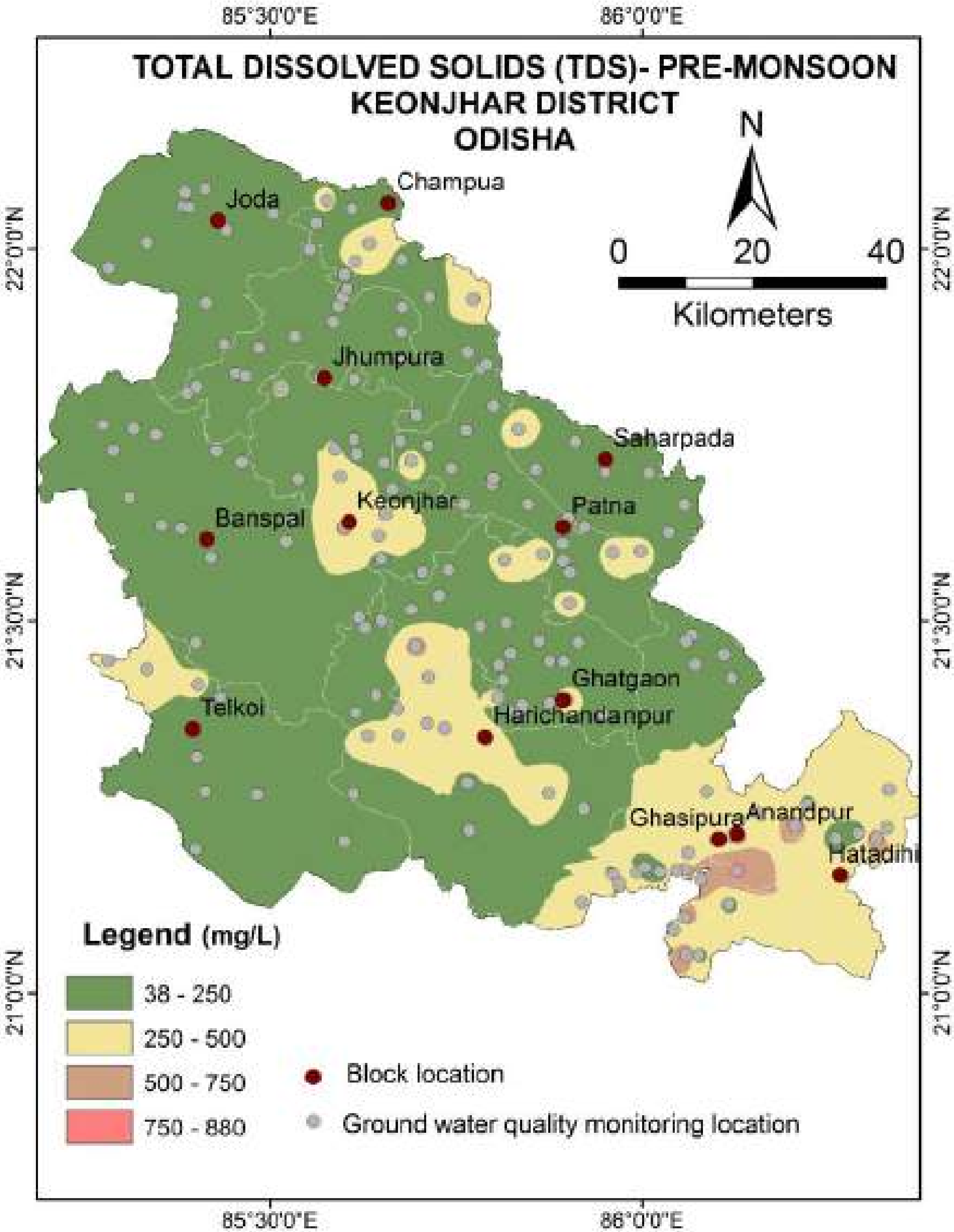

85°30'0"E
86°0'0"E
TOTAL DISSOLVED SOLIDS (TDS)- PRE-MONSOON
KEONJHAR DISTRICT
ODISHA
N
0
20
40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Joda
Champua
Jhumpura
Saharpada
Keonjhar
Patna
Banspal
Ghatgaon
Harichandanpur
Telkoi
Ghasipura
Anandpur
Hatadihi
Legend (mg/L)
38 - 250
250 - 500
500 - 750
750 - 880
Block location
Ground water quality monitoring location

PLATE – 8.4

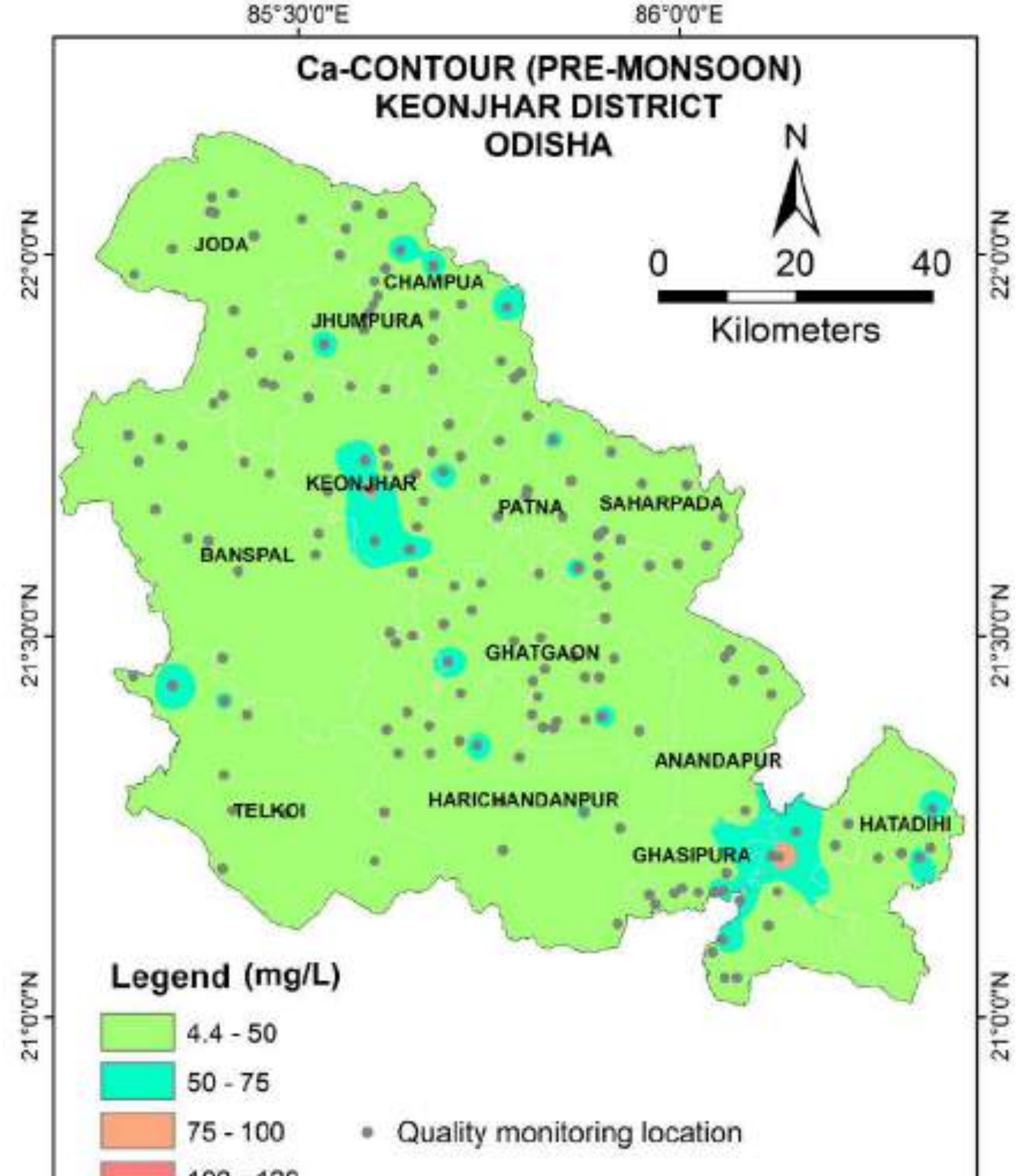
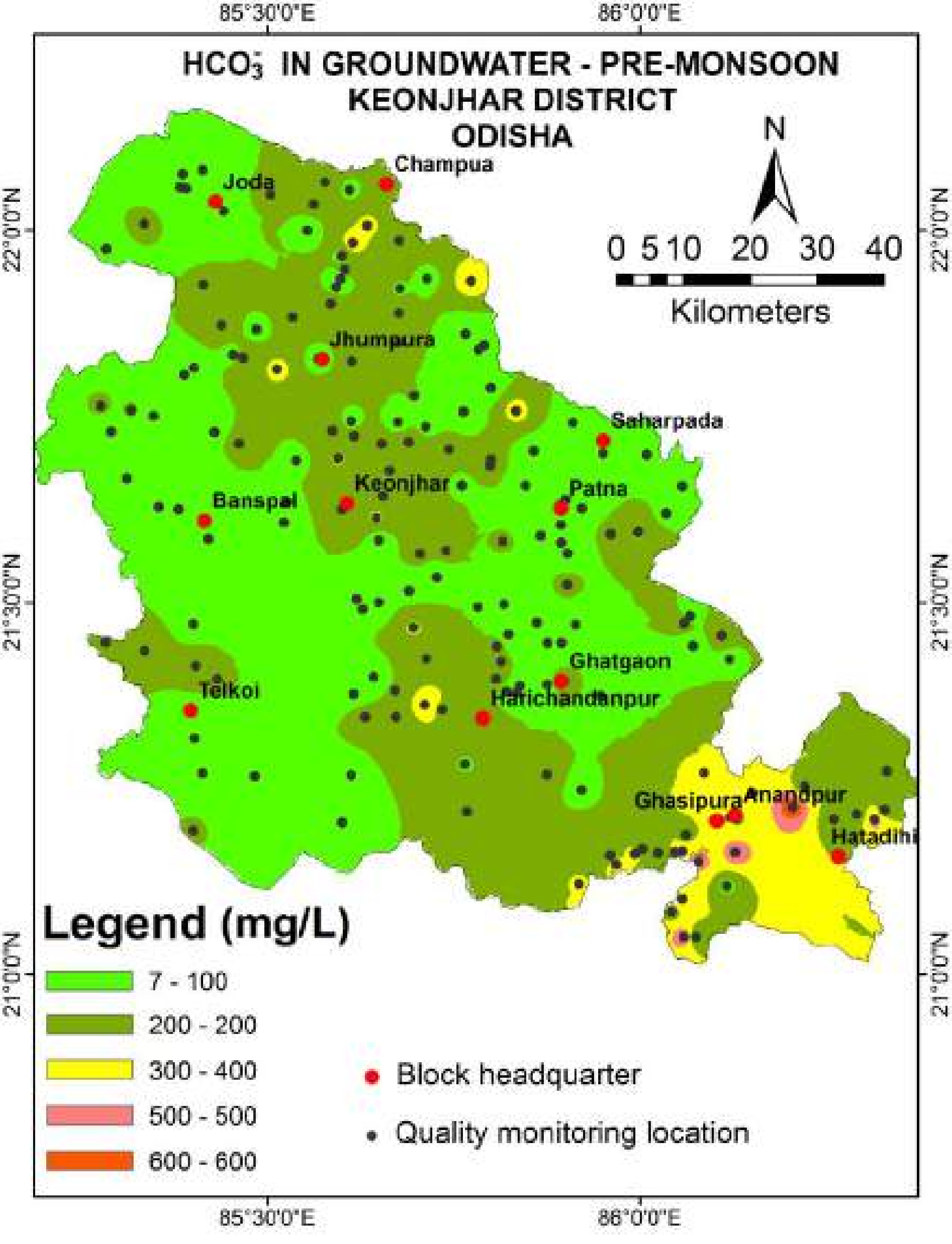
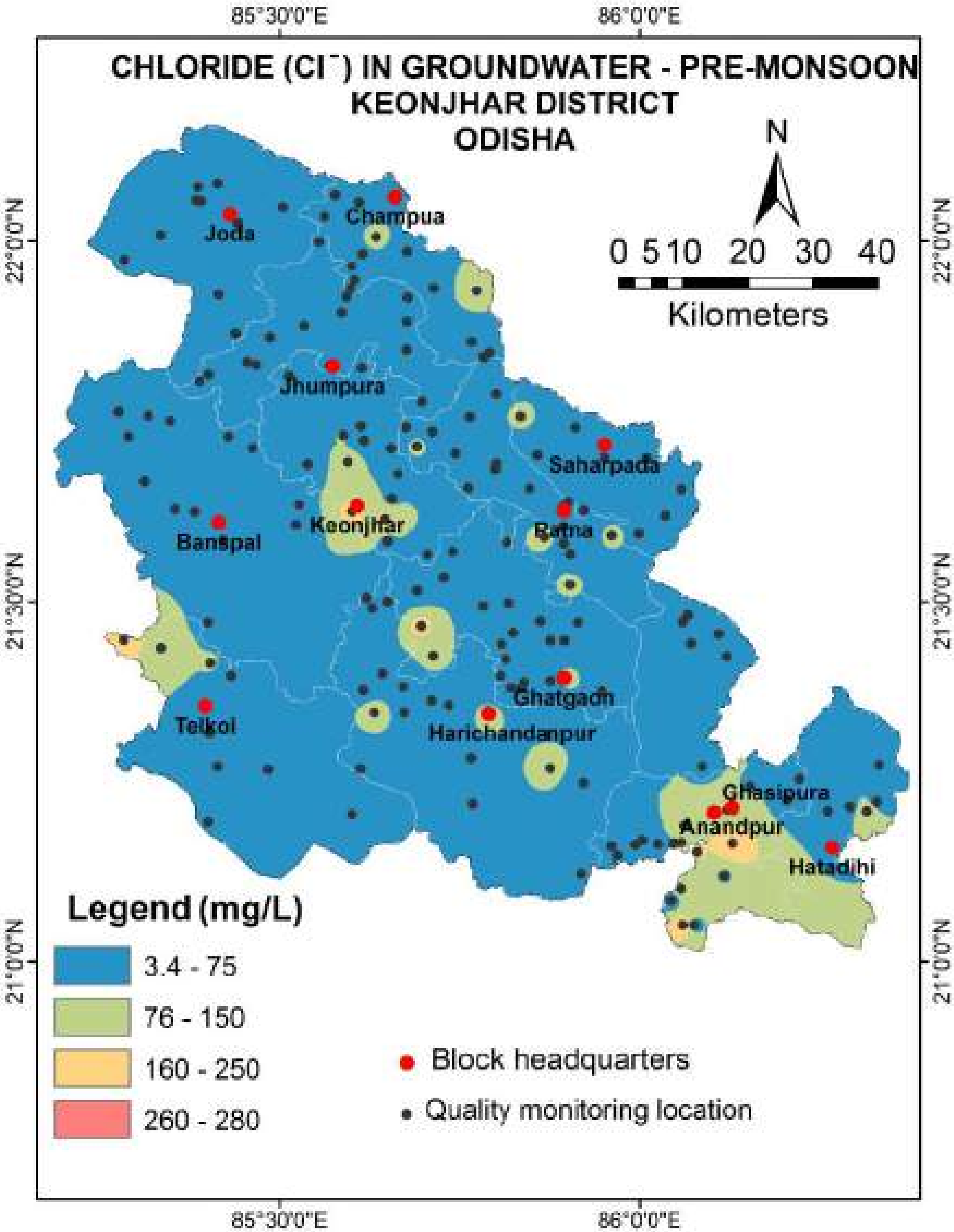

Ca-CONTOUR (PRE-MONSOON)
KEONJHAR DISTRICT
ODISHA
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
N
0 20 40
Kilometers
JODA
CHAMPUA
JHUMPURA
KEONJHAR
PATNA
SAHARPADA
BANSPAL
GHATGAON
ANANDAPUR
TELKOI
HARICHANDANPUR
GHASIPURA
HATADIHI
Legend (mg/L)
4.4 - 50
50 - 75
75 - 100
100 - 120
Quality monitoring location

PLATE – 8.5



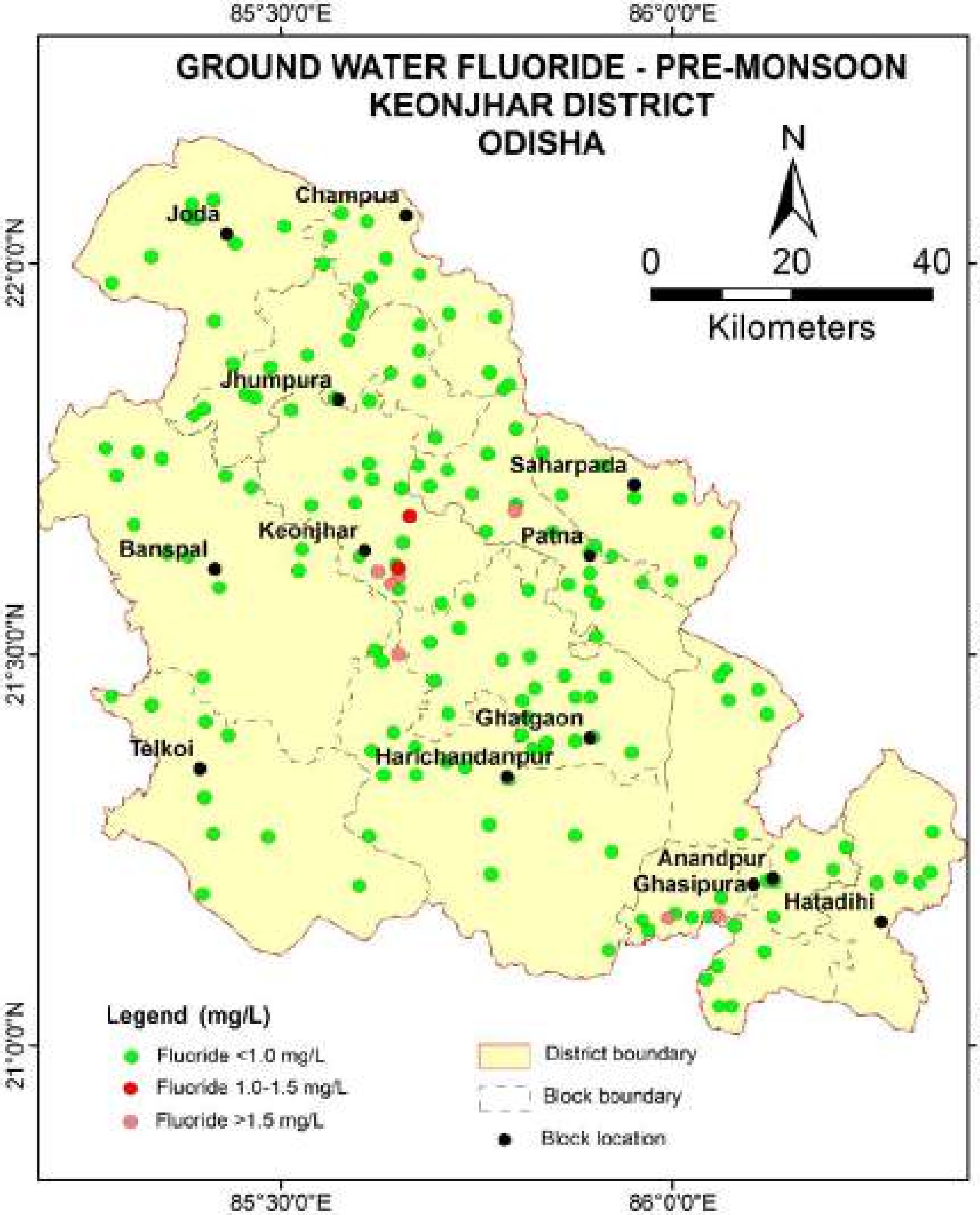
85°30'0"E
86°0'0"E
HCO_3^- IN GROUNDWATER - PRE-MONSOON
KEONJHAR DISTRICT
ODISHA
N
0 5 10 20 30 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Champua
Joda
Jhumpura
Saharpada
Keonjhar
Patna
Banspal
Ghatgaon
Telkoi
Harichandanpur
Ghasipura
Anandpur
Hatadihi
Legend (mg/L)
7 - 100
200 - 200
300 - 400
500 - 500
600 - 600
Block headquarter
Quality monitoring location

PLATE – 8.6



85°30'0"E
86°0'0"E
CHLORIDE (Cl⁻) IN GROUNDWATER - PRE-MONSOON
KEONJHAR DISTRICT
ODISHA
N
0 5 10 20 30 40
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Joda
Champua
Jhumpura
Saharpada
Keonjhar
Banspal
Patna
Telkoi
Ghatgaon
Harichandanpur
Ghasipura
Anandpur
Hatadihi
Legend (mg/L)
3.4 - 75
76 - 150
160 - 250
260 - 280
Block headquarters
Quality monitoring location

PLATE – 8.7



GROUND WATER FLUORIDE - PRE-MONSOON
KEONJHAR DISTRICT
ODISHA
85°30'0"E
86°0'0"E
22°0'0"N
21°30'0"N
21°0'0"N
N
0 20 40
Kilometers
Champua
Joda
Jhumpura
Saharpada
Keonjhar
Patna
Banspal
Ghatgaon
Telkoi
Harichandanpur
Anandpur
Ghasipura
Hatadihi
Legend (mg/L)
Fluoride <1.0 mg/L
Fluoride 1.0-1.5 mg/L
Fluoride >1.5 mg/L
District boundary
Block boundary
Block location

9.0 GROUND WATER RESOURCE ESTIMATION

Precise quantifications of exploitable groundwater resource are essential prerequisites for any programme for development, judicious and optimal exploitation of groundwater resources. It involves quantification and identification of various factors affecting groundwater recharge and discharge and demarcation of potential areas for groundwater development. The principal sources of recharge to groundwater are rainfall, seepage from canals, return flow from applied irrigation, seepage from tanks and ponds. Groundwater exploitation for domestic use in the district is mainly through private dug wells and hand pumps fitted government bore wells/tube wells. The extraction of groundwater for irrigation purpose is mainly through dug wells, dug-cum-bore wells and to a lesser extent from bore wells. Ground water occurs under water table condition in the weathered residuum and the fracture zone which largely depends on the thickness of the weathered residuum. The weathered zone and the saturated fractured zones form the main repository of groundwater in the district. The dynamic groundwater resource is estimated based on the seasonal fluctuation of water level in the weathered zone, which represents the groundwater regime in the shallow weathered zone and the near surface fractured zone hydraulically connected to it. Data pertaining to various parameters such as rainfall, water level fluctuation, specific yield, groundwater abstraction structures for various utilities, irrigation and other data recorded and / or collected by CGWB, SE region and GWS & I, Government of Orissa and other state government agencies have been utilized to estimate the dynamic groundwater resource of Keonjhar district. The annual groundwater draft of a groundwater abstraction structure is computed by multiplying the average discharge and the annual working hours of the structure.

9.1 Ground water resource components

This section deals with the aquifer wise estimation of different groundwater resource components for the 1st Aquifer System as well as the 2nd Aquifer System. The details of the resource components and the aquifer systems have been schamatically depicted in Fig 9.1 and are briefed below:

1. Annually replenishable dynamic groundwater resource in the shallow, unconfined/ weathered zone aquifer in the 1st Aquifer System / unconsolidated

alluvium/laterite zone. This is the resource component generated owing to recharge of aquifers every year. It fluctuates between the pre- and post-monsoon water levels in the aquifer. The dug wells and some of the hand pumps in the district sustain in the zone.Its thcikness varies between 6.0 – 60 m.

2. Static/ in-storage groundwater resource in the bottom part of the unconfined/1st Aquifer System. The resource remains in reserve below the water lvel fluctuation zone beyond the deepest water level. It includes the fracture aquifer and may be the bottom part of the weathered zone aquifer if it is quite thick. In the district of Keonjhar, it goes down to the depth of 100 m bgl. Major number of fractures are encountered within this depth.

3. Static/in-storage groundwater resource in the semi-confined/confined 2nd Aquifer System which have separate groundwater hydraulics with limited or no connection with the overlying 1st Aquifer System. In the district of Keonjhar, it goes dwn to the depth of 200 m bgl.

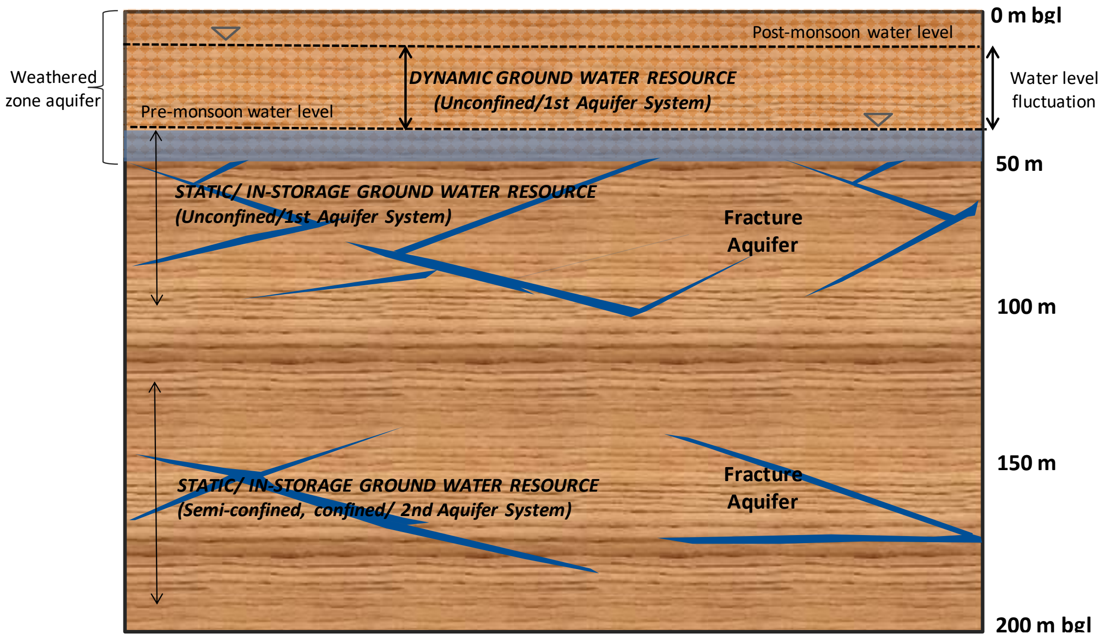


Figure 9.1: Schematic diagram illustrating different groundwater resource components and their depth relation in Keonjhar district, Odisha.

9.1.1 Dynamic groundwater resource (1st Aquifer System)

Based on the norms recommended by Ground Water Estimation Committee (G.E.C. 2015) block-wise availability of dynamic groundwater resources for the district of Keonjhar has been estimated (as on 31st March 2017). The total annual dynamic groundwater resource of Keonjhar district is assessed to be 83868.9 hectare meter (Ham) (Table 9.1). The existing gross groundwater draft in the district stands at 33508.7 Ham, out of which the irrigation draft is 27433.5 Ham (~82% of total draft). The draft for domestic and drinking constitute 17% of the gross draft. The annual utilizable resource which remains for irrigation use (after allocation for domestic and drinking up to the year 2025) has been estimated at 49577.5 Ham. The annual utilizable groundwater resource earmarked for domestic use is 6421.3 Ham which is based on the projection of requirement by the year 2025. The stage of groundwater development varies between the minimum of 20.3% in the Ghatgaon block and the maximum of 68.3% in the Joda block, with the average stage of groundwater development for the district as 40.0%. The block-wise dynamic groundwater resource position of Keonjhar district is presented in **Fig 9.2**. There are only two blocks in the district, namely, Joda and Saharpada, where the stage of groundwater development exceeds 50%. Thus, there exists lots of scope for groundwater development for irrigation use in each block in the district.

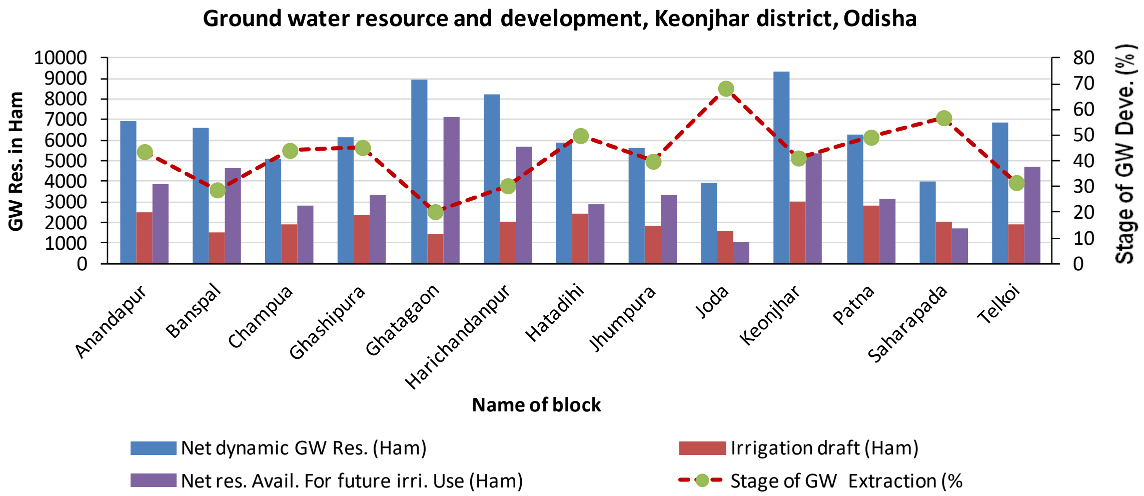


Figure 9.2: Annually replenishable dynamic groundwater resource and the stage of development, Keonjhar district, Odisha (as on 31st Mar 2017).

Table 9.1: Dynamic annual replenishable groundwater resources of the Keonjhar district (phreatic auifer/1st Aquifer) and the development status (as on 31st Mar 2017)

Sl No	Assessment Unit Name	Ground Water Recharge(Ham)				Total Ann. GW (Ham) Rech. (3+4+5+6)	Total Nat. Disch. (Ham)	Ann. Extractable GW Rech. (Ham) (7-8)	Current Ann. GW Extract.ion (Ham)				Ann. GW Allo. for for Domestic Use as on 2025	Net GW Avail. for future use (9-10-11-14)	Stage of GW Extraction (%) (13/9)*100))	Cate. (OE/ Critical/ Semicritical/Safe)
		Monsoon Season		Non-monsoon season					Irri. Use	Ind. Use	Dom. Use	Total Extraction (10+11+12)				
		Rech. from Rainfall	Rech. from Other Sources	Rech. from Rainfall	Rech. from Other Sources											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	Anandapur	5415.5	352.9	1063.5	485.8	7317.7	365.9	6951.9	2500.5	26.4	506.9	3033.8	563.8	3861.2	43.6	Safe
2	Banspal	5661.5	222.5	672.0	380.4	6936.4	346.8	6589.6	1551.9	57.4	287.4	1896.7	333.2	4647.0	28.8	Safe
3	Champua	4374.2	281.7	638.2	404.7	5698.7	569.9	5128.9	1912.2	6.4	344.3	2262.9	389.2	2821.0	44.1	Safe
4	Ghashipura	3836.0	1012.4	866.4	818.1	6532.8	404.3	6128.6	2365.1	7.2	400.7	2773.0	438.7	3317.5	45.3	Safe
5	Ghatagaon	6601.8	467.5	1705.6	724.9	9499.7	524.1	8975.7	1471.8	23.9	326.2	1822.0	369.4	7110.6	20.3	Safe
6	Harichandanpur	5747.6	691.4	1492.2	764.1	8695.3	475.6	8219.8	2058.2	34.6	404.3	2497.1	460.9	5666.1	30.4	Safe
7	Hatadihi	3137.9	1195.8	588.5	1433.6	6355.8	476.2	5879.6	2430.3	50.2	452.7	2933.3	510.5	2888.6	49.9	Safe
8	Jhumpura	4830.2	250.1	656.2	477.2	6213.8	621.4	5592.4	1854.6	49.4	327.4	2231.4	370.4	3317.9	39.9	Safe
9	Joda	3132.4	145.4	665.7	429.9	4373.4	437.3	3936.1	1565.7	81.6	1040.8	2688.1	1250.3	1038.5	68.3	Safe
10	Keonjhar	6746.0	718.3	1269.6	1141.7	9875.5	557.8	9317.8	3009.9	49.2	775.9	3835.0	890.4	5368.3	41.2	Safe
11	Patna	4446.6	849.6	714.1	936.6	6946.9	694.7	6252.2	2796.5	10.0	272.0	3078.4	294.7	3151.0	49.2	Safe
12	Saharapada	3370.3	222.3	476.4	387.5	4456.5	445.7	4010.9	2018.6	22.4	238.9	2279.9	262.7	1707.2	56.8	Safe
13	Telkoi	5936.6	218.3	704.3	388.8	7248.1	362.4	6885.7	1898.0	17.9	261.2	2177.1	287.1	4682.7	31.6	Safe
	District total	**63237**	**6628.1**	**11513**	**8774**	**90151**	**6282**	**83869**	**27434**	**437**	**5639**	**33509**	**6421.3**	**49578**	**40.0**	**Safe**

Abbreviations: GW-groundwater, Ann.- annual, Rech.- reharge, Disn.- discharge, Ham- hectare meter, Avail.- available, OE- over exploited
+

The net dynamic groundwater resource available in meter per unit area has been calculated taking the recharge worthy area in each block. It vaires between 0.07 – 0.17 m in the blocks with the district average of 0.13 m (Table 9.2).

Table 9.2: Block-wise available of net dynamic groundwater resource if Keonjhar district.

Sl No	Name of Block	Recharge worthy area (Ha)	Net dynamic GW Res. (Ham)	Dynamic GW Res. Avai. Per unit area (m)
1	Anandapur	46049	6951.85	0.15
2	Banspal	75487	6589.57	0.09
3	Champua	36958	5128.85	0.14
4	Ghashipura	38022	6128.57	0.16
5	Ghatagaon	65154	8975.67	0.14
6	Harichandanpur	84749	8219.76	0.10
7	Hatadihi	34271	5879.6	0.17
8	Jhumpura	47190	5592.38	0.12
9	Joda	53175	3936.1	0.07
10	Keonjhar	53765	9317.76	0.17
11	Patna	48112	6252.19	0.13
12	Saharapada	39088	4010.89	0.10
13	Telkoi	62770	6885.7	0.11
			District average	**0.13**

9.1.2 Static/in-storage groundwater resource (1st Aquifer System)

The static/in-storage groundwater resource for each block in the district has been estimated using the “Specific Yield Method”, following the guyidelines recommended by GEC 2015. The avalable thickness of the 1st Aquifer System has been found out using the following relation:

Bottom depth of the 1st Aquifer System (100 m) – deepest pre-monsoon water level

The average and representative specific yield values have been taken for estimating the resource for each different block depending on the lithology. For the hard rock areas such values were taken within 2.0 – 3.0%, while for the alluvial area, it was taken as 8.0%. The resources have been estimated using the following relation:

Area of the block suitable for recharge X thickness of the aquifer X perecnt of fracture/granular zone X Specific Yield.

In the alluvial areas of Anandapur, Ghasipura and Hatadihi blocks, the percent of granular zones in the alluvium was taken at 20% of the entire thickness. In the alluvial area, where the thcikness the alluvium exceeds ~30 m, the resource in the alluvium was only estimated, since all the tube wells and dug wells in the area remain restricted to the alluvial depth. In the marginal parts of the alluvium, where the thcikness of alluvium remains less than 10-15 m, the resource up to 100 m was estimated, since most of the groundwater abstraction structures go beyond the alluvium and tap the fractures.

The static/in-storage groundwater resource of the 1st Aquifer System has been produced in Table 9.3. The total in-storage resource for the district has been estimated as 90659.4 Ham. The block-wise in-storage resource of the 1st Aquifer System has been given in Fig 9.3. Such resources in the Anandapur, Ghasipura and Hatadihi blocks surpass all other blocks owing to the existence of alluvial areas in those blocks.

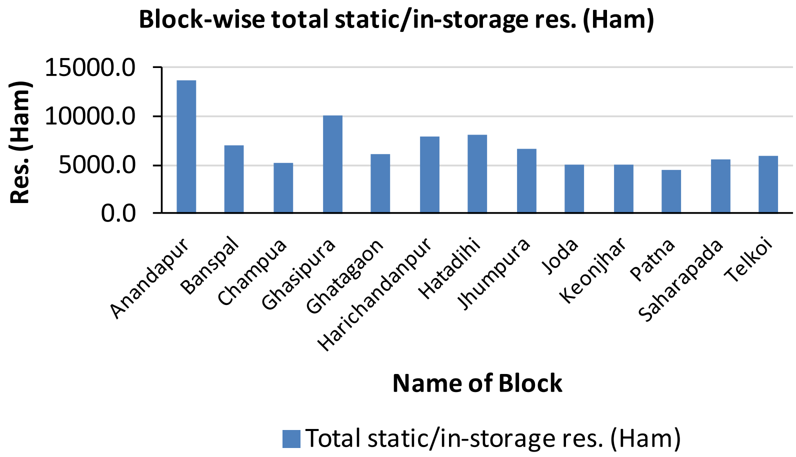


Figure 9.3: Bar diagram showing block-wise instorage groundwater resources of the 1st Aquifer System.

9.1.3 Static/in-storage resource of 2nd Aquifer System

The 2nd Aquifer System in te district largely extends between the depth ranges 100-200 mbgl. Its thickness has been considered a uniform of 100 m for all the blocks in the district. The exploratory data indicates the existence of less number of fracture systems in this depth range. Therefore, a uniform 2% effective thickness of the aquifer system has been considered. The resource has been estimated following the “Storativity Concept”, using the following relation:

Area of the block suitable for recharge (deducting the alluvial areas) X thickness of the aquifer X perecnt of fracture/granular zone X storativity

A storativity value of 0.0001 has been considered for all the blocks while estimating the static resource for the 2nd Aquifer System. The district total of 137.1 Ham of static resource for the aquifer system has been estimated, which has been produced in Table 9.4.

Table 9.3: Static /In-storage groundwater resources of unconfined /1st Aquifer (as on 31st Mar 2017) in Keonjhar district, Odisha.

Sl No	Name of the block	Static Resources Area	Pre-monsoon water level	Bottom of unconfined aquifer	Difference (5-4)	Effective Aquifer Thickness Allu.: 5%, 20% Hard rock: 5%	Specific Yield	Total Static/in-storage Res. (Ham) (3)*(7)*(8)
1	2	3	4	5	6	7	8	9
1	Anandapur	Allu. (38773.3), hard rock (7275.7)	6.03	Allu.: 20% area-100 m, 80% area-30 m Hard rock: 100 m	Allu.: 20% area-94 m, 80% area-24 m Hard rock: 100 m	Allu.: 20% area-4.7, 80% area-4.8 Hard rock: 4.7	Allu.: 20% area-0.02, 80% area-0.08 Hard rock: 0.03	13666.0
2	Banspal	75487	6.4	100	93.6	4.68	0.02	7065.6
3	Champua	36958	6.43	100	93.57	4.68	0.03	5187.2
4	Ghashipura	Allu. (24790.3), hard rock (13231.7)	5.54	Allu.: 20% area 100 m, 80% area 30 m Hard rock: 100 m	Allu.: 20% area-94.5 m, 80% area-24.5 m Hard rock: 94.5 m	Allu.: 20% area-4.73 m, 80% area-4.9 m Hard rock: 4.73 m	Allu.: 20% area-0.02, 80% area-0.08 Hard rock: 0.03	10120.8
5	Ghatagaon	65154	6.15	100	93.85	4.69	0.02	6114.7
6	Harichandanpur	84749	6.1	100	93.9	4.70	0.02	7957.9
7	Hatadihi	Allu. (17169.8), hard rock (17101.2)	6.03	Allu.: 20% area 100 m, 80% area 40 m Hard rock: 100 m	Allu.: 20% area-94 m, 80% area-24 m Hard rock: 100 m	Allu.: 20% area-4.7, 80% area-4.8 Hard rock: 4.7	Allu.: 20% area-0.02, 80% area-0.08 Hard rock: 0.03	8008.6
8	Jhumpura	47190	5.95	100	94.05	4.70	0.03	6657.3
9	Joda	53175	6.7	100	93.3	4.67	0.02	4961.2
10	Keonjhar	53765	6.05	100	93.95	4.70	0.02	5051.2
11	Patna	48112	6.22	100	93.78	4.69	0.02	4511.9
12	Saharapada	39088	6.35	100	93.65	4.68	0.03	5490.9
13	Telkoi	62770	6.55	100	93.45	4.67	0.02	5865.9
District total								**90659.4**

Table 9.4: In-storage groundwater resources of Confined/ semi-onfined /2nd Aquifer (as on 31st Mar 2017) in Keonjhar district, Odisha.

S.No	Name of the Assessment Unit	Area of the Confined Aquifer	Storativity	Pre monsoon Piezometric head	Bottom of top confining layer	Effective Aquifer Thickness {(200-100)*2%}	Total Instorage Resource of Confined Aquifer (3)*(4)*(7)
1	2	3	4	5	6	7	8
1	Anandapur	80509	0.0001	100	200	2	16.1
2	Banspal	75487	0.0001	100	200	2	15.1
3	Champua	36958	0.0001	100	200	2	7.4
4	Ghashipura	18189.8	0.0001	100	200	2	3.6
5	Ghatagaon	65154	0.0001	100	200	2	13.0
6	Harichandanpur	84749	0.0001	100	200	2	16.9
7	Hatadihi	20535.2	0.0001	100	200	2	4.1
8	Jhumpura	47190	0.0001	100	200	2	9.4
9	Joda	53175	0.0001	100	200	2	10.6
10	Keonjhar	53765	0.0001	100	200	2	10.8
11	Patna	48112	0.0001	100	200	2	9.6
12	Saharapada	39088	0.0001	100	200	2	7.8
13	Telkoi	62770	0.0001	100	200	2	12.6
			District total				**137.1**

9.1.4 Total groundwater resources

The total available groundwater resources in the blocks and the Keonjhar district has been estimated after summing up the net annual dynamic resource of 1st Aquifer System), the static/in-storage groundwater resource of the 1st Aquifer System) and the static/in-storage groundwater resource of the 2nd Aquifer System. The total available groundwater resource in the district has been estimated as 174665.4 Ha. The details are produced in Table 9.5 and depicted Fig 9.4.

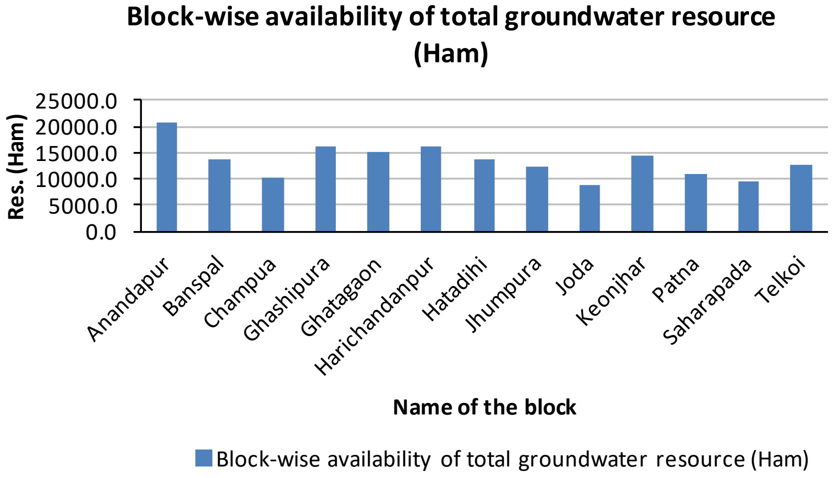


Figure 9.4: Bar diagram showing block-wise availability of total groundwater resources in Keonjhar district.

Table 9.5: Total groundwater resources avalability in Keonjhar district, Odisha (as on 31st Mar 2017)

Sl no	Name of the Assessment Unit	Annual Extractable (dynamic) groundwater Recharge of unconfined /1st Aquifer	In storage groundwater Resources of Unconfined /1st Aquifer	Total groundwater Availability of Unconfined/1st Aquifer (3+4)	Dynamic groundwater Resources of Confined Aquifer	In storage groundwater Resources of Confined/ 2nd Aquifer	Total ground water Availability of Confined/2nd Aquifer (6+7)	Total groundwater Availability of the Assessment Unit (5+8)
		Unconfined/1st Aquifer			Confined Aquifer/2nd Aquifer			
1	2	3	4	5	6	7	8	9
1	Anandapur	6951.9	13666.0	20617.8	0.0	16.1	16.1	20633.9
2	Banspal	6589.6	7065.6	13655.2	0.0	15.1	15.1	13670.3
3	Champua	5128.9	5187.2	10316.1	0.0	7.4	7.4	10323.5
4	Ghashipura	6128.6	10120.8	16249.4	0.0	3.6	3.6	16253.1
5	Ghatagaon	8975.7	6114.7	15090.4	0.0	13.0	13.0	15103.4
6	Harichandapur	8219.8	7957.9	16177.7	0.0	16.9	16.9	16194.6
7	Hatadihi	5879.6	8008.6	13888.2	0.0	4.1	4.1	13892.3
8	Jhumpura	5592.4	6657.3	12249.7	0.0	9.4	9.4	12259.1
9	Joda	3936.1	4961.2	8897.3	0.0	10.6	10.6	8908.0
10	Keonjhar	9317.8	5051.2	14369.0	0.0	10.8	10.8	14379.7
11	Patna	6252.2	4511.9	10764.1	0.0	9.6	9.6	10773.8
12	Saharapada	4010.9	5490.9	9501.8	0.0	7.8	7.8	9509.6
13	Telkoi	6885.7	5865.9	12751.6	0.0	12.6	12.6	12764.1
	District total	**83868.9**	**90659.4**	**174528.3**	**0.0**	**137.1**	**137.1**	**174665.4**

10.0 AQUIFER MANAGEMENT PLAN

In the present scenario, groundwater plays a significant role in the food supply and the national economy. Unscientific and rampant exploitation of the available aquifers for irrigation at several places in the country has created serious conditions of groundwater decline, which has become very difficult to revive. Judicious and scientific exploitation of aquifers, keeping in mind the aquifer sustainability, has been of paramount significance. In order to give justice to both the aquifer sustainability and the growing demand for groundwater for different needs, the aquifer management plan is the need of the hour. With the help of the studies carried out in this aquifer mapping programme, integrating all the available information from the older studies, data available with the state governments, the aquifer management plan for the district has been prepared. To formulate the aquifer management plan, the need was to delineate the aquifer/groundwater related issues in the district. The major issues identified in the district are as below:

1. Under-utilization of available groundwater resource.
2. Low yield of aquifers and groundwater scarcity
3. Ground water fluoride contamination in pockets

10.1 Enhancing groundwater utilization (supply side management)

Ground water in Keonjhar district is the main source of drinking in both the rural and urban areas. About 82% of the existing groundwater draft in the district goes to meet the irrigation needs. Industrial use of groundwater in the district is very limited. The need of the hour is for the sustainable development of the available groundwater resources to meet the present and other emerging needs. The groundwater in the district is mainly developed by the means of dug wells, hand pumps, dug-cum-bore wells, bore wells and some tube wells.

The district has a net sown area of 272919 Ha and the gross sown area of 383437 Ha with 140.5% of cropping intensity. The Salandi irrigation project and the Kanupur irrigation project are the major irrigation projects in the district benefiting the blocks Hatadih, Champua, Joda, Jhumpura and keonjhar. Kanjhari and Remal irrigation projects are the medium irrigation projects benefiting the blocks like Patna, Keonjhar, Ghatagaon, Ghasipura and Harichandanpur. There are number of Minor Irrigation Projects (Flow) and Lift Irrigation Projects working in the district. The main objective of these irrigation projects is protective irrigation to mitigate the effect of draught in the district. Ground water is also utilized for irrigation but to a limited extent and mostly on private ownership. However, considerable parts of the district remain fallow due to lack of irrigation facilities and the vagaries of rainfall. Even in irrigation command areas patches of unirrigated land exist which are not covered by canal irrigation during *rabi* season. Draught condition is a frequent phenomenon, which adversely affects the agricultural activities in the district. The main constraints of canal irrigation in the command areas are:

i) Frequency of erratic monsoon and draught conditions in the area.

ii) Non supply of irrigation water for summer cultivation restricting the crop intensity

iii) The per hectare low yield, which is probably due to inadequate and untimely supply of irrigation water mostly in the tail end areas of canal command.

For augmenting the irrigation facilities and to boost food grain production optimal utilization of both surface and groundwater is a must. In the present scenario, the average stage of groundwater development in the district is only 40% with the minimum of 20.3% in Ghatgaon block and the maximum of 68.3% in Joda block. There is ample scope to enhance the groundwater utilization up to 60% to meet the challenges during the drought situations and in areas without the scope of canal water irrigation. The available surplus groundwater resources in the district can help in mitigating the vagaries in the rain-fed agriculture and can assure the food grain production. Although, major parts of the district is underlain by crystalline rocks, favorable hydrogeological conditions for construction of suitable groundwater abstraction structures exist in the undulating plains and intermontane valleys, where the weathered residuum is moderately thick and the rocks are intensely fractured.

Table 10.1 presents the additional number of groundwater abstraction structures feasible in the districts and in various blocks of it. Three kinds of structures have been suggested; dug wells (DWs), dug-cum-bore wells (DBWs) and bore wells (BWs). But while constructing additional groundwater abstraction structures, one should take into consideration of the safe spacing criteria between any two structures. The distance between any two DWs/DBWs fitted with pump set should be kept at least 100 m, while that between two BWs may be kept between 150-200 m.

Dug well (DW): The DWs are the most common groundwater abstraction structures in the district. The most favourable locations for DWs are topographic lows, abandoned and burried stream channels, areas in the close vicinity of rivers and streams etc. In such areas water table is generally shallow and thickness of the weathered residuum is maximum. In the areas with shallow water table, centrifugal pumps can work satisfactorily and under favourable conditions DWs can cater to the irrigation needs of up to about 4 Ha area of land. Depending upon the hydrogeological set-up, thickness of weathered residuum the yield may be up to 2 to 3 lps. The recommended dimensions of the DW in the district are depth 9 to 15 m, diameter 4.5 to 6 m. The wells may be fitted with 1.5 to 2 H.P. centrifugal pumps for extraction of water. In areas having deeper water table (more than 6 m below ground level), submersible pumps may be installed and can run for 3 to 4 hours daily. The DWs should tap the whole saturated thickness of the weathered mantle till the hard rock is touched as far as practicable. Diameter of the DWs should be governed by the water requirement depending on cropping pattern. In general a well should be pumped for about 4 hours a day to irrigate about 1 Ha during *Kharif* and 0.5 Ha during *rabi* seasons and about 0.5 Ha during summer with low water requiring crops.

All the DWs should be energized for the optimal utilization of their potential. Total number of additional DWs worked out to be feasible in the district to utilize 50% of the available surplus groundwater resource (considering deleopment up to 60%) stands at 32960 (Table 10.1).

***Dug-cum-bore well (DBW)*:** The DBWs can be constructed in the areas where the thickness of weathered residuum is less than 15 meters deep. The vertical hole drilled in the DW increases the yield of the well. Depth of the DW should be up to 12 metres with diameter of 4.5 to 6 metres. The depth of the vertical borehole should be about 25 to 30 metres. The diameter of the borehole may be 102 or 152 mm.

The DBWs should be facilitated by centrifugal pumps or submersible pumps, where necessary, for the optimal utilization of their potential. Number of additional DBWs feasible in the district has been worked out in conjunction with the number of BWs. Including either of the DBWs or BWs, the number stands at 3878. In joda block, no additional structures are feasible, since the existing stage of groundwater development has already exceeded 60%.

Bore Wells: The results of the recent surveys and groundwater exploration are quite encouraging for the exploitation of groundwater through bore wells in different parts of the district, constructed at suitable locales. Deeper water bearing fracture zones may be tapped through bore wells. Usually two to five water saturated fractured zones are encountered in a depth range of about 150 m and the fractured zones are more common within a depth of about 100m. The bore wells are suitable groundwater abstraction structures even in the areas where water level is deeper and hard rocks are encountered at shallow depths. The bore wells may be 100 to 150 m deep having casing in the top weathered zone with diameter of about 152 to 203 mm. Based on the availability of productive fractured zones, the depth of the bore well is decided. Depending upon the discharge and drawdown of the bore wells, suitable pumps may be fitted for the optimum utilization of groundwater resources. The recommended capacity is 2 to 3 H.P. submersible pumps and the yield of the wells may go up to 10 lps.

10.2 Creating additional irrigation potential

The existing irrigation facility in the district covers 120803 Ha constituting 31.1% of the total cropped area. Expanding the infrastructural facilities to enhance the groundwater deleopment up to 60% in the district can help in creating additional groundwater based irrigation potential. Table 10.2 presents block-wise additional irrigation potential which can be developed for various crops like paddy, ground-nuts, oil seeds and vegetables. For paddy, resource between 40-80% (min.: Telkoi block; max.: Ghasipura and Hatadihi blocks) has been allocated for different block depending on their cropping pattern. Similarly, 5-30% of the resource has been allocated for the ground-nut and oil seed crops in different blocks (min.: Hatadihi block; max.: Banspal and Jhumpura block). For the vegetable crops, resource allocation varies between 1o-40% (min.: Ghasipura block; max.: Telkoi block). The crop water requirements have been taken as 1.0 m for paddy and 0.4 m for ground-nuts/oil seeds and vegetables.

The total projected area to be irrigated utilizing the surplus groundwater resource stands at 29321.6 Ha including 9017.4 Ha for paddy, 9119.4 Ha for ground-nuts/oil seeds and 11184.8 Ha for vegetables. The blocks which come out with maximum area for potential irrigation include Ghatgaon, Hatadihi, Telkoi, Keonjhar and Banspal (Table 10.2). This projected area if irrigated can enhance the average irrigation in the district from the existing 31.1% to 39% (Table 10.3). The table also shows the block-wise irrigation status which can be achieved by creating additional irrigation potential.

Table 10.1: Number of additional feasible groundwater abstraction structures in Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No	Block	Net dynamic GW avail. (Ham)	Stage of GW deve. (%)	Present GW Draft (Ham)	Ground Water draft at 60% Stage of deve. (Ham)	Addi. water to be deve. (Ham)	Addi. No of BW/ DBW feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	No. of DW Reco. in Each block (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus
1	Anandapur	6951.9	43.6	3033.8	4171.1	1137.3	257	2187
2	Banspal	6589.6	28.8	1896.7	3953.7	2057.0	465	3956
3	Champua	5128.9	44.1	2262.9	3077.3	814.4	184	1566
4	Ghashipura	6128.6	45.3	2773.0	3677.1	904.1	205	1739
5	Ghatgaon	8975.7	20.3	1822.0	5385.4	3563.4	806	6853
6	Harichandanpur	8219.8	30.4	2497.1	4931.9	2434.8	551	4682
7	Hatadihi	5879.6	49.9	2933.3	3527.8	594.5	135	1143
8	Jhumpura	5592.4	39.9	2231.4	3355.4	1124.0	254	2162
9	Joda	3936.1	68.3	2688.1	2361.7	*nil*	*nil*	*nil*
10	Keonjhar	9317.8	41.2	3835.0	5590.7	1755.7	397	3376
11	Patna	6252.2	49.2	3078.4	3751.3	672.9	152	1294
12	Saharapada	4010.9	56.8	2279.9	2406.5	126.6	29	244
13	Telkoi	6885.7	31.6	2177.1	4131.4	1954.3	442	3758
	District total	**83868.9**	**40.0**	**33508.7**	**50321.3**	**16812.6**	**3878**	**32960**

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability; BW- bore well; DW- dug well; DBW- dug-cum-bore well

Table 10.2: Irrigation potential likely to be created in Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No	Block	Present Stage of GW Development (%)	Surplus GW Avai. for 60% stage of Deve. (Ham)	Irri, Pot. likely to be created for Paddy (Ha)	Irri. Pot. likely to be created for Ground Nut, Oil seed (Ha)	Irri. Pot. likely to be created for veg. (Ha)	Proj. Area to be Irri. (ha)
1	Anandapur	43.6	1137.3	682.4	568.7	568.7	1819.7
2	Banspal	28.8	2057.0	1028.5	1542.8	1028.5	3599.8
3	Champua	44.1	814.4	407.2	610.8	407.2	1425.2
4	Ghashipura	45.3	904.1	723.3	226.0	226.0	1175.3
5	Ghatgaon	20.3	3563.4	1781.7	1781.7	2672.6	6236.0
6	Harichandanpur	30.4	2434.8	1217.4	1217.4	1826.1	4260.8
7	Hatadihi	49.9	594.5	475.6	74.3	222.9	772.8
8	Jhumpura	39.9	1124.0	562.0	843.0	562.0	1967.0
9	Joda	68.3	*nil*	*nil*	*nil*	*nil*	*nil*
10	Keonjhar	41.2	1755.7	877.8	877.8	1316.8	3072.5
11	Patna	49.2	672.9	403.7	336.4	336.4	1076.6
12	Saharapada	56.8	126.6	76.0	63.3	63.3	202.6
13	Telkoi	31.6	1954.3	781.7	977.2	1954.3	3713.2
	Distrit total	**40.0**	**16812.644**	**9017.4**	**9119.4**	**11184.8**	**29321.6**

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected; pot.- potential

Table 10.3: Block-wise Irrigation status in Keonjhat district which can be achieved by creating additional groundwater based irrigation potential.

Sl. No.	Block	Existing status of agriculture		GW based addi. Irri. Pot. to be created	Existing % of irri.	% of irri. which can be attained
		Irrigated	Rainfed			
1	Anandapur	8790	19451	1819.7	31.1	37.6
2	Banspal	2357	20077	3599.8	10.5	26.6
3	Champua	7963	23672	1425.2	25.2	29.7
4	Ghasipura	12462	20014	1175.3	38.4	42.0
5	Ghatgaon	11058	19313	6236.0	36.4	56.9
6	Harichandanpur	8341	24940	4260.8	25.1	37.9
7	Hatadihi	20030	17025	772.8	54.1	56.1
8	Jhumpura	5709	23178	1967.0	19.8	26.6
9	Joda	2942	12115	**nil**	19.5	19.5
10	Keonjhar	16398	17932	3072.5	47.8	56.7
11	Patna	13429	14612	1076.6	47.9	51.7
12	Saharpada	4289	22955	202.6	15.7	16.5
13	Telkoi	7035	14511	3713.2	32.7	49.9
District total/avergae		**120803**	**249795**	**29321.6**	**31.1**	**39.0**

10.3 Dealing with low yield of aquifers and water scarcity

In Keonjhar district, several areas in granitic rocks the yield of the bore wells remains low, even less than 1.0 lps, which can seldom meet the requirements. In such water scarcity areas, large diameter dug wells (5-10 m wide) tapping the entire weathered residuum can give ample water for the needs of irrigation and drinking.

10.4 Poor groundwater quality

Based on the chemical analyses of water samples collected from different aquifers, it is observed that almost all chemical constituents are well within the permissible limit for drinking as well as irrigational purposes, excepting at some localized patches at (Jhumpura – 53 mg/L, Barbil – 86 mg/L, Joda – 204 mg/L, and Narla – 120 mg/L) where it crosses the maximum permissible limit of 45 mg/l. Similarly, the groundwater fluoride beyond the desirable limit of 1.0 mg/L and the maximum permissoble limit of 1.5 mg/L is observed in certain minor patches in the district. Such locations fall in four blocks, namely, Keonjhar, Patna, Harichandanpur and Ghasipura.

The groundwater source points (hand pumps, dug wells) which yield water with fluoride concentration beyond 1.5 mg/L should be stopped immediately from use. In that case some alternate aquifers, if any, need to be explored in the locality for exploitation for drinking and domestic use. In many cases, the dug wells yield less groundwater fluoride. However, their use should be preceded with groundwater testing for fluoride content.

10.5 Augmenting groundwater resources (supply side management)

Depletion of phreatic aquifer in the foot-hills and piedmont zones of mountain belts is a common phenomenon during summer seasons in Orissa. The Baitarani and Karo river basins in Keonjhar district is surrounded by hill ranges and the runoff generated in the basin is mostly drained by Baitarani River and its tributaries. The phreatic zone gets replenished through rainfall recharge and accounts for the dynamic groundwater resources. The weathered zone developed on massive crystallines is shallow and serves as the phreatic aquifer system for groundwater storage and movement. Rapid decline in water level during the post-monsoon period renders most of the shallow dug wells drying up or unproductive. However, this lowering of groundwater level is due to out-flow from the basin in the form of base-flows through perennial and ephemeral streams in the area.

Though, there are patches in the district, where long term (decadal) decline in water level >0.1 m has been observed, those patches are very limited and some of them possess water level within 5.0 m bgl. Thus, the areas which show post-monsoon water levels beyond 5.0 m bgl have only been demarcated where artificial recharge to groundwater has been suggested. Such suitable patches of areas have been produced in Plate 10.1. The block-wise distribution of area of such patches has been produced in Table 10.4. The areas have been grouped into two classes; (1) areas with DTW 5.0-7.5 m bgl, and (2) areas with DTW 7.5-9.3 m bgl. Total area suitable for artificial recharge to the groundwater comes as 1547.99 km^2 with maximum of 700.4 km^2 area falling in the Banspal block followed by 246.73 km^2 in the Joda block. In Table 10.5, total thickness of the aquifer, aquifer volume and total volume of water required to recharge the aquifers have been worked out for different blocks in the district (considering raising the water level up to 3.0 m bgl). The volume of aquifer that is proposed to be recharged has been calculated by using the following equation:

V in MCM = (Area in km2) x (Average post-monsoon DTWL in m - 3m)

Total volume of water required has been worked out to be 17874 Ham or 178.74 MCM. A specific yield value of 3% (depending on area hydrogeology) has been considered while estimating the volume of water to be recharged.

Table 10.4: Areas in each block with depth to water level (DTW) >5.0 m bgl

Sl No	Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
		DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
1	Anandapur	19.73	7.14	26.87
2	Banspal	512.49	187.91	700.40
3	Champua	26.05	1.08	27.13
4	Ghasipura	27.19	1.10	28.29
5	Ghatgaon	78.37	5.79	84.16
6	Hatadihi	0.00	0.00	0.00
7	Harichandanpur	139.34	33.10	172.44
8	Jhumpura	24.19	1.97	26.16
9	Joda	232.02	14.71	246.73
10	Keonjhar	58.76	4.69	63.45
11	Patna	1.10	0.00	1.10
12	Saharpada	65.62	0.00	65.62
13	Telkoi	104.07	1.58	105.65
District total		**1288.93**	**259.06**	**1547.99**

10.5.1 Artificial recharge structures and cost estimates

The most feasible artificial recharge and rain water harvesting structures are percolation tanks, sub-surface dykes, nala/contour bunding, small check dams/weirs, renovation of old tanks to percolation tanks, water spreading, gully plugging, gabion structures etc. Table 10.6 shows the estimated feasible numbers of some artificial recharge structures in the district. Allocation of different types of artificiaal recharge structures, presented in Table 10.6 have been done based on the topography. The area is a kind of mid-land area with rolling topography (300-600 m asl elevation). Thus, as per the state artificial recharge plan, 40%, 15%, 15% and 30% have been considered for percolation ponds, sub-surface dykes, nala/contour bunding and check dams/weirs. The number of structures to be constructed is worked out taking average gross capacity of one percolation tank as 200 TCM, for Nala bund/contour bunding/check dam as 150 TCM in multiple fillings.

The total number of recharge structures has been estimated as 357, 179, 179 and 357 for the percolation ponds, sub-surface dykes, nala/contour bunding and check dams/weirs respectively. The maximum numbers of such structures have been worked out for the blocks of Banspal followed by Joda, Harichandanpur, Telkoi, Ghatgaon (Table 10.6).

Costing of the recharge structures have been produced in Table 10.7. It is estimated at 116.18 crore with the maximum share for the percolation ponds at 71.49 crores.

Table 10.5: Estimation of volume of water required for artificial recharge to groundwater

Sl No	Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to recharge (MCM)
1	Anandapur	708.00	26.87	7	4	107.47	3.22
2	Banspal	1115.00	700.40	7	4	2801.60	84.05
3	Champua	289.00	27.13	6.5	3.5	94.95	2.85
4	Ghasipura	410.00	28.29	6.5	3.5	99.02	2.97
5	Ghatgaon	613.00	84.16	6.5	3.5	294.54	8.84
6	Hatadihi	607.00	0.00	0	-3	0.00	0.00
7	Harichandanpur	782.00	172.44	7	4	689.76	20.69
8	Jhumpura	594.00	26.16	6.5	3.5	91.55	2.75
9	Joda	727.00	246.73	7	4	986.94	29.61
10	Keonjhar	697.00	63.45	6.5	3.5	222.08	6.66
11	Patna	423.00	1.10	6	3	3.30	0.10
12	Saharpada	402.00	65.62	6	3	196.87	5.91
13	Telkoi	961.00	105.65	6.5	3.5	369.76	11.09
District total		**8328.00**	**1547.99**	**6.08**	**40.00**	**5957.84**	**178.74**

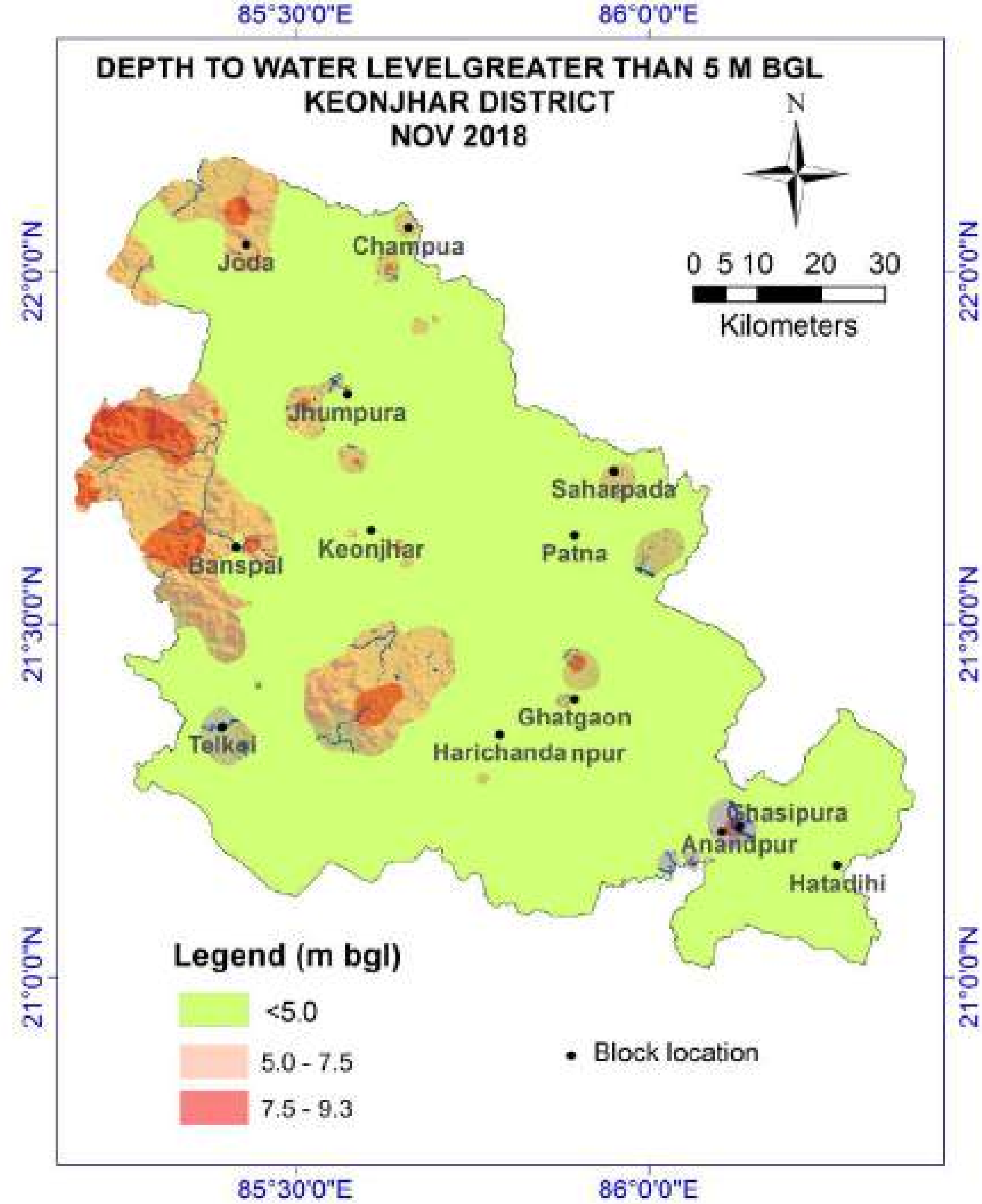
Table 10.6: Number of feasible structures for artificial recharge to groundwater

Sl No	Name of block	Total reharge volume required (MCM)	No of different freasible structures			
			Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
1	Anandapur	3.22	6	3	3	6
2	Banspal	84.05	168	84	84	168
3	Champua	2.85	6	3	3	6
4	Ghasipura	2.97	6	3	3	6
5	Ghatgaon	8.84	18	9	9	18
6	Hatadihi	0.00	0	0	0	0
7	Harichandanpur	20.69	41	21	21	41
8	Jhumpura	2.75	5	3	3	5
9	Joda	29.61	59	30	30	59
10	Keonjhar	6.66	13	7	7	13
11	Patna	0.10	0	0	0	0
12	Saharpada	5.91	12	6	6	12
13	Telkoi	11.09	22	11	11	22
District total		**178.74**	**357**	**179**	**179**	**357**

Table 10.7: Estimation of cost of artificial recharge structures, Keonjhar district.

Sl No	Name of block	Cost of artificial recharge structures				Total cost (rupees in crores)
		Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
1	Anandapur	1.29	0.32	0.16	0.32	2.10
2	Banspal	33.62	8.40	4.20	8.40	54.63
3	Champua	1.14	0.28	0.14	0.28	1.85
4	Ghasipura	1.19	0.30	0.15	0.30	1.93
5	Ghatgaon	3.53	0.88	0.44	0.88	5.74
6	Hatadihi	0.00	0.00	0.00	0.00	0.00
7	Harichandanpur	8.28	2.07	1.03	2.07	13.45
8	Jhumpura	1.10	0.27	0.14	0.27	1.79
9	Joda	11.84	2.96	1.48	2.96	19.25
10	Keonjhar	2.66	0.67	0.33	0.67	4.33
11	Patna	0.04	0.01	0.00	0.01	0.06
12	Saharpada	2.36	0.59	0.30	0.59	3.84
13	Telkoi	4.44	1.11	0.55	1.11	7.21
	District total	**71.49**	**17.87**	**8.94**	**17.87**	**116.18**

PLATE – 10.1



85°30'0"E
86°0'0"E
DEPTH TO WATER LEVELGREATER THAN 5 M BGL
KEONJHAR DISTRICT
NOV 2018
N
0 5 10 20 30
Kilometers
22°0'0"N
21°30'0"N
21°0'0"N
Joda
Champua
Jhumpura
Saharpada
Keonjhar
Patna
Banspal
Ghatgaon
Telkoi
Harichanda npur
Ghasipura
Anandpur
Hatadihi
Legend (m bgl)
<5.0
5.0 - 7.5
7.5 - 9.3
Block location

11.0 CONCLUSIONS

- Keonjhar district, with a total geographical area of about 8340 km2, is characterized by hilly and rugged terrain with thick forest covers. From groundwater point of view, the important hydro-geomorphic units include pediments, buried pediments (of both shallow and medium types) intermontane valleys, valley filles, linear ridges/dykes, lateritic uplands and alluvial plains, which cover ~45% of the district area. The alluvial plain, is another unit that covers ~5% of the area. A major part of the district is covered by land slopes (<20%) suitable for water infiltration and generation of groundwater resource. Only about 8% of the district area exceeds the critical slope of 20%, which is not worthy of groundwater recharge. The soils in the districts can broadly be grouped into (1) Alfisols and (2) Ultisols. Soils of the district are generally having average to good fertility status and can support all common type of crops.
- The Baitarani River along with its tributaries like Kanjhari, Ardei, Musal, Kusei, Sita, Mohalda, Bamri, Neorojol, Nermeda and Salandi forms the major drainage system. The rivers flow north-easterly, easterly, southeasterly to southerly. The streams like Samakoi flow in the the south-west direction to meet the river Brahmani in the west of the district. The drainage pattern is mostly dendritic but at places it is rectangular where it is structurally controlled by joints, fractures and other lineaments
- The south-west monsoon is the principal source of precipitation in the district. The normal annual rainfall is 1379 mm, out of which about 80-85% is received during monsoon season (mid June to mid October).
- The geological formations in Keonjhar district are widely divergent and predominated by Precambrian rocks, covering around 95% of the district area. The Quaternary and Recent unconsolidated alluvium (consisting of sand, silt and clay) occur in the Baitarani River Basin. The Singhbhum Granites covers around 50% (in the central and eastern parts) of the geographical area of the district. The Iron Ore Group constitutes the next major rock types and covers the western and south western boundaries of the district. These are made up of low grade metasediments including phyllites, tuffaceous shales, BHJ and BHQ with iron ore, ferrugeuous quartzite and metavolcanics. Among other rocks, the Older Metamorphic Group of rocks including micaceous quartzites, amphibolites, pelitic schists, tonalite gneiss, and the proterozoic volcanics and Kolhan sedimentaries, gabbro-anorthosite intrusives and dolerite dykes. Swarms of newer

dolerite dykes are observed intruding the Singhbhum Granites in the eastern parts of the district.

- The weathered residuum and the fracture systems at deeper levels in the hard rock areas, and the granular porous formations in alluvium form the main groundwater repositories in the district. Iron ore group of rocks have high yield potentials in the upper 75 m depth. Kolhan sedimentaries occurring in valley areas (e.g. near Suakati) have good potentials up to 60 m depth wherever truncated by dolerite dykes. The granitic rocks (both Older Metamorphic Tonalite Gneiss and Singhbhum Granite) show moderate to good yield in the saprolite horizon. The newer dolerite dykes, though have fractures, those die out with depth and are less productive due to lack of any tectonic relationship with the Singhbhum Granite and other country rocks.
- The unconsolidated formations consist of laterite and alluvium. Unless highly consolidated, the laterites bear moderate to good groundwater potential. The alluvium, comprising an admixture of clay, silt, sand and calcareous concretions often forms prolific aquifers. The thickness of alluvium reaches up to around 100 m bgl.
- The depths to water levels (DTWs) levels during pre- and post-monsoon periods varied in the ranges of 0.95-13.8 m (ave.: 6.07 m bgl) and 0.4-9.3 m bgl (ave.: 4.0 m bgl). Areas covered by water levels of <2.5 m and 2.5-5.0 m bgl expanded (1.3% to 20.4% and 25.2% to 61.4%), while those of 5.0 - 7.5 m and 7.5 - 10.0 m shrinked (54.1% to 15.1% and 17.9% to 3.0%) during post-monsoon period. Thus, the post-monsoon DTWs reflect good recharge of the phreatic aquifer from the rainfall.
- The pre- and post-monsoon (year 2018) water level measurements indicated fluctuations between -0.7 m (water level decline) and 8.65 m (rise in water level). The average fluctuation stood at 2.20 m. The minor declines in water levels were observed in particularly the alluvial areas.
- The groundwater flow-nets indicated the effluent character of the rivers (groundwater-fed). The gradient of the potentiometric surface (range: 1:50 - 1:600) was reasonably flat in the eastern and central parts of the district in parts (blocks Champua, Jhumpura, Patna, Keonjhar, Telkoi and in the alluvial parts of Anandapur and Hatadihi), indicating favorable groundwater conditions in such parts.

- The decadal (2009–2018) water level trends indicated rising trends in water level in 33% 31% of the monitoring stations during the pre- and post-monsoon periods respectively. Falling trend was observed in 20% (max.: 0.71 m) and 32% (max.: 0.71 m) of the wells during the periods.
- Similar to the phreatic aquifers, the water levels in the piezometers (fracture zones: 30-50 m bgl) ranged between 4.66 – 7.29 ml and 1.96-5.01 m bgl during the pre- and post-monsoon periods respectively. Similar shallow water levels (range: 0.62-10.0) were also measured in different periods of time in 85% of the exploratory wells (EWs) tapping fracture zones in the depth range of 27-203 m bgl.
- The thickness of weathered zone in the district varied between 6.5-60 m with the average value of 22.7 m. The northern half of the district is predominated with the thickness range of 40.0 – 50.0 m, whereas in the southern parts, the range 10.0 – 20.0 m predominates. A major part of the district is occupied by the thickness range of 20.0 – 30.0 m.
- Within the depth of 200 m bgl, 1-6 sets of fractures have been encountered with spatial variation in their occurrence. Within 100 m bgl, the maximum recurring of the fractures takes place in the depth ranges of 15-40m, 45-65m and 70-90m bgl. Beyond the depth of 100 m bgl, the incidences of fractures are less and also irregular. The maximum reccurrence of fractures takes place in the depth ranges of 100-105m, 115-120m and 145-150 m bgl.
- The maximum numbers of fractures (2-5 sets) within the depth of 200 m bgl are found in the northern half of the district. In south-eastern parts in Anandapur and Ghasipura blocks in some cases 2-3 sets of fractures are encountered in the bore wells. In the central, eastern and western parts, in parts of the blocks Harichandanpur, Ghatgaon, Saharpada and Banspal, maximum up to 2 sets of fractures are encountered in the bore wells.
- If depth-wise assessed, maximum numbers of fracture sets are located within the depth of 100 m bgl only. However, within this depth, the south-central parts covering parts of the blocks Harichandanpur, Ghatgaon, Anandapur, Ghasipura and Patna possess 0-1 sets of fractures only. Within the depth of 100-200 m bgl, a major part of the district is covered by the area with only 0-1 sets of fractures. Only in certain pockets in the north-eastern side in the blocks of Joda, Champua, Jhumpura and Patna, in the central parts

in blocks of Harichandanpur and Ghatgaon, and in the south-eastern side in the blocks of Harichandanpur and Ghasipura, more than one sets of fractures are encountered.

- Based on the fractutes zones analysis, the aquifers have been put into two categories: 1st aquifer system extending from ground surface up to depth of 100 m bgl, and 2nd aquifer system extending between the depth ranges of 100-200 m bgl. The former aquifer system possesses fractures zones up to 5 sets (more commonly 2-3 sets), while the later one is predominantly characterized by 0-1 sets of fractures.
- The yield potential of the fracture aquifers within ~27.0-200.0 m bgl varied from negligible at several places to the maximum of ~20 lps at Kanjipani in the Banspal block. Except a few wells, major numbers of them exhibited discharge more than 1.0 lps. Common yields of 2.5–5.0 lps were found in the central, southern, northwestern and northern parts, and yields of 1.0 – 2.5 lps in the north-eastern and south-central parts. The bore wells registering yields more than 5.0 lps largely fall in the south-eastern parts of districts in the blocks of Anandapur, Ghasipura and Hatadihi.
- The 1st aquifer system is more potential with the average yield of 4.2 lps (range: 0 – 20 lps) in comparison to the 2nd aquifer system with the average yield of 3.2 lps only (range: 0.12 – 8.0 lps).
- The alluvial aquifer in Keonjhar district is considerably more potential than the fracture aquifers. The yield of tube wells in alluvium has been reported in the range of 15-31 lps with the average value of 23 lps. The aquifers with thickness between 10-40 m, comprising medium to coarser granular materials are conspicously high potential.
- In spite of higher incidence of fractures, the wells in the north-eastern parts yield less, which is due to the dry fractures within the dolerite dykes. The area is traversed by number of sub-surface dolerite dykes which cross-cut the Singhbhum Granite. The fractures in the dykes do not possess any tectonic perturbation relation with the country rock.
- The bore wells in the district showed drawdowns in the range of 1.0-39.0 m for pumping rates varying between 0-20 lps and pumping duration between 100-300 minutes. The discharge per unit drawdown (m3/hour/m) in the well, defined as specific capacity, varied between 0.6-31 m^3/hour/m. It also indicates poor aquifer potential in the north/north-eastern parts of the district (in parts of blocks of Joda, Jhumpura,

Champua, Keonjhar, Saharpada and Patna), where the specific capacity of wells remain low at <1.5 m^3/hour/m. In the southern parts of the district, except a patch covering parts of Harichandanpur and Ghatgaon blocks, major parts exhibit higher values of specific capacity in the range of 1.5-31 m^3/hour/m. In alluvial areas, the specific capacity remains high in the range of 8-21 m^3/hour/m with drawdown varying between 4.6-8.3 m.

- The transmissivity (T) of the fracture aquifers ranged between 0.18-361.5 m^2/day with the average of 32.3 m^2/day. The aquifers with relatively high T (>40 m^2/day) are clustered more towards central and south-eastern parts of the district, specifically in the blocks of Banspal, Harichandanpur, Ghatgaon, Ghasipura, Anandapur and parts of Patna. The northern and north-eastern parts of the district are rich in fracture zones due to existence of several sets of sub-surface dolerite dykes. However, the wells in these areas are less transmissive as well as less productive. The 1st aquifer system is more transmissive with the T values varying between 0.27-361.5 m^2/day and average of 39 m^2/day. In the 2nd aquifer system the T values range between 0.18-59.3 m^2/day with the average of only 14.2 m^2/day.
- The storativity (S) values varied between the maximum of $3.6 X 10^{-2}$ at Nalda in Joda block to minimum of $2.4 X 10^{-5}$ at Dhenkikote in Ghatgaon block. The values of S indicated unconfined to confined character of the aquifers.
- Based on the overlay analysis of several input parameters (i.e., geomorphology, geology, slope, soil, drainage density, lineament density, land use/land cover, rainfall, and thickness of weathered residuum) which control groundwater condition it is indicated that around 34.6 % and 37.3% of the district area are occupied by moderate (Champua, Saharpada and Ghatgaon blocks) and good (Jhumpura, Keonjhar and Patna blocks) groundwater potential zones respectively. Around 13.6% of the district area is covered by very good groundwater potential zones, falling in the blocks of Anandapur, Ghasipura, Hatadihi, Banspal, Keonjhar and Jhumpura.
- The groundwater quality in the phreatic as well as deeper fracture aquifers is marginally alkaline in nature. The average EC values fall within the permissible limits with exceptions in a few patches. Nitrate (NO_3) and fluoride values are well within the permissible limit except certain minor patches. Groundwater fluoride contamination in certain patches has been observed in the Naranpur Gram Panchayat in Keonjhar block.

The quality of groundwater from the shallows as well as deeper aquifers is generally good and is suitable for drinking and irrigation purposes.

- In the shallow phreatic aquifer, the water types were predominantly Ca-HCO_3. In the alluvium, water types like Na-HCO_3 and other mixed varieties like Ca-Mg-HCO_3, Na-Cl-HCO_3, Ca-HCO_3-Cl, Mg-HCO_3-Cl, Mg-Na-HCO_3 were also found. In the deeper fracture aquifers the water types were predominantly Ca-HCO_3 followed by Mg-HCO_3.
- The total annual dynamic groundwater resource of Keonjhar district is assessed to be 83868.9 hectare meter (Ham). The existing gross groundwater draft is 33508.7 Ham including an irrigation draft of 27433.5 Ham (~82% of total draft). The annual utilizable resource which remains for irrigation use (after allocation for domestic and drinking up to the year 2025) has been estimated at 49577.5 Ham. The stage of groundwater development varies between the minimum of 20.3% in the Ghatgaon block and the maximum of 68.3% in the Joda block, with the average stage of groundwater development for the district as 40.0%.
- Total static/in-storage groundwater resources of 90659.4 Ham and 137.1 Ham have been estimated for the 1st and 2nd aquifer systems. The total available groundwater resource (including the dynamic component) in the district has been estimated as 174665.4 Ha.
- At 40% as average stage of groundwater development, there exists ample scope to enhance the groundwater utilization up to 60% to meet the challenges during the drought situations and in areas withount the scope of canal water irrigation. The number of additional DWs, and dug-cum-bore wells/bore wells which are feasible in the district stood at 32960 and 3878 respectively.
- The district has a net sown area of 272919 Ha and the gross sown area of 383437 Ha with 140.5% of cropping intensity. Irrigation potential of an additional area of 29321.6 Ha can be created to utilize the available surplus groundwater. It can help in increasing the existing irrigation facility of 31.1% to 39%.
- In the water scarcity areas, where the bore wells either fail to yield or yield meagre volume of water, large diameter dug wells (5-10 m wide) tapping the entire weathered residuum can give ample water for the needs of irrigation and drinking.

- The groundwater source points (hand pumps, dug wells) which yield water with fluoride concentration beyond 1.5 mg/L should be stopped immediately from use. In that case some alternate aquifers, if any, need to be explored in the locality for exploitation for drinking and domestic use. In the absence of such aquifer, pipe water supply can be ensured for drinking. In many cases, the dug wells yield less groundwater fluoride. However, their use should be preceded with groundwater testing for fluoride content.
- The areas showing depth to water levels >5.0 m bgl can be adopted for artificial recharge to groundwater. The suitable structures include percolation ponds, nala/contour bunds, check dams/weirs and sub-surface dykes etc. Total such area suitable for artificial recharge has been assessed at 1547.99 km^2. Total volume of water required has been worked out to be 17874 Ham or 178.74 MCM.
- The total number of recharge structures has been estimated as 357, 179, 179 and 357 for the percolation ponds, sub-surface dykes, nala/contour bunding and check dams/weirs respectively. Total cost of executing such projects will be around 116.18 crore with the maximum share for the percolation ponds at 71.49 crores.

12.0 RECOMMENDATIONS

1. As there is large scope for development of groundwater, suitable schemes may be launched for groundwater development to boost agricultural production in the district. The financial institutions should generously finance such schemes.
2. Since the thickness of weathered mantle is more than 20 m in major parts of the district (max.: 60 m), shallow tube wells and large diameter dug wells would be feasible for groundwater extraction for irrigation and domestic use.
3. Most of the productive fractures are located within the depth of 100 m below ground. The aquifers within this depth can be exploited for irrigation and drinking. This aquifer system gets regular recharge form rainfall.
4. Reckless pumping from the bore wells for long durations should be avoided for sustainability. It may cause rapid decline in water level.
5. In construction of groundwater abstraction structures, such as dug wells, dug-cum-bore wells and bore wells, for irrigation minimum safe spacing should be maintained to avoid interference of the wells.
6. For optimum utilization of the groundwater potential, necessary steps should be taken for energisation of the wells.
7. The yield of existing dug wells may be enhanced by converting those into dug-cum-bore wells wherever feasible and the wells should be provided with brick lining which will facilitate the free flow of groundwater into the well.
8. Rapid decline in water level in uplands or hill slope areas during the post-monsoon period renders most of the shallow dug wells drying up or unproductive. Therefore, suitable structures like percolation ponds, sub-surface dykes, nala-contour bunding, check dams/weirs and other surface run-off conservation measures should be adopted as artificial recharge structures. The structures can be designed at suitable locations based on prevailing site specific hydrological conditions in the area for sustainable development of water resources.
9. Construction of check dams, nalla/contour bunds, and percolation tanks at suitable locations will help in effecting additional recharge to the groundwater reservoir. Sub-surface dykes may also be constructed at hydrogeologically suitable sites to arrest sub-

surface out-flow of groundwater in the weathered mantle of hard massive rocks. This will increase the dynamic groundwater storage in the adjacent phreatic aquifer.

10. With increase in mining activities in Joda-Barbil sector, of Joda block, Gandhamardan Iron ore group of mines in Sadar block, it is apprehended that there may be decline in groundwater table with passage of time. Hence proper remedial measures in terms of proper utilization of mine water, dumping of mining waste, land leveling and afforestation measures in and around the area may be taken to safeguard the environment.

11. With ongoing rapid industrialization in the district, the groundwater withdrawal in pockets may affect the present groundwater regime. To overcome such situation proper monitoring by the concerned industrial houses may be regularly done and artificial recharge methods like rain water harvesting, recharging through borewells, run-off conservation structures in the peripheral areas may be adopted.

12. The point sources (dug wells, hand pumps, bore wells) which yield groundwater with high fluoride content (>1.5 mg/L) should be stopped immediately from use. In that case, alternate sources of safe drinking may be provided.

13. Detailed surface geophysical survey aided by photogeological & remote-sensing studies may be taken up in the district to identify the exact thickness of weathered zone and occurrence and extent of lineaments, which form potential aquifer zones.

14. The agricultural extension services should motivate and guide the farmers to adopt suitable cropping patterns to maximize the benefits of irrigation through dug wells / bore wells.

15. Groundwater monitoring in the district, for water level and water quality, through National Hydrograph Stations should be strengthened to assess the impact of envisaged groundwater development on the groundwater regime.

16. Conjunctive use studies in canal command areas of Salandi and Kanupur irrigation projects may be undertaken in future for judicious management of groundwater and surface water.

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14.0 ANNEXURES

Annexure 1: Last 20 years block-wise yearly rainfall of Keonjhar district (source: Govt. of Odisha)

Sl no.	Block/Monitoring station	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Anandapur	2310	1777	1500	1376	1893	1533	1567	1688	1793	1390
2	Banspal	868	690	727	363	629	-	-	-	-	1509
3	Champua	1621	1997	1918	1203	1787	1514	1769	1496	2096	1551
4	Ghasipura	2240	1614	1679	1171	1568	1337	1592	1803	1896	1547
5	Ghatgaon	2189	1167	1740	460	1497	1063	2981	2458	2853	2379
6	Harichandanpur	1246	803	999	624	959	766	1303	1167	1509	1344
7	Hatadihi	1337	1085	1118	749	1358	907	1110	1119	1305	1533
8	Jhumpura	1537	943	1371	1077	1351	1120	2301	1357	1675	1535
9	Joda	1571	1282	1167	956	1185	1711	1144	1608	3060	2215
10	Keonjhar	1596	1158	1787	871	1336	1118	1230	1477	1627	1655
11	Patna	1065	869	1138	470	1002	650	1527	1738	1802	1299
12	Saharpada	950	586	944	660	992	761	1488	1430	1600	1312
13	Telkoi	2157	1099	1794	1217	2512	-	-	-	-	2120
	Dist. Average	**1591**	**1159**	**1376**	**861**	**1390**	**1238**	**2129**	**1610**	**1920**	**1656**

Annexure 1 (Contd..): Last 20 years block-wise yearly rainfall of Keonjhar district (source: Govt. of Odisha)

Sl no.	Block/Monitoring station	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Anandapur	1276	2040	3688	1269	2095	2094	1218	1431	1327	1629
2	Banspal	729	767	1284	1236	1680	1319	1245	1037	1255	1412
3	Champua	1092	931	1821	1109	1883	1027	795	1486	1305	1468
4	Ghasipura	1512	1353	1373	1114	1479	1336	921	1254	1571	1878
5	Ghatgaon	1957	1497	2282	2176	2297	1547	1286	1203	1700	2050
6	Harichandanpur	1282	1194	1439	927	1097	640	550	1137	1445	1833
7	Hatadihi	1616	1310	1501	795	1468	1182	964	1307	811	2011
8	Jhumpura	894	1158	1700	964	1369	1161	957	1162	1238	1490
9	Joda	1688	1430	2797	1527	2583	1553	1021	1221	1262	1558
10	Keonjhar	1298	1223	1871	1068	1423	1643	1230	1116	1198	1325
11	Patna	1302	1251	1633	1355	1316	1446	939	991	926	1624
12	Saharpada	1143	769	1227	1018	1370	1230	876	1068	942	1531
13	Telkoi	1393	852	2216	1768	1408	1238	1123	1336	990	1850
	Dist. Average	**1322**	**1213**	**1910**	**1256**	**1651**	**1340**	**1009**	**1211**	**1228**	**1666**

Annexure 2: Pre-monsoon depth to water level from National Hydrograph monitoring stations, Keonjhar district, Odisha.

Sl no.	**Block**	**Village**	**DTW**
1	ANANDPUR	Nuagaon	2.13
2	ANANDPUR	Bhagomunda	3.92
3	BANSPAL	Kanjipani	6.4
4	BANSPAL	Suakati	5.53
5	CHAMPUA	Champua	8.84
6	CHAMPUA	Parsora	7.08
7	CHAMPUA	Sasang	5.7
8	CHAMPUA	Jaymangalpur	2.41
9	GHASIPURA	Kesudapal-Ii	3.35
10	GHASIPURA	Kesurdapal	2.2
11	GHASIPURA	Balarampur	5.16
12	GHASIPURA	Birgovindpur	6.53
13	GHASIPURA	Deogan	4.06
14	GHASIPURA	Barpada	3.34
15	GHATGAON	Rajpat	4.08
16	GHATGAON	Melana	2.82
17	GHATGAON	Baxibarigan	6.72
18	GHATGAON	Dhenkikot	9.75
19	GHATGAON	Patilo	8.66
20	GHATGAON	Ghatgaon	2.37
21	GHATGAON	Gadadharpur	4.42
22	GHATGAON	Dhangadiha	10.66
23	HARICHADANPUR	Harichandanpur	1.8
24	HATADIHI	Mathadai	2.49
25	HATADIHI	Nuasahi	1.81
26	HATADIHI	Ghasipur	8.39
27	JHUMPURA	Ukunta	1.88
28	JHUMPURA	Katalaposhi	10.9
29	JHUMPURA	Badaposhi	6.9
30	JHUMPURA	Jhumpura	6.52
31	JODA	Guali	7.8
32	JODA	Rugudi	5.54
33	JODA	Bhadrasahi	7.78
34	JODA	Joda	6.47
35	KENDUJHARGARH	Jhadbelda	7.4
36	KENDUJHARGARH	Brahmandgram	3.57
37	KENDUJHARGARH	Keonjhar-Ii Old Town	8.55
38	KENDUJHARGARH	Naranpur	8.6
39	KENDUJHARGARH	Haridagot	3.2
40	KENDUJHARGARH	Gopalpur	4.25
41	KENDUJHARGARH	Padampur	10.8
42	KENDUJHARGARH	Muktapur	7.3
43	KENDUJHARGARH	Keonjhargarh	4.3
44	PATANA	Kothaghar	2.91

45	PATANA	Tangarpada	3.47
46	PATANA	Burikapuri	5.36
47	PATANA	Turmunga	4.6
48	PATANA	Malliposi	2.89
49	PATANA	Khiritangiri	6.48
50	PATANA	Balaniposi	6.9
51	SAHARAPADA	Badbil	7.6
52	SAHARAPADA	Gajitangri	4.05
53	SAHARAPADA	Udaipur	4.23
54	SAHARAPADA	Swampatna	1.38
55	TELKOI	Pitanali	8.78
56	TELKOI	Kuntapada	6.1
57	TELKOI	Padang	4.87
58	TELKOI	Bimala	5.77
59	TELKOI	Jagmohanpur	5.91
60	TELKOI	Kaliahata	4.42
61	TELKOI	Telkoi	4.5
62	TELKOI	Akul	5.23

Annexure 3: Post-monsoon depth to water level from National Hydrograph monitoring stations, Keonjhar district, Odisha.

Sl no.	**Block**	**Village**	**DTW**
1	ANANDPUR	Nuagaon	2.6
2	ANANDPUR	Bhagomunda	2.57
3	BANSPAL	Banspal-Ii	4
4	BANSPAL	Suakati	3.88
5	CHAMPUA	Jodipada	4.05
6	CHAMPUA	Champua	5.77
7	CHAMPUA	Sasang	3.3
8	CHAMPUA	Jaymangalpur	1.97
9	GHASIPURA	Kesurdapal	1.38
10	GHASIPURA	Balarampur	2.75
11	GHASIPURA	Birgovindpur	4.95
12	GHASIPURA	Deogan	4.08
13	GHASIPURA	Barpada	1.2
14	GHATGAON	Rajpat	2.6
15	GHATGAON	Melana	2.5
16	GHATGAON	Baxibarigan	4.8
17	GHATGAON	Dhenkikot	2.25
18	GHATGAON	Patilo	5.2
19	GHATGAON	Gadadharpur	3.72
20	GHATGAON	Dhangadiha	4.85
21	HATADIHI	Mathadai	1.14
22	HATADIHI	Ghasipur	8.04
23	JHUMPURA	Ukunta	2.3
24	JHUMPURA	Katalaposhi	2.25

25	JHUMPURA	Badaposhi	2.8
26	JHUMPURA	Jhumpura	3.8
27	JODA	Bhadrasahi	4.9
28	JODA	Joda	5.42
29	KENDUJHARGARH	Jhadbelda	2.55
30	KENDUJHARGARH	Brahmandgram	2.8
31	KENDUJHARGARH	Keonjhar-Ii Old Town	7.2
32	KENDUJHARGARH	Naranpur	8.5
33	KENDUJHARGARH	Haridagot	5.5
34	KENDUJHARGARH	Gopalpur	2.12
35	KENDUJHARGARH	Padampur	7.65
36	KENDUJHARGARH	Muktapur	2.9
37	KENDUJHARGARH	Keonjhargarh	3.35
38	PATANA	Kothaghar	4.31
39	PATANA	Tangarpada	2.65
40	PATANA	Turmunga	2.3
41	PATANA	Malliposi	2.29
42	PATANA	Kendeiposhi	4.19
43	PATANA	Khiritangiri	2.53
44	PATANA	Balaniposi	2.4
45	SAHARAPADA	Badbil	4.9
46	SAHARAPADA	Gajitangri	4
47	SAHARAPADA	Udaipur	3.15
48	SAHARAPADA	Swampatna	2.13
49	TELKOI	Pitanali	5.2
50	TELKOI	Gonasika	3
51	TELKOI	Kuntapada	6.1
52	TELKOI	Padang	3.52
53	TELKOI	Bimala	3.57
54	TELKOI	Jagmohanpur	2.83
55	TELKOI	Telkoi	5.55
56	TELKOI	Patakhali	2.6
57	TELKOI	Akul	3.35

Annexure 4: Key well details of pre-monsoon season 2018

Sl. No	BLOCK	VILLAGE	LONGITUDE	LATITUDE	MP(M)	DIA(M)	DEPTH(M)	SWL(mbgl)	GEOLOGY
1	Anandpur	Kuldiha	86.12	21.42	0.3	2.1	8.8	5.5	Alluvium and Singbhum Granite
2	Anandpur	Janjali	86.11	21.46	GL	5.1	8.3	4.4	Alluvium and Singbhum Granite
3	Anandpur	Baniajodi	86.07	21.44	0.5	2.3	18.15	1.9	Alluvium and Singbhum Granite
4	Anandpur	Manoharpur	86.07	21.48	0.3	4.2	9.3	5.5	Alluvium and Singbhum Granite
5	Anandpur	Badakushapada	86.06	21.47	GL	3.1	6.4	3	Alluvium and Singbhum Granite
6	Anandpur	Sagadapata	85.92	21.25	0.3	3.1	10.3	6.2	Alluvium and Singbhum Granite
7	Banspal	Talakainsari	85.53	21.63	0.35	1.2	10	5.2	Volcanics/ metavolcanics
8	Banspal	Khajurimundi	85.44	21.61	0.5	1.5	8	13.8	Volcanics/ metavolcanics
9	Banspal	Padakasada	85.42	21.59	0.7	1.8	9.5	4	Volcanics/ metavolcanics
10	Banspal	Mereisahi	85.38	21.62	0.3	1.2	11	12.8	Volcanics/ metavolcanics
11	Banspal	Dhanagadi	85.35	21.63	0.7	2.1	12.5	9.1	Quartzites
12	Banspal	Kandhakala	85.31	21.67	0.55	1.5	14	8.5	Volcanics/ metavolcanics
13	Banspal	Nayakot	85.29	21.73	0.6	1.6	12	9.95	Volcanics/ metavolcanics
14	Banspal	Kadakala	85.32	21.76	1.01	1.4	11.5	10.1	Volcanics/ metavolcanics
15	Banspal	Narsingpur	85.28	21.76	0.75	1.2	14	10.6	Volcanics/ metavolcanics

16	Banspal	Sundra	85.35	21.75	0.6	1.3	15	7.95	Metasediments
17	Banspal	Kusumita	85.46	21.71	0.45	1.25	12.5	8.6	Volcanics/ metavolcanics
18	Banspal	Phuljhor	85.43	21.73	0.34	1.5	12.5	4.5	Metasediments
19	Banspal	Duarsuni	85.63	21.49	0.25	1.6	12.5	6.45	Volcanics/ metavolcanics
20	Banspal	Bogamunda	85.62	21.50	0.8	1.4	12	4.8	Volcanics/ metavolcanics
21	Champua	Unchbali	85.77	21.93	0.75	1.6	10.5	8.15	Singhbhum Granite
22	Champua	Kasipal	85.71	21.94	0.35	1	11	8.6	Singhbhum Granite
23	Champua	Tolakananda	85.68	21.99	0.45	1.2	11.5	6.7	Singhbhum Granite
24	Champua	Kanchanpur	85.63	22.01	0.65	1.3	12.5	10.75	Granite gneiss
25	Champua	Kalikaprasad	85.61	21.98	0.35	1.5	12.5	9.75	Granite gneiss
26	Champua	Rimuli	85.60	21.97	1.2	1.4	11	1.3	Singhbhum Granite
27	Champua	Kodagadia	85.56	22.03	0.5	1.5	10.8	6.25	Granite gneiss
28	Champua	Jodipada	85.61	22.05	0.5	1.6	12.5	8.9	Granite gneiss
29	Champua	Rangamatia	85.60	21.93	0.7	2.5	12.5	1.4	Granite gneiss
30	Ghasipura	Ganpur	86.08	21.05	0.4	1.9	14	3.4	Alluvium and Singbhum Granite
31	Ghasipura	Purunabandhagoda	86.06	21.05	0.5	1.45	9.35	2.85	Alluvium and Singbhum Granite
32	Ghasipura	Jarak	86.04	21.08	0.3	1.2	9.8	8.4	Alluvium and Singbhum Granite

33	Ghasipura	Patilo	86.06	21.10	0.3	2.07	10.8	2.8	Alluvium and Singbhum Granite
34	Ghasipura	Kanpur	86.08	21.15	0.5	1.6	10.2	3.6	Alluvium and Singbhum Granite
35	Ghasipura	Hathisila	86.06	21.17	0.45	1.4	10.65	7.4	Alluvium and Singbhum Granite
36	Ghasipura	Rekutia	86.02	21.16	0.6	1.3	12.15	9.7	Alluvium and Singbhum Granite
37	Ghasipura	Balipala	85.99	21.16	0.4	1.1	9.3	4.2	Alluvium and Singbhum Granite
38	Ghasipura	Khalapal	85.97	21.15	0.5	1.2	10.8	7	Alluvium and Singbhum Granite
39	Ghasipura	Radhikadeipur	85.96	21.16	0.4	1.2	6.8	1.4	Alluvium and Singbhum Granite
40	Ghatagaon	Binajhari	85.88	21.39	0.4	1.5	10.4	7.6	Singbhum Granite
41	Ghatagaon	Masinabilla	85.86	21.47	0.65	2.4	6.6	5.65	Singbhum Granite
42	Ghatagaon	Dehuriposhi	85.90	21.45	0.8	1.5	13.85	9.6	Singbhum Granite
43	Ghatagaon	Nalabila	85.91	21.47	GL	4.2	9.4	5.7	Singbhum Granite
44	Ghatagaon	Nuapada	85.90	21.52	0.5	1.9	9.6	6.3	Singbhum Granite
45	Ghatagaon	Bankapatuli	85.74	21.57	GL	3.3	8.4	7.1	Singbhum Granite
46	Ghatagaon	Jharbeda	85.73	21.53	GL	2.7	10.4	4	Singbhum Granite
47	Ghatagaon	Pichora	85.69	21.52	GL	3.5	9.3	7.1	Singbhum Granite
48	Ghatagaon	Pandapada	85.70	21.47	0.3	1.3	9.3	7.1	Singbhum Granite
49	Ghatagaon	Dhangardiha	85.82	21.38	0.2	2.4	10.35	8.2	Singbhum Granite

50	Ghatagaon	Barhatipura	85.81	21.42	0.6	2.2	6.3	2.6	Singbhum Granite
51	Ghatagaon	Nushriposhi	85.81	21.44	0.45	1.3	8.45	1.45	Singbhum Granite
52	Ghatagaon	Santrapur	85.82	21.46	0.4	1.8	9.35	5.7	Singbhum Granite
53	Ghatagaon	Mahulagadia	85.82	21.50	GL	3.6	9.3	4.9	Singbhum Granite
54	Ghatagaon	Gondsila	85.78	21.49	0.6	2.7	11.8	6.9	Singbhum Granite
55	Harichandanpur	Dhangardiha	85.83	21.38	0.5	1.57	9.8	9.8	Singbhum Granite
56	Harichandanpur	Balipokhari	85.81	21.40	0.8	1.6	10.3	5.3	Singbhum Granite
57	Harichandanpur	Kamalangi	85.77	21.28	0.5	2.5	11.4	8.5	Singbhum Granite
58	Harichandanpur	Revana Palaspal	85.77	21.22	0.3	1.6	8.75	6.8	Singbhum Granite
59	Harichandanpur	Bamhanipal	85.92	21.12	0.6	1.6	8.4	2	Singbhum Granite
60	Harichandanpur	Jamjodi	85.73	21.36	0.4	1.4	9.4	5.6	Singbhum Granite
61	Harichandanpur	Manpur	85.71	21.36	GL	4	6.3	3.6	Singbhum Granite
62	Harichandanpur	Panasia	85.67	21.38	0.4	1.2	10.8	9.2	Singbhum Granite
63	Harichandanpur	Burhakhaman	85.64	21.40	GL	3.3	13.4	11.5	Singbhum Granite
64	Harichandanpur	Kalapat	85.67	21.35	0.45	4.6	8.85	6.9	Singbhum Granite
65	Harichandanpur	Pithagola	85.63	21.35	0.7	1.6	8.3	6	Singbhum Granite
66	Harichandanpur	Songiri	85.62	21.38	0.4	2.4	12.3	11.2	Singbhum Granite
67	Hatadihi	Belabahali	86.13	21.16	0.5	1.2	8.3	2.5	Ultramafics metaGabbro and Singbhum Granite
68	Hatadihi	Janghara	86.15	21.24	0.6	1.6	13.8	5.1	Ultramafics metaGabbro and Singbhum Granite

69	Hatadihi	Kathakata	86.22	21.25	0.6	1.9	10.9	1.8	Ultramafics metaGabbro and Singbhum Granite
70	Hatadihi	Saralapasi	86.26	21.21	0.5	2.4	8.5	5.7	Ultramafics metaGabbro and Singbhum Granite
71	Hatadihi	Barigan	86.32	21.21	0.6	1.6	11.5	1.9	Ultramafics metaGabbro and Singbhum Granite
72	Hatadihi	Soso	86.33	21.22	GL	1.5	8.35	3.6	Ultramafics metaGabbro and Singbhum Granite
73	Hatadihi	Dhenka	86.29	21.21	0.7	1.1	13.1	1.95	Ultramafics metaGabbro and Singbhum Granite
74	Hatadihi	Khamarnandi	86.20	21.22	GL	2.2	9.45	4.8	Ultramafics metaGabbro and Singbhum Granite
75	Jhumpura	Badaneuli	85.70	21.78	1.1	2.4	10	4.25	Singhbhum Granite
76	Jhumpura	Baria	85.68	21.85	0.55	2.2	11	1.9	Singhbhum Granite
77	Jhumpura	Manima	85.68	21.92	0.65	2	11.5	9.55	Singhbhum Granite
78	Jhumpura	Nardapur	85.55	22.00	0.75	1.9	12	3.75	Singhbhum Granite
79	Jhumpura	Murusuan	85.59	21.92	0.45	2.3	11.5	5.7	Singhbhum Granite
80	Jhumpura	Balibandha	85.59	21.90	0.4	1.5	10.5	4.1	Singhbhum Granite
81	Jhumpura	Basantpur	85.39	21.81	0.35	1.6	10	7.8	Metasediments
82	Jhumpura	Rugudisahi	85.40	21.81	0.7	1.5	10.5	2.45	Metasediments
83	Jhumpura	Unknown	85.45	21.83	0.85	1.3	11	3.95	Metasediments
84	Jhumpura	Dhatika	85.47	21.83	0.75	2.1	12	7.1	Singhbhum Granite
85	Jhumpura	Chipinda	85.49	21.87	0.65	2.5	12.5	4.8	Metasediments
86	Jhumpura	Nahada	85.53	21.88	0.6	2.5	11	5.7	Singhbhum Granite
87	Joda	Bhadrasahi1	85.38	22.06	0.45	1.6	10.5	7	Iron Ore group of metasediments
88	Joda	Jamkundiya	85.53	22.11	0.35	1.3	11.5	7	Iron Ore group of metasediments

89	Joda	Jagudipur	85.51	22.07	0.7	1.8	12	6.25	Iron Ore group of metasediments
90	Joda	Bileipada	85.48	22.06	0.3	1.7	10.5	6.4	Iron Ore group of metasediments
91	Joda	Basudevpur	85.53	22.02	0.55	1.5	11.5	2	Iron Ore group of metasediments
92	Joda	Banspani	85.42	22.00	0.3	2.2	12.5	5	Iron Ore group of metasediments
93	Joda	Kandra	85.50	22.05	0.45	2.6	12.5	7	Iron Ore group of metasediments
94	Joda	Nalda Barbil	85.39	22.08	0.6	2	12.5	7	Iron Ore group of metasediments
95	Joda	Soyabali	85.41	22.08	0.35	2.8	14.5	13	Iron Ore group of metasediments
96	Joda	Nayagarh	85.44	21.87	0.45	3.5	12.5	4.55	Metasediments
97	Keonjhar	Shankarpur	85.64	21.67	0.6	1.5	11	9.05	Singhbhum Granite
98	Keonjhar	Jharbeda	85.66	21.68	0.5	2.8	10.5	8.05	Singhbhum Granite
99	Keonjhar	Potala	85.65	21.71	0.7	3.5	11.5	7.55	Singhbhum Granite
100	Keonjhar	Barakhanda	85.74	21.65	0.35	4	11	4	Singhbhum Granite
101	Keonjhar	Maidankel	85.72	21.66	0.65	2.5	11.8	6.25	Singhbhum Granite
102	Keonjhar	Chaka	85.66	21.64	0.6	1.6	12	8	Singhbhum Granite
103	Keonjhar	Raikala	85.61	21.82	0.5	1.5	10.5	7.35	Singhbhum Granite
104	Keonjhar	Shendcap	85.61	21.74	0.4	1.7	9.5	6.3	Singhbhum Granite
105	Keonjhar	Sahadapur	85.62	21.72	0.65	2	10.5	9.05	Singhbhum Granite
106	Keonjhar	Harshapur	85.59	21.69	0.5	1.5	11	5.9	Singhbhum Granite
107	Keonjhar	Dhanurjayapur	85.51	21.81	0.25	1.4	10.5	9	Singhbhum Granite
108	Keonjhar	Mahadeipur	85.54	21.69	0.35	1.8	9.8	4.4	Singhbhum Granite
109	Patna	Rudhiapada	85.90	21.57	GL	1.7	9.8	7.7	Singhbhum Granite

110	Patna	Dianali	85.89	21.60	0.5	2.2	9.45	7.2	Singhbhum Granite
111	Patna	Patna	85.89	21.63	0.5	2.5	12.8	9	Singhbhum Granite
112	Patna	Saraskula	85.87	21.59	GL	2.2	9.4	8.5	Singhbhum Granite
113	Patna	Hirapasi	85.68	21.74	0.4	3.5	9.5	2.95	Singhbhum Granite
114	Patna	Childa	85.76	21.76	0.6	1.5	10.5	0.95	Singhbhum Granite
115	Patna	Kantiapada	85.74	21.71	0.35	1.6	10	7.6	Singhbhum Granite
116	Patna	Jodichatar	85.76	21.66	0.5	1.5	10.5	9	Singhbhum Granite
117	Patna	Kendeipasi	85.80	21.68	0.5	1.4	10	7.3	Singhbhum Granite
118	Patna	Baunsuli	85.71	21.74	0.6	1.6	10.5	6.95	Singhbhum Granite
119	Sadar	Barigan	85.82	21.58	0.45	1.3	11	6.9	Singhbhum Granite
120	Saharpada	Balabhadrapur	85.95	21.70	0.35	1.8	11.5	8.35	Singhbhum Granite
121	Saharpada	Digapasi	86.01	21.70	0.65	2.5	12	4.95	Singhbhum Granite
122	Saharpada	Machhagarh	86.06	21.66	0.5	3.1	11.5	3.1	Singhbhum Granite
123	Saharpada	Belasarei	86.04	21.62	0.35	2.5	10.5	6.85	Singhbhum Granite
124	Saharpada	Kendujoda	86.00	21.59	0.3	1.6	9.8	8.5	Singhbhum Granite
125	Saharpada	Kapundi	85.92	21.63	0.4	1.6	11	3.25	Singhbhum Granite
126	Saharpada	Rajnagar	85.83	21.76	0.4	1.9	10.5	6.25	Singhbhum Granite
127	Telkoi	Kadua	85.61	21.27	0.6	2.6	5.4	4.5	Basalt,Quarttzite Alluvium,Lower Bonai Granite
128	Telkoi	Bendih	85.40	21.47	0.4	1.4	9.85	7.6	Basalt,Quarttzite Alluvium,Lower Bonai Granite
129	Telkoi	Binjhabahal	85.28	21.45	0.45	4.4	15.3	7.1	Basalt,Quarttzite Alluvium,Lower Bonai Granite
130	**Telkoi**	**Kantalei**	**85.40**	**21.32**	**0.6**	**1.25**	**14.8**	**11.4**	**Basalt,Quarttzite Alluvium,Lower Bonai Granite**

Annexure 5: Key of well details of post-monsoon season 2018.

Sl. No	BLOCK	VILLAGE	LONGITUDE	LATITUDE	MP(M)	DIA(M)	DEPTH(M)	SWL(mbgl)	GEOLOGY
1	Ghasipura	Ganpur	86.08	21.05	0.4	1.9	9.8	1.8	Alluvium and Singbhum Granite
2	Ghasipura	Purunabandhagoda	86.06	21.05	0.5	1.45	9.35	2.2	Alluvium and Singbhum Granite
3	Anandpur	Kuldiha	86.12	21.42	0.3	2.1	8.8	4.6	Alluvium and Singbhum Granite
4	Anandpur	Janjali	86.11	21.46	GL	5.1	8.3	4.2	Alluvium and Singbhum Granite
5	Anandpur	Baniajodi	86.07	21.44	0.5	2.3	18.15	2	Alluvium and Singbhum Granite
6	Anandpur	Manoharpur	86.07	21.48	0.3	4.2	9.3	3.3	Alluvium and Singbhum Granite
7	Anandpur	Badakushapada	86.06	21.47	GL	3.1	6.4	2.7	Alluvium and Singbhum Granite
8	Anandpur	Sagadapata	85.92	21.25	0.3	3.1	10.3	1.7	Alluvium and Singbhum Granite
9	Banspal	Banspal	85.41	21.61	1.5	2.1	11.5	2.45	Metasediments
10	Banspal	Baraguda	85.34	21.61	0.75	3.2	12	8.5	Metasediments
11	Banspal	Bogamunda	85.62	21.50	0.8	1.4	12	1.4	Volcanics/ metavolcanics
12	Banspal	Dhanagadi	85.35	21.63	0.7	2.1	12.5	6.15	Quartzites
13	Banspal	Duarsuni	85.63	21.49	0.25	1.6	12.5	8.2	Volcanics/ metavolcanics
14	Banspal	Kadakala	85.32	21.76	1.01	1.4	11.5	6.1	Volcanics/ metavolcanics
15	Banspal	Kandhakala	85.31	21.67	0.55	1.5	14	5.25	Volcanics/ metavolcanics
16	Banspal	Khajurimundi	85.44	21.61	0.5	1.5	8	9.1	Volcanics/ metavolcanics
17	Banspal	Kusumita	85.46	21.71	0.45	1.25	12.5	8.4	Volcanics/ metavolcanics
18	Banspal	Mereisahi	85.38	21.62	0.3	1.2	11	7.15	Volcanics/ metavolcanics
19	Banspal	Narsingpur	85.28	21.76	0.75	1.2	14	5	Volcanics/ metavolcanics
20	Banspal	Nayakot	85.29	21.73	0.6	1.6	12	2	Volcanics/ metavolcanics
21	Banspal	Padakasada	85.42	21.59	0.7	1.8	9.5	6.4	Volcanics/ metavolcanics
22	Banspal	Phuljhor	85.43	21.73	0.34	1.5	12.5	4.3	Metasediments
23	Banspal	Sundra	85.35	21.75	0.6	1.3	15	7	Metasediments
24	Banspal	Talakainsari	85.53	21.63	0.35	1.2	10	8.6	Volcanics/ metavolcanics
25	Banspal	Tilaposi	85.34	21.62	0.55	1.8	12.8	7	Metasediments

26	Champua	Baleswar	85.69	21.94	0.7	1.5	10.5	3.55	Metasediments
27	Champua	CS Pur	85.70	21.94	0.5	2	11.5	4.2	Singhbhum Granite
28	Champua	Jodipada	85.61	22.05	0.5	1.6	12.5	3.6	Granite gneiss
29	Champua	Kalikaprasad	85.61	21.98	0.35	1.5	12.5	7.45	Granite gneiss
30	Champua	Kanchanpur	85.63	22.01	0.65	1.3	12.5	5.1	Granite gneiss
31	Champua	Kanjiasula	85.69	21.95	0.5	1.8	11.5	0.4	Singhbhum Granite
32	Champua	Kanjiasula vill	85.69	21.94	0.6	1.5	12	1.1	Singhbhum Granite
33	Champua	Kasipal	85.71	21.94	0.35	1	11	4.15	Singhbhum Granite
34	Champua	Kodagadia	85.56	22.03	0.5	1.5	10.8	1.95	Granite gneiss
35	Champua	Rangamatia	85.60	21.93	0.7	2.5	12.5	3.85	Granite gneiss
36	Champua	Rimuli	85.60	21.97	1.2	1.4	11	1.45	Singhbhum Granite
37	Champua	Silipunji	85.70	21.93	1.35	2.8	12.5	2.8	Singhbhum Granite
38	Champua	Tolakananda	85.68	21.99	0.45	1.2	11.5	6.95	Singhbhum Granite
39	Champua	Unchbali	85.77	21.93	0.75	1.6	10.5	0.85	Singhbhum Granite
40	Ghasipura	Jarak	86.04	21.08	0.3	1.2	9.8	4.8	Alluvium and Singbhum Granite
41	Ghasipura	Patilo	86.06	21.10	0.3	2.07	10.8	3.9	Alluvium and Singbhum Granite
42	Ghasipura	Kanpur	86.08	21.15	0.5	1.6	10.2	3.2	Alluvium and Singbhum Granite
43	Ghasipura	Hathisila	86.06	21.17	0.45	1.4	10.65	7.9	Alluvium and Singbhum Granite
44	Ghasipura	Rekutia	86.02	21.16	0.6	1.3	12.15	6.9	Alluvium and Singbhum Granite
45	Ghasipura	Balipala	85.99	21.16	0.4	1.1	9.3	4.3	Alluvium and Singbhum Granite
46	Ghasipura	Khalapal	85.97	21.15	0.5	1.2	10.8	3.8	Alluvium and Singbhum Granite
47	Ghasipura	Radhikadeipur	85.96	21.16	0.4	1.2	6.8	1.1	Alluvium and Singbhum Granite
48	Ghatagaon	Binajhari	85.88	21.39	0.4	1.5	10.4	5.7	Singbhum Granite
49	Ghatagaon	Masinabilla	85.86	21.47	0.65	2.4	6.6	3.3	Singbhum Granite
50	Ghatagaon	Dehuriposhi	85.90	21.45	0.8	1.5	13.85	9.4	Singbhum Granite
51	Ghatagaon	Nalabila	85.91	21.47	GL	4.2	9.4	2.6	Singbhum Granite
52	Ghatagaon	Nuapada	85.90	21.52	0.5	1.9	9.6	4.3	Singbhum Granite
53	Ghatagaon	Bankapatuli	85.74	21.57	GL	3.3	8.4	3.6	Singbhum Granite

54	Ghatagaon	Jharbeda	85.73	21.53	GL	2.7	10.4	3.7	Singbhum Granite
55	Ghatagaon	Pichora	85.69	21.52	GL	3.5	9.3	Abandoned	Singbhum Granite
56	Ghatagaon	Pandapada	85.70	21.47	0.3	1.3	9.3	6.2	Singbhum Granite
57	Ghatagaon	Dhangardiha	85.82	21.38	0.2	2.4	10.35	4.7	Singbhum Granite
58	Ghatagaon	Barhatipura	85.81	21.42	0.6	2.2	6.3	1.8	Singbhum Granite
59	Ghatagaon	Nushriposhi	85.81	21.44	0.45	1.3	8.45	1.6	Singbhum Granite
60	Ghatagaon	Santrapur	85.82	21.46	0.4	1.8	9.35	4.1	Singbhum Granite
61	Ghatagaon	Mahulagadia	85.82	21.50	GL	3.6	9.3	3.7	Singbhum Granite
62	Ghatagaon	Gondsila	85.78	21.49	0.6	2.7	11.8	4	Singbhum Granite
63	Harichandanpur	Dhangardiha	85.83	21.38	0.5	1.57	9.8	3.7	Singbhum Granite
64	Harichandanpur	Balipokhari	85.81	21.40	0.8	1.6	10.3	3.3	Singbhum Granite
65	Harichandanpur	Kamalangi	85.77	21.28	0.5	2.5	11.4	5.1	Singbhum Granite
66	Harichandanpur	Revana Palaspal	85.77	21.22	0.3	1.6	8.75	3.2	Singbhum Granite
67	Harichandanpur	Bamhanipal	85.92	21.12	0.6	1.6	8.4	2.5	Singbhum Granite
68	Harichandanpur	Jamjodi	85.73	21.36	0.4	1.4	9.4	3.4	Singbhum Granite
69	Harichandanpur	Manpur	85.71	21.36	GL	4	6.3	1.4	Singbhum Granite
70	Harichandanpur	Panasia	85.67	21.38	0.4	1.2	10.8	6.1	Singbhum Granite
71	Harichandanpur	Burhakhaman	85.64	21.40	GL	3.3	13.4	7.5	Singbhum Granite
72	Harichandanpur	Kalapat	85.67	21.35	0.45	4.6	8.85	3	Singbhum Granite
73	Harichandanpur	Pithagola	85.63	21.35	0.7	1.6	8.3	5	Singbhum Granite
74	Harichandanpur	Songiri	85.62	21.38	0.4	2.4	12.3	9.3	Singbhum Granite
75	Hatadihi	Belabahali	86.13	21.16	0.5	1.2	8.3	3.2	Ultramafics metaGabbro and Singbhum Granite
76	Hatadihi	Janghara	86.15	21.24	0.6	1.6	13.8	3.5	Ultramafics metaGabbro and Singbhum Granite
77	Hatadihi	Kathakata	86.22	21.25	0.6	1.9	10.9	2.1	Ultramafics metaGabbro and Singbhum Granite

78	Hatadihi	Saralapasi	86.26	21.21	0.5	2.4	8.5	3.7	Ultramafics metaGabbro and Singbhum Granite
79	Hatadihi	Barigan	86.32	21.21	0.6	1.6	11.5	3	Ultramafics metaGabbro and Singbhum Granite
80	Hatadihi	Soso	86.33	21.22	GL	1.5	8.35	3.2	Ultramafics metaGabbro and Singbhum Granite
81	Hatadihi	Dhenka	86.29	21.21	0.7	1.1	13.1	2.1	Ultramafics metaGabbro and Singbhum Granite
82	Hatadihi	Khamarnandi	86.20	21.22	GL	2.2	9.45	3.7	Ultramafics metaGabbro and Singbhum Granite
83	Jhumpura	Badaneuli	85.70	21.78	1.1	2.4	10	3.6	Singhbhum Granite
84	Jhumpura	Balibandha	85.59	21.90	0.4	1.5	10.5	1.7	Iron Ore group of metasediments
85	Jhumpura	Barakhanda	85.74	21.65	0.35	4	11	6.65	Singhbhum Granite
86	Jhumpura	Baria	85.68	21.85	0.55	2.2	11	1.95	Singhbhum Granite
87	Jhumpura	Basantpur	85.39	21.81	0.35	1.6	10	2.65	Singhbhum Granite
88	Jhumpura	Bhadrasahi1	85.38	22.06	0.45	1.6	10.5	1.7	Singhbhum Granite
89	Jhumpura	Bhalu sahi	85.56	21.84	0.5	2.1	12	3.45	Singhbhum Granite
90	Jhumpura	Bhaluka	85.57	21.83	0.6	1.8	12	7.9	Singhbhum Granite
91	Jhumpura	Bhaluka1	85.57	21.83	0.35	2	11	1.3	Singhbhum Granite
92	Jhumpura	Bishunpur	85.56	21.83	0.5	1.5	11.5	3.4	Singhbhum Granite
93	Jhumpura	Chaka	85.66	21.64	0.6	1.6	12	4.45	Singhbhum Granite
94	Jhumpura	Chipinda	85.49	21.87	0.65	2.5	12.5	3.5	Singhbhum Granite
95	Jhumpura	Dhanurjayapur	85.51	21.81	0.25	1.4	10.5	1.95	Singhbhum Granite
96	Jhumpura	Dhatika	85.47	21.83	0.75	2.1	12	1.45	Singhbhum Granite
97	Jhumpura	Ghutkeswari	85.65	21.60	0.4	2.5	14	6.75	Singhbhum Granite
98	Jhumpura	Goudasahi	85.65	21.61	0.5	2	11.5	3.75	Singhbhum Granite
99	Jhumpura	Haldia Tangiri	85.64	21.62	0.6	3.5	12.5	5.2	Singhbhum Granite
100	Jhumpura	Harshapur	85.59	21.69	0.5	1.5	11	6.15	Singhbhum Granite

101	Joda	Jamunalia	85.66	21.59	0.6	1.6	10.5	4.35	Singhbhum Granite
102	Joda	Jharbeda	85.66	21.68	0.5	2.8	10.5	4.05	Iron Ore group of metasediments
103	Joda	Kandra	85.50	22.05	0.45	2.6	12.5	5.1	Singhbhum Granite
104	Joda	Mahadeipur	85.54	21.69	0.35	1.8	9.8	9.25	Metasediments
105	Keonjhar	Maidankel	85.72	21.66	0.65	2.5	11.8	2.65	Metasediments
106	Keonjhar	Manima	85.68	21.92	0.65	2	11.5	3.65	Singhbhum Granite
107	Keonjhar	Murusuan	85.59	21.92	0.45	2.3	11.5	4.3	Singhbhum Granite
108	Keonjhar	Nahada	85.53	21.88	0.6	2.5	11	2.7	Singhbhum Granite
109	Keonjhar	Nalda Barbil	85.39	22.08	0.6	2	12.5	3.1	Singhbhum Granite
110	Keonjhar	Naranpur1	85.65	21.61	0.7	2.5	12.5	2.8	Singhbhum Granite
111	Keonjhar	Nardapur	85.55	22.00	0.75	1.9	12	3.45	Singhbhum Granite
112	Keonjhar	Old town KJR	85.58	21.62	0.6	1.5	10.5	3.1	Singhbhum Granite
113	Keonjhar	Potala	85.65	21.71	0.7	3.5	11.5	3.8	Singhbhum Granite
114	Keonjhar	Raikala	85.61	21.82	0.5	1.5	10.5	2.3	Singhbhum Granite
115	Keonjhar	Raikala	85.61	21.82	0.5	1.5	10.5	7.55	Iron Ore group of metasediments
116	Keonjhar	Rugudisahi	85.40	21.81	0.7	1.5	10.5	1.25	Singhbhum Granite
117	Keonjhar	Sahadapur	85.62	21.72	0.65	2	10.5	2.65	Singhbhum Granite
118	Keonjhar	Saharposi	85.64	21.60	0.35	1.5	9.5	2.25	Singhbhum Granite
119	Keonjhar	Shankarpur	85.64	21.67	0.6	1.5	11	3.05	Singhbhum Granite
120	Keonjhar	Shendcap	85.61	21.74	0.4	1.7	9.5	1.9	Singhbhum Granite
121	Keonjhar	Soyabali	85.41	22.08	0.35	2.8	14.5	4.75	Iron Ore group of metasediments
122	Keonjhar	Srirampur1	85.58	21.82	0.8	4.5	12.5	10.45	Iron Ore group of metasediments
123	Keonjhar	Tangarapolasa	85.64	21.62	0.5	2	10.5	5.7	Singhbhum Granite
124	Keonjhar	Tulasi choura1	85.64	21.59	0.5	2.1	11.5	2.8	Singhbhum Granite
125	Keonjhar	Tulasi choura2	85.64	21.58	0.3	2.5	10.5	2.65	Singhbhum Granite
126	Keonjhar	Unknown	85.45	21.83	0.85	1.3	11	0.7	Metasediments
127	Patna	Rudhiapada	85.90	21.57	GL	1.7	9.8	4.8	Singbhum Granite
128	Patna	Dianali	85.89	21.60	0.5	2.2	9.45		Singbhum Granite

129	Patna	Patna	85.89	21.63	0.5	2.5	12.8		Singbhum Granite
130	Patna	Saraskula	85.87	21.59	GL	2.2	9.4		Singbhum Granite
131	Patna	Hirapasi	85.68	21.74	0.4	3.5	9.5	0	Singbhum Granite
132	Patna	Childa	85.76	21.76	0.6	1.5	10.5	0.8	Singbhum Granite
133	Patna	Kantiapada	85.74	21.71	0.35	1.6	10	2.45	Singbhum Granite
134	Patna	Jodichatar	85.76	21.66	0.5	1.5	10.5	1.95	Singbhum Granite
135	Patna	Kendeipasi	85.80	21.68	0.4	1.6	11	5	Singbhum Granite
136	Patna	Baunsuli	85.71	21.74	0.6	1.6	10.5	2.7	Singbhum Granite
137	Patna	Dhanurjaypur	85.73	21.74	0.5	1.9	12	1.55	Singbhum Granite
138	Sadar	Barigan	85.82	21.58	0.5	1.3	9.4	3.5	Singbhum Granite
139	Saharpada	Balabhadrapur	85.95	21.70	0.35	1.8	11.5	6.3	Singbhum Granite
140	Saharpada	Digapasi	86.01	21.70	0.65	2.5	12	4.65	Singbhum Granite
141	Saharpada	Machhagarh	86.06	21.66	0.5	3.1	11.5	2.45	Singbhum Granite
142	Saharpada	Belasarei	86.04	21.62	0.35	2.5	10.5	5.35	Singbhum Granite
143	Saharpada	Kendujoda	86.00	21.59	0.5	1.4	10	5.9	Singbhum Granite
144	Saharpada	Kapundi	85.92	21.63	0.3	1.6	9.8	3.3	Singbhum Granite
145	Saharpada	Rajnagar	85.83	21.76	0.4	1.9	10.5	2.35	Singbhum Granite
146	Telkoi	Kadua	85.61	21.27	0.6	2.6	5.4	3.5	Basalt,Quarttzite Alluvium,Lower Bonai Granite
147	Telkoi	Bendih	85.40	21.47	0.4	1.4	9.85	5.6	Basalt,Quarttzite Alluvium,Lower Bonai Granite
148	Telkoi	Binjhabahal	85.28	21.45	0.45	4.4	15.3	door locked	Basalt,Quarttzite Alluvium,Lower Bonai Granite
149	**Telkoi**	**Kantalei**	**85.40**	**21.32**	**0.6**	**1.25**	**14.8**	**door locked**	**Basalt,Quarttzite Alluvium,Lower Bonai Granite**

Annexure 6: Ground water quality in the shallow phreatic aquifer, Keonjhar district, Odisha (Pre-monsoon 2018)

LOCATIONS	pH	EC (μS per cm at 25^{0}C)	Parameters in mg/L											
			TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3=	HCO3-	Cl-	SO4=	F -
Jharbeda	8.2	380	192	133	165	37	10	23.9	0.4	0	197	15	8.99	2.18
Potala	7.9	370	199	133	155	39	9	19.4	4.2	0	185	32	4.30	0.22
Hirapasi	7.5	130	68	36	46	10	2	12.1	0.9	0	49	15	1.00	0.17
Childa	7.11	100	52	26	21	8	1	9.3	1.7	0	25	20	0.00	0.13
Kantiapada	8.3	410	203	143	165	37	12	27.5	0.4	0	180	23	14.50	0.83
Jodichatar	7.5	300	154	97	98	29	6	21.2	2.9	0	107	38	4.10	0.29
Kendeipasi	8.3	350	175	117	149	35	7	25.1	0.3	0	163	28	0.00	1.06
Balabhadrapur	7.9	270	139	102	108	29	7	10.0	8.7	0	118	23	3.80	0.13
Digapasi	7.65	250	120	92	93	20	10	11.7	4.1	0	101	25	0.00	0.09
Machhagarh	8.15	100	53	36	36	10	2	6.8	0.9	0	39	13	1.00	0.08
Belasarei	7.8	250	128	107	93	31	7	7.0	1.9	0	101	13	18.95	0.20
Kendujoda	8.24	640	306	230	242	41	30	37.0	8.1	0	264	60	1.00	0.18
Kapundi	6.9	70	38	20	10	4	2	5.7	0.8	0	11	3	16.80	0.09
Chaka	8.05	480	242	189	144	37	23	18.9	5.5	0	157	58	22.52	0.16
Rajnagar	8.15	820	429	255	294	57	27	54.4	25.9	0	320	105	3.10	0.26
Baunsuli	8.15	230	117	87	88	27	5	9.8	3.7	0	96	23	1.00	0.17
Badaneuli	8	290	157	117	118	43	2	11.1	2.3	0	129	18	17.54	0.29
Baria	7.93	470	241	168	201	49	11	18.8	17.1	0	219	38	0.00	0.14
Manima	8.04	240	124	66	108	27	0	21.8	0.9	0	118	15	1.30	0.36
Unchbali	8.3	990	535	260	319	61	26	81.1	44.3	0	349	148	3.80	0.35
Kasipal	7.8	270	138	77	72	25	4	23.2	1.9	0	79	45	0.00	0.13

Tolakananda	8.24	470	240	194	221	55	13	12.7	12.0	0	242	23	5.48	0.24
Kanchanpur	8.3	750	420	214	252	67	11	56.7	28.0	0	275	113	9.50	0.50
Kalikaprasad	8.24	830	406	260	335	41	38	68.7	3.1	0	365	73	3.10	0.33
Rimuli	7.8	240	127	66	77	20	4	22.9	2.2	0	84	33	4.00	0.12
Nardapur	7.5	120	69	31	36	10	1	12.9	0.3	0	39	8	17.20	0.83
Kandra	8.25	430	215	138	160	39	10	33.4	1.0	0	174	30	16.10	0.28
Kodagadia	8.3	480	254	148	160	37	13	39.0	4.4	0	174	75	0.00	0.15
Jodipada	8	190	92	82	82	18	9	5.6	0.5	0	90	15	0.00	0.09
Murusuan	8.15	250	132	87	88	29	4	14.0	1.2	0	96	18	19.18	0.18
Balibandha	8.3	500	256	153	196	35	16	37.3	11.3	0	214	50	2.10	0.12
Raikala	8	340	170	143	160	45	7	9.8	4.2	0	174	15	4.20	0.23
Shendcap	7.5	240	126	102	88	37	2	4.1	5.1	0	96	28	3.10	0.18
Sahadapur	8	370	217	102	134	27	9	20.8	26.0	0	146	30	32.37	0.22
Harshapur	8.2	840	459	245	247	86	7	60.8	33.0	0	270	131	9.33	0.19
Talakainsari	8	350	191	148	103	51	5	6.2	9.2	0	112	65	0.00	0.17
Padakasada	7.5	120	63	46	52	16	1	3.0	5.1	0	56	10	0.00	0.10
Mereisahi	7.8	190	93	77	93	25	4	4.2	2.6	0	101	8	0.00	0.10
Dhanagadi	7.6	130	64	56	52	20	1	3.1	2.1	0	56	10	0.00	0.13
Kandhakala	7.6	110	55	46	46	16	1	3.6	1.6	0	51	8	0.00	0.09
Nayakot	7.5	170	85	56	41	16	4	9.1	3.5	0	45	30	0.00	0.08
Kadakala	7.8	270	134	112	129	45	0	8.5	3.1	0	141	8	0.00	0.16
Narsingpur	8.1	270	138	122	134	45	2	4.6	2.0	0	146	13	0.00	0.15
Sundra	7.8	90	45	31	41	8	2	5.1	3.2	0	45	5	0.00	0.10
Basantpur	7.4	90	44	36	26	8	4	2.0	1.0	0	28	10	5.30	0.88
Rugudisahi	8.3	240	121	92	88	33	2	12.0	2.3	0	96	25	0.00	0.16
Bamebari	8	280	134	112	129	31	9	10.0	1.8	0	141	13	0.00	0.16
Nayagarh	8.1	470	257	173	237	51	11	25.3	3.5	0	223	20	19.06	0.49
Unknown	8.2	130	64	56	52	14	5	3.1	1.0	0	56	10	3.90	0.16

Dhanurjayapur	7.9	590	269	255	273	39	38	16.9	3.0	0	298	23	2.80	0.51
Mahadeipur	8.1	190	100	82	72	31	1	4.5	1.1	0	79	23	1.00	0.28
Kusumita	8.1	330	161	133	155	37	10	12.0	2.8	0	169	13	3.20	0.45
Phuljhor	8.2	200	101	82	77	29	2	6.0	1.0	0	84	13	9.00	0.20
Dhatika	7.8	520	253	230	221	55	22	11.0	3.4	0	242	43	0.00	0.21
Chipinda	8.2	170	87	61	52	12	7	10.0	1.2	0	56	20	9.30	0.13
Nahada	7.8	500	257	189	216	63	7	23.3	8.3	0	236	40	0.00	0.45
Rangamatia	8.3	110	54	46	36	12	4	3.1	1.0	0	39	15	0.00	0.23
Bhadrasahi1	8.3	230	115	87	82	25	6	8.5	3.5	0	90	28	0.00	0.18
Nalda Barbil	7.5	160	76	71	57	12	10	3.0	1.0	0	62	20	0.00	0.13
Soyabali	7.6	110	66	51	5	8	7	1.0	0.8	0	6	3	43.10	0.18
Duarsuni	8.3	330	165	122	129	29	12	15.0	5.1	0	141	35	0.00	0.22
Bogamunda	6.7	120	82	36	31	14	0	8.1	2.3	0	34	5	22.00	0.16
Ganpur	7.24	220	107	86	64	27	5	9.0	0.8	0	79	26	2.00	0.15
Purunabandhagoda	7.8	1720	833	662	465	39	138	58.0	3.6	0	507	261	55.00	0.52
Jarak	7.79	400	177	158	166	35	18	7.0	0.3	0	202	17	2.00	0.18
Patilo	7.89	1150	607	331	281	77	34	49.0	83.2	0	342	141	55.00	0.31
Kanpur	8.05	1440	744	408	437	60	63	119.0	2.2	0	460	172	67.00	0.72
Belabahali	7.71	1650	882	283	377	35	48	226.0	1.8	0	460	282	64.00	0.89
Kuldiha	7.77	250	115	101	78	27	8	5.0	1.9	0	95	19	7.00	0.20
Janjali	7.67	410	204	163	156	44	13	18.0	1.4	0	191	34	0.00	0.19
Baniajodi	7.77	170	75	62	46	15	6	6.0	1.2	0	56	19	1.00	0.05
Manoharpur	7.59	230	112	86	78	17	11	9.0	5.5	0	95	17	6.00	0.20
Badakushapada	7.61	420	209	130	143	31	13	35.0	0.8	0	174	36	8.00	0.29
Janghara	7.76	800	382	298	262	69	30	36.0	5.7	0	320	62	22.00	0.26
Kathakata	7.78	410	208	144	110	35	14	22.0	5.7	0	135	45	20.00	0.12
Saralapasi	7.63	330	161	144	124	48	6	6.0	2.6	0	152	17	7.00	0.12
Barigan	8.1	1440	822	346	373	69	42	61.0	176.2	0	455	182	69.00	0.41

Soso	7.71	390	193	149	133	35	15	6.0	20.0	0	163	19	18.00	0.19
Dhenka	7.68	260	129	96	78	27	7	13.0	3.1	0	95	26	7.00	0.11
Khamarnandi	7.7	1270	632	298	501	35	51	111.0	63.9	0	612	26	45.00	0.17
Hathisila	7.83	1000	538	202	281	54	16	82.0	59.6	0	342	108	51.00	1.04
Rekutia	7.47	280	139	91	78	29	5	19.0	1.5	0	95	31	7.00	0.25
Balipala	7.62	580	271	158	253	23	25	46.0	0.5	0	309	19	7.00	1.13
Khalapal	7.61	620	295	240	239	33	39	22.0	1.2	0	292	36	21.00	0.25
Radhikadeipur	7.37	480	240	168	147	42	15	25.0	1.2	0	180	50	19.00	0.17
Binajhari	7.29	230	109	91	74	23	8	7.0	1.1	0	90	24	1.00	0.06
Dhangardiha	7.46	300	162	96	78	29	6	23.0	4.5	0	95	50	4.00	0.08
Balipokhari	7.52	620	309	197	221	39	25	39.0	3.3	0	269	50	21.00	0.89
Kamalangi	7.418	480	239	187	97	46	18	20.0	1.7	0	118	67	29.00	0.13
Revana Palaspa	7.28	350	165	130	143	31	13	11.0	4.5	0	174	19	1.00	0.20
Bamhanipal	7.55	550	260	197	207	33	28	24.0	0.9	0	253	45	5.00	0.20
Sagadapata	7.94	180	89	59	51	11	8	10.0	0.9	0	62	18	10.00	0.30
Masinabilla	7.73	270	146	77	35	26	3	21.0	6.8	0	43	59	9.00	0.08
Dehuriposhi	8.13	260	125	91	81	26	7	16.0	1.7	0	99	23	4.00	0.11
Nalabila	7.6	140	70	50	25	9	7	5.0	5.5	0	31	26	2.00	0.09
Nuapada	8.37	650	340	209	167	47	22	37.0	21.9	15	173	100	10.00	0.23
Rudhiapada	8.09	230	121	68	71	18	6	11.0	10.4	0	86	23	10.00	0.13
Dianali	8.14	200	98	59	56	15	6	13.0	3.0	0	68	20	7.00	0.17
Patana	7.81	240	126	68	51	9	11	17.0	1.6	0	62	23	23.00	0.06
Saraskula	8.36	760	442	195	131	67	7	45.0	52.9	12	136	123	68.00	0.36
Barigan	8.33	520	278	159	111	46	11	32.0	17.2	0	136	77	27.00	0.11
Bankapatuli	8.48	430	227	127	141	40	7	31.0	6.9	6	160	33	25.00	0.80
Jharbeda	7.94	230	115	59	35	15	6	20.0	1.5	0	43	38	14.00	0.19
Pichora	8.24	290	156	100	76	29	7	9.0	11.3	0	92	23	32.00	0.31
Pandapada	8.5	1110	625	245	242	73	15	116.0	30.2	12	271	197	47.00	0.15
Jamjodi	8.55	600	322	186	202	60	9	48.0	1.8	12	222	33	49.00	0.48

Manpur	8.72	800	365	336	323	46	54	12.0	0.8	3	388	20	33.00	0.25
Panasia	8.35	510	259	164	146	26	24	15.0	20.9	6	130	46	38.00	0.16
Burhakhaman	7.87	120	67	36	25	7	4	7.0	4.5	0	31	10	18.00	0.15
Kalapat	8.38	480	258	155	106	33	18	17.0	20.9	3	123	61	44.00	0.28
Pithagola	8.42	700	381	141	141	24	20	46.0	57.2	0	173	128	19.00	0.26
Songiri	8.1	250	123	59	56	16	4	18.0	7.9	0	68	31	12.00	0.11
Kadua	8.34	280	138	105	96	20	13	9.0	1.2	3	93	20	15.00	0.11
Bendih	8.32	400	205	155	96	42	12	12.0	4.0	6	105	61	15.00	0.13
Binjhabahal	8.21	980	502	350	146	36	63	50.0	5.7	0	179	214	40.00	0.16
Kantalei	7.95	120	55	41	35	11	3	2.0	2.6	0	43	5	10.00	0.18
Dhangardiha	7.89	320	173	100	51	27	8	20.0	6.2	0	62	51	30.00	0.06
Barhatipura	8.41	370	183	100	126	16	14	27.0	7.9	9	136	28	12.00	0.22
Nushriposhi	8.4	430	223	159	136	38	15	18.0	1.4	6	154	23	44.00	0.32
Santrapur	8.09	300	164	100	61	31	6	13.0	13.7	0	74	36	28.00	0.14
Mahulagadia	8.4	460	247	150	106	46	9	22.0	11.2	6	117	56	39.00	0.33
Gondsila	8.36	480	252	173	126	44	15	18.0	7.9	18	117	51	39.00	0.31
Akul	7.72	195	117	85	59	20	9	7.5	4.0	0	72	38	2.20	0.21
Anandapur	7.67	950	510	390	181	120	22	48.8	1.6	0	221	158	48.90	0.13
Badaposhi	7.82	420	228	150	123	48	7	25.0	7.0	0	149	55	11.20	0.23
Balarampur	7.74	835	441	235	157	46	29	57.1	34.4	0	191	148	31.20	0.36
Barpada	7.48	320	163	135	64	26	17	13.2	1.3	0	78	60	6.20	0.10
Baxibarigaon	8.12	160	98	50	64	16	2	17.8	0.7	0	78	22	0.10	1.05
Bhadrasahi	8.1	215	129	115	93	30	10	5.1	1.8	0	114	24	1.30	0.21
Bhagamunda	7.83	715	351	285	152	52	38	23.3	1.5	0	185	110	33.40	0.45
Bimala	7.97	410	209	170	113	44	15	5.4	10.1	0	137	55	11.30	0.23
Birgovindpur	7.93	470	260	190	201	44	19	32.0	2.2	0	245	36	3.90	0.44
Burikhapuri	8.16	235	124	100	83	24	10	8.7	0.7	0	102	29	0.20	0.30
Dhangardiha	7.83	175	111	60	54	14	6	16.8	3.4	0	66	34	3.30	0.11
Champua	7.82	505	283	185	191	52	13	34.9	2.0	0	233	43	22.00	0.26

Deogaon1	8.27	620	348	260	216	60	27	27.1	16.4	0	263	62	24.50	0.14
Gadadharpur	7.46	140	80	55	34	14	5	8.9	1.8	0	42	29	0.30	0.09
Gajitangri	7.31	200	93	60	44	16	5	9.5	5.4	0	54	29	0.60	0.19
Ghasipura	8.1	570	312	225	206	46	27	34.6	3.5	0	251	55	20.40	0.34
Ghatgaon	7.9	715	382	255	167	70	19	46.2	6.2	0	203	105	34.60	0.17
Gopalpur-2	7.89	350	204	145	127	48	6	14.3	8.3	0	155	34	16.10	0.42
Guali	7.95	180	116	90	74	26	6	8.5	3.1	0	90	24	3.20	0.26
Harichandanpur	8.15	725	377	285	167	46	41	31.4	18.0	0	203	103	36.40	0.19
Haridagot	7.79	360	183	90	54	26	6	26.5	9.3	0	66	60	22.50	0.16
Jagmohanpur	7.94	650	329	260	132	62	26	31.7	1.5	0	161	120	6.90	0.34
Jhumpura	7.94	260	156	75	59	26	2	29.1	1.2	0	72	60	1.30	0.22
Joda	7.88	265	147	125	64	24	16	5.4	3.0	0	78	29	31.00	0.21
Kaliahata	7.51	100	67	35	25	10	2	9.3	3.9	0	30	26	0.70	0.15
Katalaposi	7.96	305	176	140	113	42	9	9.8	3.6	0	137	38	4.60	0.29
Kendeiposi	8.24	360	205	150	118	34	16	25.0	0.5	0	143	50	7.80	0.86
Keonjhargarh	7.64	1070	555	350	176	72	41	75.2	13.6	0	215	191	54.90	0.22
Kesurdapal	7.53	310	174	150	108	38	13	10.8	2.3	0	132	34	9.80	0.17
Khireitangri	7.97	785	410	330	196	76	34	22.0	15.3	0	239	110	32.70	0.55
Khuntapada	7.55	80	53	30	25	10	1	8.1	0.7	0	30	17	1.00	0.18
Kothagarh	8.07	655	350	215	142	50	22	21.9	41.2	0	173	98	30.10	0.15
Malliposi	7.61	225	136	65	54	16	6	21.0	9.0	0	66	43	8.40	0.12
Melana	7.73	355	205	110	74	22	13	27.8	15.4	0	90	67	15.00	0.12
Naranpur	7.96	1085	560	325	225	78	32	75.8	9.1	0	275	182	46.00	0.35
Nuagaon	7.68	230	143	100	59	22	11	10.1	8.2	0	72	34	21.60	0.40
Nuasahi	7.78	510	270	195	167	52	16	32.4	1.1	0	203	48	19.20	0.23
Padampur2	8.07	555	271	230	127	72	12	12.8	0.7	0	155	81	14.80	0.23
Padang	7.6	155	93	50	34	14	4	13.9	3.7	0	42	36	0.60	0.15
Parsora	8.1	400	227	140	152	46	6	28.3	3.8	0	185	50	0.50	0.26
Patilo	8.08	650	356	215	181	40	28	35.7	25.3	0	221	98	18.20	0.21

Rugudi	7.92	360	200	165	127	40	16	3.8	9.8	0	155	41	12.20	0.27
Suakati	7.5	55	36	20	25	8	0	5.1	1.3	0	30	7	0.00	0.15
Swampatna	7.66	445	250	155	123	40	13	17.0	31.3	0	149	55	19.00	0.14
Tangarpada	7.3	175	109	50	39	10	6	21.6	0.9	0	48	43	3.70	0.81
Telkoi	8.16	565	282	195	127	52	16	35.5	1.2	0	155	81	19.30	0.23
Turumunga	7.84	245	137	70	59	24	2	23.7	2.5	0	72	48	1.20	0.28
Udaipur	7.72	155	97	55	49	14	5	16.2	0.7	0	60	26	5.20	0.12

Annexure 7: Ground water quality in the fracture aquifers obtained from CGWB exploratory wells, Keonjhar district, Odisha.

LOCATION	***pH***	***E.C (μS per cm at 25^{0}C)***	***Parameters in mg/L***											
			TDS	**CO_3**	**HCO_3**	**Cl**	**SO_4**	**NO_3**	**F**	**TH**	**Ca**	**Mg**	**Na**	**K**
Alati	7.83	620	360	0	399	26	0.9		0.82	217	28	35	71	3
Balabhadrapur	7.41	310	156	0	153	18	5.0		0.3	120	30	11	17	0.5
Balabhadrapur	7.55	350	177	0	171	25	4.0		0.2	140	32	15	17	0.5
Balijodi	7.82	520	225	0	250	32	6.0		0.49	152	16	27	47	1
Banspal	6.77	160	104	0	74	7.1	2.3	14	0.08	65	20	3.6	2.3	2.1
Barhatpura	7.74	539	350	0	293	25	0.9	0	1.3	190	52	43	1.4	15
Barigaon	7.07	380	190	0	201	18	2.0		0.3	155	36	16	17	2.5
Baripal	7.39	1000	388	0	391	31	7.0		0.54	263	39	43	46	3
Bashdevpur	8.25	288	187	0	159	11	3.0	0.58	0.3	110	26	21	0.6	11
Baxibargaon	7.94	730	475	0	402	18	0.9	0.7	0.26	335	10	12	4.3	75
Belbahali	8	618	402	0	268	50	22.0	0.2	0.47	105	35	83	3	15
Bhagamunda	7.21	660	331	0	268	74	5.0		0.5	240	46	30	40	4.7
Bhalukuma	8.11	581	378	0	305	3.5	2.0	0.4	0.31	205	34	29	38	5.4
Champila	8.24	372	242	0	183	25	8.2	21	4.7	150	34	16	19	0.5

Champua	8.12	384	250	0	195	25	8.5	0.09	0.46	155	34	17	19	0.8
Deogaon	8.25	595	387	0	226	74	13.0	0.3	0.51	105	26	94	2.1	9.7
Dhenkikot O/W	8.17	426	277	0	226	12	4.3	0.9	1.07	145	48	6.1	27	1.2
Gelhamunda	7.33	280	139	0	116	28	0.0		0.4	100	28	7	14	5.5
Ghatgaon	7.28	510	332	0	268	28	6.8	1	0.49	215	60	16	23	2.1
Godipatna	7.51	550	269	0	264	15	24.4		0.64	164	26	24	49	1
Jamunga	8.1	108	70	0	49	7.1	0.1	5.7	0.47	15	4	1.2	17	0.8
Janghira	8.13	346	225	0	153	14	0.9	4.4	2.1	125	33	23	1.2	10
Jhantelda	8.19	144	94	0	79	5.3	0.1	1	0.67	55	18	2.4	8.1	0.2
Jhumpura	8.14	221	144	0	92	23	5.3	0.2	0.46	75	24	3.6	16	0.6
Joda	8.22	165	107	0	85	5.3	1.4	1.4	0.23	70	24	2.4	5.3	0.6
Jyotipur	8.27	417	271	0	220	21	0.1	1	0.46	145	50	4.9	26	14
Kainipura	8.02	520	224	0	213	28	2.0		0.34	174	30	26	16	1
Kalikaprasad	6.86	248	161	0	128	7.1	2.5	2.6	0.56	90	28	4.9	12	1
Kanjipani	6.67	46	30	0	24	3.5	0.0	2.4	0	20	5	1.8	0.9	0.2
Kanto	8.05	530	345	0	275	18	14.0	0.3	0.4	205	62	21	2.3	1.2
Karanja	7.26	491	319	0	220	28	13.0	1.6	0.39	165	24	26	30	1.6
Kenjiipur	8.02	263	171	0	79	27	2.0	15	0.67	95	24	8.5	19	0.6
Keonjhar	8.12	283	184	0	140	11	2.5	7	0.72	175	52	11	32	1.2
Khadibahal	7.21	650	306	0	348	25	3.0		0.7	245	32	40	33	2.8
Khadibahal	7.21	650	306	0	348	25	3.0		0.7	245	32	40	33	2.8
Kodapada	8.28	330	183	0	244	7	0.0		0.36	167	30	22	26	3
Maliposi E/W	7.28	319	207	0	207	3.5	0.9	0.2	0.48	130	34	11	17	1.2
Marshapal	7.66	640	314	0	346	25	2.2		0.72	184	38	22	57	1
Naduan	7.73	470	239	0	272	15	3.0		0.51	162	26	23	37	1
Nalda	8.17	168	109	0	67	11	3.7	12	0.21	70	16	7.3	7.6	0.2
Padanpur	7.7	1300	499	0	135	208	29.3		0.51	393	84	45	65	0
Pandpada	7.2	352	229	0	201	7.1	0.9	0.04	2.4	113	27	29	1.2	11
Raghunathpur	8.43	1260	662	21	278	243	6.0		0.29	215	22	39	181	14

Raishuan	8.03	648	421	0	134	103	19.0	15	0.73	210	54	47	1.2	1.2
Saharpada	7.54	157	102	0	61	14	1.0	5.9	0.26	50	14	10	1.5	3.6
Sailong O/W	8.24	520	338	0	238	50	4.5	2	0.51	185	20	33	43	2
Samukanandi	7.76	220	117	0	105	12	2.5		0.19	79.6	26	4	19	0
Sanikul	8.1	432	281	0	256	14	0.7	0.1	0.4	110	32	29	1.8	22
Sivampatna	8.24	483	314	0	256	7.1	3.6	3	0.65	175	52	11	32	1.2
Suakati O/W	7.14	369	240	0	226	7.1	1.0	0.8	0.36	155	36	16	17	1
Taneipal	7.21	420	206	0	209	20	6.9		0.57	122	36	8	39	1
Tarmakant	7.7	397	258	0	177	7.1	4.0	0.5	0.14	135	34	12	15	1.2
Udaipur	7.56	348	226	0	177	21	2.8	0.4	0.85	135	38	21	2.3	1.7
Ukunda-1	8.12	401	261	0	122	43	33.0	15	4.7	130	40	73	29	0.8

Annexure 8: Exploratory and Observation wells drilled in by CGWB in Keonjhar district, Odisha.

Location	Long	lat	Drilled Depth (m)	Casing Depth (m)	Formation/	Fracture depth,mbgl	Disch. in lps (cum.)	Water Level,mbgl	T (m2/day)	Drawdown (m)	Sorativity
Alati	86.0744	21.0733	153	14	Fractured Singhbhum granite with dykes	100,110	2.93	_0.28 (auto-flow)	18.55	28.32	**0.00053**
Anandpur	86.1487	21.1867	200.00	21.00	Fractured Singhbhum granite with dykes	23.30, 110.20	8.6	5.000	66.71	0.99	
Badajamposi	85.9081	21.4550	190.5	32.2		102.3	1.5	7.2			
Badamasinabila	85.8661	21.4856	190.5	13		102.1	1.8	8.6			
Badapichula	85.6178	21.4917			Fractured Singhbhum granite		8.5	11.9	55	8.85	
Badapurunapani	86.1361	21.4222	196.5	19.6	Fractured Singhbhum granite with dykes		negligible				
Balabhadrapur	85.6811	21.5008	150	23		36.90,45.10,60.30	4	7.05			
Baladuan OW	86.1870	21.2465	162.1	18.2	Fractured Singhbhum granite, minor alluvium top	18-21					
Baladuan	86.1861	21.2461	196.5	18.2	Fractured Singhbhum granite, minor alluvium top	21-23	11	4.7	116.07	3..34	**0.00026**
Balijodi	85.9403	21.3775	199.5	6.5	Fractured Singhbhum granite	151	0.442	1.4	0.18	30	

Banspal	85.4167	21.6167	154.4	17.6	Proterozoic volcanics	17.2-18.2	0.5	3.15	1.82 (slug test)	
Baratipura	85.8224	21.4241	145	19.1	Fractured Singhbhum granite	46.7-47.7,141.2-143.0	1.25	10.15	7.91	13.3
Barbil	85.9625	21.6775	150.3	22.7		76.6	2	9.95		
Barigaon	85.9350	21.1811	178	17	Fractured Singhbhum granite	70, 120 , 150 , 178	1.5	3.5		
Baripal OW	85.9790	21.1920	200.5	20	Fractured Singhbhum granite	20	2.97	1.72		
Baripal	85.9786	21.1889	92.8	13.6	Fractured Singhbhum granite	89-92.6	8.06	4.64	20.9	4.42
Barpada	86.1044	21.1228	166	30.5	Fractured Singhbhum granite	64	2	2.38	2.77	30.7
Bartonia	85.9321	21.6529	147.9	43.4		53.30,82.70	10	8.3		
Basudevpur	85.4779	22.0284	200.00	26.50	Granite & Dolerite	58.9, 106.7, 140.3	2.4	7.090	4.04	27.18
Bata Harichandanpur	85.8733	21.4353	62.4	6.5		10.5	1.5	9.5		
Belbahali	86.1221	21.1471	143.20	24.25	Fractured Singhbhum granite	40.6, 76.00, 59, 80, 104	4.3	4.76	2.73	18.64
Bhagamunda	85.8733	21.2681	201	26	Fractured Singhbhum granite	77-78	2	18.7		
Bhagamunda	85.8769	21.2664	190	10.1	Fractured Singhbhum granite	80.6	2.5			
Bhalughara	85.9078	21.5894	80.6	10		15				

Bhalukuma	86.0832	21.2805	111.80	27.25	Fractured Singhbhum granite with dykes	27, 48.3	9	10.680	15.37	12.14	**0.000539**
Buxibarigaon	85.6754	21.4840	200.20	13.60	Fractured Singhbhum granite with dykes	132.10	0.12				
Champua	85.6411	22.0638	108.30	21.00	Fractured OMG tonalite gneiss	28.40, 37.50, 100.60, 103.60	12.3	3.850	84.36	7.17	
Champua OW	85.6411	22.0638	87.50	21.00	Fractured OMG tonalite gneiss		13	3.800	38.21	9.93	
Chilikidhara	85.8322	21.2500	202.1	24.8	Fractured Singhbhum granite	83, 87.5	0				
Dehuriposi	85.8950	21.4467	196.6	21.3		176.2	1	9.65			
Deobandh	85.7319	21.4647									
Deogaon	86.0608	21.1813	137.20	17.30	Fractured Singhbhum granite	126, 132.1	3.9	6.155	3.31	23.99	
Deogaon OW	86.0610	21.1818	131.3	16	Fractured Singhbhum granite	101, 124, 126	4	6.22	1.71	21.82	
Deojharan	86.1389	21.4019	196.5	13	Fractured Singhbhum granite	75	2.88	5.85			
Dhenkikote	85.8236	21.4798	143.50	8.00	Granite, Dolerite Dyke	113, 115	4.5	6.540	9	17.29	**0.000024**
Dhenkikote OW	85.8236	21.4798	117.00	8.00	Granite, Dolerite Dyke		4.5	7.050			
Gelhamunda	85.8603	21.2419	202.6	10.4	Granite	18	2				
Ghasipura	86.1102	21.1775	200.00	31.50	Fractured Singhbhum granite with dykes	54, 55, 117.56	4.5	14.860	6.94	11.61	

Ghatgaon	85.8862	21.3768	138.00	22.00	Fractured Singhbhum granite	137	4.5	3.570	59.28	16.25
Godipatana	86.0889	21.1486	200	47	Fractured Singhbhum granite	45-49	2.9	6.95	17	12.5
Harichandanpur	85.7867	21.3287	200.00	11.50	Fractured Singhbhum granite	82	1.83	2.160	2.7	21.93
Haridagotha	85.6897	21.5403								
Janghira	85.6243	21.4258	202.4	13.5	Fractured Singhbhum granite		NIL			
Janghira OW	85.6250	21.4171	154.50	24.20	Fractured Singhbhum granite	93.5	2.2	3.000	31.62	9.65
Jarada	86.1120	21.0585	202.6	38.5	Fractured Singhbhum granite with dykes	46	negligible			
Jharbeda	85.7314	21.5394	111.2	21.6	Fractured Singhbhum granite	26.4	4	4		
Jharbelda	85.6619	21.6462	200.00	60.00	Basalt & Quartz Vein	93.50, 96.50	2.8	5.110	1.85	26.18
Jhumpura	85.5789	21.8013	200.00	25.00	Granite	31.60, 41.60	3.4	3.380	59.28	16.25
Joda	85.3808	22.0414	57.00	51.00	BHQ	35, 55, 57	3.4	10.490	11.76	12.48
Jyotipur	85.7563	21.9345	191.70	23.10	Dolerite & Granite	33.15, 47.8, 148, 149	1.35	5.790	1.69	26.29
Kainipura	86.0997	21.1961	196.5	30.5	Fractured Singhbhum granite		2.9	2	1.35	35
Kalikaprasad	85.5515	21.9774	111.80	22.50	Fractured OMG tonalite gneiss	22.3, 40.60, 73.1, 100.60	2.13	13.675	56.12	16.65

Kalikaprasad OW	85.5520	21.9778	200	25.31	Fractured OMG tonalite gneiss	63.2, 114.0	1	14.12	3.69 (slug test)		
Kalikaprasad OW	85.5525	21.9780	27	27	Weathered OMG tonalite gneiss	63.2, 114.0		13.89			
Kanjhari Dam	85.5989	21.5853	56.1	12.7		55.1	6	4.3			
Kanjipani	85.4698	21.4687	87.70	48.25	Shale, SST & Dolerite Dyke	4.1, 73.74, 87.70	20.2	13.785	80.66	6.51	**0.00271**
Kanto	86.0534	21.3174	175.0 0	27.15	Fractured Singhbhum granite with dykes	37.00	1.6	10.210	361.49	12.31	
Karanjia	85.6540	21.9536	200.0 0	4.90	Dolerite & Granite	15.80, 69.20, 82.50	1	4.840	1.11 (slug test)		
Kathakata	86.2250	21.2531	202.6	15	Fractured Singhbhum granite	No fracture	NIL				
Kendua	85.9369	21.1703	123.3	18	Fractured Singhbhum granite	118-118.5	12	8.94	26.13	13.14	**0.000372**
Keonjhar	85.6122	21.6022	200.0 0	46.40	Fractured Singhbhum granite	28.40, 198.00	5.4	3.590	21.46	14.82	
Khadibahal	85.9356	21.2478	157.8	28.7	Fractured Singhbhum granite with dykes	156.0-157.8	6.2	9.9	51.68	7.82	
Khaliamenta	86.0530	21.2134	196.5	15	Fractured Singhbhum granite	16	1				
Kodapada	86.0967	21.2803	202.6	31.5	Fractured Singhbhum granite with dykes	82.3	0.77	7.74	0.27	27	
Langalkanti	86.3339	21.4811									

Marshapal OW	86.0690	21.2896	123.3	27.5	Fractured Singhbhum granite	30-33	10.12	4.6	66	12.84	**0.00038**
Marshapal	86.0683	21.2894	153.8	26.8	Fractured Singhbhum granite	129.4-135.5	8	4.69			
Molliposi	85.8914	21.5695	114.00	31.35	Fractured OMG tonalite gneiss	79.2, 94.5, 112.6, 114	10.77	5.829	89.6	7.28	
Molliposi OW	85.8920	21.5696	110.7	30.35	Fractured OMG tonalite gneiss		7.8	5.76	89	10.35	
Nadabara	86.0498	21.0362	130	31.7	Fractured Singhbhum granite with dykes	35.5	2.5				
Naduan	86.0836	21.1831	202.5	12.5	Fractured Singhbhum granite	76-78	1.22	1.75	1.28	25	
Nalda	85.4015	22.1437	50.80	39.00	Porous Mangani ferrous shale	26.4, 31.4, 40.6, 44.7	1.8	9.760	3.86	13.13	**0.036**
Padanpur	86.0317	21.2042	172.1	20.7	Fractured Singhbhum granite	162-168	2.9	6.07	4.1	18.5	
Panasagadia OW	86.0820	21.4590	196.5	21.5	Granite and Gabbro	21-23	2.5				
Panasagadia	86.0812	21.4585	98.9	19	Granite and Gabbro	21-23, 28-31	14				
Pandapada	85.7170	21.4836	160.10	19.20	Fractured Singhbhum granite	20.30, 102.60	4.8	13.240	168.64	2.26	
Pandua	86.1530	21.1356	200	38.5	Fractured Singhbhum granite overlain by alluvium up to ~35m		11.16	8.38	18	22.62	

Pandua OW	86.1528	21.1356	86	36.3	Fractured Singhbhum granite overlain by alluvium up to ~35m	45-48, 51-54	9.2	6.9	18.67	12.5
Pipila OW	85.7466	21.5324	62.4	7.5		9	0.5	12.4		
Pipilia	85.7717	21.5628	180.00	6.00	Fractured Singhbhum granite	11.1, 14.10	0.1	5.590	1.26 (slug test)	
Pitapiti	85.7461	21.3761	180	25.7	Fractured Singhbhum granite	117-120, 126-129, 174-177	2			
Pithagola	85.6311	21.3144	184.3	20.55	Fractured Singhbhum granite		3.76	5.13	14.17	16.07
Poipani	85.7828	21.6153	172.2	6.7		22.8,53.2,61.5	1.7	7.2		
Potilo	85.5044	21.3786								
Putajhari	86.103376	21.43392	184.3	13.3		35	3.3	9.22		
Raghunathpur	85.7940	21.3490	120	25.8	Fractured Singhbhum granite	117-120	2.5	7.62	5.67	17.43
Raghunathpur OW	85.7933	21.3483	80.6	30.7	Fractured Singhbhum granite	75.5	4.48	7.72	6.17	25.49
Raisuan	85.5936	21.6498	200.00	36.05	Fractured Singhbhum granite	42.6, 46.70, 61.90, 169.70	1	7.625	0.77	38.67
Ramachandrapur	85.6550	21.5759	202	13.4	Fractured Singhbhum granite		NIL			
Remuli	85.5938	22.0015	200.00	15.00	OMG Tonalite	27.4, 57.9, 60.9, 61.9, 9, 77.2	0.8	4.360	2.5	17.58

Saharpada I	85.9620	21.7096	198.90	34.00	Weathered and fractured Singhbhum granite	46.7, 77, 119	2.2	5.345	5.93	26.4	
Sailong OW	86.0992	21.2161	108.20	25.25	Amph Pegmatite	26.40, 82, 87	14	4.611	33.03	7.35	
Sailong	86.0995	21.2170	143.2	24.25	Singhbhum granite with fractured OMG amphibolites	38, 46, 65	2.7	5.91	3.09	15.07	
Sainkul OW	86.1280	21.0100	136.2	56.38	Fractured iron ore group metasedimentaries with dykes	59.9, 77.2, 110.9	5.5	5.99	20.22	10.86	
Sainkul	86.1274	21.0997	136.20	50.70	Meta Sediments	57.9, 68.1	7	4.970	12.72	20.63	
Samukanandi	86.0170	21.2290	197	17.8	Fractured Singhbhum granite	21-24	3.35	2.96			
Samukanandi OW	86.0167	21.2289	153.8	19.8	Fractured Singhbhum granite	21-24, 96-97	10	2.5	81.57	2.02	**0.00046**
Sarupat	85.7186	21.5206	121.3	18.5		116.2,118.3,120.3	8	8.45			
Shuadhala	85.8344	21.2817	202.6	8.5	Fractured Singhbhum granite	No fracture	0				
Swampatna	85.9078	21.6152	200.00	20.30	Fractured Singhbhum granite	200.00	0.6	4.020	0.56	18.38	
Suakati	85.5287	21.5723	130.1		Kolhan shale sandstone with dolerite dykes	48.7, 117.9	0.5	2.070	9.24	17.35	

Suanlo	86.0694	21.0953	190.4	40.5	Fractured Singhbhum granite with dykes	90.8	2.1	15.22	3.75	9.84
Taldi	85.8247	21.3142	100.5	24	Fractured Singhbhum granite	99-100.5	7.75			
Taneipal	86.0806	21.3306	202.2	25.8	Fractured Singhbhum granite with dykes	27	8.4	1.78	39	14.01
Tarmakant	85.2903	21.6230	177.80	40.00	Proterozoic volcanics	72, 95	0.24	2.890	0.45 (slug test)	
Telkoi-I	85.3937	21.3393			River borne boulders and weathered migmatite gneiss	Well abaondoned				
Tikira	85.9081	21.4550	105.1	10.2	Fractured Singhbhum granite	89.8	4.5	8.6		
Turmunga	85.8051	21.7613	172.80	58.00	Fractured Singhbhum granite	28.4, 39.6, 56, 96, 104, 148.0	0.8	4.240	0.32	37.16
Udaipur	85.8829	21.6919	200.20	24.00	Fractured Singhbhum granite	36.5, 39.6	0.3	4.500	0.54	
Ukhunda	85.6840	21.8326	173.80	28.20	Fractured Singhbhum granite	165.7, 22.8, 100.6, 132.1, 148.4	2.8	4.760	1.86	30.78
Ulibasa	86.1276	21.4457	196	19	Fractured Singhbhum granite with dykes	31-34	4			
Tutijhari	86.102	21.4356	184	13.3	Fractured Singhbhum granite with dykes	30.0, 162.0	2.5	8.02	28.12	10

Manoharpur	**86.0544**	**21.5053**	**184**	**15.5**	**Fractured Singhbhum granite with dykes**	**24**	**4.36**	**0.62**	**43**	**2.5**

15.0 FIELD PHOTOGRAPHS

Photo 1: Banded Haematite Jasper (BHJ) near Khandadhar in Keonjhar district

Photo 2: The unique exfoliation kind of weathering in Singhbhum Granite in Keonjhar Sadar

Photo 3: The basic intrusion (dyke) observed at Baradangua village in Patna block

Photo 4: Deep weathering in Singhbhum Granite, observed from road cut. Its more clayey in nature

Photo 5: The sandstone at Gonasika, Keonjhar presereves the beddings/cross-beddings

Photo 6: The sandstone at Gonasika, Keonjhar presereves the beddings/cross-beddings

Photo 7: Highly fractured/jointed quartzite at Gonasika, Keonjhar

Photo 8: A trench through weathered metasediment exposes the water table near Gonasika. Capillary rise of water in the vadise

zone is visible

Photo 9: The unique kind of sanitaru dug wells in Banspal block, fillted with hand pump. Ground water sampling going on

Photo 10: The unique kind of stone lined dug well found in Jhumpura and other parts of Keonjhar district.

Photo 11: A small stream in Patna block showing the nature of weathering in the granitic rock

Photo 12: The check dam constructed over the Naki nala in Patna block, Keonjhar district.

Photo 13: A stone walled dug well near Childa, Patna block never dries in a year.

Photo 14: The Baitarani River near Banspal after its emmergence near Gonasika

Photo 15: The gabbion structure for water conservatiuon over Naki nala in Patna block

Photo 16: Typical dug-cum-bore wells found in Jhumpura block, Keonjhar district

Photo 17: A photo showing the winter harvesting paddy in Keonjhar district.

Photo 18: A man with bending of spine in the Ghutkeswari village in Naranpur GP, Keonjhar block. Slightly higher (>1.0 mg/L) fluoride levels are found in groundwater.

Photo 19: An abnormal child with physical deformity in the Ghutkeswari village, Naranpur GP, Keonjhar block. Slightly higher (>1.0 mg/L) fluoride levels are found in groundwater.

Photo 20: A man with bending of spine in the Ghutkeswari village in Naranpur GP, Keonjhar block. Slightly higher (>1.0 mg/L) fluoride levels are found in groundwater.

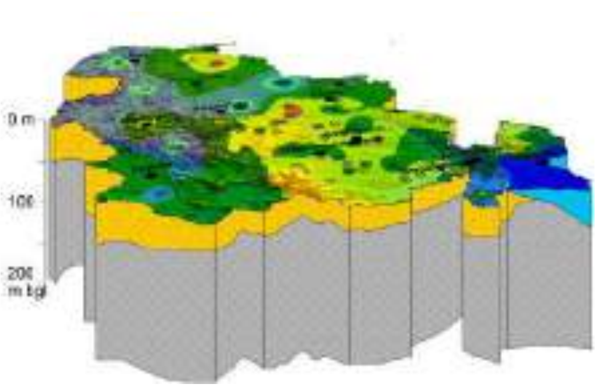
Photo 21: An abnormal child with physical deformity in the Ghutkeswari village, Naranpur GP, Keonjhar block. Slightly higher (>1.0 mg/L) fluoride levels are found in groundwater.

Thoto 22: Typical porphyritic granite in Ghutkeswari village in Naranpur GP

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

BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

HYDROGEOLOGICAL FRAMEWORK, GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN



CENTRAL GROUND WATER BOARD
SOUTH EASTERN REGION
BHUJAL BHAWAN
KHANDAGIRI SQUARE
BHUBANESWAR-751030

MAY 2020

PART II BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

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PART II BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

Author's View

The contour maps prepared in this report, taking the limited available number of aquifer parameters may vary from the real scenario in the field. Specifically, such maps for the fracture aquifers and their yield potentials have been prepared to depict their broader geographic distribution, which may bear limited practical value in the field condition.

PART II BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

HYDROGEOLOGICAL FRAMEWORK, GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

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4. GHASIPURA BLOCK

5. GHATGAON BLOCK

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9. JODA BLOCK

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PART II BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

1.0 ANANDAPUR BLOCK

1.1 Salient Information

Location, area and demography	
Location (Plate 1.1)	85^0 58' - 86^0 15' E longitude
	21^0 07' – 21^0 33' N latitude
Area	708 sq. km
No. of Gram Panchayats	16
No. of villages	127
Population (Census 2011)	1,09,669 (rural)
Literacy	54.96%
Climate and rainfall	
Climate	Hot and humid
Normal annual rainfall	1547 mm
Monsoon normal rainfall	1161 mm (75% of total)
Land use, agriculture and irrigation	
Gross cropped area (1)	26765 Ha
Net sown area (2)	16094 Ha
Area sown more than once (1-2)	10671 Ha
Cropping intensity (%)	166.3
Area under forest	6338 Ha
Area under wasteland	1699 Ha
Area under other uses	12693 Ha
Important cropping seasons	*Kharif* and *rabi*
Total irrigated area (as on 2015-16)	8790 Ha
	Kharif: 5549 Ha
	Rabi: 3241 Ha

1.2 Drainage, geomorphology and soil types

Baitarani Is the master river in the block with the major tributaries such as Musal and Kusei rivers. Several other minor rivulets/streams join the principal Baitarani River on both the banks at a few locations (Plate 1.2). Though, a significant part of the block in the middle is covered by denudational hills (Fig 1.1 and Plate 1.3), considered as poor from groundwater point of view, other prominent hydro-geomorphic units include pediments, buried pediments and the Quaternary alluvium which cover the rest of the block area in the northern and southern parts. In north, several linear basic dykes are cutting across the country rock. Around 85% of the block area is characterized by a ground slope of less than 10% (Fig 1.2 and Plate 1.4), which is quite suitable for groundwater recharge through infiltration in the soil. The soil types include the red sandy soil (alfisol), red lateritic soil (ultisol), and alluvial soil (alfisol).

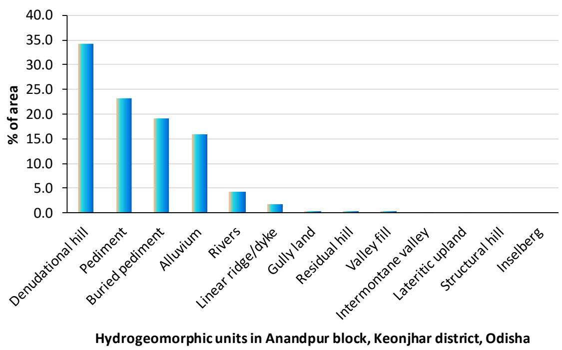


Figure 1.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Anandapur block.

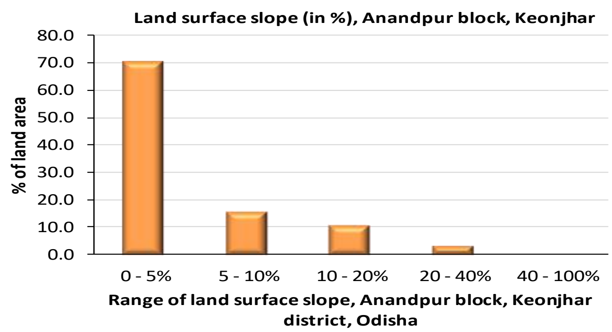


Figure 1.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Anandapur block, Keonjhar district.

1.3 Geology

A major part (~80%) of the district is covered by Singhbhum Granite of Precambrian age, which is followed by the Quaternary alluvium in the south (Fig 1.3 and Plate 1.5).

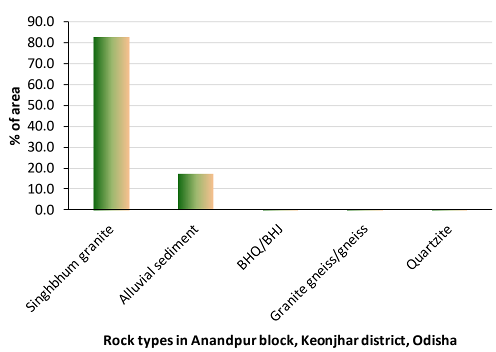


Figure 1.3: Percentage (%) of Anandapur block area (Keonjhar dist.) covered by various rock types.

1.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories. In the alluvial areas, the granular zones of sandf in the alluvium hold groundwater with different potential. The generalized hydrogeological map of the block is presented in Plate 1.6.

During the pre- and post-monsson periods of the year 2018, the water levels measured in the dug wells varied in the ranges of 1.0 – 10.0 m and 0.43 – 9.3 m bgl (Plate 1.7 & 1.8). Larger parts of the block depicted water levels < 5.0 m bgl. The annual fluctuations in the water levels largely remained between 0-2 m (Plate 1.9). Minor pockets showed little decline in water levels.

1.5 Aquifer geometry and characters

The weathered zone overlying the fresh hard rock in block is substantially thick in major parts (Plate 1.10). As depicted in Fig 1.4, 42% and 56% of the block possess weathered zone in the thickness ranges of 10-20 m and 20-30 m respectively, which form good aquifers. In Baitarani river valley, the alluvium goes up to ~50 m bgl, where the granular zones of 5-15 m thick are observed. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 1.5a-b.

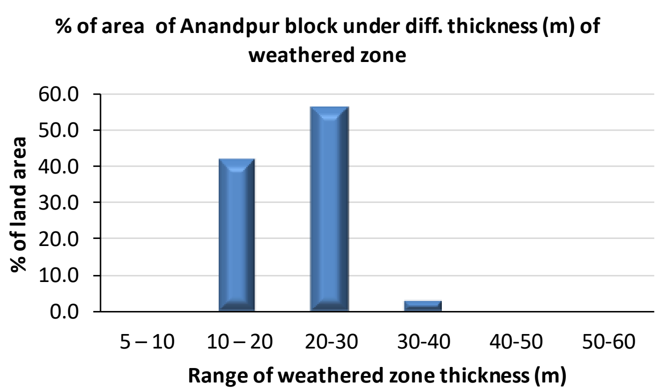


Figure 1.4: Bar diagram depicting the percentage (%) area of Anandapur block, Keonjhar district falling under different weathered zone thickness (m) ranges.

In the block, 0-4 sets of fracture zones are observed within the depth of 200 m bgl. Major such fractures are located within 100 m bgl in the 1st aquifer system (Plate 1.11). Beyond this depth in the 2nd aquifer system, hardly one fracture has been encountered during drilling (Plate 1.12). However, the bore wells in hard rock in the block yield between 2.5-7.5 lps in major parts (Plate 1.13). In the alluvial area, the tube wells are quite productive yielding in the range of 10-20 lps of water.

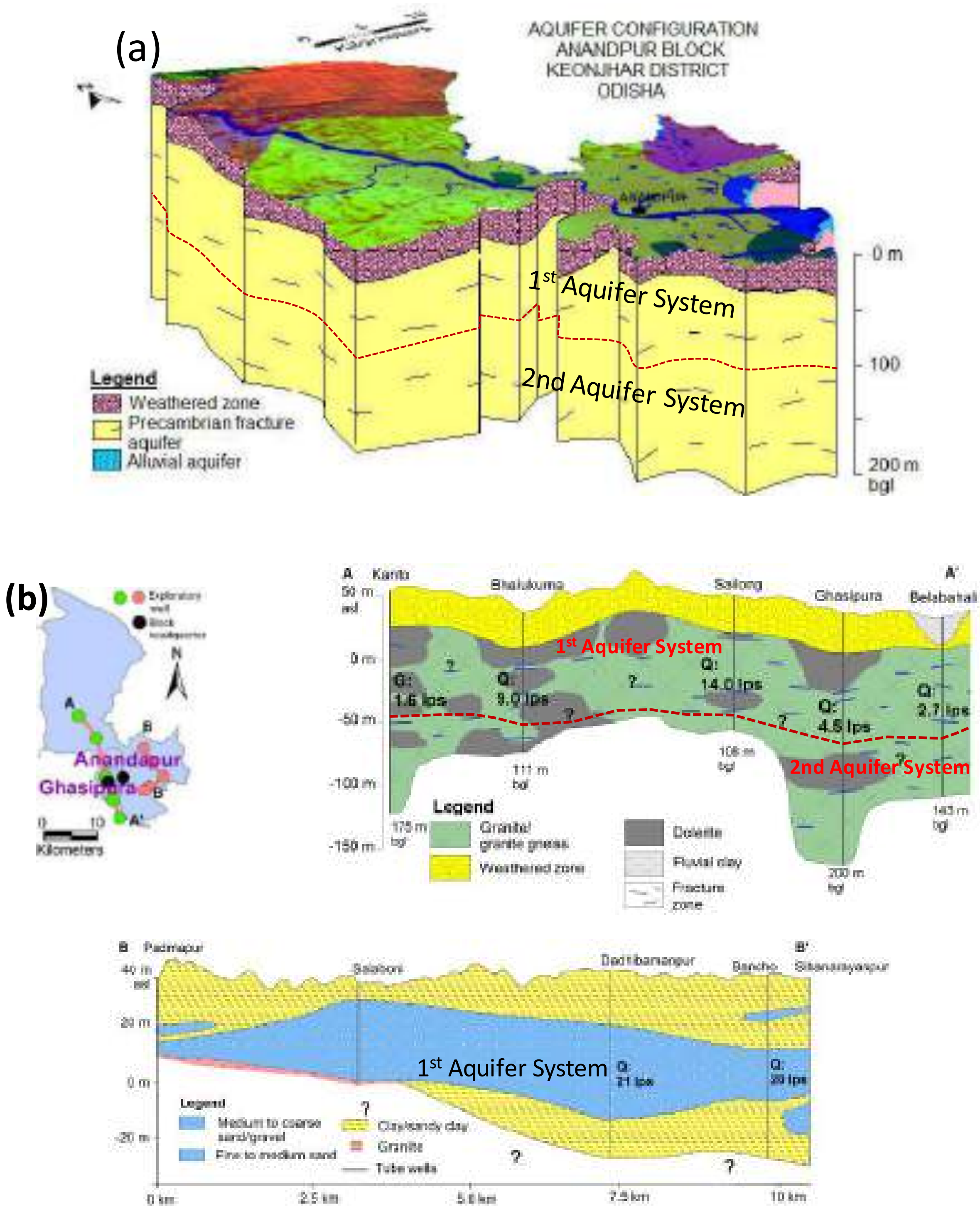


Figure 1.5: (a) 3D aquifer disposition in Anandapur block, Keonjhar district. (b) 2D hydrogeological transects A-A' and B-B' with their location map in the block.

1.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 1.14). The good to very good groundwater potential zones are located in the central and the southern (alluvial) parts of the block, constituting around 50% of the area (Fig 1.6).

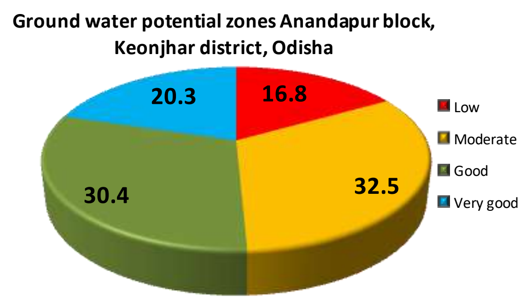


Figure 1.6: Pie diagram depicting the perentage (%) of Anandapur block, Keonjhar district, Odisha, falling under different groundwater potential zones.

1.7 Ground water quality

Ground water is alkaline (pH range: 7.6-8.1) and moderately hard to very hard (TH range: 62-390 mg/L; ave.: 198 mg/L) in nature. The ground water is low to moderately mineralised (TDS range: 75-882 mg/L, ave.: 325 mg/L) (Table 1.1). Ground water fluoride is well within the drinking limit. Overally, groundwater is fit for drinking and irrigation. Water types are predominantly Ca-HCO_3 types (Fig 1.7).

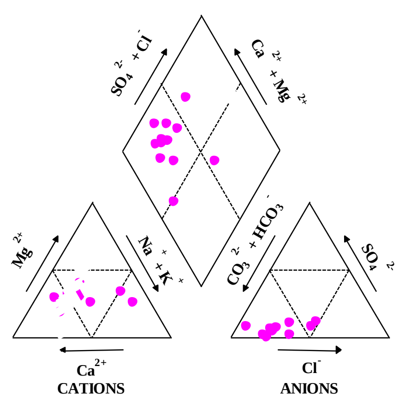


Figure 1.7: The Piper trilinear diagram depicting the groundwater quality in Anandapur block, Keonjhar district.

Table 1.1: Ground water quality at various locations in Anandapur block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO3	HCO_3	Cl	SO_4	F
Belabahali	7.71	1650	882	283	377	35	48	226	1.79	0	460	282	64	0.89
Kuldiha	7.77	250	115	101	78	27	8	5	1.92	0	95	19	7	0.2
Janjali	7.67	410	204	163	156	44	13	18	1.39	0	191	34	0	0.19
Baniajodi	7.77	170	75	62	46	15	6	6	1.19	0	56	19	1	0.05
Manoharpur	7.59	230	112	86	78	17	11	9	5.52	0	95	17	6	0.2
Badakushapada	7.61	420	209	130	143	31	13	35	0.81	0	174	36	8	0.29
Janghara	7.76	800	382	298	262	69	30	36	5.73	0	320	62	22	0.26
Kathakata	7.78	410	208	144	110	35	14	22	5.66	0	135	45	20	0.12
Khamarnandi	7.7	1270	632	298	501	35	51	111	63.9	0	612	26	45	0.17
Anandapur	7.67	950	510	390	181	120	22	48.82	1.6	0	221	158	48.9	0.13
Birgovindpur	7.93	470	260	190	201	44	19	32	2.19	0	245	36	3.9	0.44
Ghasipura	8.1	570	312	225	206	46	27	34.56	3.51	0	251	55	20.4	0.34
Min.:	**7.59**	**170**	**75**	**62**	**46**	**15**	**6**	**5**	**0.81**	**0**	**56**	**17**	**0**	**0.05**
Max.:	**8.1**	**1650**	**882**	**390**	**501**	**120**	**51**	**226**	**63.9**	**0**	**612**	**282**	**64**	**0.89**
Average	**7.8**	**633.3**	**325.0**	**197.5**	**194.9**	**43.2**	**21.8**	**48.6**	**7.9**	**0.0**	**237.9**	**65.8**	**20.5**	**0.3**

1.8 Ground water resources

The detials of the groundwater resources in the block are produced in Table 1.2-1.3. The net dynamic groundwater available is 6952 Ham and the stage of groundwater development stands at 43.6%. Net resource available for future irrigation needs stands at 3861.2 Ham (Fig 1.8). Another instorage/static groundwater resource component is quite rich at 13666.0 Ham due to the availability of granular zones in alluvium (Table 1.3).

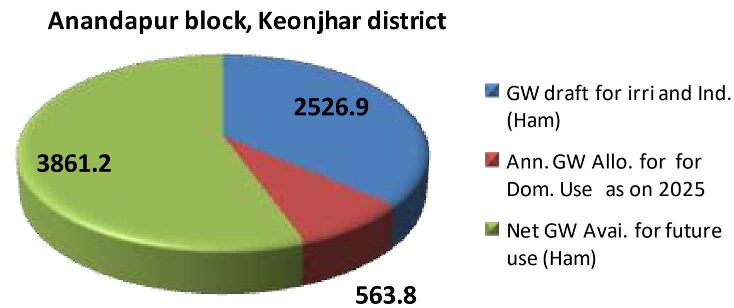


Figure 1.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Anandapur block, Keonjhar district, Odisha.

Table 1.2: Salient information on annual dynamic groundwater resources, Anandapur block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources **a**vailable (Ham)	6951.9
2. Irrigation draft (Ham)	2500.5
3. Industrial draft (Ham)	26.4
4. Domestic draft (Ham)	506.9
5. Total draft (Ham)	3033.8
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	563.8
7. Net groundwater available for future use (Ham)	3861.2
8. Stage of groundwater extraction (%)	43.6

Table 1.3: Total groundwater resoure available in the Anandapur block, Keonjhar district.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	6951.9
2	In-storage groundwater resource (Ham) of 1st Aquifer System	13666.0
3	In-storage groundwater resource (Ham) of 2nd Aquifer System	16.1
	Block total	**20633.9**

1.9 Aquifer management plan

The groundwater development in block can safely be enhanced up to 60% without much negative effect on the water level. Additional groundwater abstraction structures as estimated in Table 1.4 are required to develop the available additional resource. It can help in creating additional irrigation potential for1820 Ha (Table 1.5).

Around 26.8 km^2 area in the block showed post-monsoon depth towater levels >5.0 m bgl (Plate 1.15; Table 1.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, nala/contour bunds, check dams and sub-surface dykes. A total of 3.22 MCM of water (Table 1.7) can be recharged by the help additional 6-percolations ponds, 3-subsurface dykes, 3-nala/contour bunds and 6-check dams (Table 1.8) with a total cost of 2.10 crores (Table 1.9).

Table 1.4: Number of additional feasible groundwater abstraction structures in Anandapur block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	6951.9
2	Stage of GW deve. (%)	43.6
3	Present GW draft (Ham)	3033.8
4	Ground water draft at 60% stage of deve. (Ham)	4171.1
5	Addi. water to be deve. (Ham)	1137.3
6	Addi. No of BW/ dug-cum-bore well feasible (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	257
7	Addi. No. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	2187

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 1.5: Irrigation potential likely to be created in Anandapur block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	43.6
2	Surplus GW avai. for 60% stage of deve. (Ham)	1137.3
3	Irri, Pot. likely to be created for Paddy (Ha)	682.4
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	568.7
5	Irri. Pot. likely to be created for veg. (Ha)	568.7
6	Proj. area to be Irri. (ha)	1819.7

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 1.6: Areas in Anandapur block with depth to water level (DTW) >5.0 m bgl

Sl No	Name of block	Total area in diff. DTW ranges (Km^2)		Total area with DTW >5.0 m bgl (Km2)
		DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
1	Anandapur	19.73	7.14	26.87

Table 1.7: Estimation of volume of water required for artificial recharge to groundwater in Anandapur block, Keonjhar district.

Sl No	Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to reharge (MCM)
1	Anandapur	708.00	26.87	7	4	107.47	3.22

Table 1.8: Number of feasible recharge structures in Anandapur block, Keonjhar district for artificial recharge to groundwater

Sl No	Name of block	Total reharge volume required (MCM)	No of different freasible structures			
			Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
1	Anandapur	3.22	6	3	3	6

Table 1.9: Estimation of cost of artificial recharge structures in Anandapur block, Keonjhar district.

Sl No	Name of block	Cost of artificial recharge structures				Total cost (rupees in crores)
		Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
1	Anandapur	1.29	0.32	0.16	0.32	2.10

PLATE - 1.1

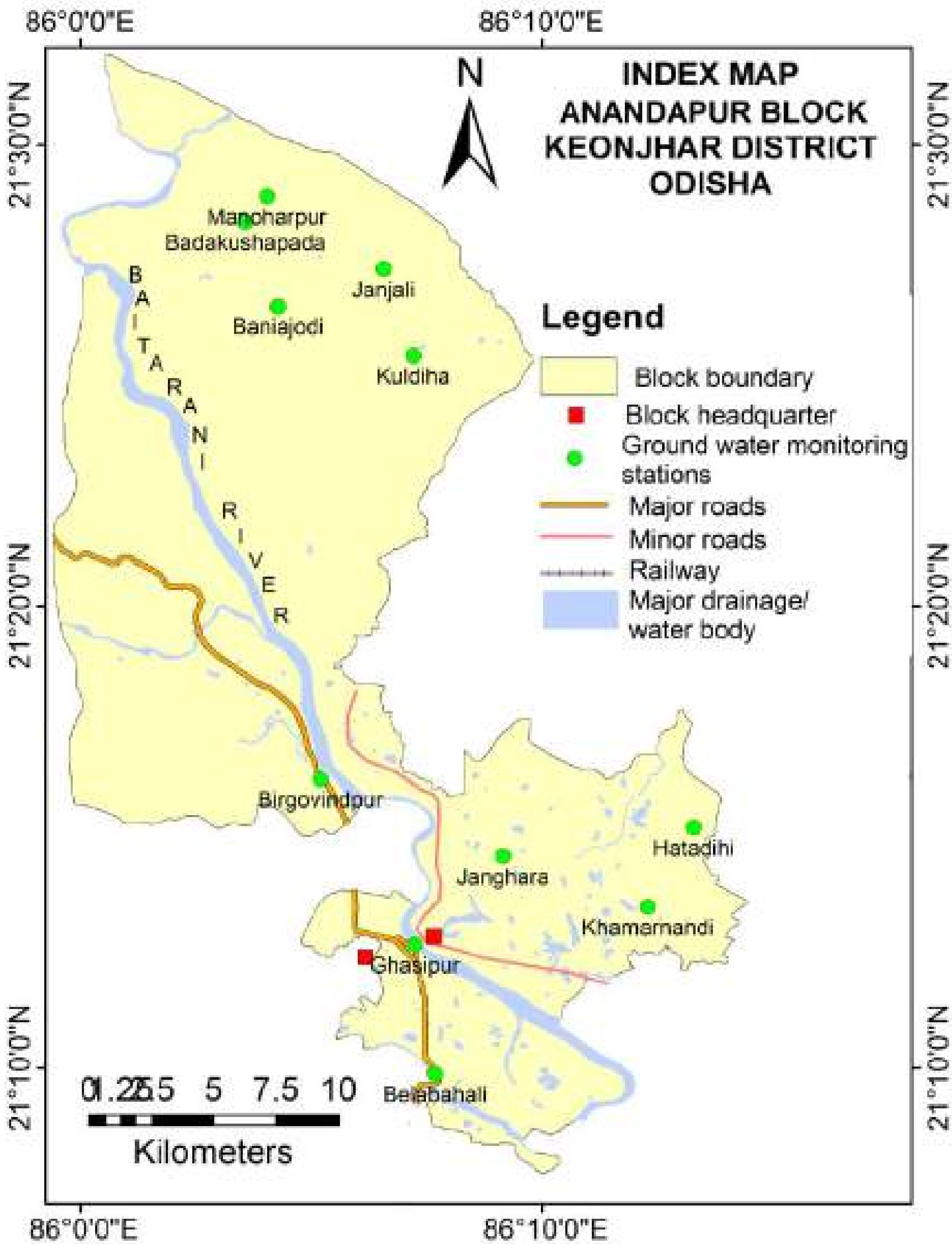

86°0'0"E
86°10'0"E
21°30'0"N
21°20'0"N
21°10'0"N
N
INDEX MAP
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body
Manoharpur
Badakushapada
Janjali
Baniajodi
Kuldiha
BAITARANI RIVER
Birgovindpur
Hatadihi
Janghara
Khamarnandi
Ghasipur
Belabahali
0 1.25 2.5 5 7.5 10
Kilometers

PLATE - 1.2

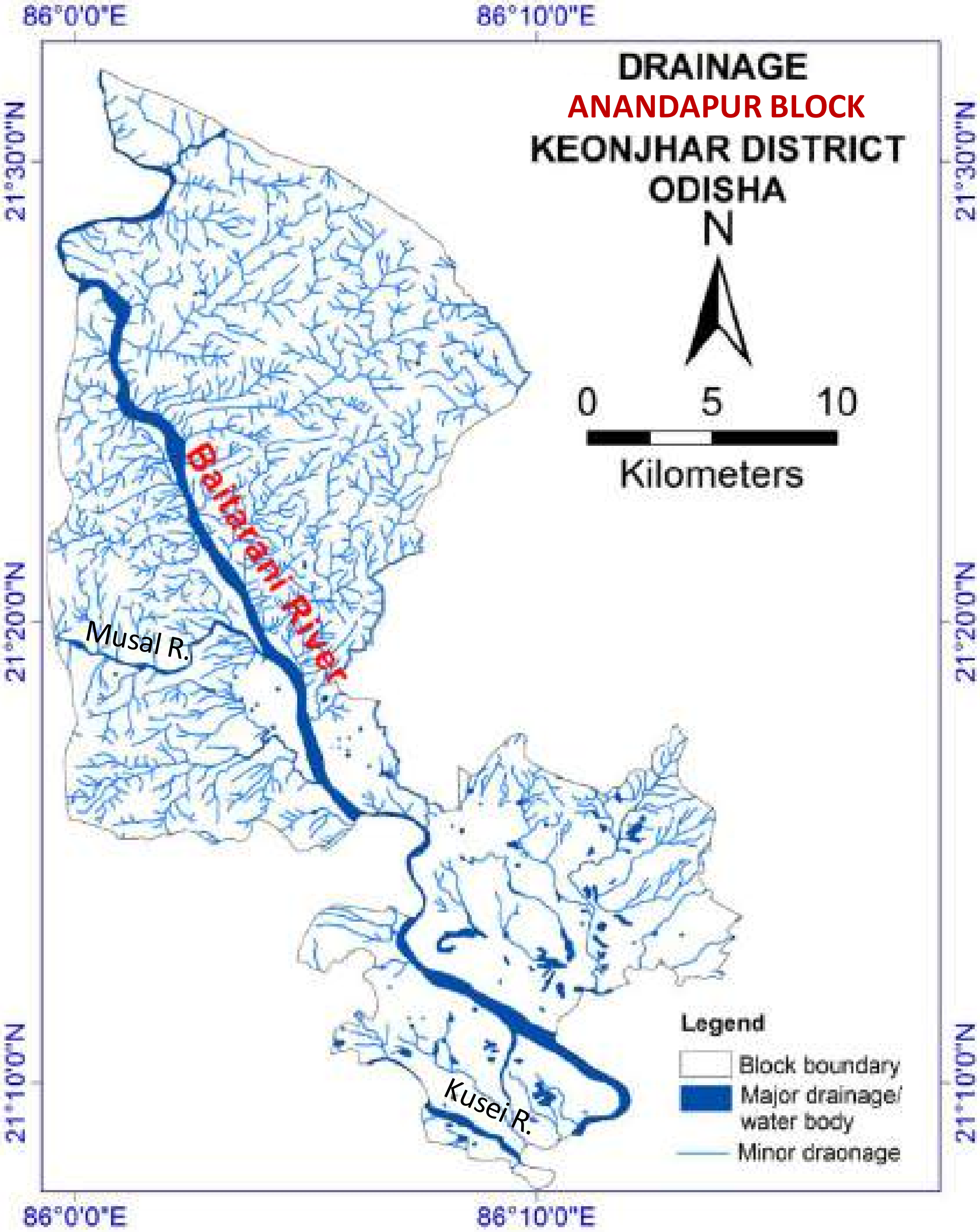

DRAINAGE
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
86°0'0"E
86°10'0"E
21°30'0"N
21°20'0"N
21°10'0"N
Baitarani River
Musal R.
Kusei R.
Legend
Block boundary
Major drainage/ water body
Minor draonage

PLATE - 1.3

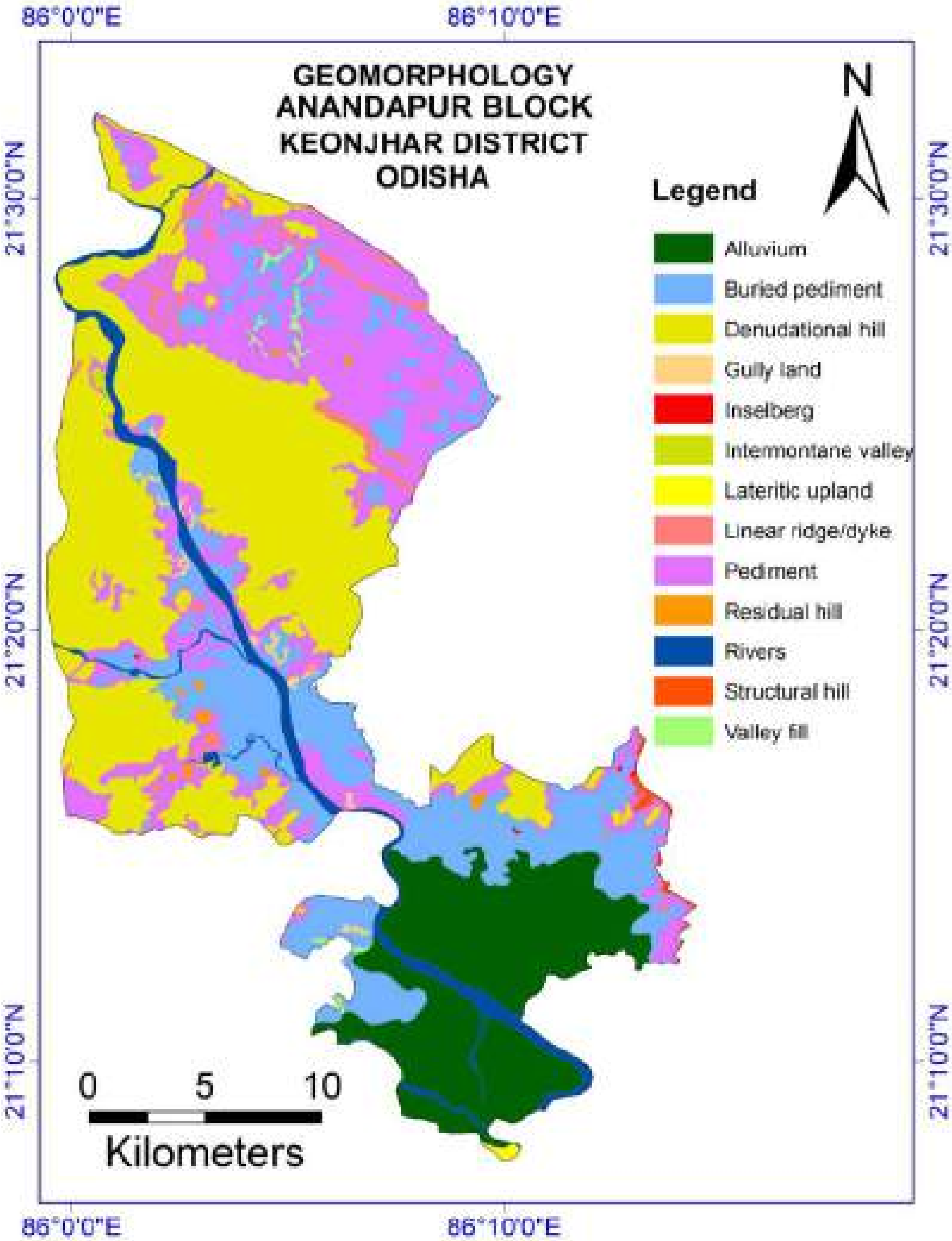

GEOMORPHOLOGY
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
Legend
Alluvium
Buried pediment
Denudational hill
Gully land
Inselberg
Intermontane valley
Lateritic upland
Linear ridge/dyke
Pediment
Residual hill
Rivers
Structural hill
Valley fill
0 5 10
Kilometers
86°0'0"E
86°10'0"E
21°30'0"N
21°20'0"N
21°10'0"N

PLATE - 1.4

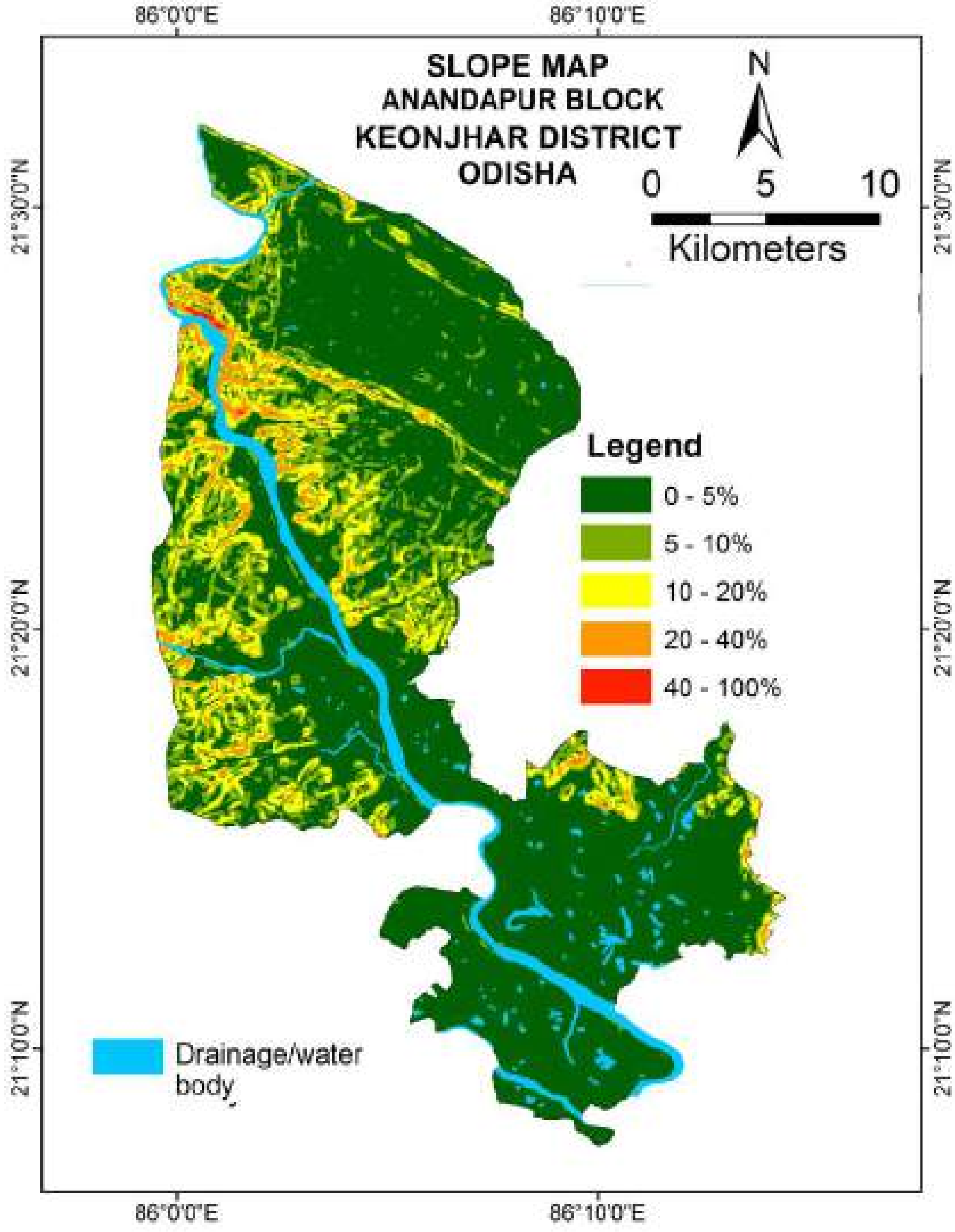

86°0'0"E
86°10'0"E
SLOPE MAP
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
21°30'0"N
21°20'0"N
21°10'0"N
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE - 1.5

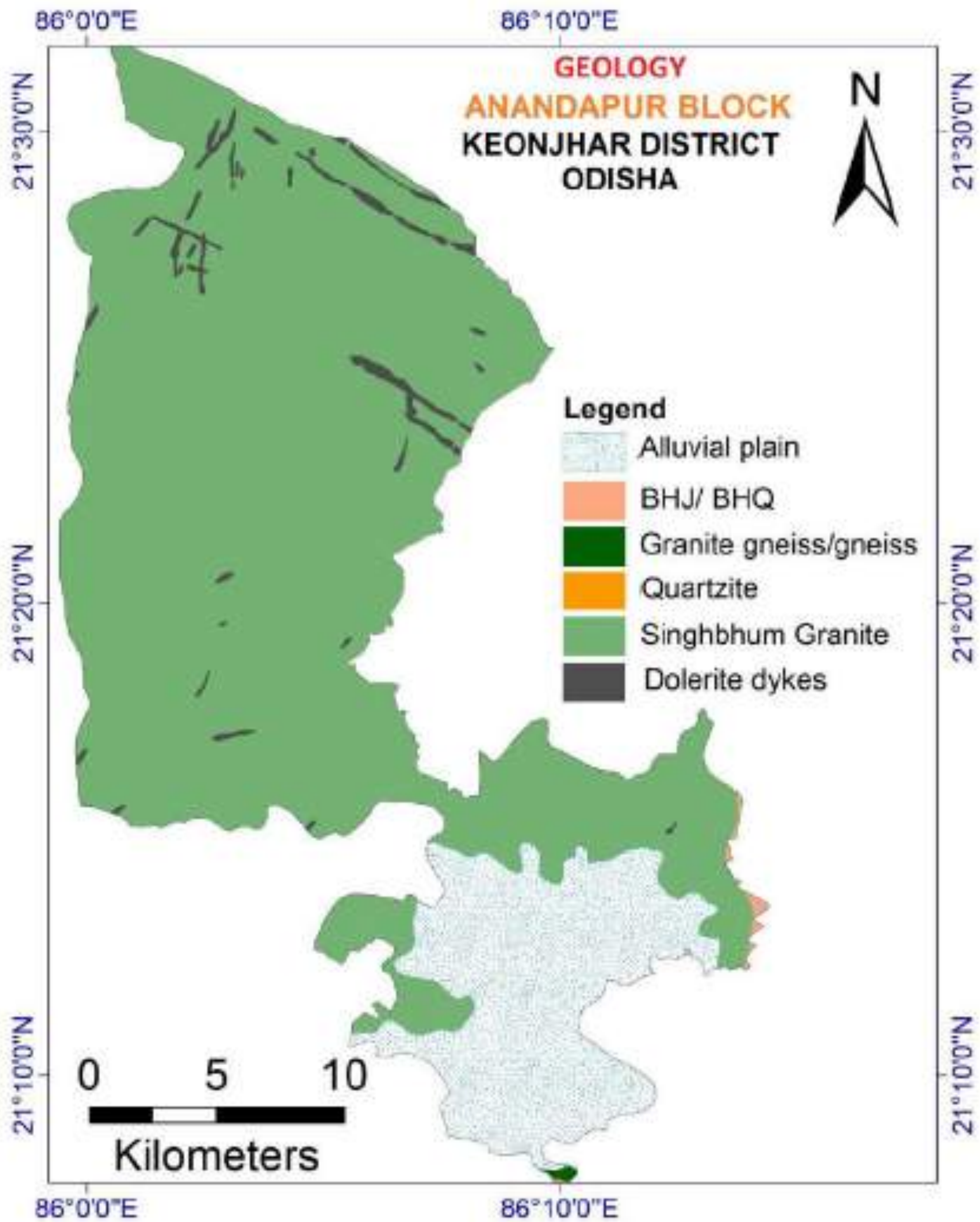

86°0'0"E
86°10'0"E
21°30'0"N
21°20'0"N
21°10'0"N
GEOLOGY
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
Legend
Alluvial plain
BHJ/ BHQ
Granite gneiss/gneiss
Quartzite
Singhbhum Granite
Dolerite dykes
0 5 10
Kilometers

PLATE - 1.6

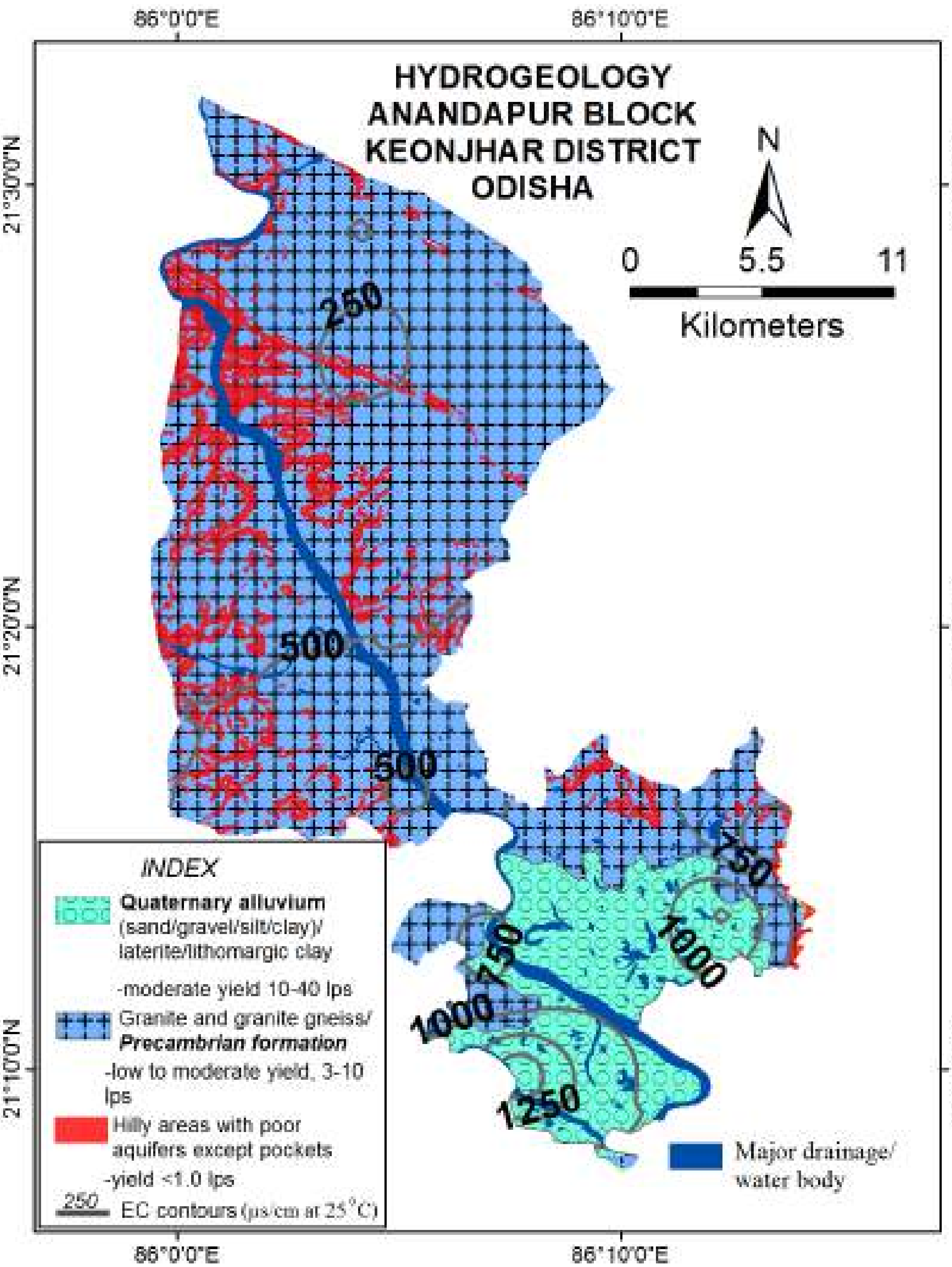

HYDROGEOLOGY
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
86°0'0"E
86°10'0"E
21°30'0"N
21°20'0"N
21°10'0"N
N
0
5.5
11
Kilometers
250
500
500
750
1000
750
1000
1250
INDEX
Quaternary alluvium (sand/gravel/silt/clay)/ laterite/lithomargic clay
-moderate yield 10-40 lps
Granite and granite gneiss/ Precambrian formation
-low to moderate yield, 3-10 lps
Hilly areas with poor aquifers except pockets
-yield <1.0 lps
250 EC contours (μs/cm at 25°C)
Major drainage/ water body

PLATE 1.7

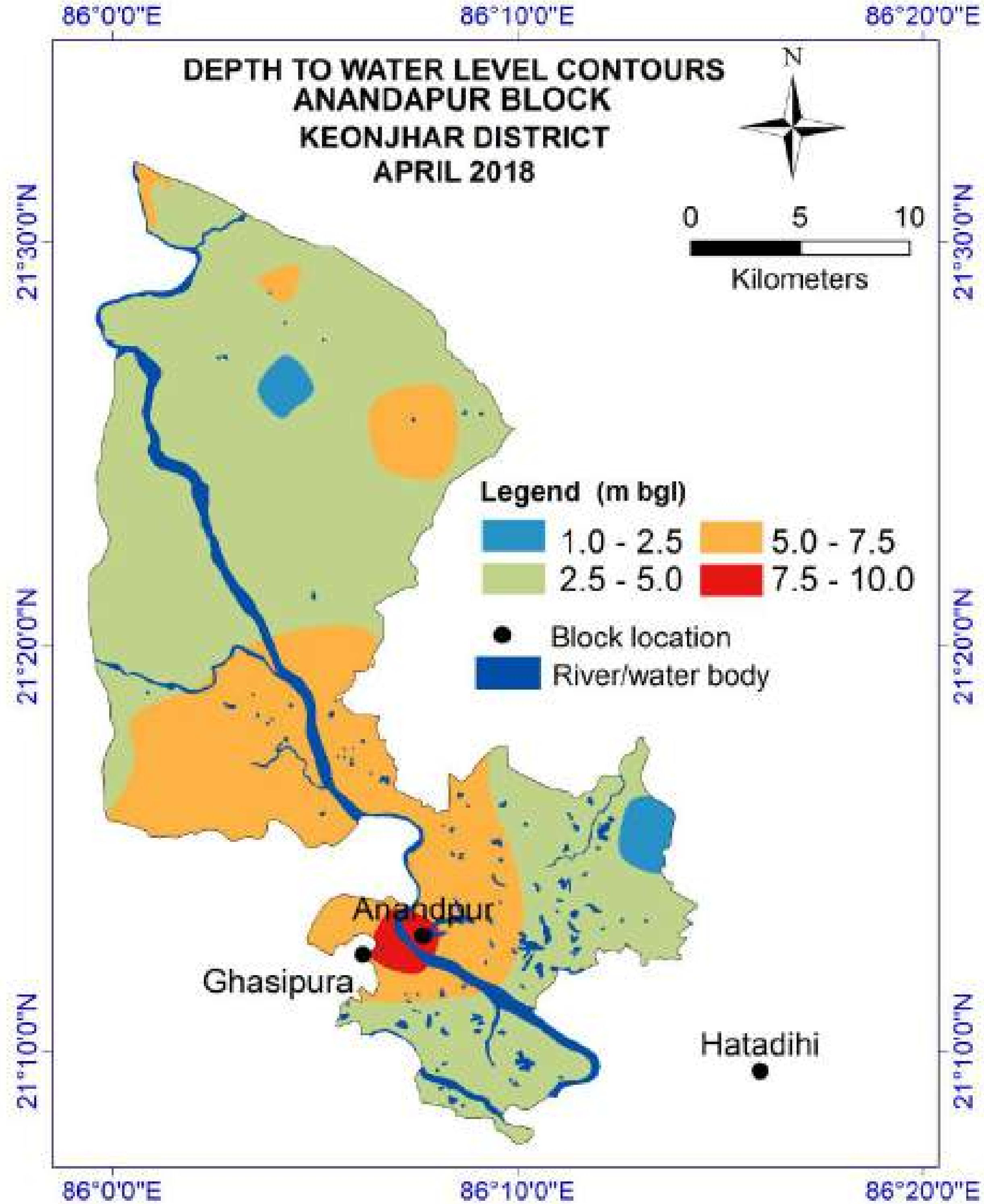

86°0'0"E
86°10'0"E
86°20'0"E
DEPTH TO WATER LEVEL CONTOURS
ANANDAPUR BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0
5
10
Kilometers
21°30'0"N
21°20'0"N
21°10'0"N
Legend (m bgl)
1.0 - 2.5
5.0 - 7.5
2.5 - 5.0
7.5 - 10.0
Block location
River/water body
Anandpur
Ghasipura
Hatadihi

PLATE – 1.8

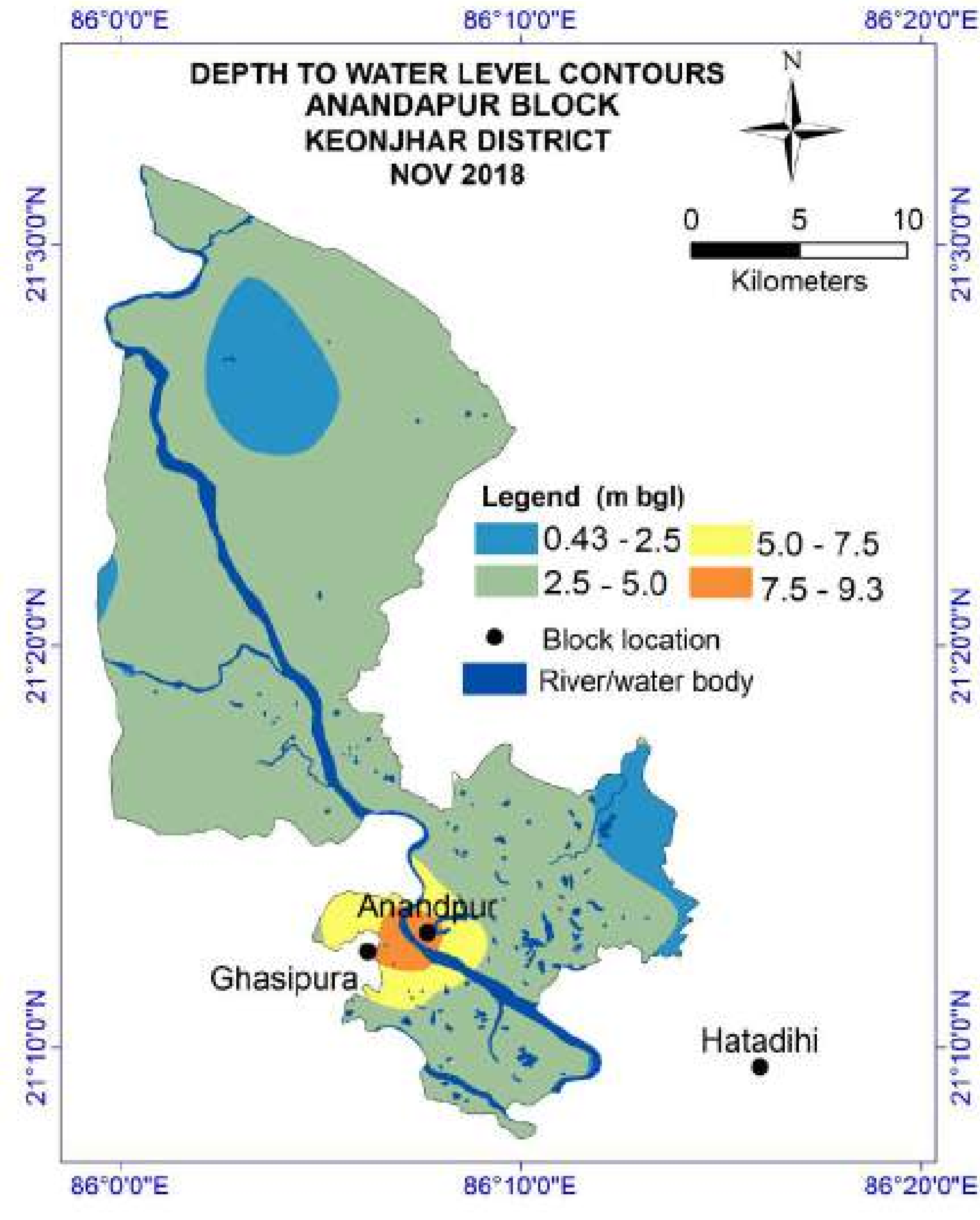

86°0'0"E
86°10'0"E
86°20'0"E
DEPTH TO WATER LEVEL CONTOURS
ANANDAPUR BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0
5
10
Kilometers
21°30'0"N
21°20'0"N
21°10'0"N
Legend (m bgl)
0.43 - 2.5
5.0 - 7.5
2.5 - 5.0
7.5 - 9.3
Block location
River/water body
Anandpur
Ghasipura
Hatadihi

PLATE – 1.9

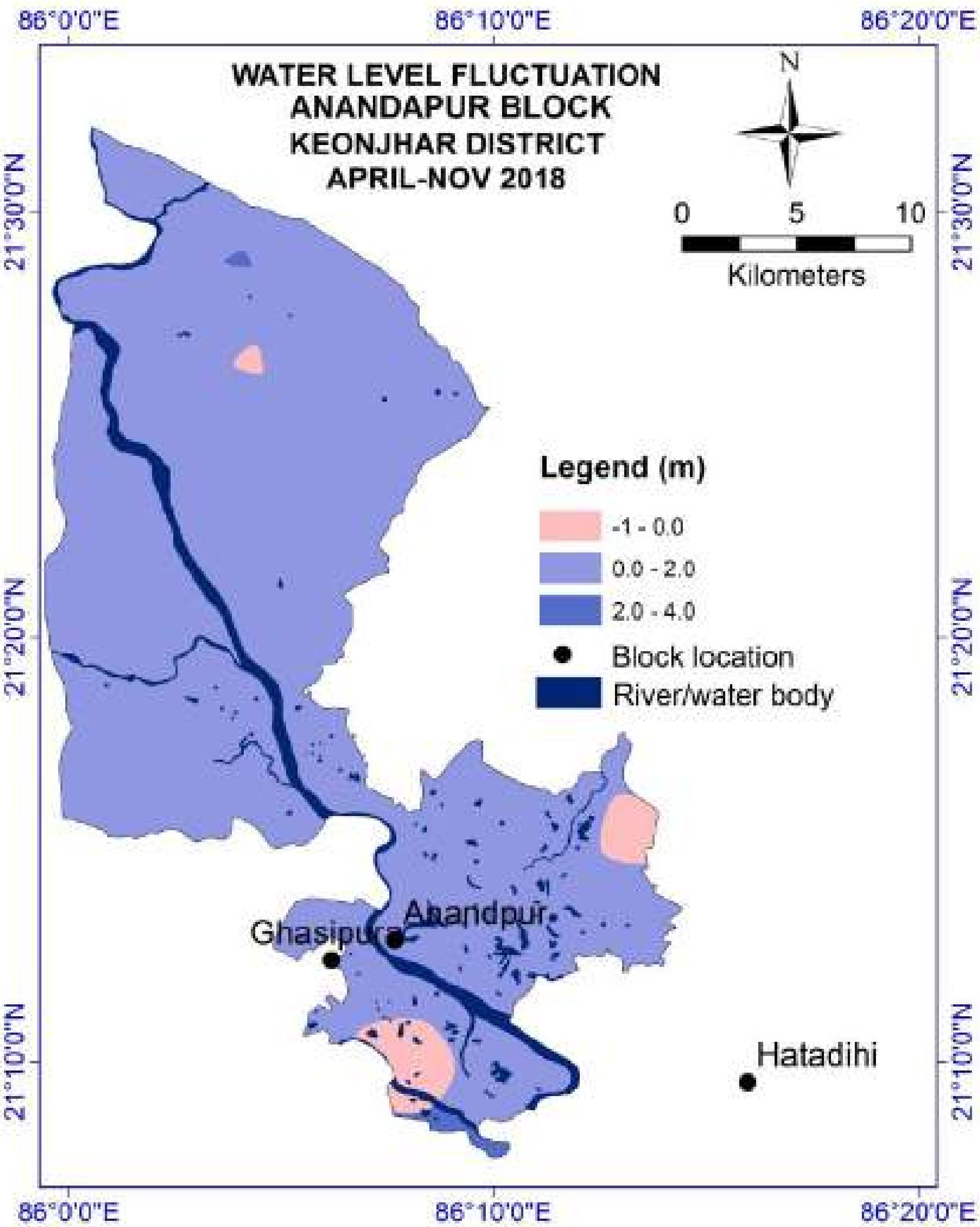

WATER LEVEL FLUCTUATION
ANANDAPUR BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0 5 10
Kilometers
Legend (m)
-1 - 0.0
0.0 - 2.0
2.0 - 4.0
Block location
River/water body
Anandpur
Ghasipura
Hatadihi
86°0'0"E
86°10'0"E
86°20'0"E
21°30'0"N
21°20'0"N
21°10'0"N

PLATE – 1.10

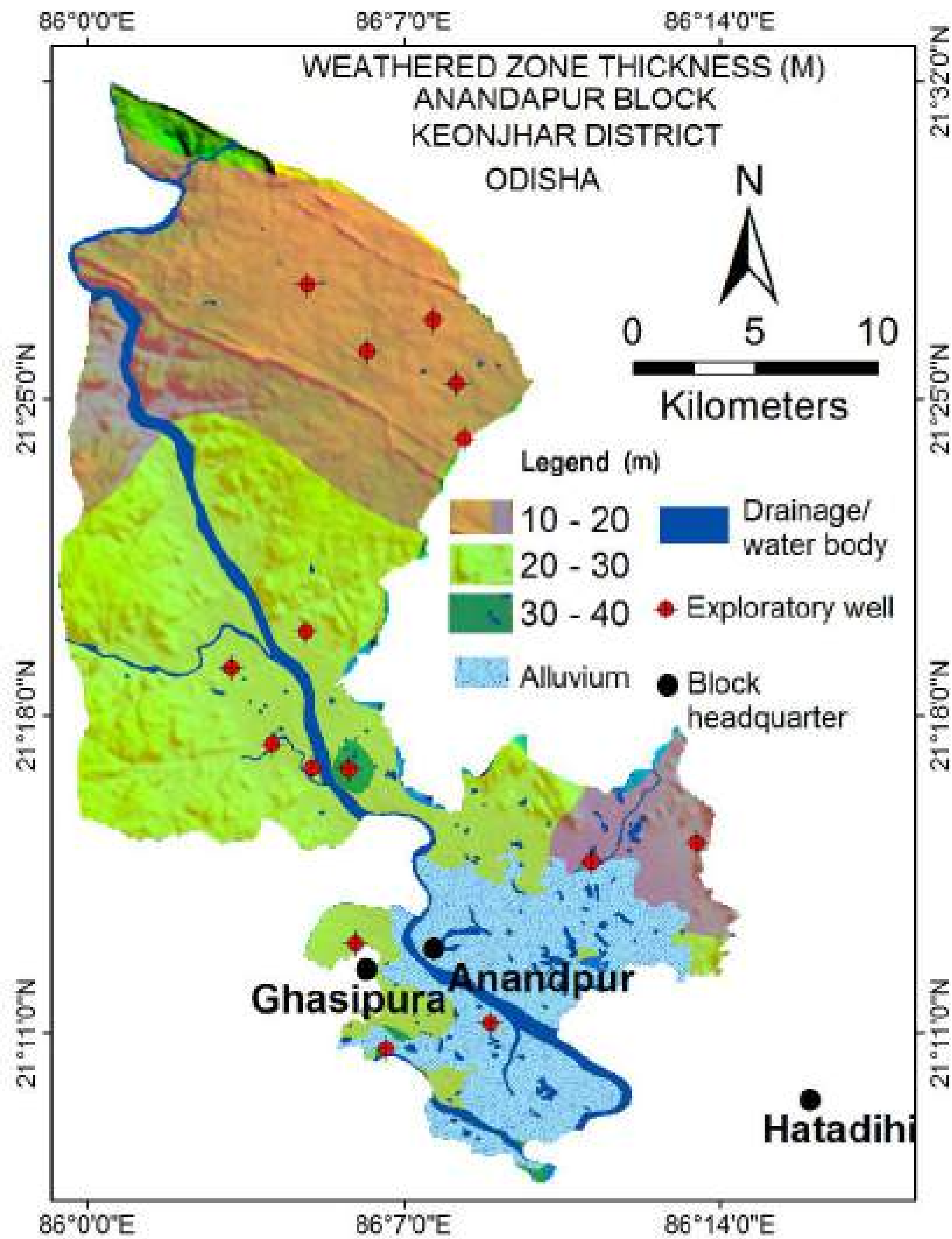

WEATHERED ZONE THICKNESS (M)
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
Legend (m)
10 - 20
20 - 30
30 - 40
Alluvium
Drainage/ water body
Exploratory well
Block headquarter
Anandpur
Ghasipura
Hatadihi
86°0'0"E
86°7'0"E
86°14'0"E
21°32'0"N
21°25'0"N
21°18'0"N
21°11'0"N

PLATE – 1.11

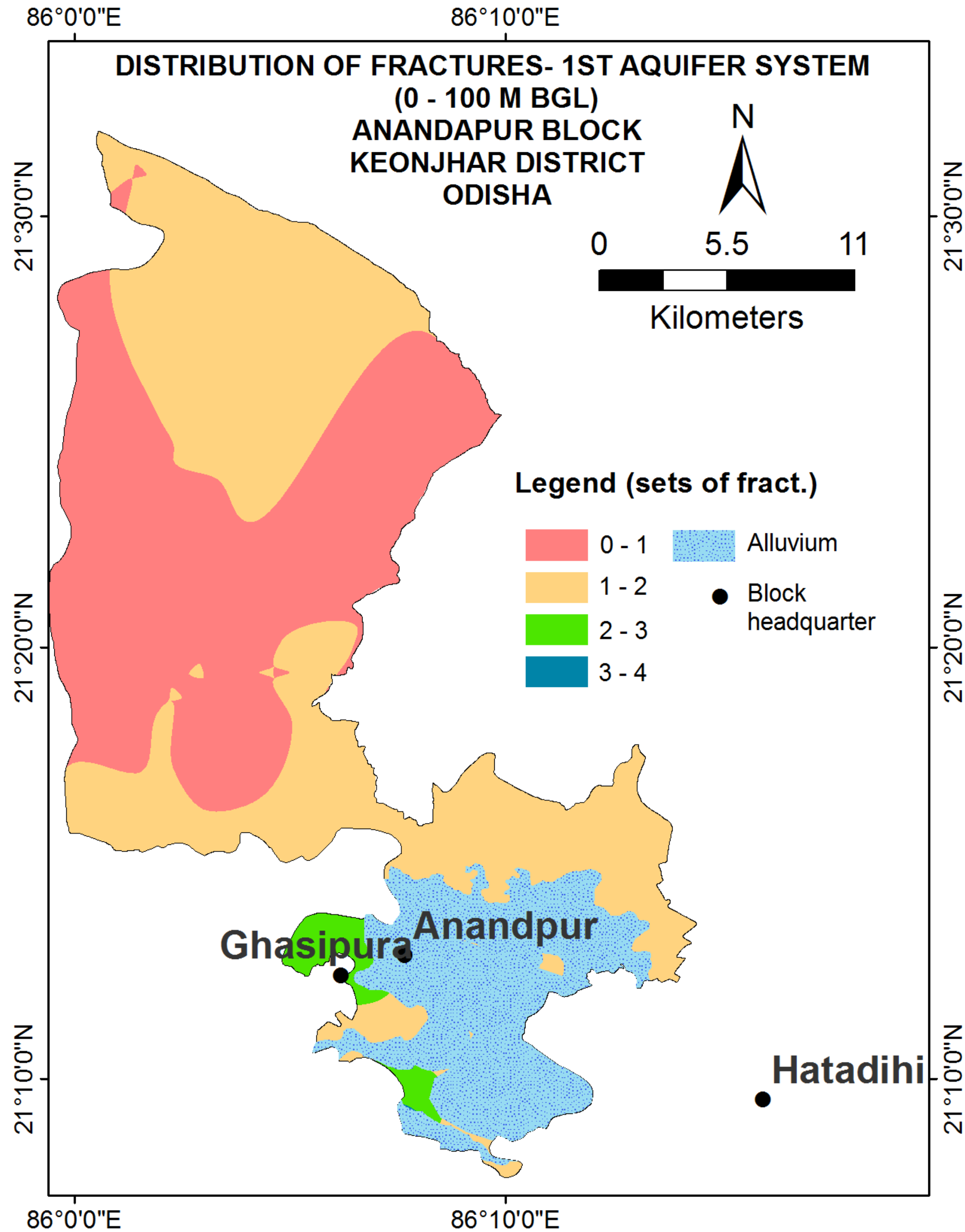

86°0'0"E
86°10'0"E
DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5.5
11
Kilometers
21°30'0"N
21°20'0"N
21°10'0"N
Legend (sets of fract.)
0 - 1
1 - 2
2 - 3
3 - 4
Alluvium
Block headquarter
Ghasipura
Anandpur
Hatadihi

PLATE – 1.12

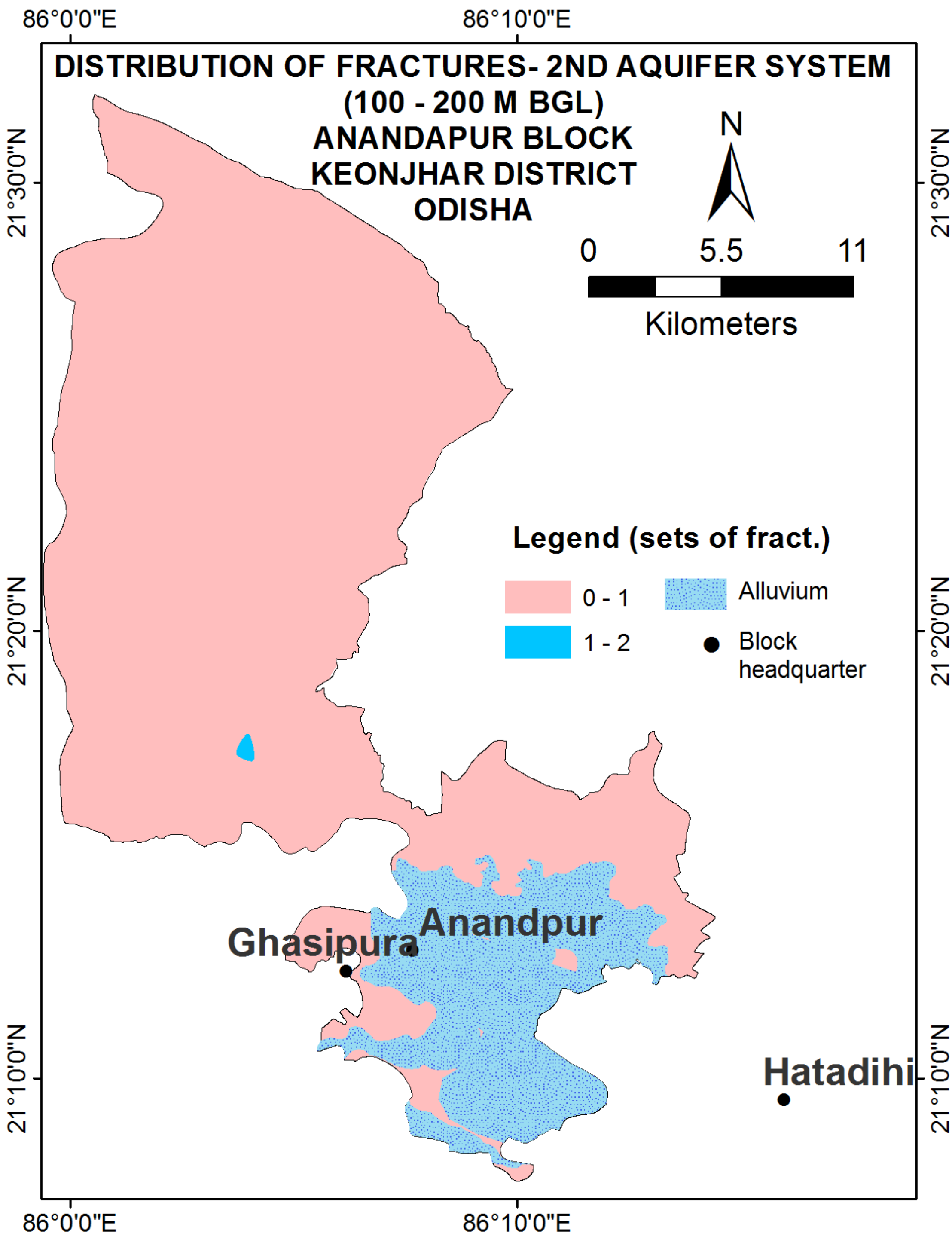

86°0'0"E
86°10'0"E
DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5.5
11
Kilometers
21°30'0"N
21°20'0"N
21°10'0"N
Legend (sets of fract.)
0 - 1
1 - 2
Alluvium
Block headquarter
Ghasipura
Anandpur
Hatadihi
86°0'0"E
86°10'0"E

PLATE – 1.13

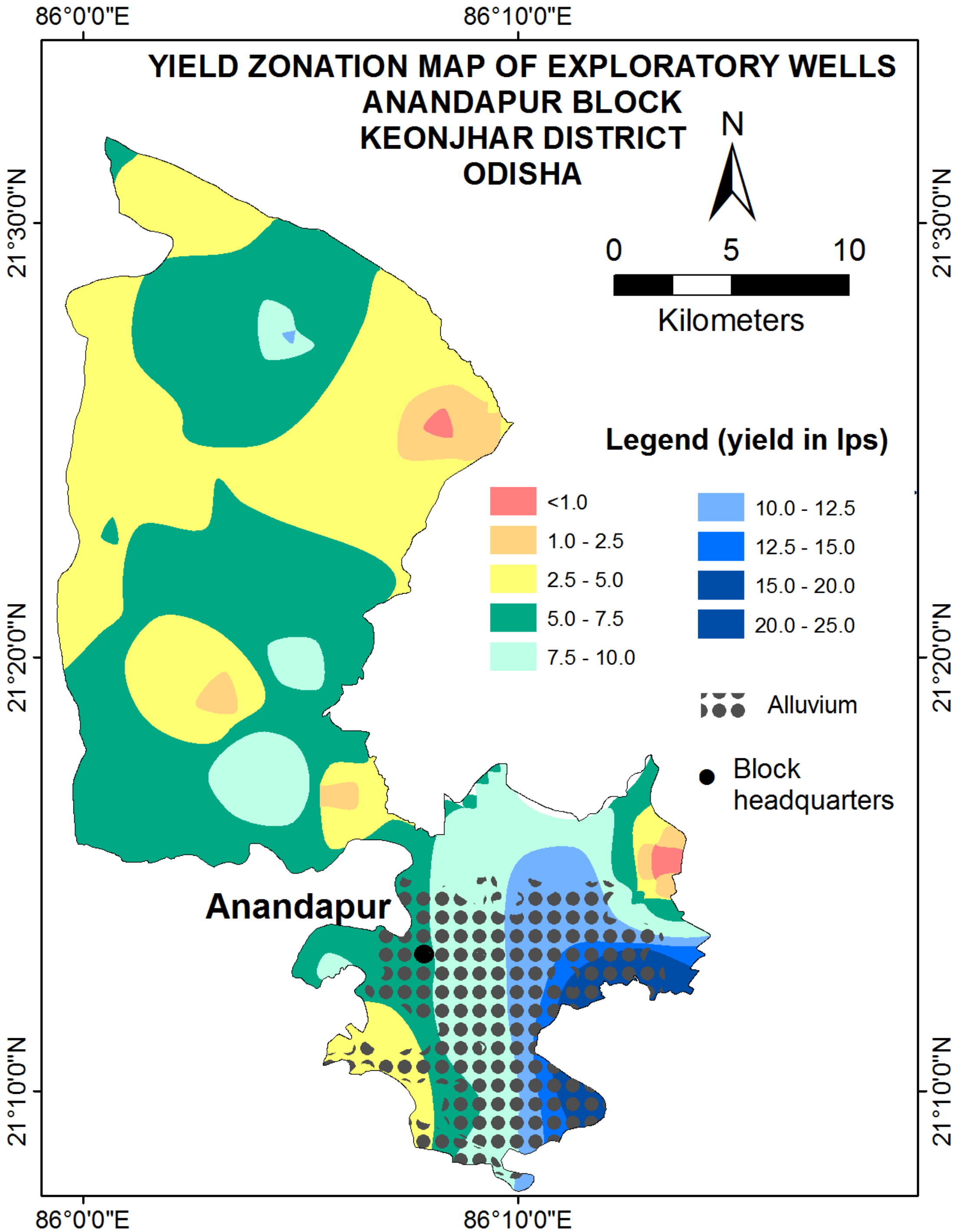

YIELD ZONATION MAP OF EXPLORATORY WELLS
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
86°0'0"E
86°10'0"E
21°30'0"N
21°20'0"N
21°10'0"N
N
0 5 10
Kilometers
Legend (yield in lps)
<1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
12.5 - 15.0
15.0 - 20.0
20.0 - 25.0
Alluvium
Block headquarters
Anandapur

PLATE – 1.14

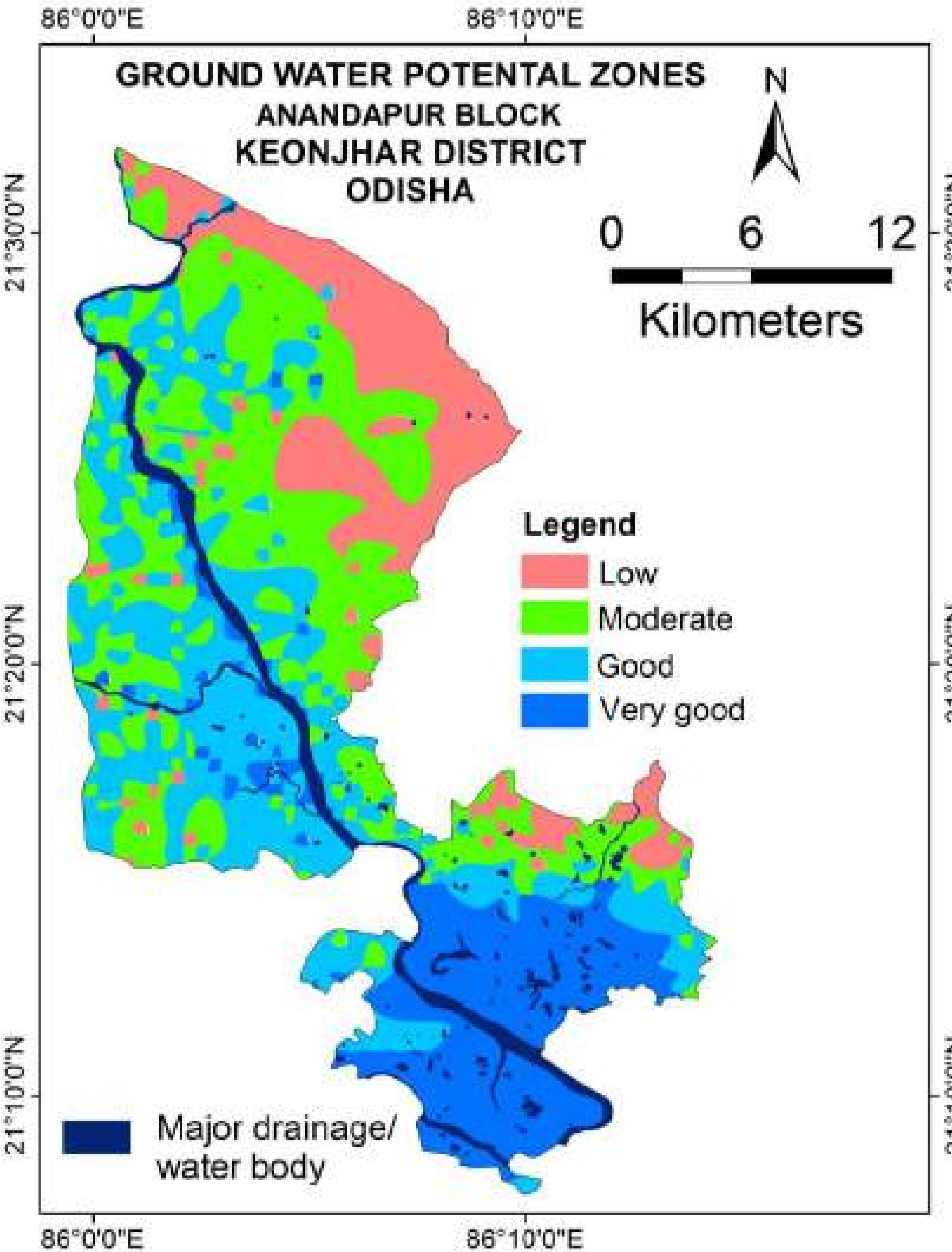
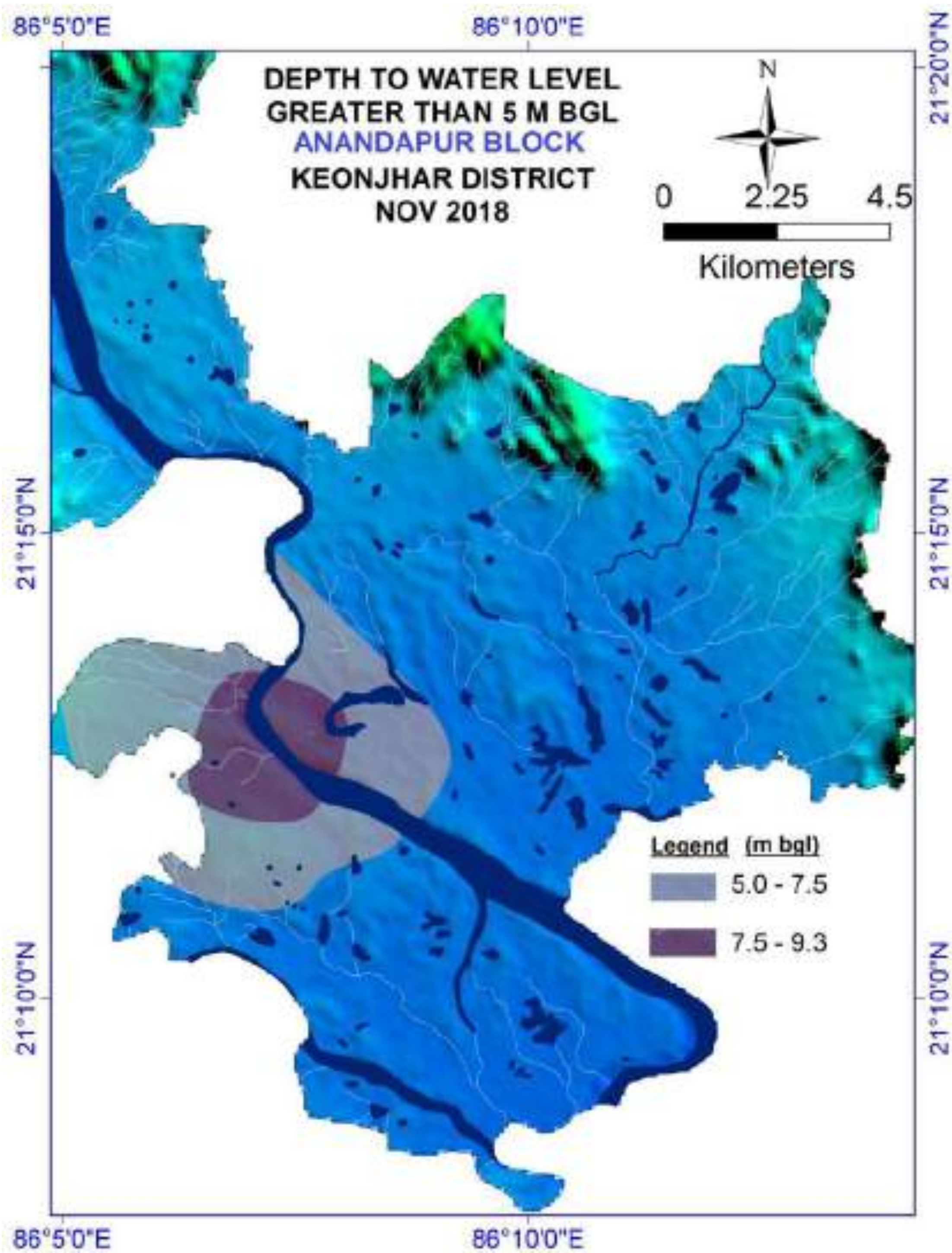

GROUND WATER POTENTAL ZONES
ANANDAPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
Legend
Low
Moderate
Good
Very good
Major drainage/
water body
86°0'0"E
86°10'0"E
21°30'0"N
21°20'0"N
21°10'0"N

PLATE – 1.15


86°5'0"E
86°10'0"E
21°20'0"N
21°15'0"N
21°10'0"N
DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
ANANDAPUR BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 2.25 4.5
Kilometers
Legend (m bgl)
5.0 - 7.5
7.5 - 9.3

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

2.0 BANSPAL BLOCK

2.1 Salient information

Location, area and demography

Location (Plate 2.1)	85^0 10' - 85^0 40' E longitude
	21^0 20' – 21^0 50'' N latitude
Area	1115 sq. km
No. of Gram Panchayats	21
No. of villages	164
Population (Census 2011)	1,02,527 (rural)
Literacy	34.5%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1170.4 mm
Monsoon normal rainfall	964.4 mm (82% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	20668 Ha
Net sown area (2)	14687 Ha
Area sown more than once (1-2)	5981 Ha
Cropping intensity (%)	140.7 Ha
Area under forest	83589 Ha
Area under wasteland	2494 Ha
Area under other uses	63014 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	2357 Ha
	Kharif: 1502 Ha
	Rabi: 855 Ha

2.2 Drainage, geomorphology and soil types

The Baitarani River takes origin in the block at Gonasika and flows in the north to north-east direction. It forms the master drainage with its prominent tributaries such as Mohalda and Bamri. The drainage pattern is dendritic to sub-trellis in nature (Plate 2.2).

A large part of the block is covered by structural hills (Fig 2.1 and Plate 2.3). The hill parts with slope more than 20% remain poor in groundwater resources owing to limited infiltration and recharge. A significant part of the block, however, is characterized by pediments, intermontane valleys and valley fills, especially along the river valleys. These units are considered as good in connection with groundwater availability. The typical weathering pattern and development of valleys perhaps indicate the characteristics that of volcanic rock terrain. The hills often exceed 10% slope. Including the river valley areas around 50% area of the block exhibits slope less than 10% (Fig 2.2). The soil types include the red sandy soil (alfisol) and red gravelly soils (ultisol).

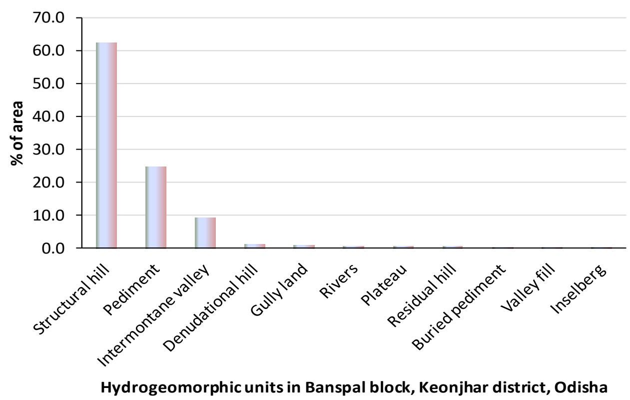


Figure 2.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Banspal block.

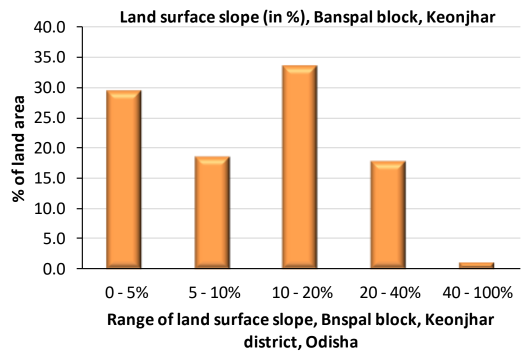


Figure 2.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Banspal block, Keonjhar district.

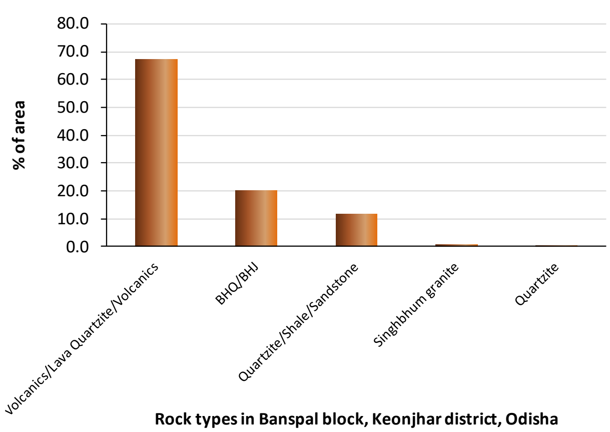


Figure 2.3: Percentage (%) of Banspal block area (Keonjhar dist.) covered by various rock types.

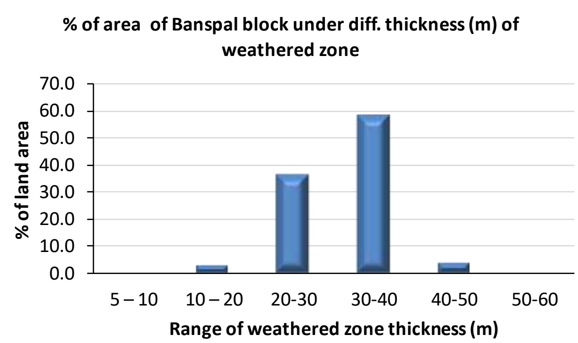


Figure 2.4: Bar diagram depicting the percentage (%) area of Banspal block, Keonjhar district falling under different weathered zone thickness (m) ranges.

2.3 Geology

A major part 67%) of the district is covered by volcanic rocks of Precambrian age (Fig 2.3 and Plate 2.5). In the border areas, metasedimentaries like Banded Haematite Jasper (BHJ), Banded Haematite Quartzite (BHQ), shales, sandstones and quartzites are found.

2.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories. The generalized hydrogeological map of the block is presented in Plate 2.6. The valley areas in the volcanics yield good amount of water (10-15 lps), whereas the aquifers in sandstones yield 3-10 lps of water.

The pre-monsoon (year 2018) measurements show deeper water levels (>5.0 m bgl) in almost the entire block. During post-monsson period also almost half (western side) of the block depict water levels >5.0 m bgl (Plate 2.7 & 2.8). The annual fluctuations in the water levels remained between 2-8.5 m (Plate 2.9), with major part of the block depicting the water level fluctuation range of 4-6 m.

2.5 Aquifer geometry and characters

The thickness of the weathered regolith overlying the fresh hard rock in block varies between 10-50 m (Plate 2.10). As depicted in Fig 2.4, 36% and 58% of the block areas possess weathered zones in the thickness ranges of 20-30 m and 30-40 m respectively, which gives better prospective of groundwater availability. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 2.5a-b. The weathered zone thickness in the block increases towards north and west.

In the block, maximum up to 3 sets of fracture zones are encountered in the bore wells within the depth of 100 m bgl (1^{st} aquifer system). In the volcanics rock predominant area, maximum of 2 sets of fractures have been found within this depth (Plate 2.11). Beyond this depth in the 2^{nd} aquifer system, the fractures are depleted and hardly one set of fracture has been encountered during drilling (Plate 2.12). The bore wells in the block yield between less than 1.0 lps to the maximum of 20 lps Plate 2.13). The southern half of the block seemed more productive.

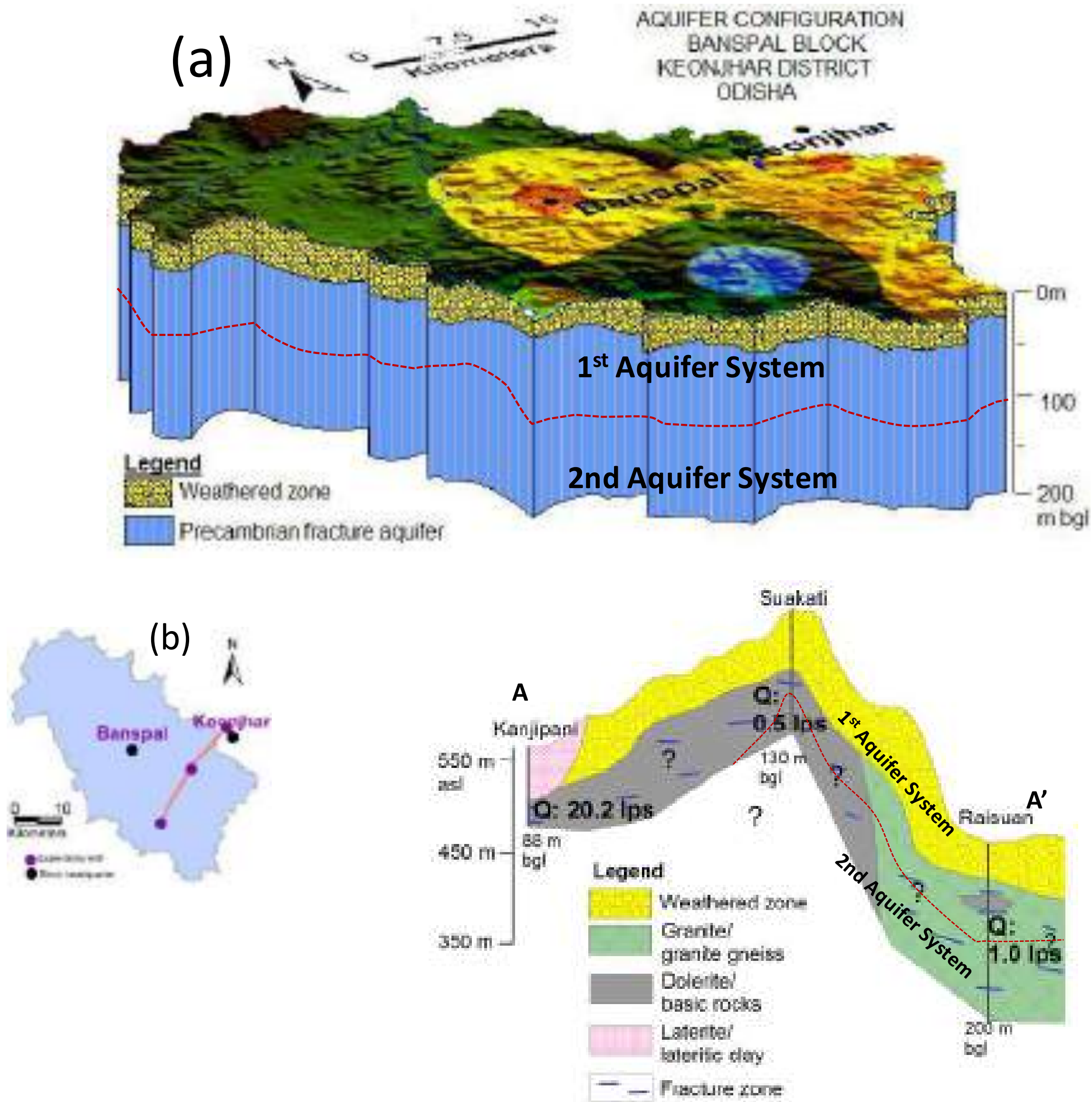


Figure 2.5: (a) 3D aquifer disposition in banspal block, Keonjhar district. (b) 2D hydrogeological transect A-A' depicting the aquifer configuration along with its location in the block.

2.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 2.14). The good to very good groundwater potential zones are located in the northern and south-central parts of the block (Fig 2.6).

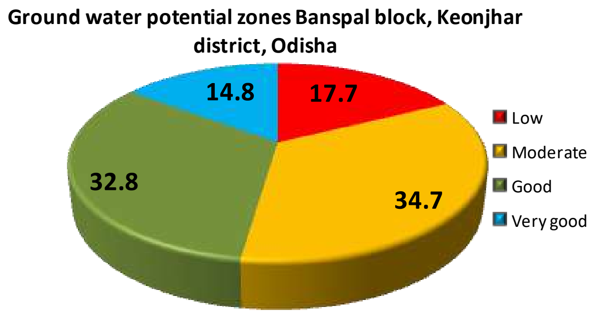


Figure 2.6: Pie diagram depicting the perentage (%) of Banspal block, Keonjhar district, Odisha, falling under different groundwater potential zones.

2.7 Ground water quality

Ground water in the block is slightly alkaline in nature (Table 2.1). The water is soft to moderately hard. The mineralization is largely low with TDS in the range of 36-205 mg/L (ave.: 105.5 mg/L). Ground water is fit for drinking and irrigation except certain pockets.

The water types are predominated with Ca-HCO_3 types with Ca and HCO3 as the principal contributing ions in the groundwater quality (Fig 2.7).

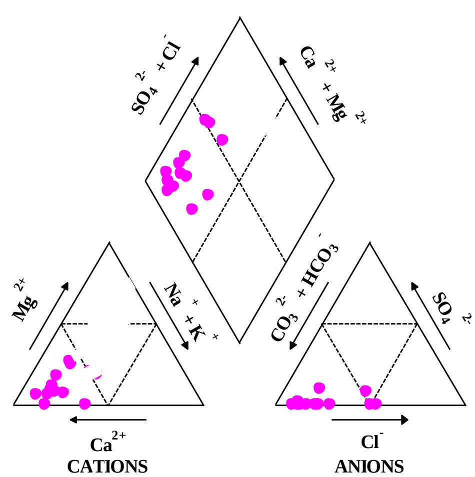


Figure 2.7: The Piper trilinear diagram depicting the groundwater quality in Banspal block, Keonjhar district.

Table 2.1: Ground water quality at various locations in Banspal block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	F
Talakainsari	8	350	191	148	103	51	5	6.2	9.2	0	112	65	0	0.17
Padakasada	7.5	120	63	46	52	16	1	3	5.1	0	56	10	0	0.10
Mereisahi	7.8	190	93	77	93	25	4	4.2	2.6	0	101	8	0	0.10
Dhanagadi	7.6	130	64	56	52	20	1	3.1	2.1	0	56	10	0	0.13
Kandhakala	7.6	110	55	46	46	16	1	3.6	1.6	0	51	8	0	0.09
Nayakot	7.5	170	85	56	41	16	4	9.1	3.5	0	45	30	0	0.08
Kadakala	7.8	270	134	112	129	45	0	8.5	3.1	0	141	8	0	0.16
Narsingpur	8.1	270	138	122	134	45	2	4.6	2	0	146	13	0	0.15
Sundra	7.8	90	45	31	41	8	2	5.1	3.2	0	45	5	0	0.10
Kusumita	8.1	330	161	133	155	37	10	12	2.8	0	169	13	3.2	0.45
Phuljhor	8.2	200	101	82	77	29	2	6	1	0	84	13	9	0.20
Bendih	8.32	400	205	155	96	42	12	12	4.03	6	105	61	15	0.13
Suakati	7.5	55	36	20	25	8	0	5.1	1.25	0	30	7	0	0.15
Min.:	***7.5***	***55***	***36***	***20***	***25***	***8***	***0***	***3***	***1***	***0***	***30***	***5***	***0***	***0.08***
Max.:	***8.32***	***400***	***205***	***155***	***155***	***51***	***12***	***12***	***9.2***	***6***	***169***	***65***	***15***	***0.45***
Average	***7.8***	***206.5***	***105.5***	***83.4***	***80.3***	***27.5***	***3.4***	***6.3***	***3.2***	***0.5***	***87.8***	***19.3***	***2.1***	***0.2***

2.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 2.2-2.3. The net dynamic groundwater available is 6589.6 Ham and the stage of groundwater development stands at 28.8%. Net resource available for future irrigation needs stands at 4647 Ham (Fig 2.8). The instorage/static groundwater resource component is 7065.6 Ham (Table 2.3). Thus, the total groundwater available in the block stands at 13670.3 Ham.

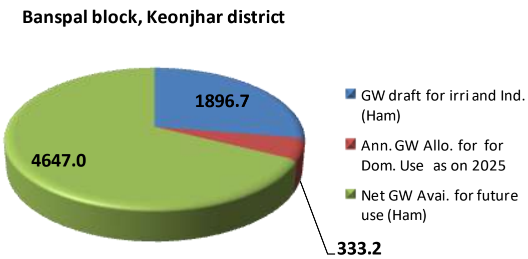


Figure 2.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Banspal block, Keonjhar district, Odisha.

Table 2.2: Salient information on annual dynamic groundwater resources, Banspal block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	6589.6
2. Irrigation draft (Ham)	1551.9
3. Industrial draft (Ham)	57.4
4. Domestic draft (Ham)	287.4
5. Total draft (Ham)	1896.7
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	333.2
7. Net groundwater available for future use (Ham)	4647.0
8. Stage of groundwater extraction (%)	28.8

Table 2.3: Total groundwater resoure available in the Banspal block, Keonjhar district, Odisha.

Sl No.	***Category of groundwater resource***	***Resource (Ham)***
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	6589.6
2	In-storage groundwater resource (Ham) of 1st Aquifer System	7065.6
3	In-storage groundwater resource (Ham) of 2nd Aquifer System	15.1
	Block total	***13670.3***

2.9 Aquifer management plan

The existing stage of groundwater development of 28.8% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction

structures as estimated in Table 2.4 (465 bore wells/dug-cum-bore wells and 3956 dug wells) are required to be constructed to develop the available additional resource of 4647 Ham. It can help in creating additional irrigation potential for 3600 Ha (Table 2.5).

Around 700 km^2 area in the block (out of total 1115 km^2) showed post-monsoon depth to water levels >5.0 m bgl (Plate 2.15; Table 2.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 84.05 MCM of water (Table 2.7) can be recharged by the help additional 168- percolations ponds, 84-subsurface dykes, 84-nala/contour bunds and 168-check dams (Table 2.8) with a total cost of 54.63 crores (Table 2.9).

Table 2.4: Number of additional feasible groundwater abstraction structures in Banspal block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	6589.6
2	Stage of GW deve. (%)	28.8
3	Present GW draft (Ham)	1896.7
4	Ground water draft at 60% stage of deve. (Ham)	3953.7
5	Addi. water to be deve. (Ham)	2057
6	Addi. no of BW/ dug-cum-bore well feasible in the block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	465
7	Addi.no. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	3956

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 2.5: Irrigation potential likely to be created in Banspal block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	28.8
2	Surplus GW avai. for 60% stage of deve. (Ham)	2057
3	Irri, Pot. likely to be created for Paddy (Ha)	1028.5
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	1542.8
5	Irri. Pot. likely to be created for veg. (Ha)	1028.5
6	Proj. area to be Irri. (ha)	3599.8

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 2.6: Areas in Banspal block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Banspal	512.49	187.91	700.40

Table 2.7: Eastimation of volume of water required for artificial recharge to groundwater in Banspal block, Keonjhar district.

Name of block	Total area of the block (km^2)	Area identified for artificial recharge (km^2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to reharge (MCM)
Banspal	1115.00	700.40	7	4	2801.60	84.05

Table 2.8: Number of feasible structures in Banspal block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (MCM)	No of different freasible structures			
		Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
Banspal	84.05	168	84	84	168

Table 2.9: Estimation of cost of artificial recharge structures in Banspal block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Banspal	33.62	8.40	4.20	8.40	54.63

PLATE – 2.1

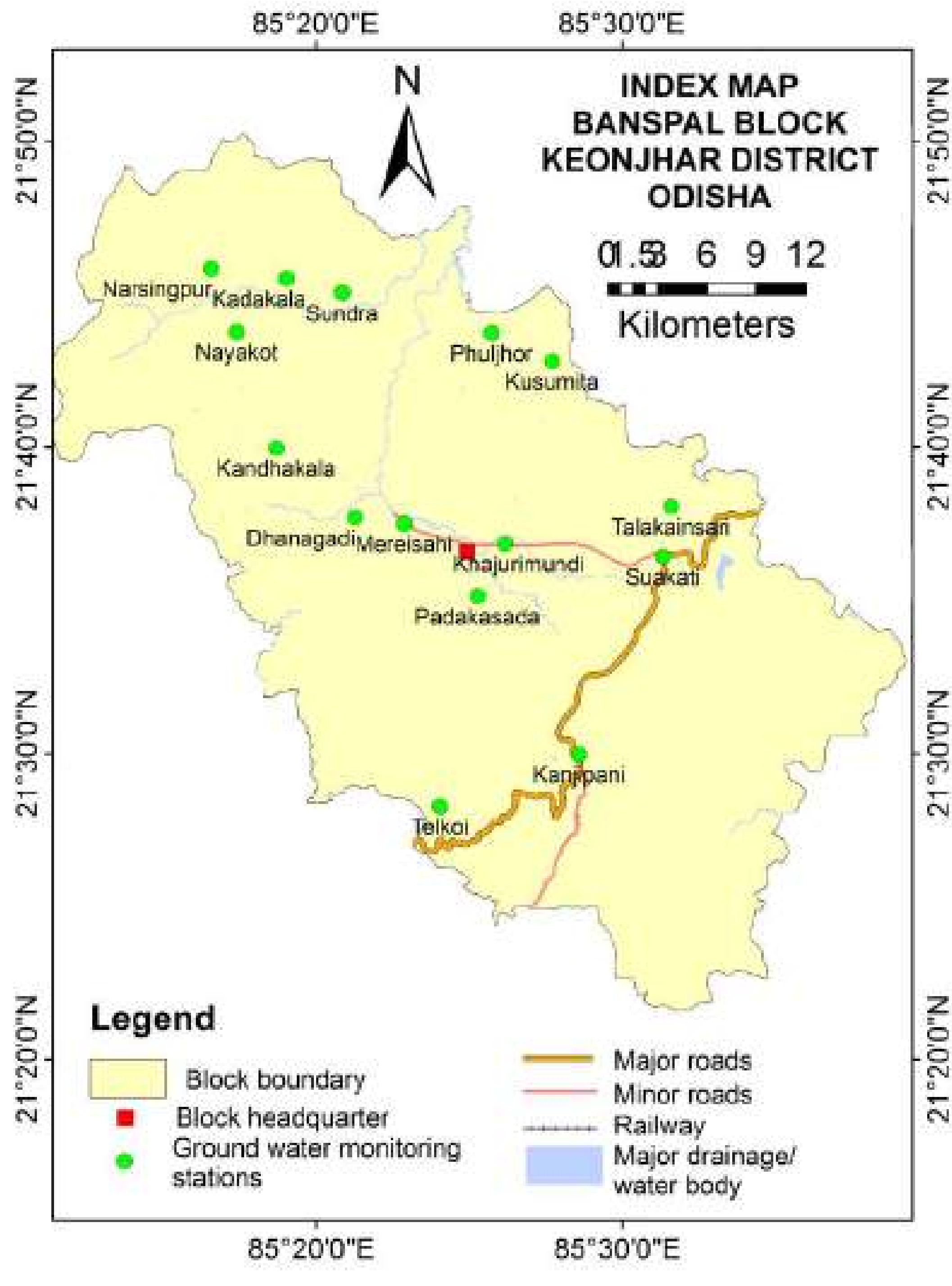
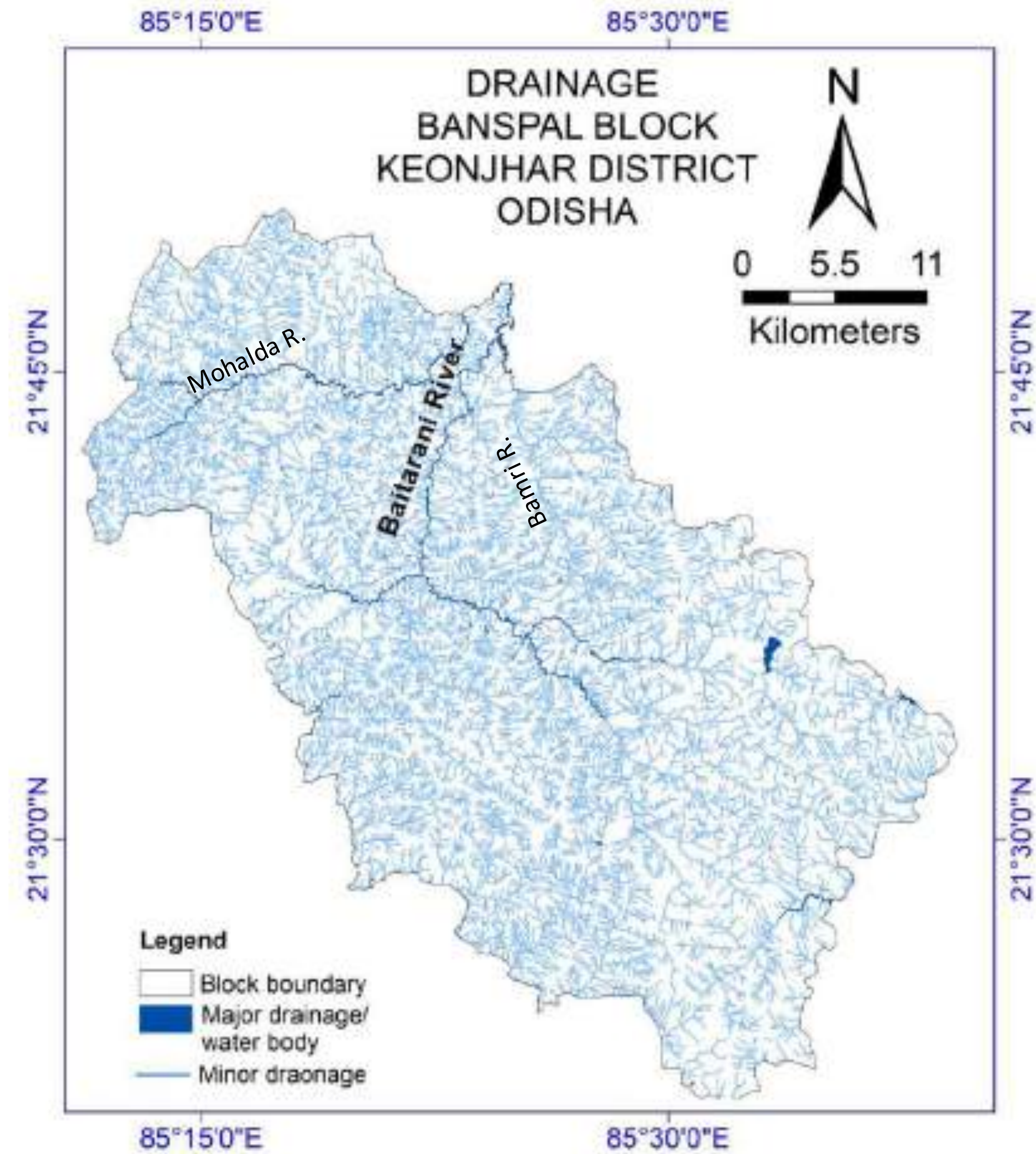

85°20'0"E
85°30'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
N
INDEX MAP
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
0 1.5 3 6 9 12
Kilometers
Narsingpur
Kadakala
Sundra
Nayakot
Phuljhor
Kusumita
Kandhakala
Dhanagadi
Mereisahi
Khajurimundi
Talakainsari
Suakati
Padakasada
Kanjipani
Telkoi
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body

PLATE – 2.2



85°15'0"E
85°30'0"E
DRAINAGE
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5.5 11
Kilometers
21°45'0"N
21°30'0"N
Mohalda R.
Baitarani River
Bamri R.
Legend
Block boundary
Major drainage/ water body
Minor draonage

PLATE – 2.3

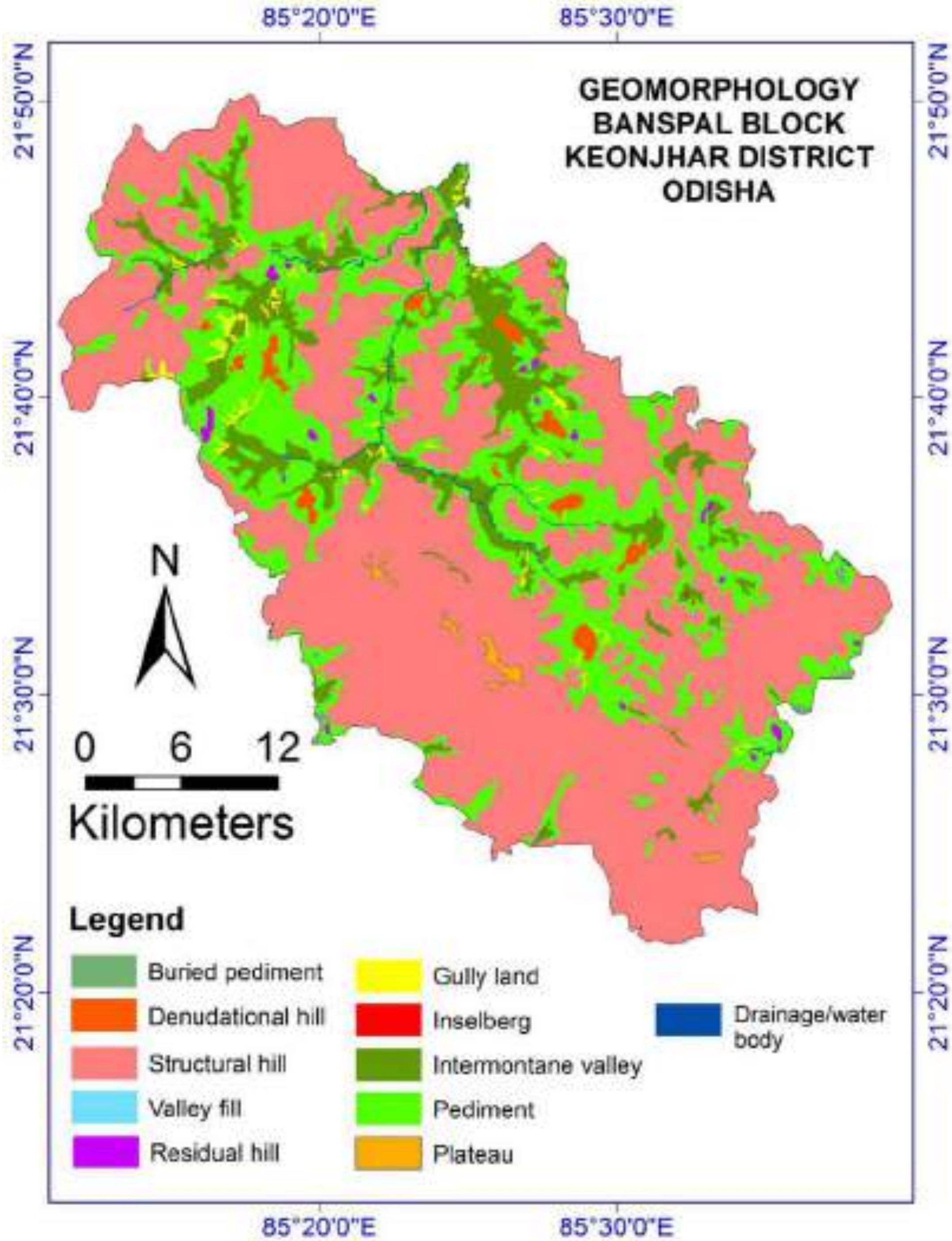

85°20'0"E
85°30'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
GEOMORPHOLOGY
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
Legend
Buried pediment
Denudational hill
Structural hill
Valley fill
Residual hill
Gully land
Inselberg
Intermontane valley
Pediment
Plateau
Drainage/water body

PLATE – 2.4

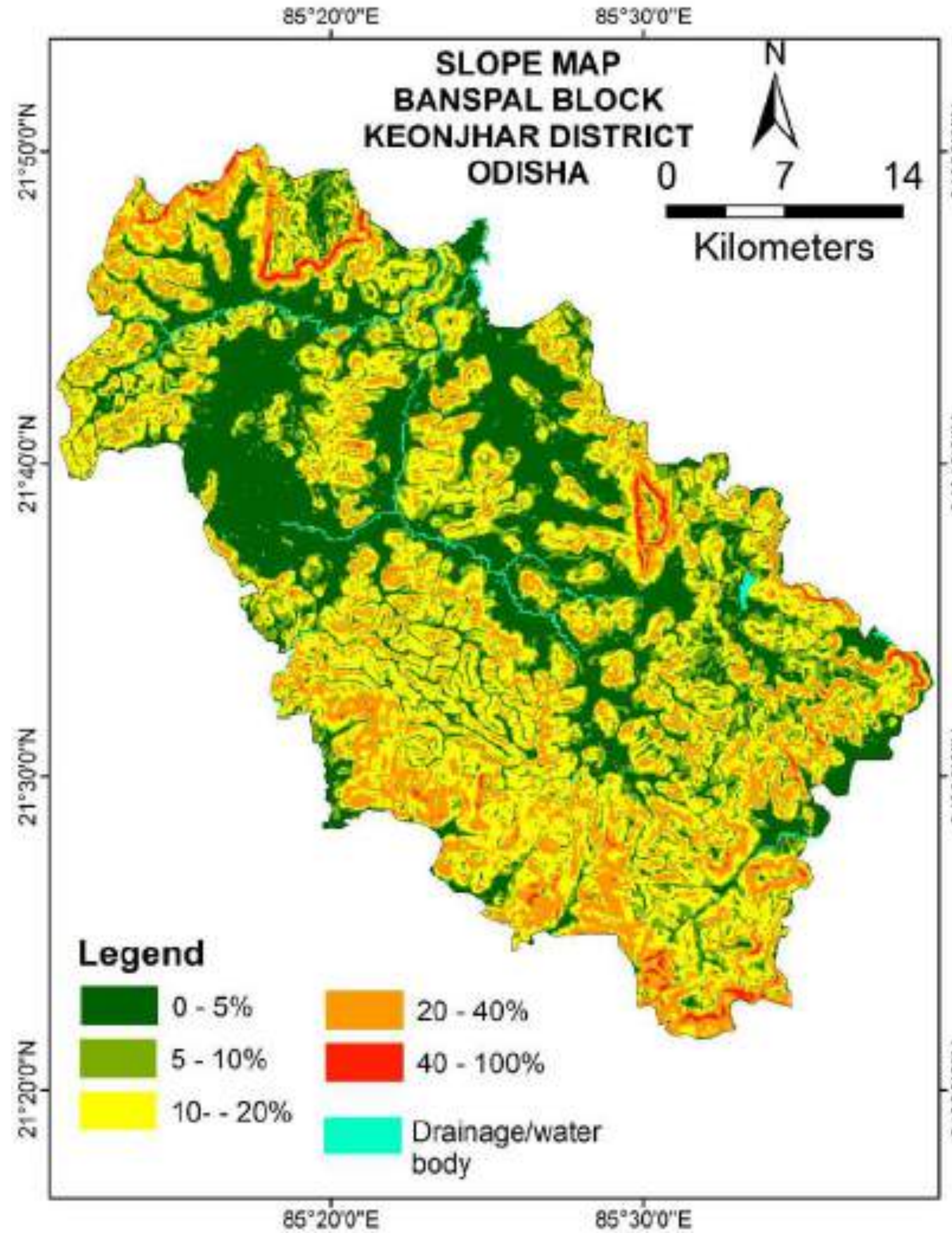

SLOPE MAP
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 7 14
Kilometers
85°20'0"E
85°30'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Legend
0 - 5%
5 - 10%
10- - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 2.5

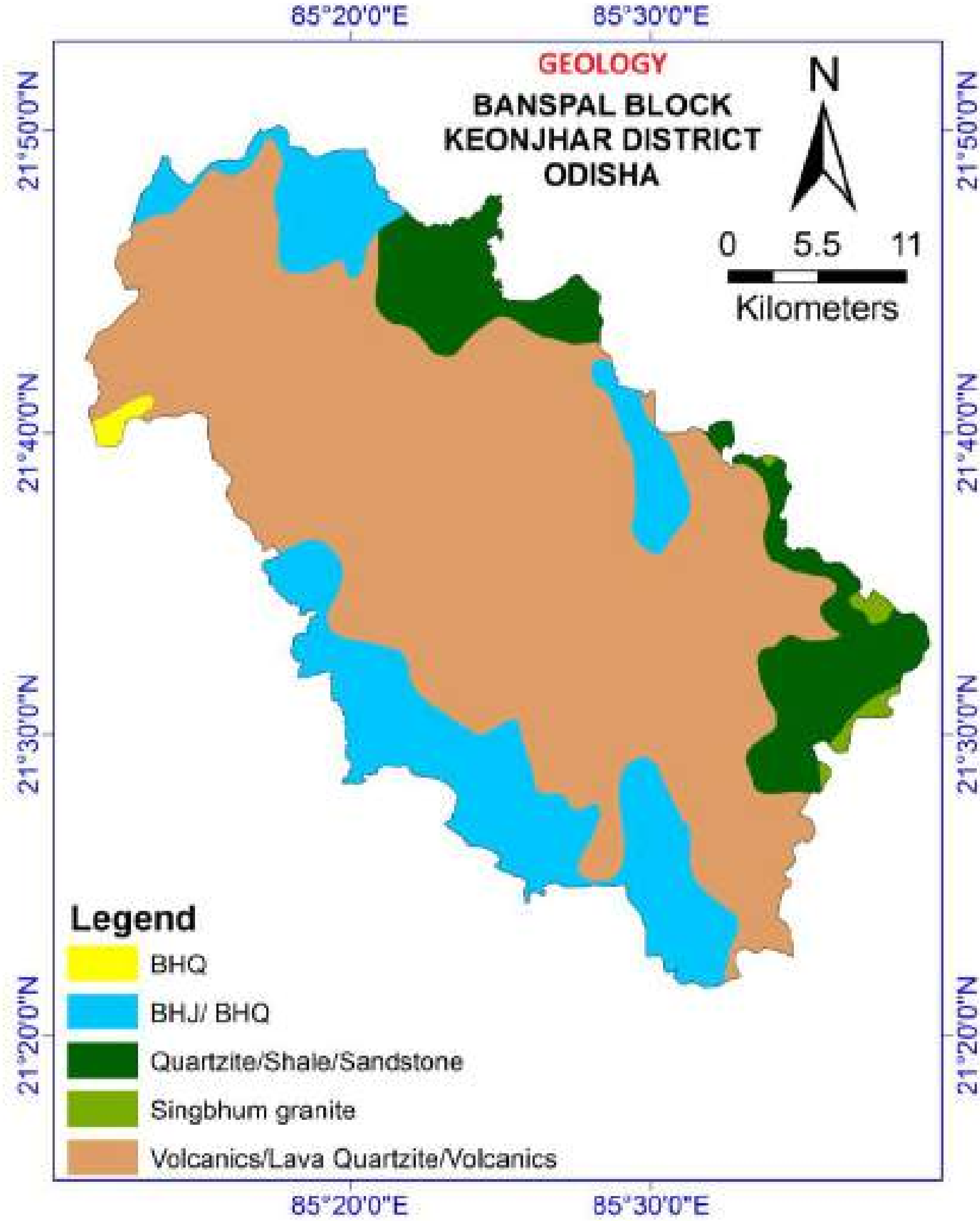
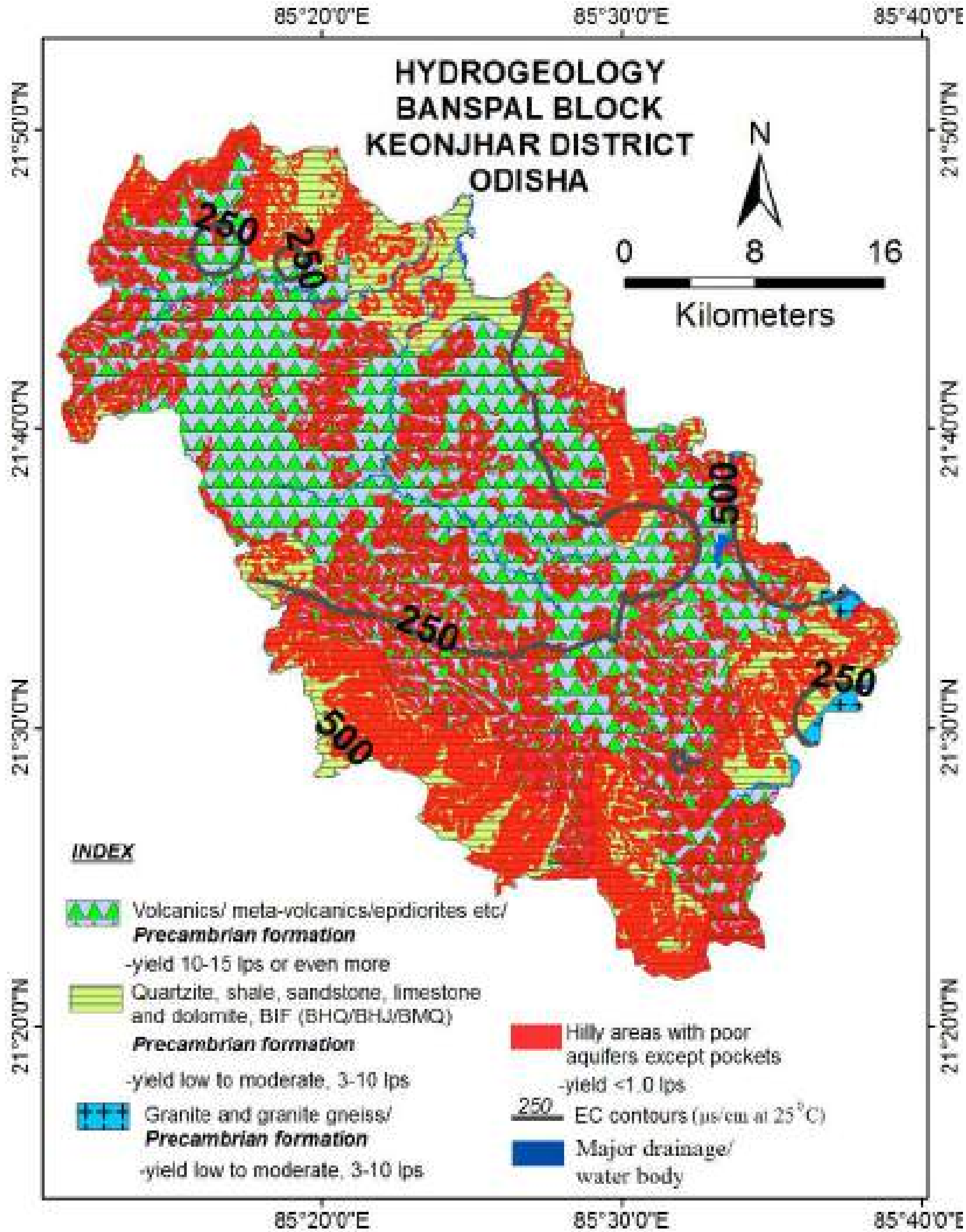
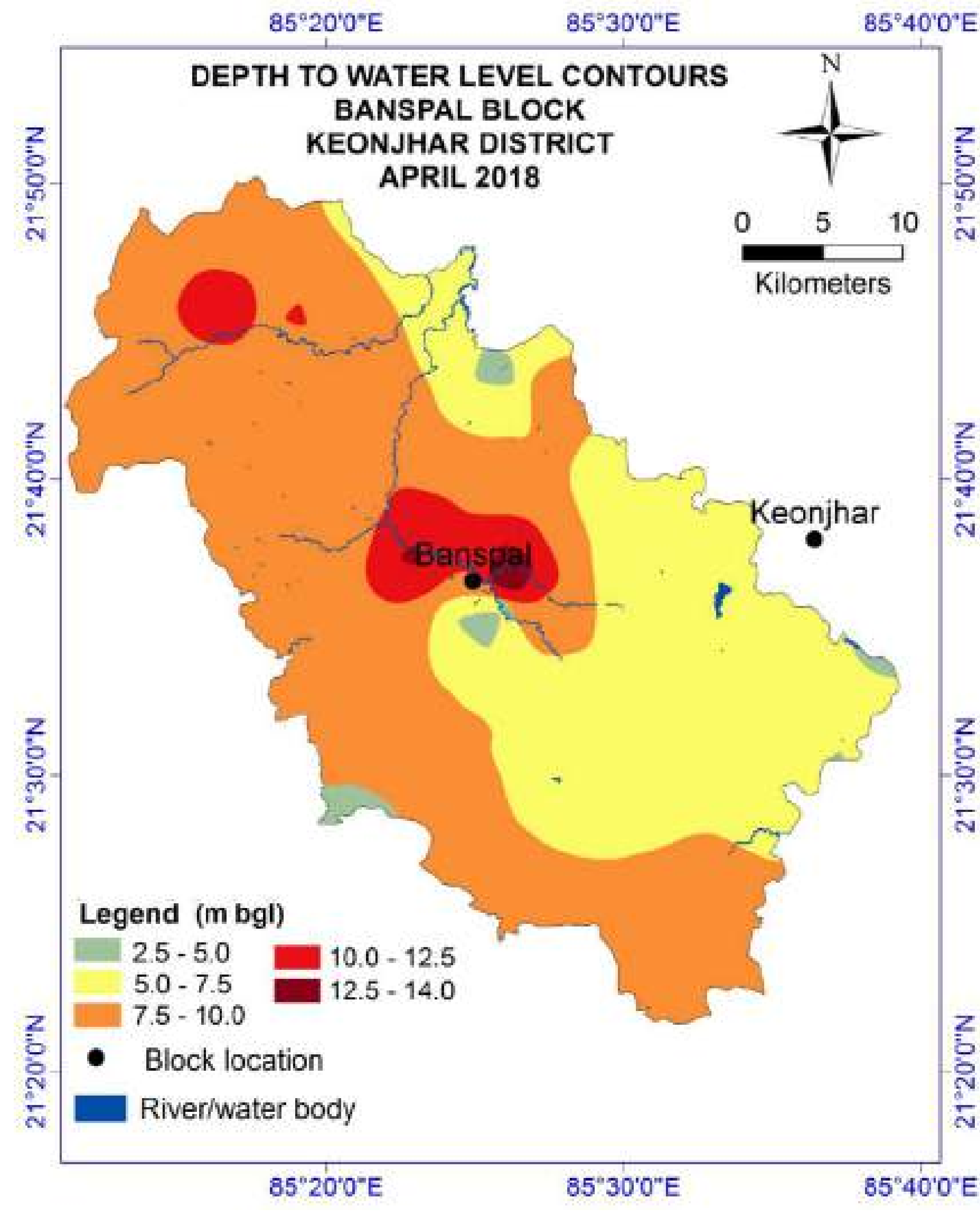

85°20'0"E
85°30'0"E
GEOLOGY
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5.5
11
Kilometers
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Legend
BHQ
BHJ/ BHQ
Quartzite/Shale/Sandstone
Singbhum granite
Volcanics/Lava Quartzite/Volcanics

PLATE – 2.6



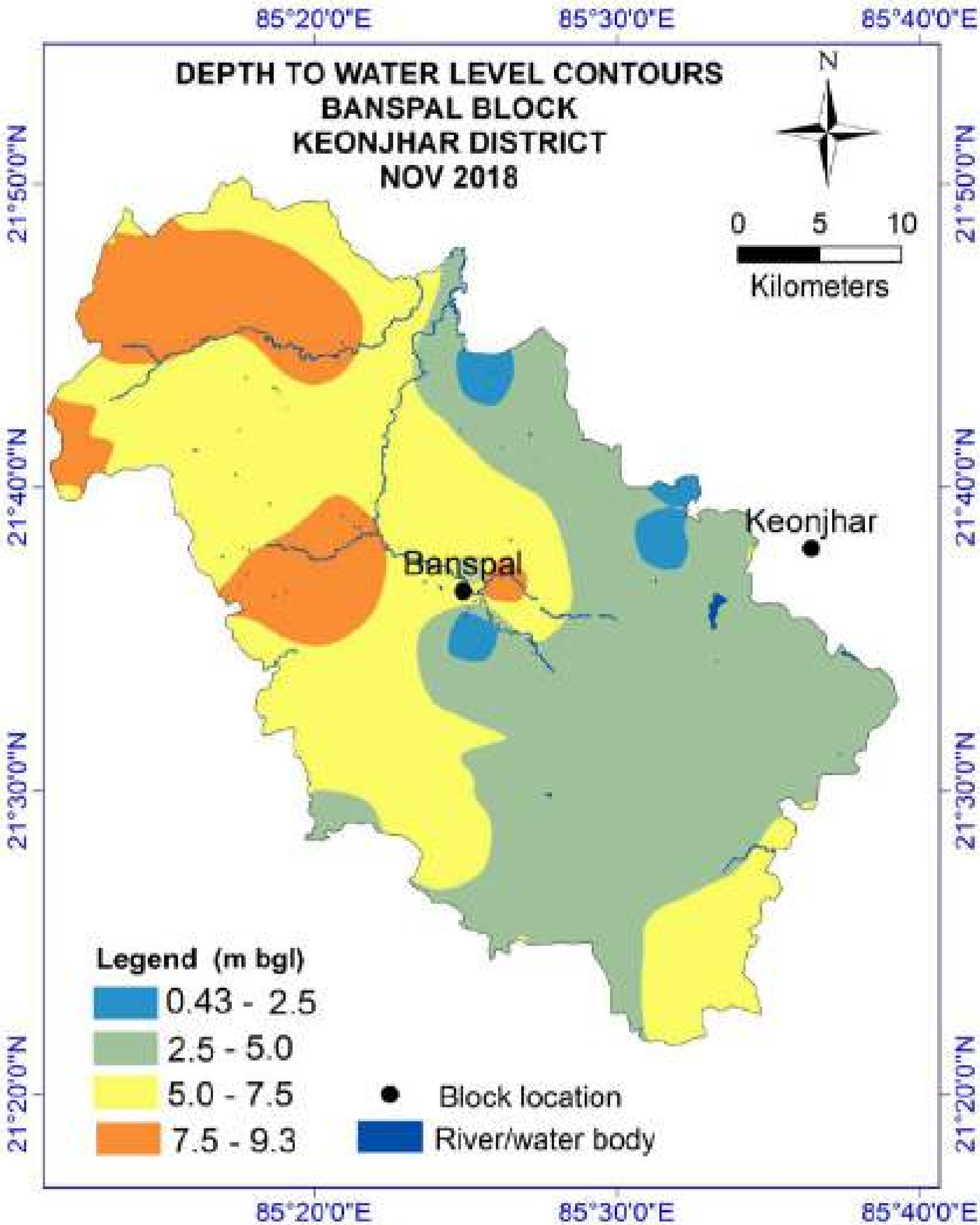
HYDROGEOLOGY
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
8
16
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
250
500
INDEX
Volcanics/ meta-volcanics/epidiorites etc/
Precambrian formation
-yield 10-15 lps or even more
Quartzite, shale, sandstone, limestone and dolomite, BIF (BHQ/BHJ/BMQ)
Precambrian formation
-yield low to moderate, 3-10 lps
Granite and granite gneiss/
Precambrian formation
-yield low to moderate, 3-10 lps
Hilly areas with poor aquifers except pockets
-yield <1.0 lps
250 EC contours (μs/cm at 25°C)
Major drainage/ water body

PLATE – 2.7



DEPTH TO WATER LEVEL CONTOURS
BANSPAL BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0 5 10
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Keonjhar
Banspal
Legend (m bgl)
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
12.5 - 14.0
Block location
River/water body

PLATE – 2.8



DEPTH TO WATER LEVEL CONTOURS
BANSPAL BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 5 10
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Keonjhar
Banspal
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
River/water body

PLATE – 2.9

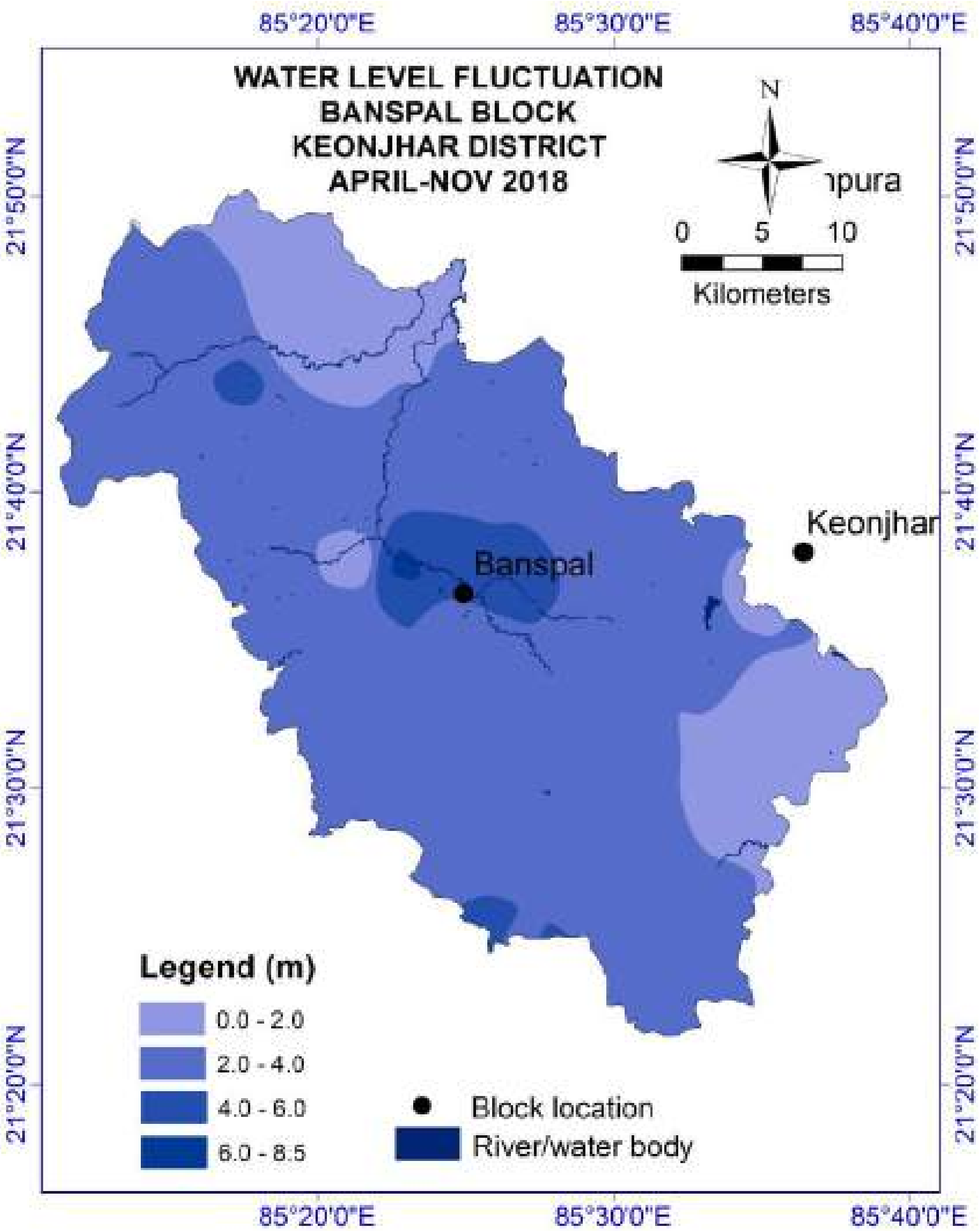

WATER LEVEL FLUCTUATION
BANSPAL BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
ıpura
0 5 10
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Keonjhar
Banspal
Legend (m)
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
6.0 - 8.5
Block location
River/water body

PLATE – 2.10

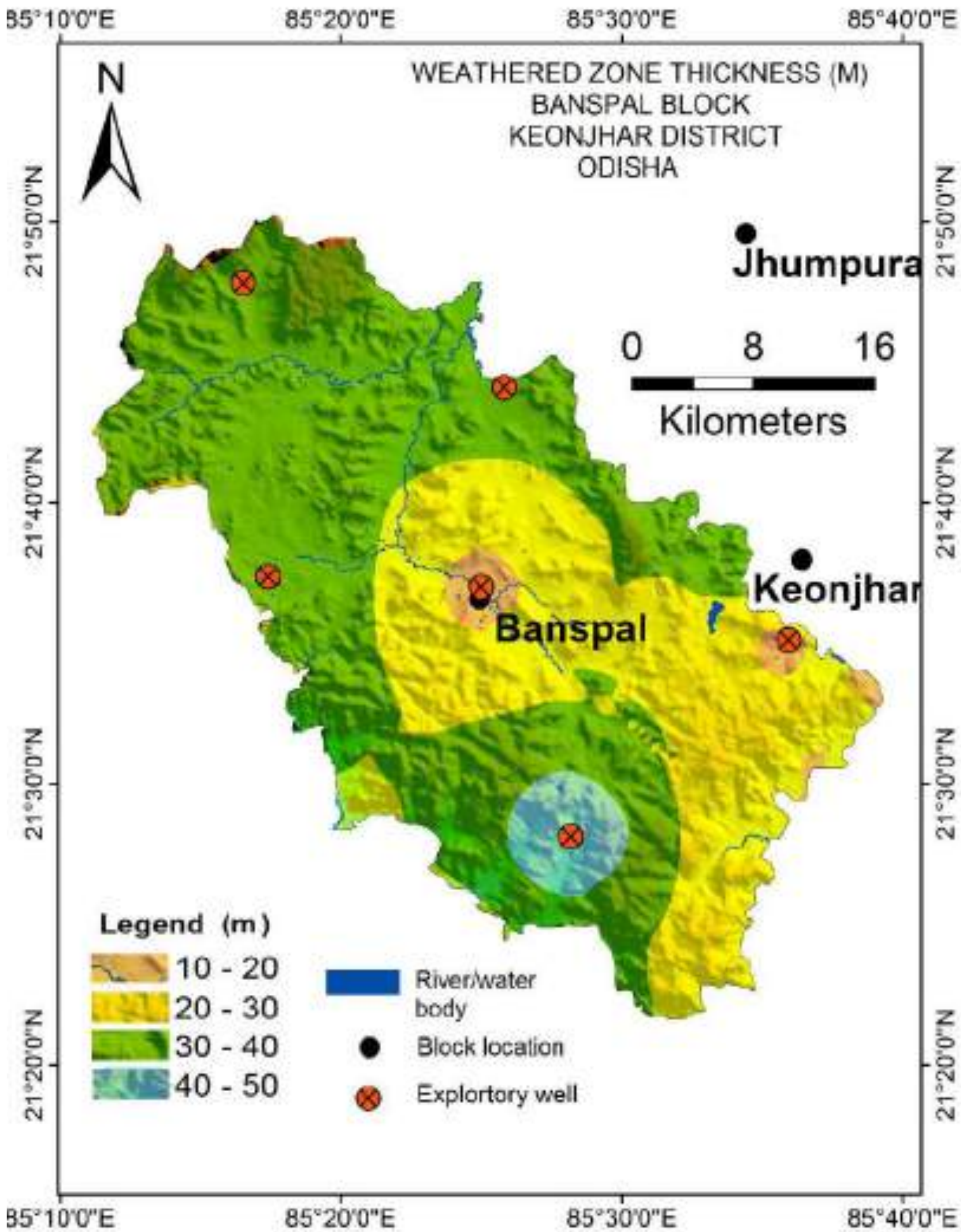

WEATHERED ZONE THICKNESS (M)
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
N
85°10'0"E
85°20'0"E
85°30'0"E
85°40'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Jhumpura
Keonjhar
Banspal
0 8 16
Kilometers
Legend (m)
10 - 20
20 - 30
30 - 40
40 - 50
River/water body
Block location
Explortory well

PLATE – 2.11

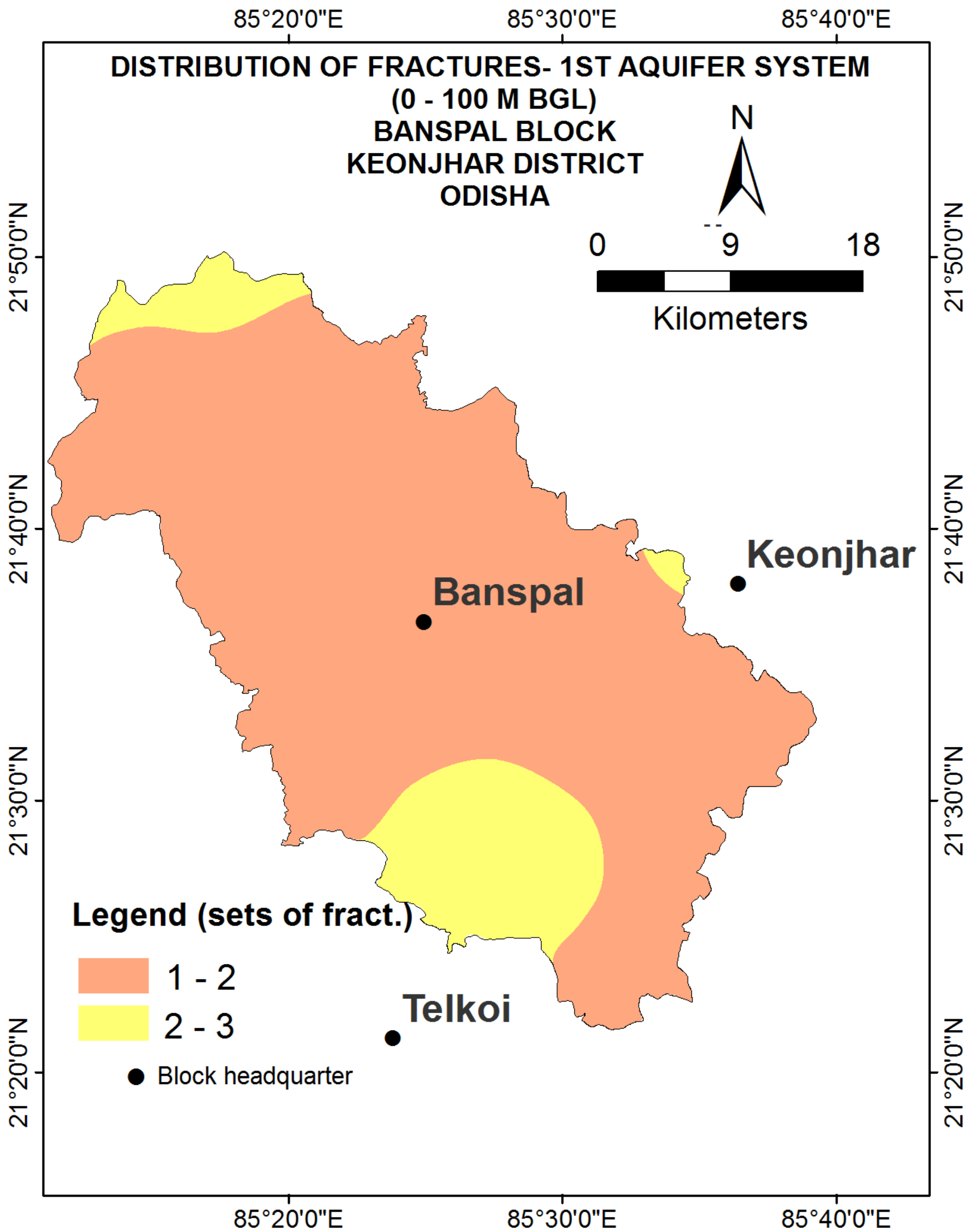

85°20'0"E
85°30'0"E
85°40'0"E
DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
9
18
Kilometers
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Keonjhar
Banspal
Telkoi
Legend (sets of fract.)
1 - 2
2 - 3
Block headquarter

PLATE – 2.12

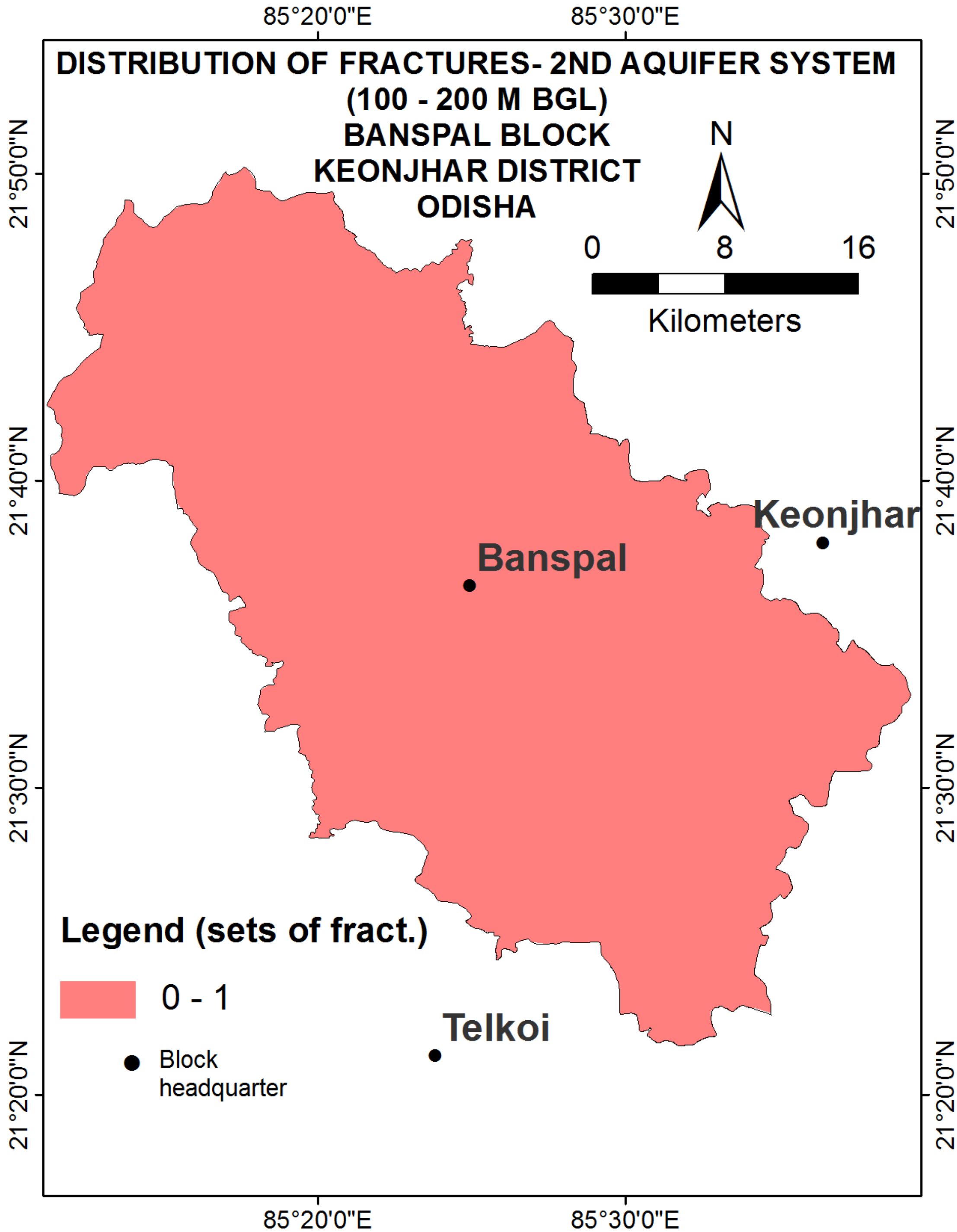

DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
8
16
Kilometers
Keonjhar
Banspal
Telkoi
Legend (sets of fract.)
0 - 1
Block headquarter
85°20'0"E
85°30'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N

PLATE – 2.13

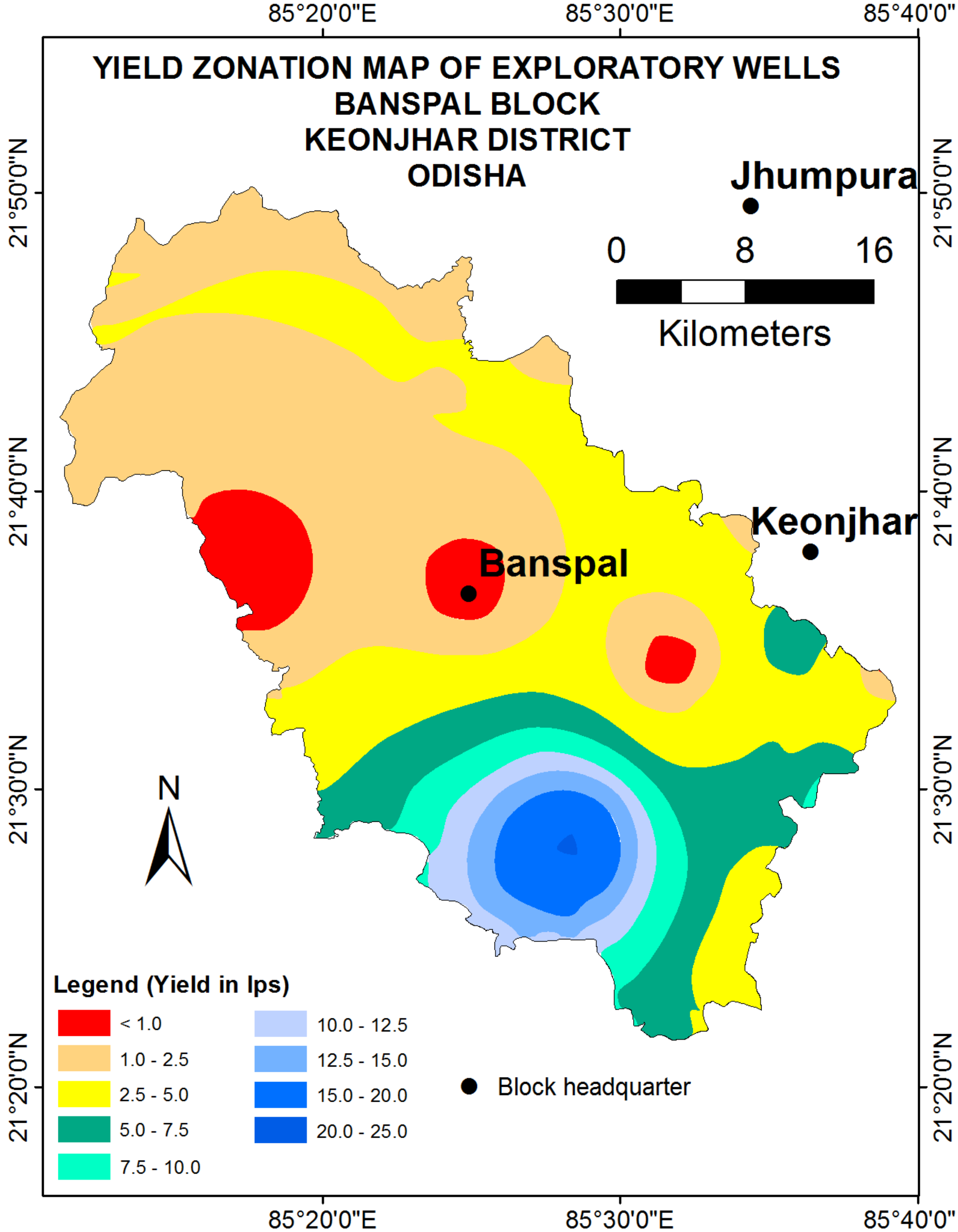

YIELD ZONATION MAP OF EXPLORATORY WELLS
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
85°20'0"E
85°30'0"E
85°40'0"
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Jhumpura
Keonjhar
Banspal
0 8 16
Kilometers
N
Legend (Yield in lps)
< 1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
12.5 - 15.0
15.0 - 20.0
20.0 - 25.0
Block headquarter

PLATE – 2.14

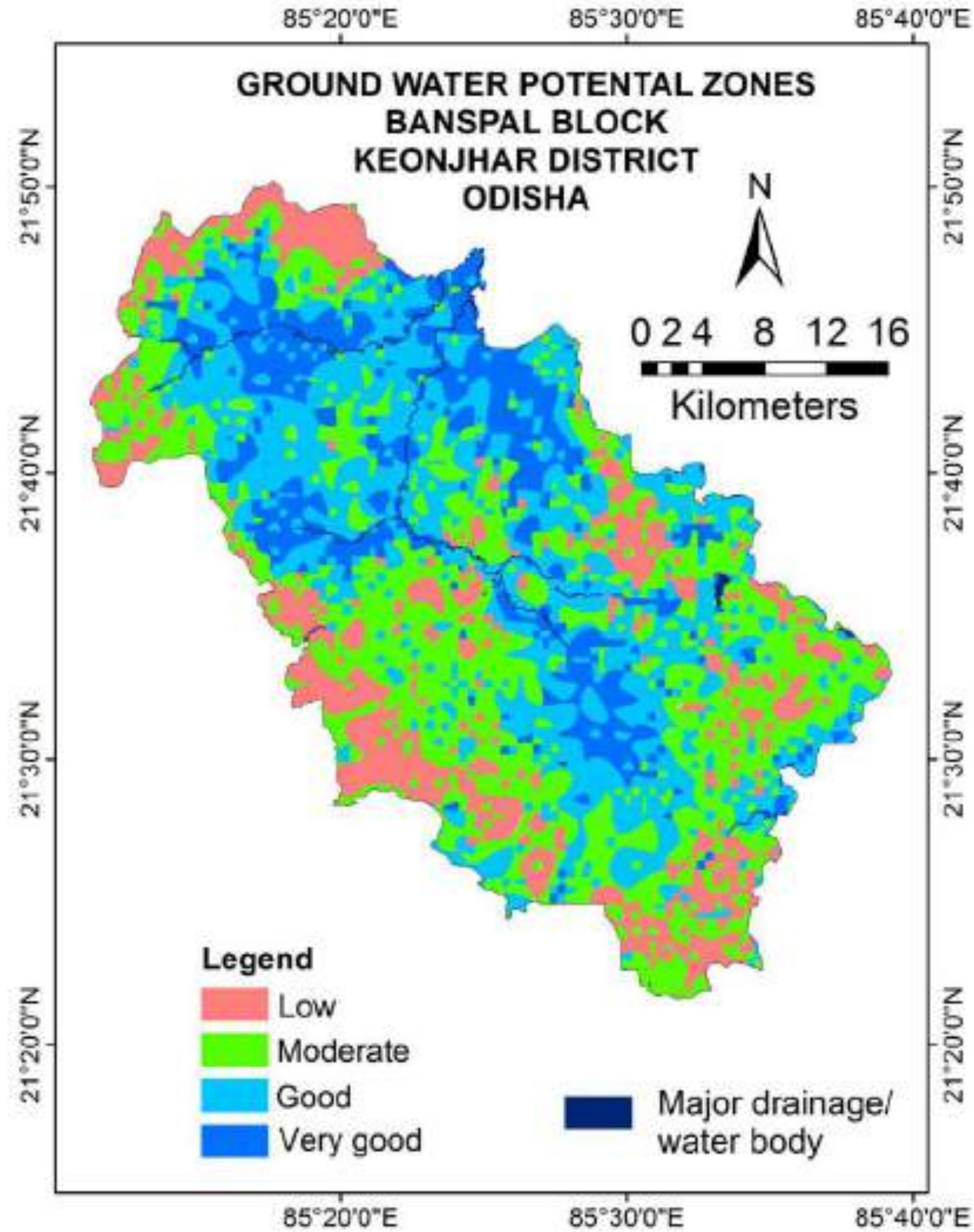
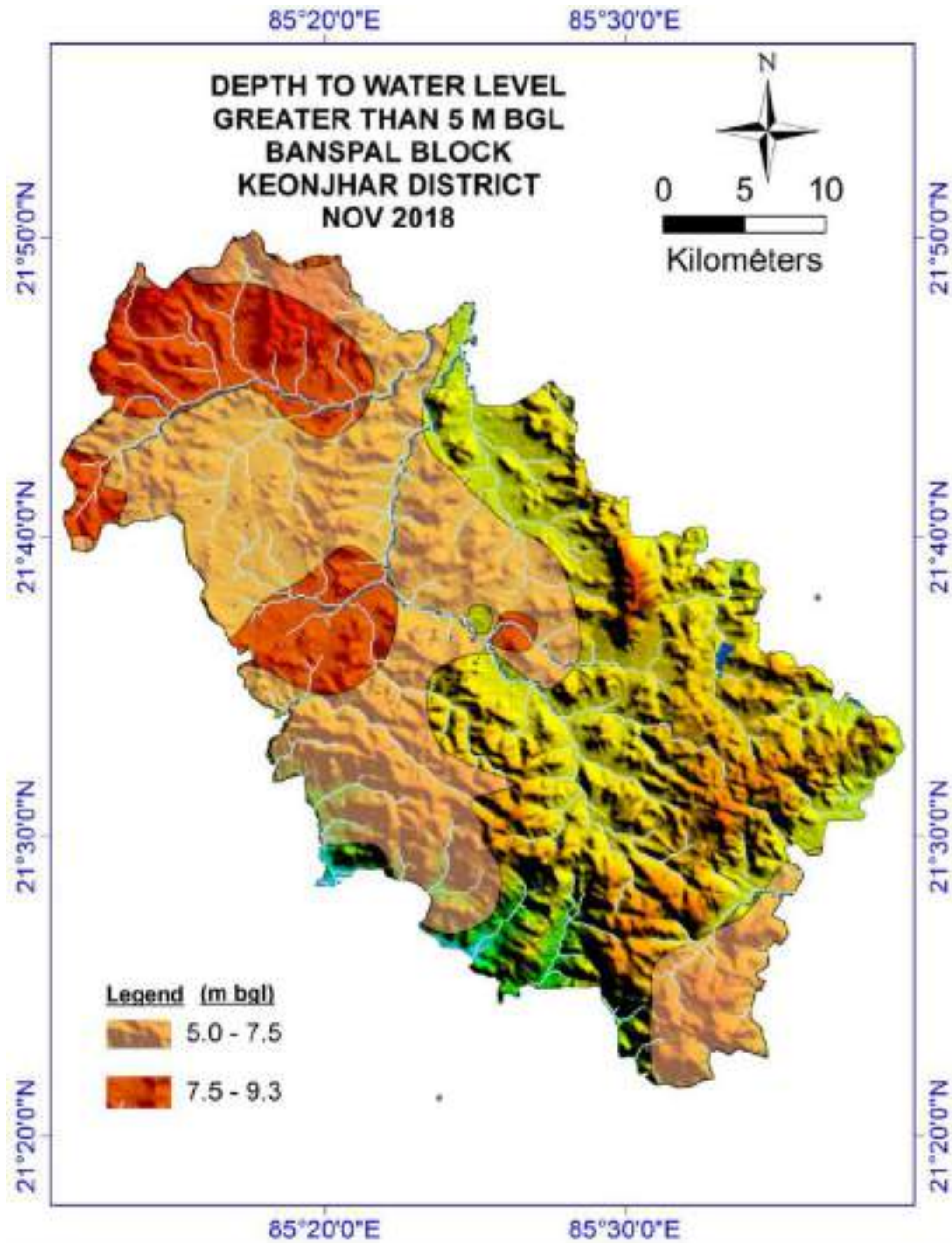

GROUND WATER POTENTAL ZONES
BANSPAL BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 2 4 8 12 16
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Legend
Low
Moderate
Good
Very good
Major drainage/
water body

PLATE – 2.15


85°20'0"E
85°30'0"E
DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
BANSPAL BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 5 10
Kilometers
21°50'0"N
21°40'0"N
21°30'0"N
21°20'0"N
Legend (m bgl)
5.0 - 7.5
7.5 - 9.3

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

3.0 CHAMPUA BLOCK

3.1 Salient information

Location, area and demography

Location (Plate 3.1)	85^0 32' - 85^0 50' E longitude 21^0 45' – 22^0 06'' N latitude
Area	289 sq. km
No. of Gram Panchayats	23
No. of villages	150
Population (Census 2011)	1,15,321 (rural) Rural: 1,04,927 Urban: 10,394
Literacy	61.37%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1448.7 mm
Monsoon normal rainfall	1131.2 mm (78% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	30955 Ha
Net sown area (2)	21714 Ha
Area sown more than once (1-2)	9241 Ha
Cropping intensity (%)	142.6 Ha
Area under forest	5862 Ha
Area under wasteland	2439 Ha
Area under other uses	7367 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	7963 Ha *Kharif:* 4308 Ha *Rabi:* 3655 Ha

3.2 Drainage, geomorphology and soil types

The river Baitarani is master drainage and flows north-easterly to south-easterly along the northern and the eastern borders of the block. The Ardei and Nermeda are its two major tributaries that flow easterly to northeasterly to join the Baitarani on its right bank. The drainage pattern is dendritic to sub-trellis in nature. There are several small water bodies in the block (Plate 3.2).

The block is mostly covered by the hydro-geomorphic units like buried pediments, pediments and valley fills, accounting for about 95% of the block area (Fig 3.1 and Plate 3.3). These units are considered as potential from as far as groundwater occurrenec is concerned. There are several linear basic (dolerite) dykes in the block that run in two prominent directions; NE-SW and NW-SE. The valley fills cover the linear and narrow river valleys. Most of the block area possesses land surface slope of <5% (Fig 3.2), except the minor patches in the northern half in the denudational hills and the linear dykes (Plate 3.4). The soil types include the red sandy soil (alfisol) and red gravelly soils (ultisol).

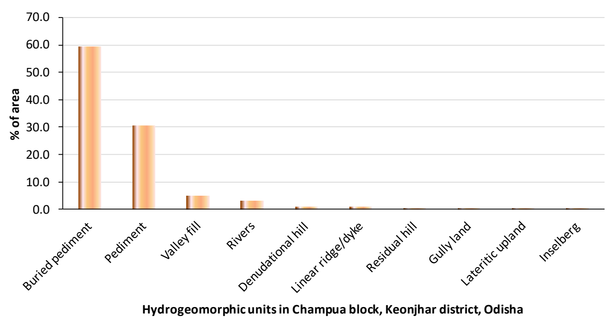


Figure 3.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Champua block.

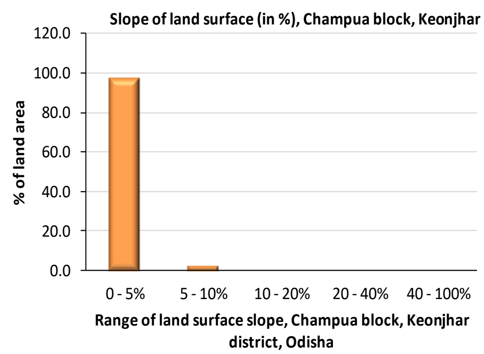


Figure 3.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Champua block, Keonjhar district.

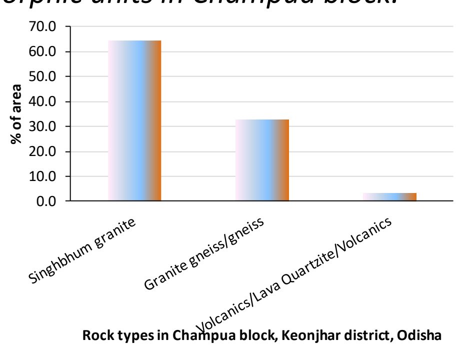


Figure 3.3: Percentage (%) of Champua block area (Keonjhar dist.) covered by various rock types.

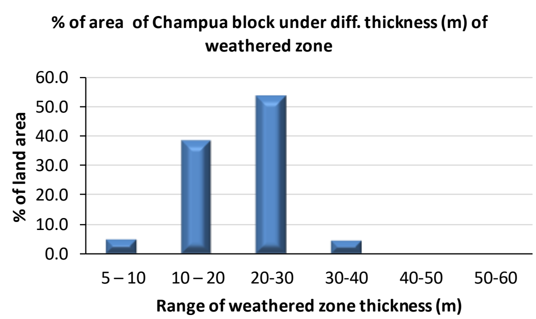


Figure 3.4: Bar diagram depicting the percentage (%) area of Champua block, Keonjhar district falling under different weathered zone thickness (m) ranges.

3.3 Geology

The block is occupied the Signhbhum Granites (central and eastern parts) and schists / gneisses (western parts) kind of rocks which cover ~64% and ~33% respectively. The rest 3% area (in extreme west) is occupied by volcanics suite of rocks (Fig 3.3 and Plate 3.5).

3.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories. The generalized hydrogeological map of the block is presented in Plate 3.6. The Singhbhum Granites posses low to moderate yield potential varying between 3-10 lps, whereas the schists/gneisses give low yield between 1-5 lps. The volcanics yield good amount of water between 10-15 lps.

The water levels in pre-monsoon (year 2018) largely varied between 1.0-10 m bgl with a significant part falling in the range of 7.5-10 m bgl (Plate 3.7). During the post-monsson period, however, almost the entire block (except smaller patches in west) depicted water levels <5.0 m bgl, indicating good recharge from rainfall (Plate 3.8). The annual fluctuations in the water levels remained between <2– 6 m (Plate 3.9), with major part of the block depicting the water level fluctuation range of 2-4 m.

3.5 Aquifer geometry and characters

The thickness of the weathered regolith overlying the fresh hard rock in block varies between 5– 50 m (Plate 3.10). As depicted in Fig 3.4, 38% and ~53% of the block areas possess weathered zones in the thickness ranges of 10-20 m and 20-30 m respectively, which gives moderate prospective of groundwater availability. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 3.5a-b. The weathered zone thickness in the block increases towards north and west.

In the block, maximum up to 5 sets of fracture zones are encountered in the bore wells within the depth of 100 m bgl (1^{st} aquifer system). In major parts, 2-3 sets of fractures are found (Plate 3.11). Number of fractures increase towards west. Beyond this depth in the 2^{nd} aquifer system, the fractures are depleted and maximum of 3 sets of fracture zones are encountered during drilling (Plate 3.12). Though, a bore well at Champua yields ~12.5 lps of water, the general yield of bore wells in the block range between 1.0-2.5 lps Plate 3.13).

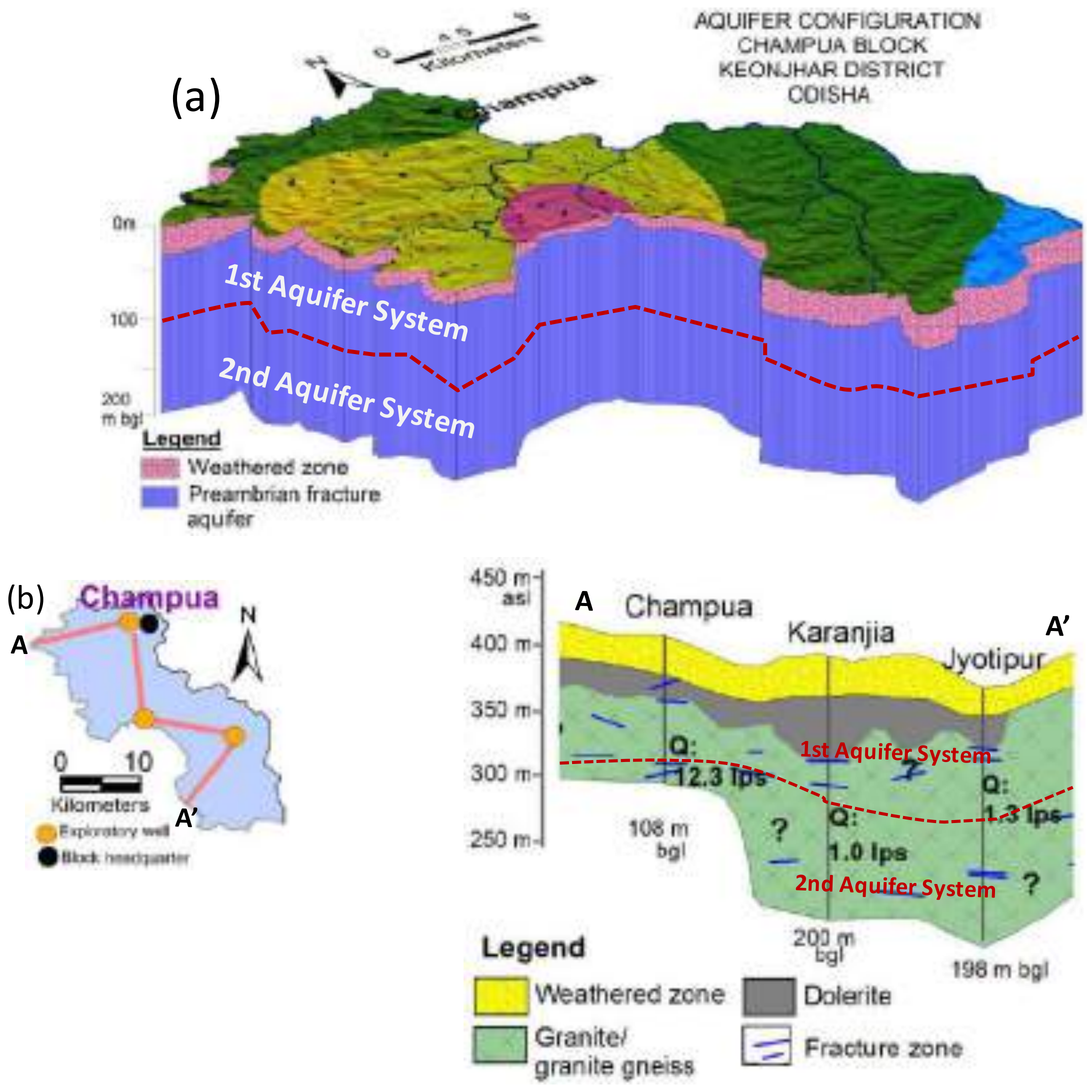


Figure 3.5: (a) 3D aquifer disposition in Champua block, Keonjhar district. (b) 2D hydrogeological transect (including the location map) depicting the aquifer disposition in the block.

3.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 3.14). The good to very good groundwater potential zones are located in the western, south-central and southern parts of the block (Fig 3.6).

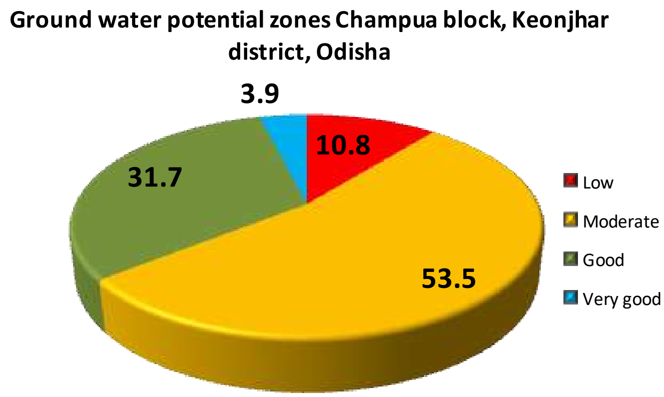


Figure 3.6: Pie diagram depicting the perentage (%) of Champua block, Keonjhar district, Odisha, falling under different groundwater potential zones.

3.7 Ground water quality

Ground water in the block is alkaline in nature (Table 3.1) and pH often reaches 8.0. The water is moderately hard to very hard. The mineralization is low to moderate with TDS in the range of 53-535 mg/L (ave.: 229 mg/L). Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly Ca-HCO_3 types with Ca^{2+} and HCO_3^- as the principal contributing ions in the groundwater quality (Fig 3.7).

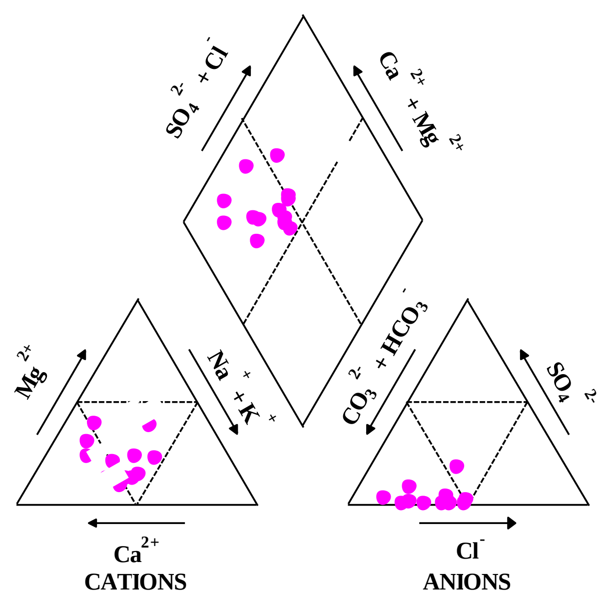


Figure 3.7: The Piper trilinear diagram depicting the groundwater quality in Champua block, Keonjhar district.

Table 3.1: Ground water quality at various locations in Champua block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Unchbali	8.3	990	535.2	260	319	61	26	81.14	44.25	0	349	148	3.8	0.35
Kasipal	7.8	270	137.8	77	72	25	4	23.23	1.86	0	79	45	0	0.13
Tolakananda	8.24	470	239.8	194	221	55	13	12.74	12	0	242	23	5.48	0.24
Kanchanpur	8.3	750	419.93	214	252	67	11	56.68	28	0	275	113	9.5	0.50
Kalikaprasad	8.24	830	405.73	260	335	41	38	68.73	3.05	0	365	73	3.1	0.33
Rimuli	7.8	240	127.3	66	77	20	4	22.9	2.24	0	84	33	4	0.12
Kodagadia	8.3	480	253.66	148	160	37	13	38.97	4.43	0	174	75	0	0.15
Jodipada	8	190	92.19	82	82	18	9	5.64	0.45	0	90	15	0	0.09
Rangamatia	8.3	110	54.21	46	36	12	4	3.1	1	0	39	15	0	0.23
Champua	7.82	505	283.4	185	191	52	13	34.9	2	0	233	43	22	0.26
Khuntapada	7.55	80	52.84	30	25	10	1	8.1	0.74	0	30	17	1	0.18
Nuagaon	7.68	230	142.9	100	59	22	11	10.1	8.2	0	72	34	21.6	0.40
Parsora	8.1	400	227.11	140	152	46	6	28.32	3.79	0	185	50	0.5	0.26
Min.:	**7.55**	**80**	**52.84**	**30**	**25**	**10**	**1**	**3.1**	**0.45**	**0**	**30**	**15**	**0**	**0.09**
Max.:	**8.3**	**990**	**535.2**	**260**	**335**	**67**	**38**	**81.14**	**44.25**	**0**	**365**	**148**	**22**	**0.5**
Average	**8.0**	**426.5**	**228.6**	**138.6**	**152.4**	**35.8**	**11.8**	**30.4**	**8.6**	**0.0**	**170.5**	**52.6**	**5.5**	**0.2**

3.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 3.2-3.3. The net dynamic groundwater available is 5128.9 Ham and the stage of groundwater development stands at 44.1%. Net resource available for future irrigation needs stands at 2821 Ham (Fig 3.8). The in-storage/static groundwater resource component of 5187.2 Ham (Table 3.3) comes from the 1st aquifer system within 100 m bgl. The total groundwater available in the block stands at 10323.5 Ham.

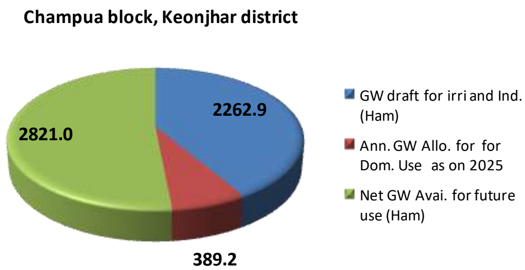


Figure 3.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Champua block, Keonjhar district, Odisha.

Table 3.2: Salient information on annual dynamic groundwater resources, Champua block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resource available (Ham)	5128.9
2. Irrigation draft (Ham)	1912.2
3. Industrial draft (Ham)	6.4
4. Domestic draft (Ham)	344.3
5. Total draft (Ham)	2262.9
6. Annual groundwater resource (Ham) allocation for domestic use up to 2025	389.2
7. Net groundwater available for future use (Ham)	2821.0
8. Stage of groundwater extraction (%)	44.1

Table 3.3: Total groundwater resoure available in the Champua block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	5128.9
2	Static/In-storage groundwater resource (Ham) of 1st Aquifer System	5187.2
3	Static/In-storage groundwater resource (Ham) of 2nd Aquifer System	7.4
	Block total	**10323.5**

3.9 Aquifer management plan

The existing stage of groundwater development of 41.1% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction

structures as estimated in Table 3.4 (184 bore wells/dug-cum-bore wells and 1566 dug wells) are required to be constructed to develop the available additional resource of 2821 Ham. It can help in creating additional irrigation potential for 1425.2 Ha (Table 3.5).

Only around 27 km^2 area in the block (out of total 289 km^2) showed post-monsoon depth to water levels >5.0 m bgl (Plate 3.15; Table 3.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 2.85 MCM of water (Table 3.7) can be recharged by the help additional 6- percolations ponds, 3-subsurface dykes, 3-nala/contour bunds and 6-check dams (Table 3.8) with a total cost of 1.85 crores (Table 3.9).

Table 3.4: Number of additional feasible groundwater abstraction structures in Champua block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	5128.9
2	Stage of GW deve. (%)	44.1
3	Present GW draft (Ham)	2262.9
4	Ground water draft at 60% stage of deve. (Ham)	3077.3
5	Addi. water to be deve. (Ham)	814.4
6	Addi. no of BW/ dug-cum-bore wells feasible in Each block (assuming unit draft as 3.21/ ham/struct./ yr) using 50% of surplus	184
7	Addi. no. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	1566

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 3.5: Irrigation potential likely to be created in Champua block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	44.1
2	Surplus GW avai. for 60% stage of deve. (Ham)	814.4
3	Irri, Pot. likely to be created for Paddy (Ha)	407.2
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	610.8
5	Irri. Pot. likely to be created for veg. (Ha)	407.2
6	Proj. area to be Irri. (ha)	1425.2

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 3.6: Areas in Champua block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Champua	26.05	1.08	27.13

Table 3.7: Estimation of volume of water required for artificial recharge to groundwater in Champua block, Keonjhar district.

Name of block	Total area of the block (km^2)	Area identified for artificial recharge (km^2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to reharge (MCM)
Champua	289.00	27.13	6.5	3.5	94.95	2.85

Table 3.8: Number of feasible structures in Champua block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (MCM)	No of different freasible structures			
		Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
Champua	2.85	6	3	3	6

Table 3.9: Estimation of cost of artificial recharge structures in Champua block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Champua	1.14	0.28	0.14	0.28	1.85

PLATE – 3.1

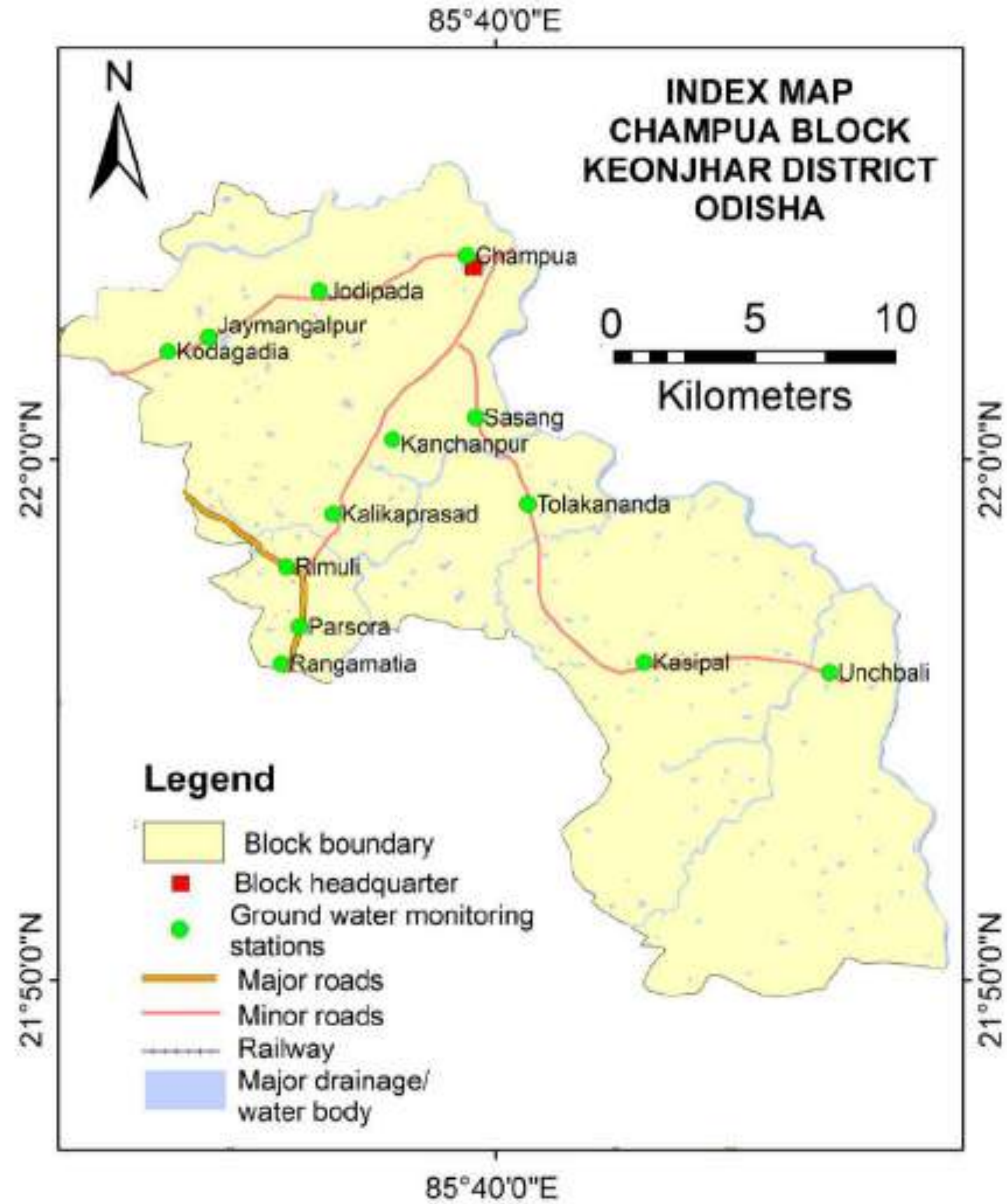

85°40'0"E
N
INDEX MAP
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
Champua
Jodipada
Jaymangalpur
Kodagadia
0
5
10
Kilometers
Sasang
Kanchanpur
Tolakananda
Kalikaprasad
Rimuli
Parsora
Rangamatia
Kasipal
Unchbali
22°0'0"N
21°50'0"N
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body
85°40'0"E

PLATE – 3.2

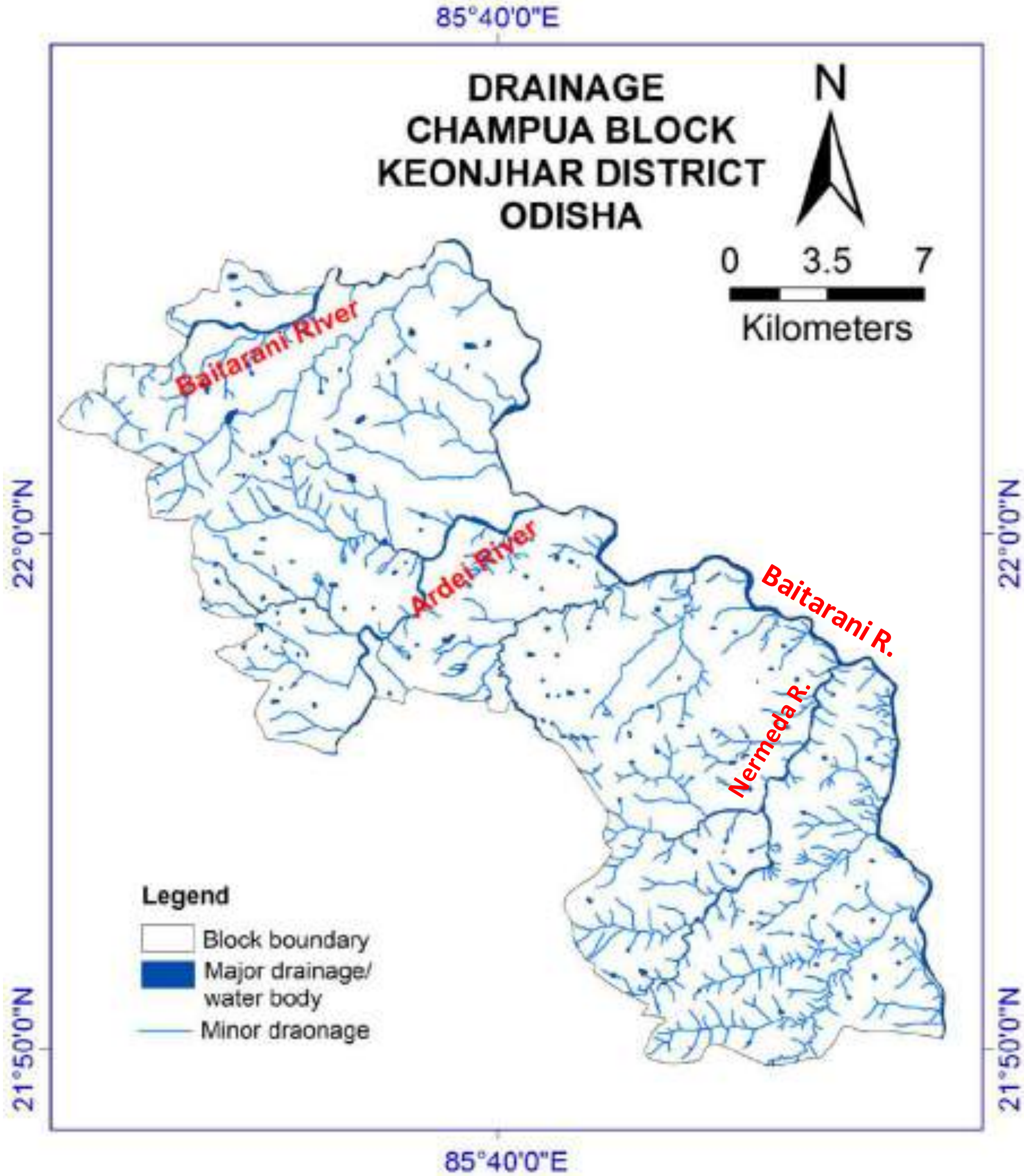

85°40'0"E
DRAINAGE
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 3.5 7
Kilometers
Baitarani River
Ardei River
Baitarani R.
Nermeda R.
22°0'0"N
21°50'0"N
Legend
Block boundary
Major drainage/ water body
Minor draonage
85°40'0"E

PLATE – 3.3

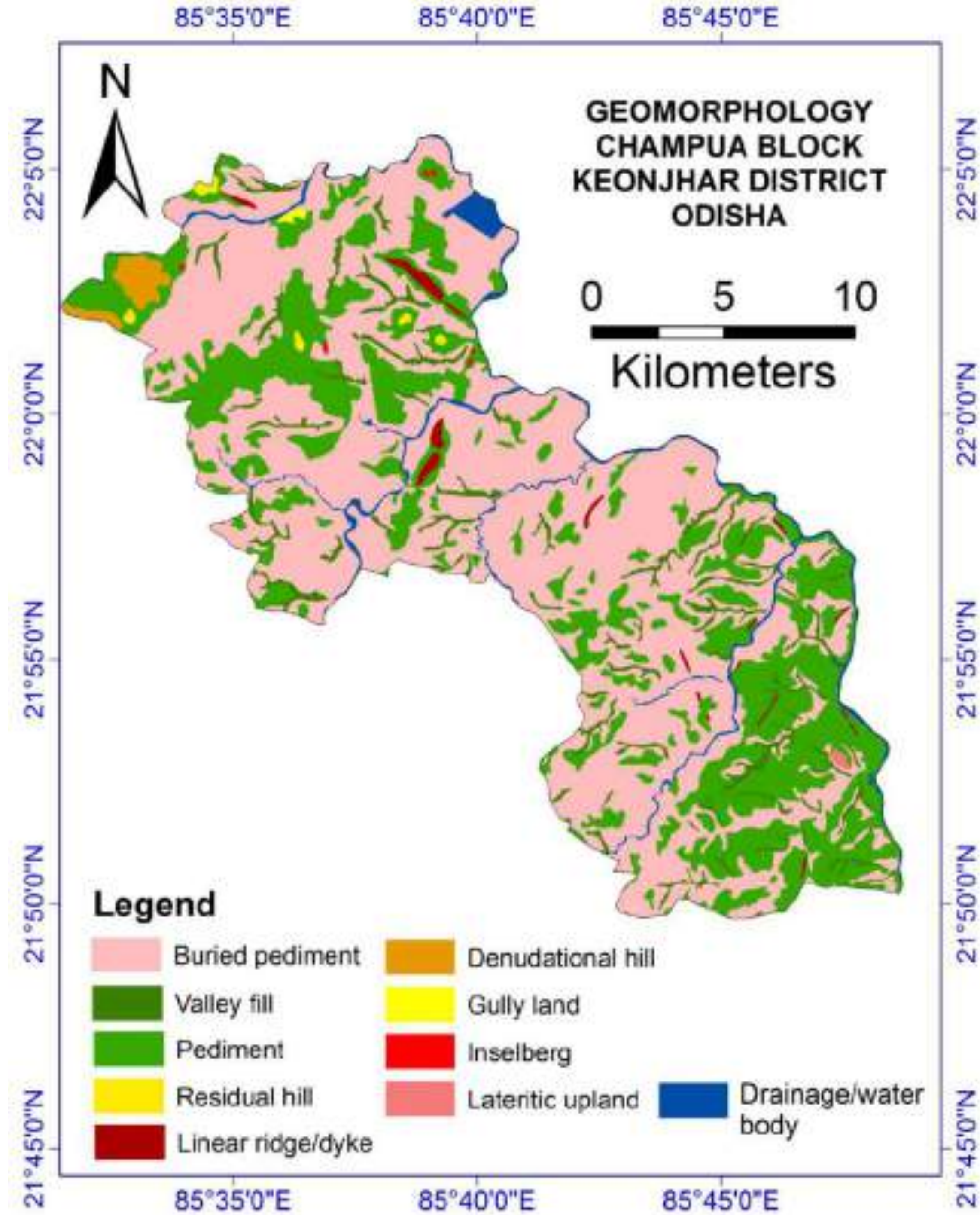

85°35'0"E
85°40'0"E
85°45'0"E
22°5'0"N
22°0'0"N
21°55'0"N
21°50'0"N
21°45'0"N
N
GEOMORPHOLOGY
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
0 5 10
Kilometers
Legend
Buried pediment
Valley fill
Pediment
Residual hill
Linear ridge/dyke
Denudational hill
Gully land
Inselberg
Lateritic upland
Drainage/water body

PLATE – 3.4

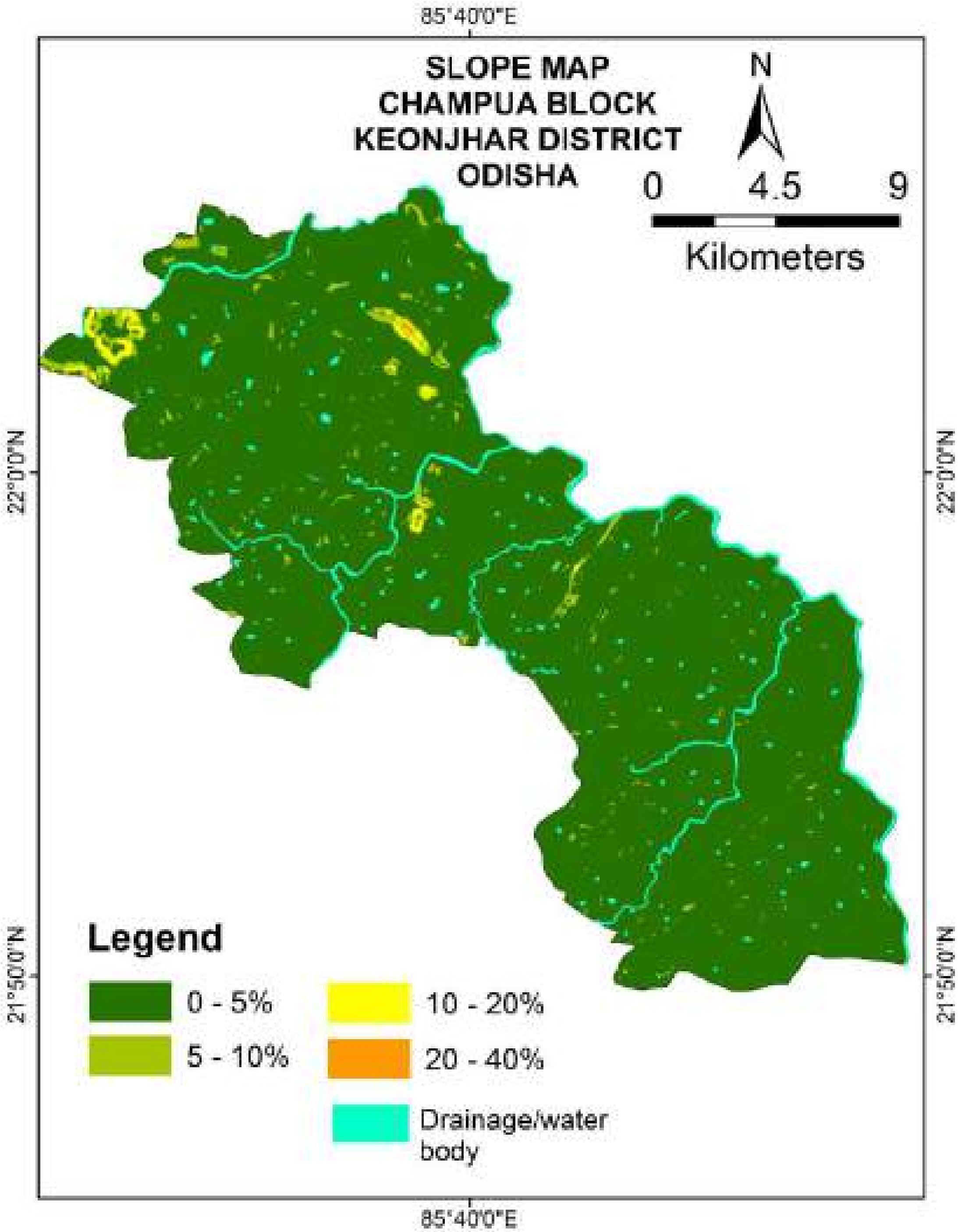
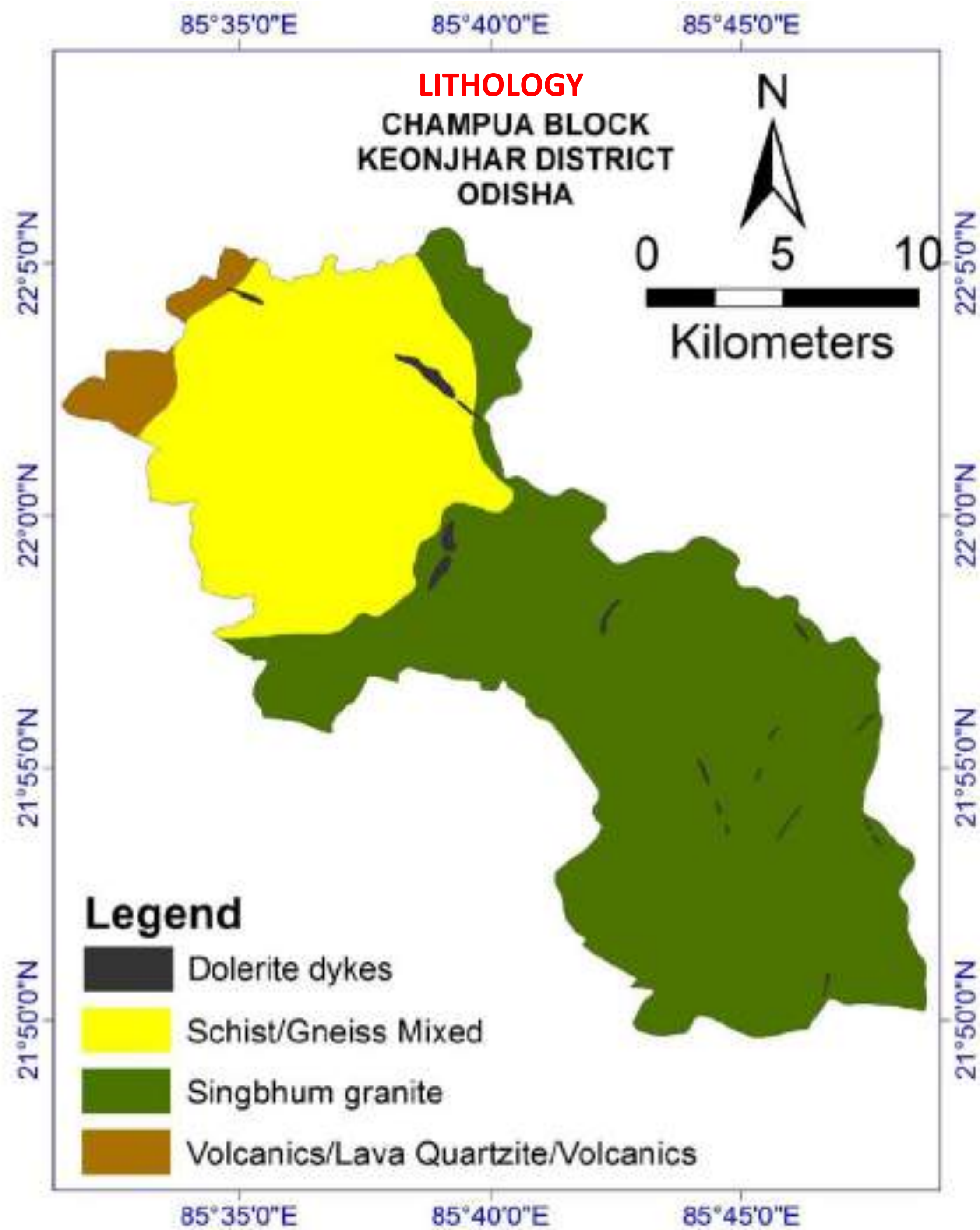

85°40'0"E
SLOPE MAP
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 4.5 9
Kilometers
22°0'0"N
21°50'0"N
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
Drainage/water body
85°40'0"E

PLATE – 3.5


85°35'0"E
85°40'0"E
85°45'0"E
LITHOLOGY
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
22°5'0"N
22°0'0"N
21°55'0"N
21°50'0"N
Legend
Dolerite dykes
Schist/Gneiss Mixed
Singbhum granite
Volcanics/Lava Quartzite/Volcanics

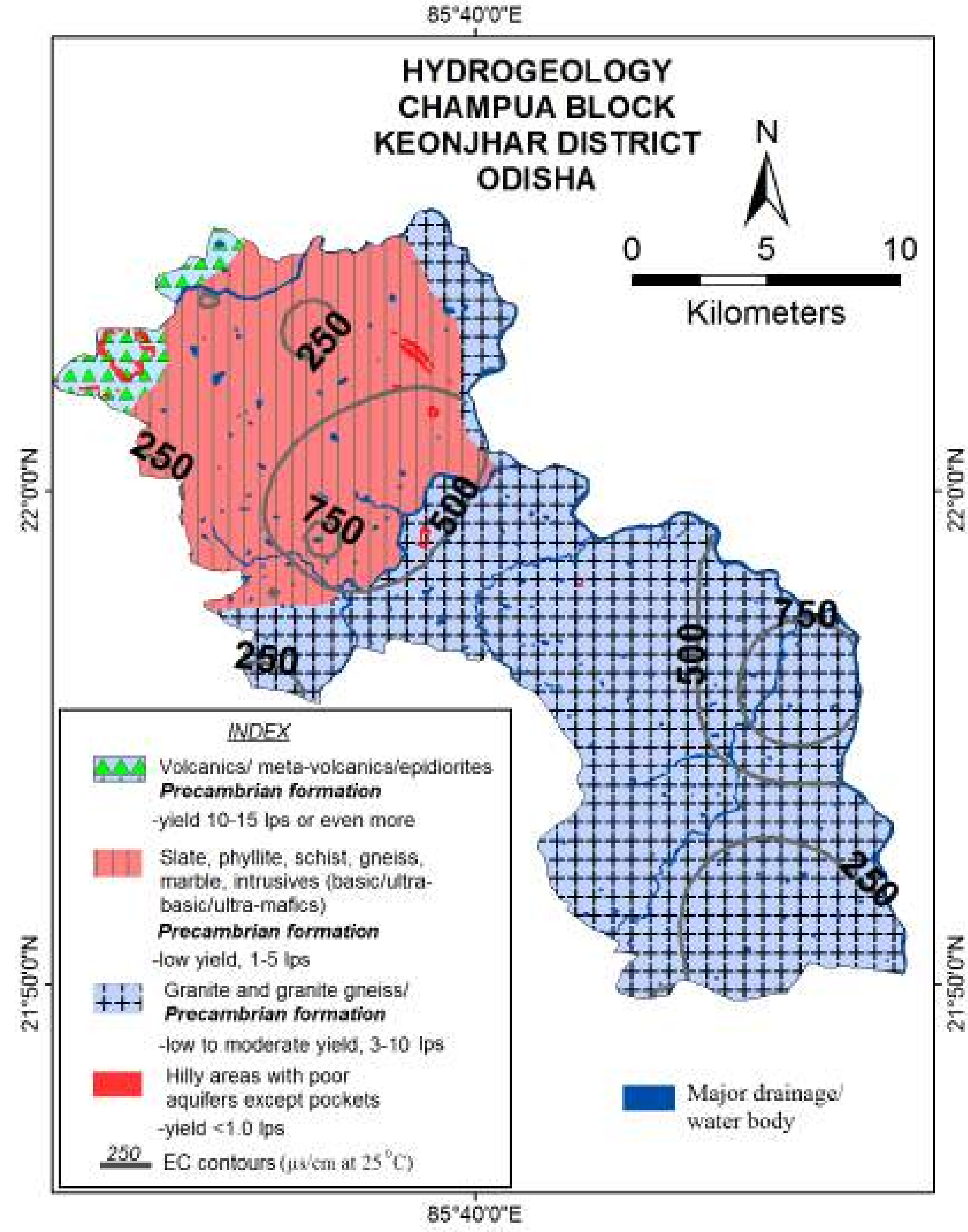

85°40'0"E
HYDROGEOLOGY
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
250
250
750
500
250
750
500
250
22°0'0"N
21°50'0"N
INDEX
Volcanics/ meta-volcanics/epidiorites
Precambrian formation
-yield 10-15 lps or even more
Slate, phyllite, schist, gneiss, marble, intrusives (basic/ultra-basic/ultra-mafics)
Precambrian formation
-low yield, 1-5 lps
Granite and granite gneiss/
Precambrian formation
-low to moderate yield, 3-10 lps
Hilly areas with poor aquifers except pockets
-yield <1.0 lps
250 EC contours (μs/cm at 25 °C)
Major drainage/ water body

PLATE – 3.7

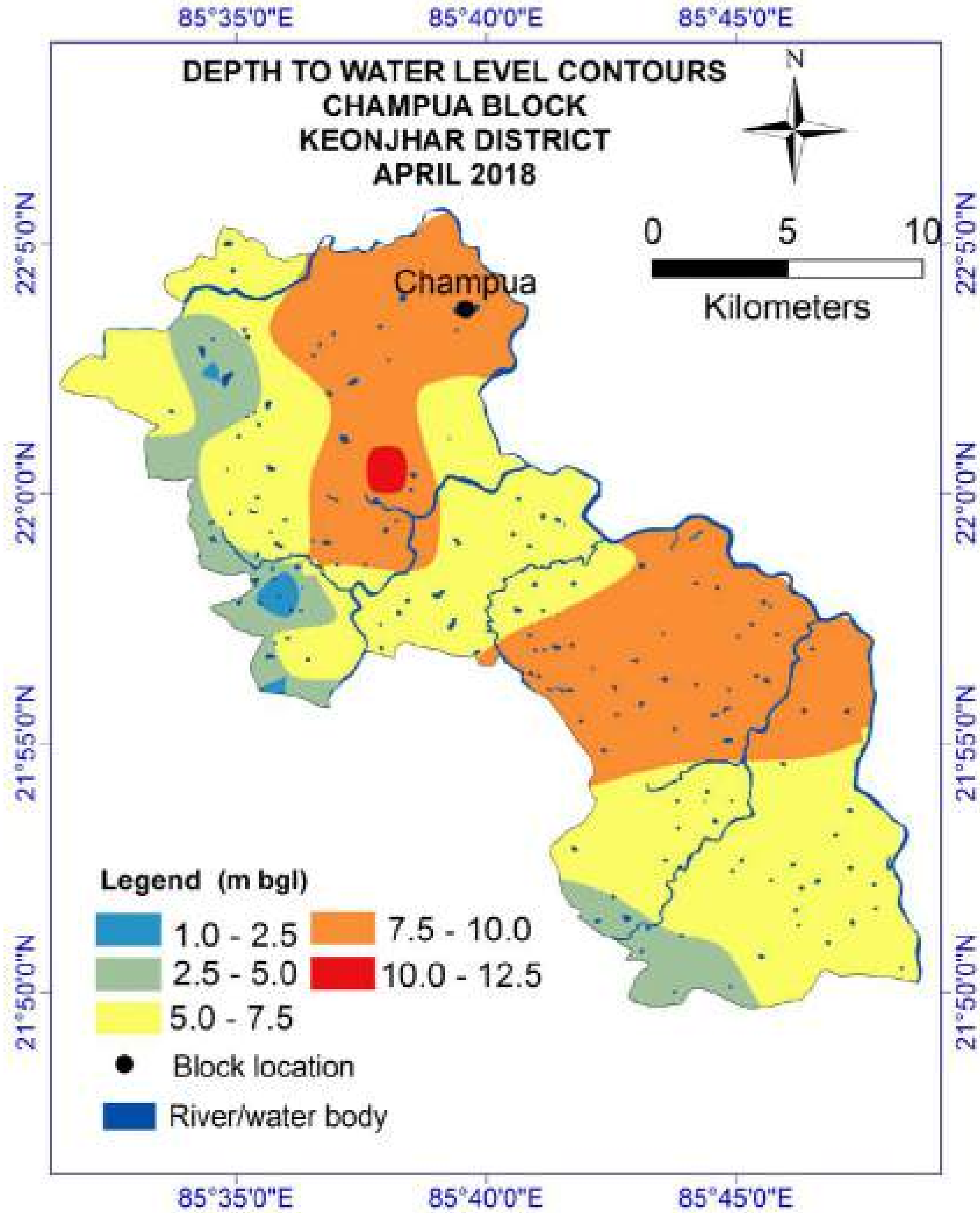

DEPTH TO WATER LEVEL CONTOURS
CHAMPUA BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0 5 10
Kilometers
Champua
85°35'0"E
85°40'0"E
85°45'0"E
22°5'0"N
22°0'0"N
21°55'0"N
21°50'0"N
Legend (m bgl)
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
Block location
River/water body

PLATE – 3.8

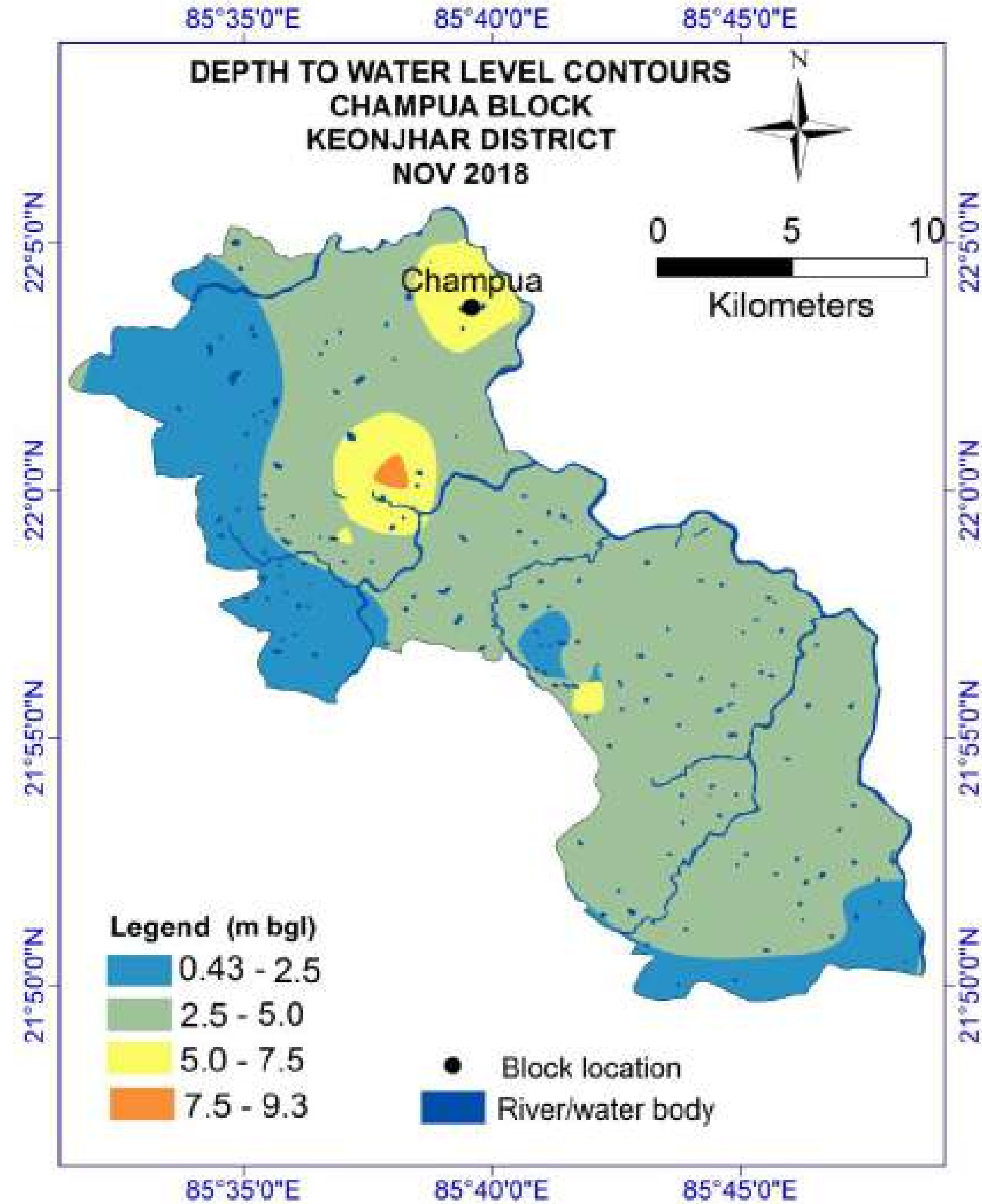

DEPTH TO WATER LEVEL CONTOURS
CHAMPUA BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 5 10
Kilometers
Champua
85°35'0"E
85°40'0"E
85°45'0"E
22°5'0"N
22°0'0"N
21°55'0"N
21°50'0"N
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
River/water body

PLATE – 3.9

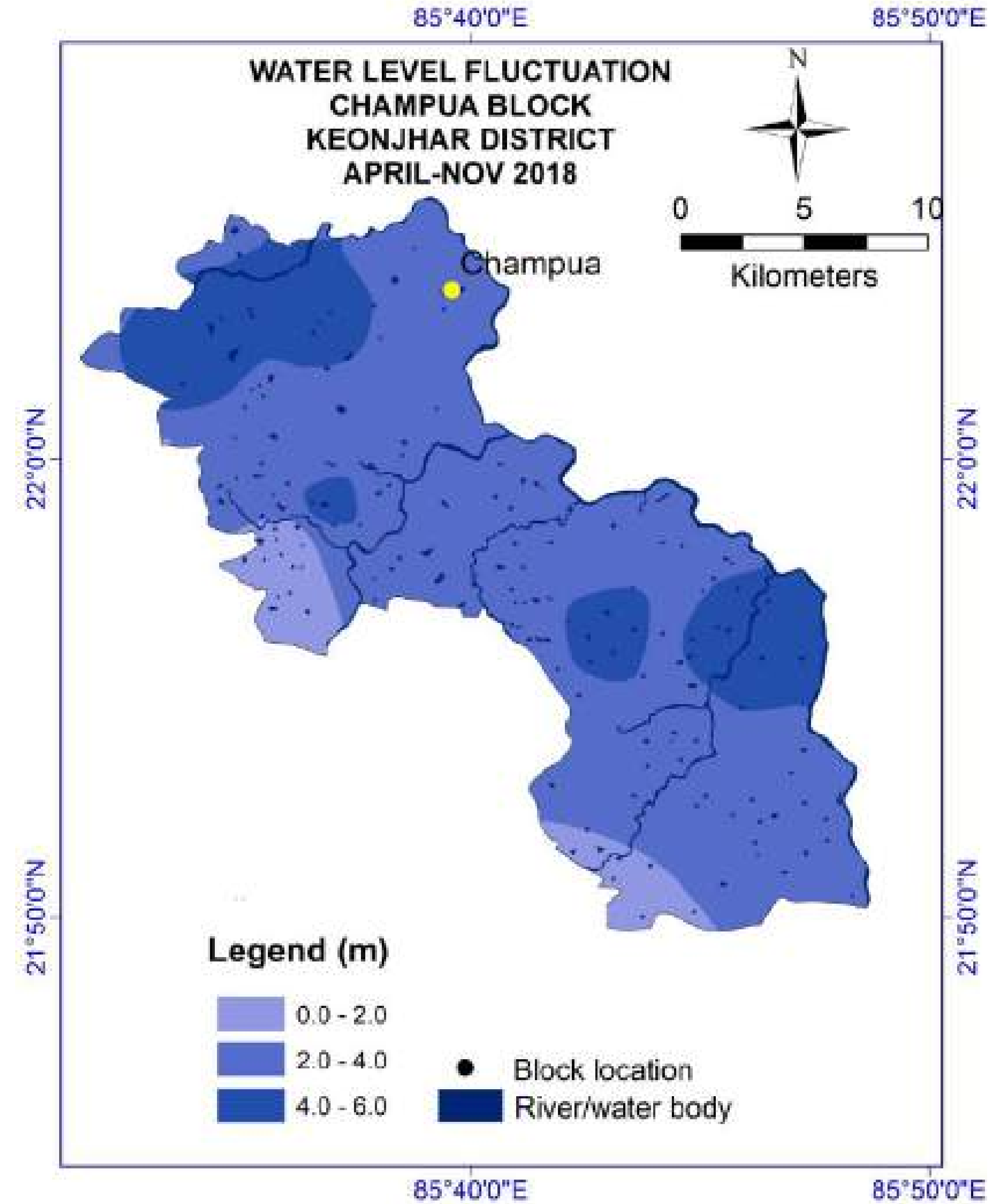

WATER LEVEL FLUCTUATION
CHAMPUA BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
85°40'0"E
85°50'0"E
22°0'0"N
21°50'0"N
N
0 5 10
Kilometers
Champua
Legend (m)
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
Block location
River/water body

PLATE – 3.10

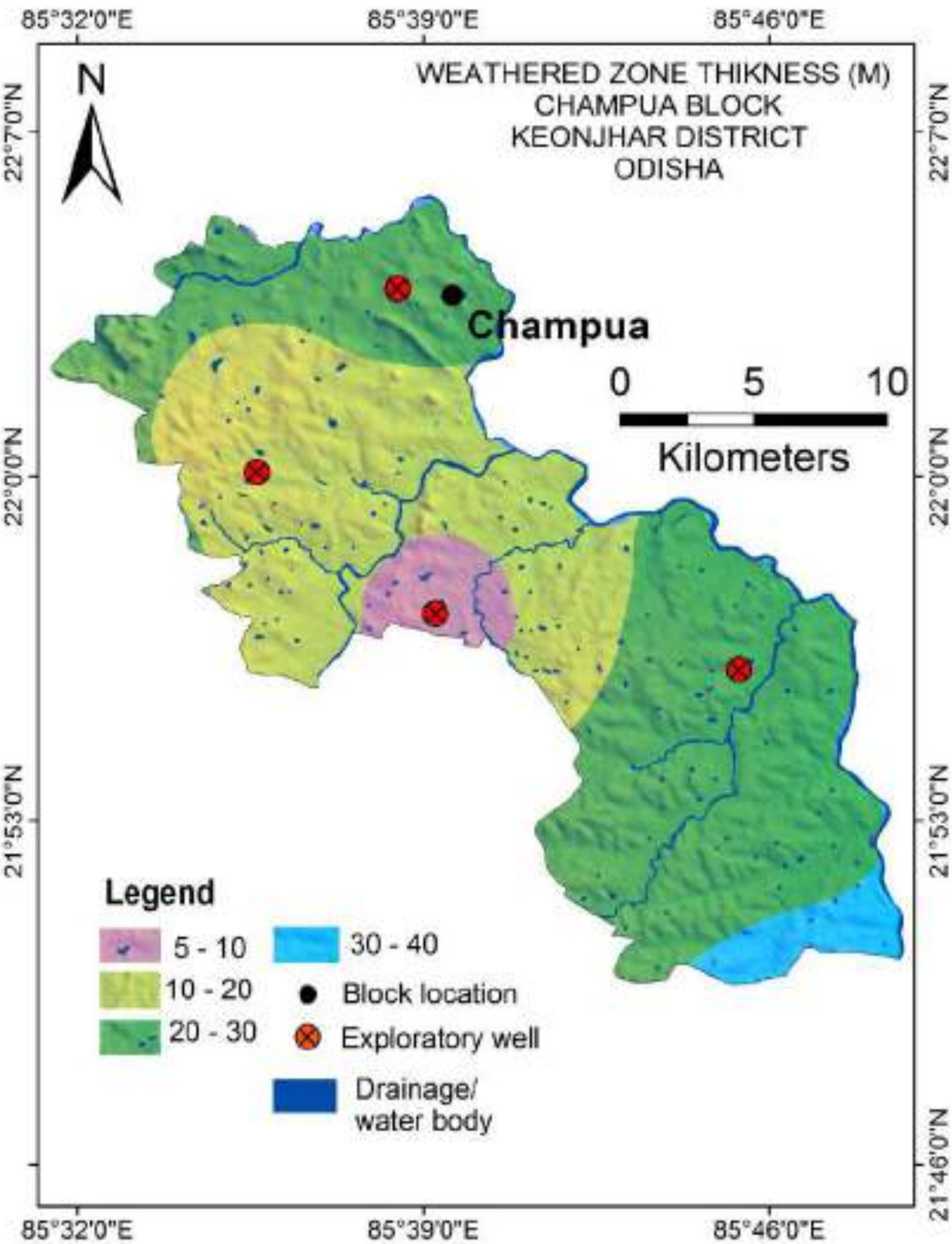

WEATHERED ZONE THIKNESS (M)
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
N
Champua
0 5 10
Kilometers
85°32'0"E
85°39'0"E
85°46'0"E
22°7'0"N
22°0'0"N
21°53'0"N
21°46'0"N
Legend
5 - 10
10 - 20
20 - 30
30 - 40
Block location
Exploratory well
Drainage/
water body

PLATE – 3.11

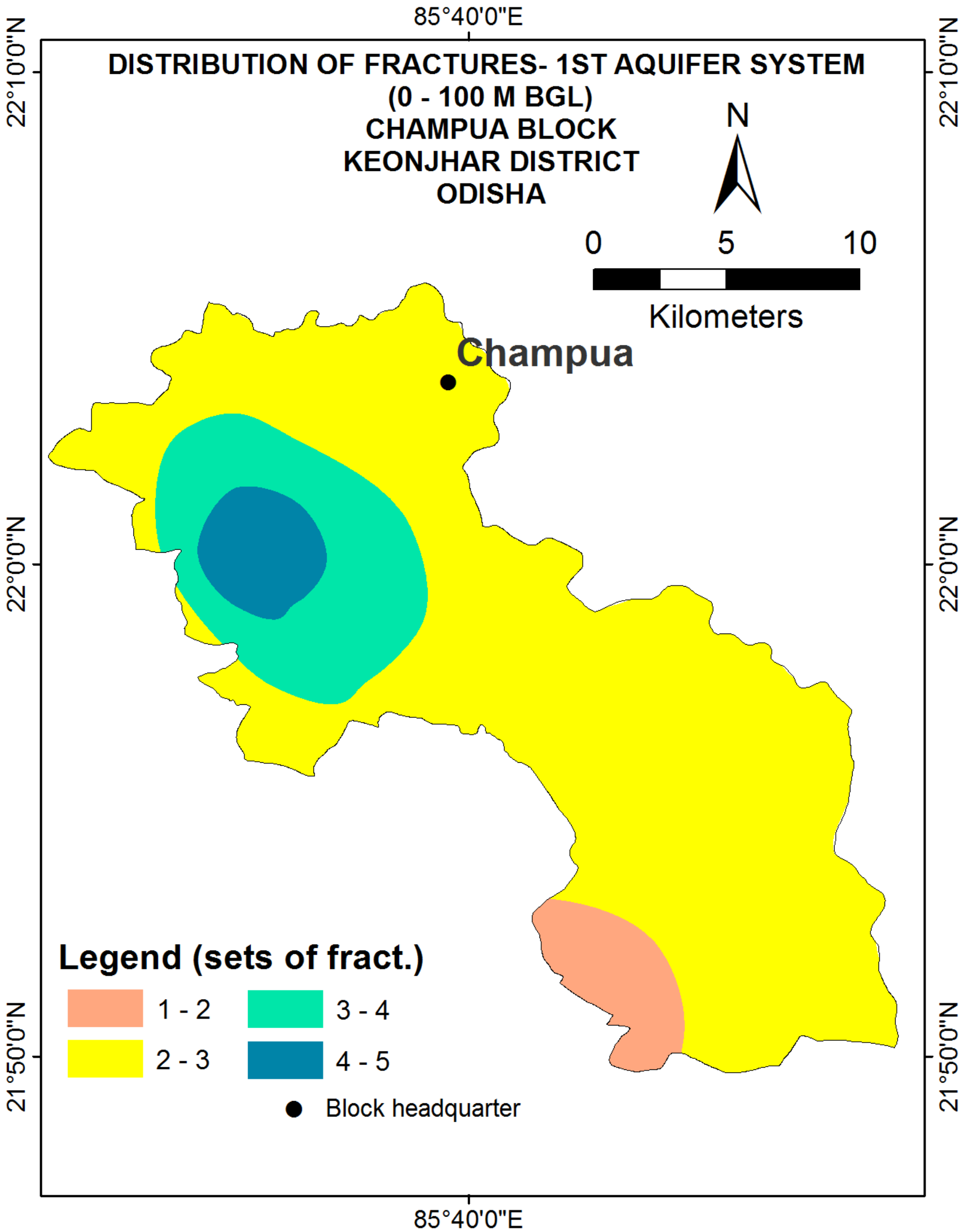

DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5
10
Kilometers
Champua
85°40'0"E
22°10'0"N
22°0'0"N
21°50'0"N
Legend (sets of fract.)
1 - 2
2 - 3
3 - 4
4 - 5
Block headquarter

PLATE – 3.12

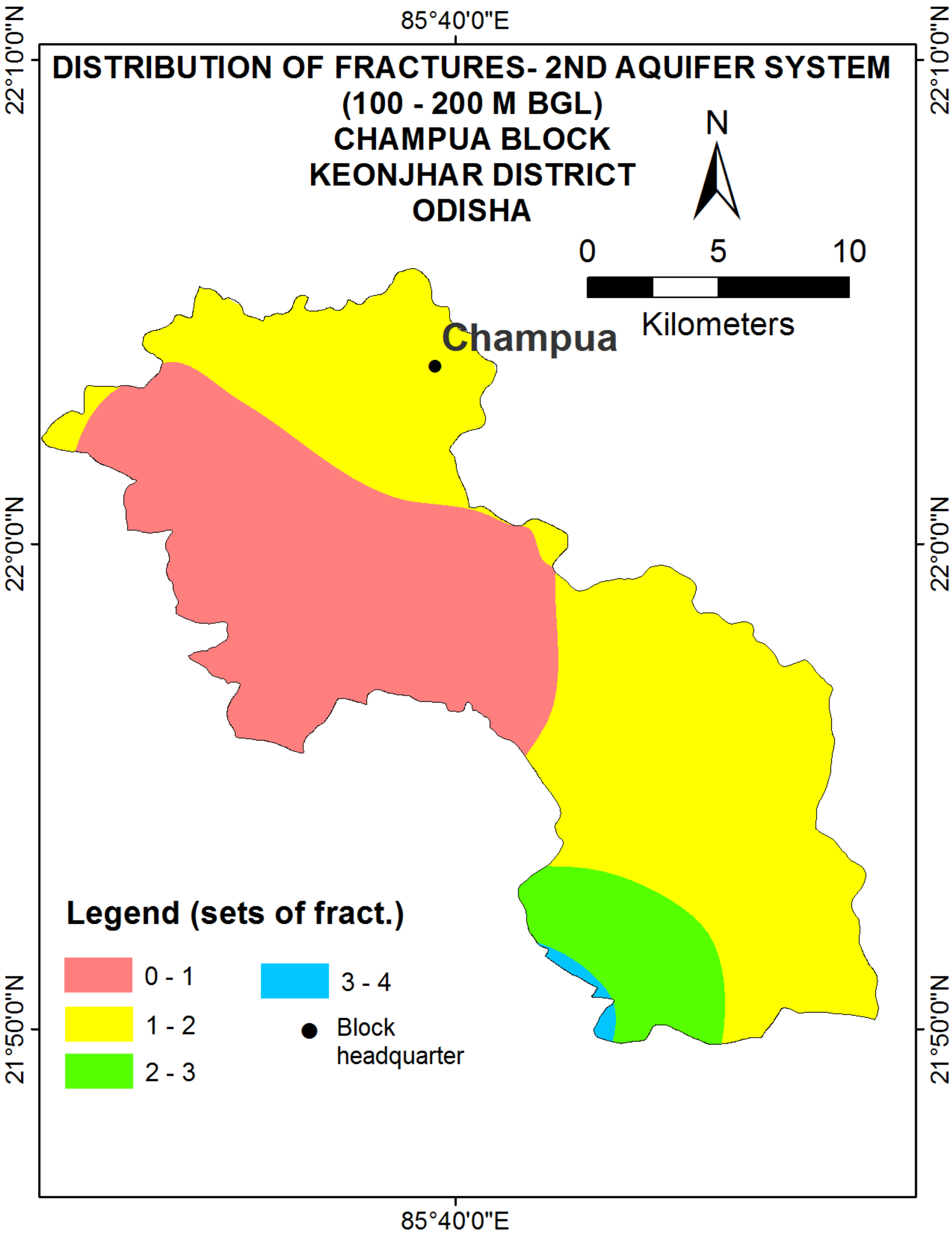

85°40'0"E
22°10'0"N
22°0'0"N
21°50'0"N
DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
Champua
Legend (sets of fract.)
0 - 1
1 - 2
2 - 3
3 - 4
Block headquarter

PLATE – 3.13

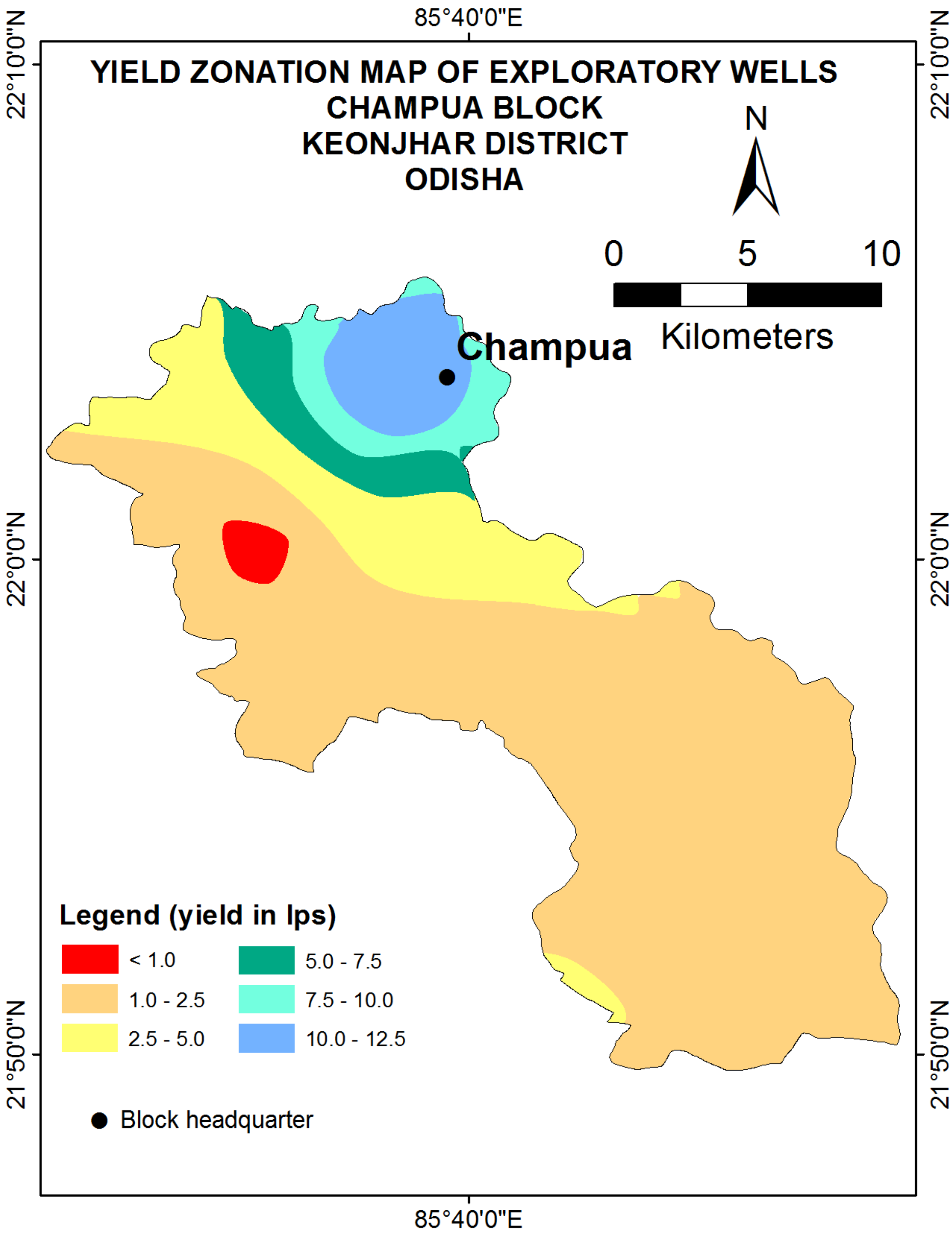

85°40'0"E
22°10'0"N
22°0'0"N
21°50'0"N
YIELD ZONATION MAP OF EXPLORATORY WELLS
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
Champua
Legend (yield in lps)
< 1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
Block headquarter

PLATE – 3.14

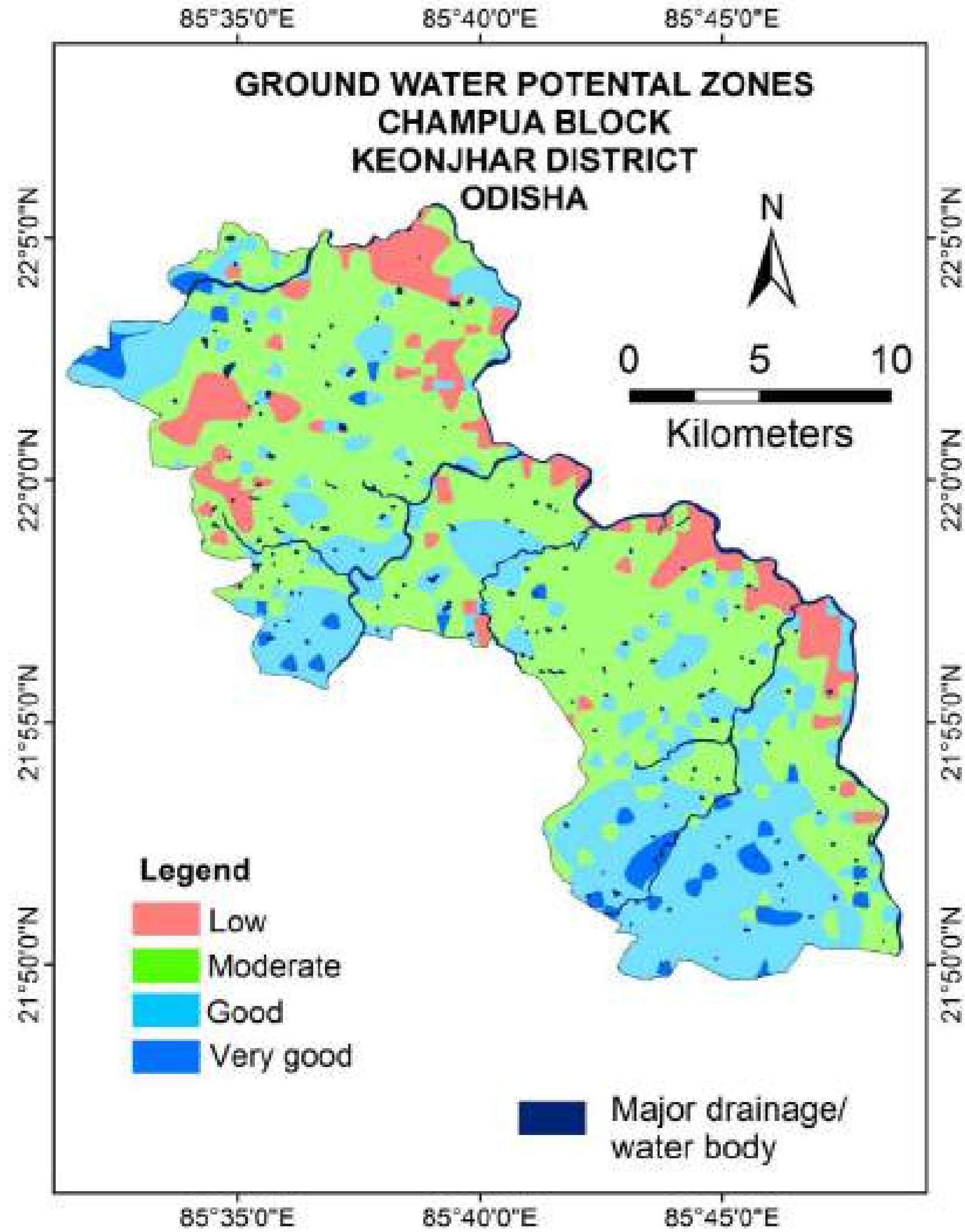
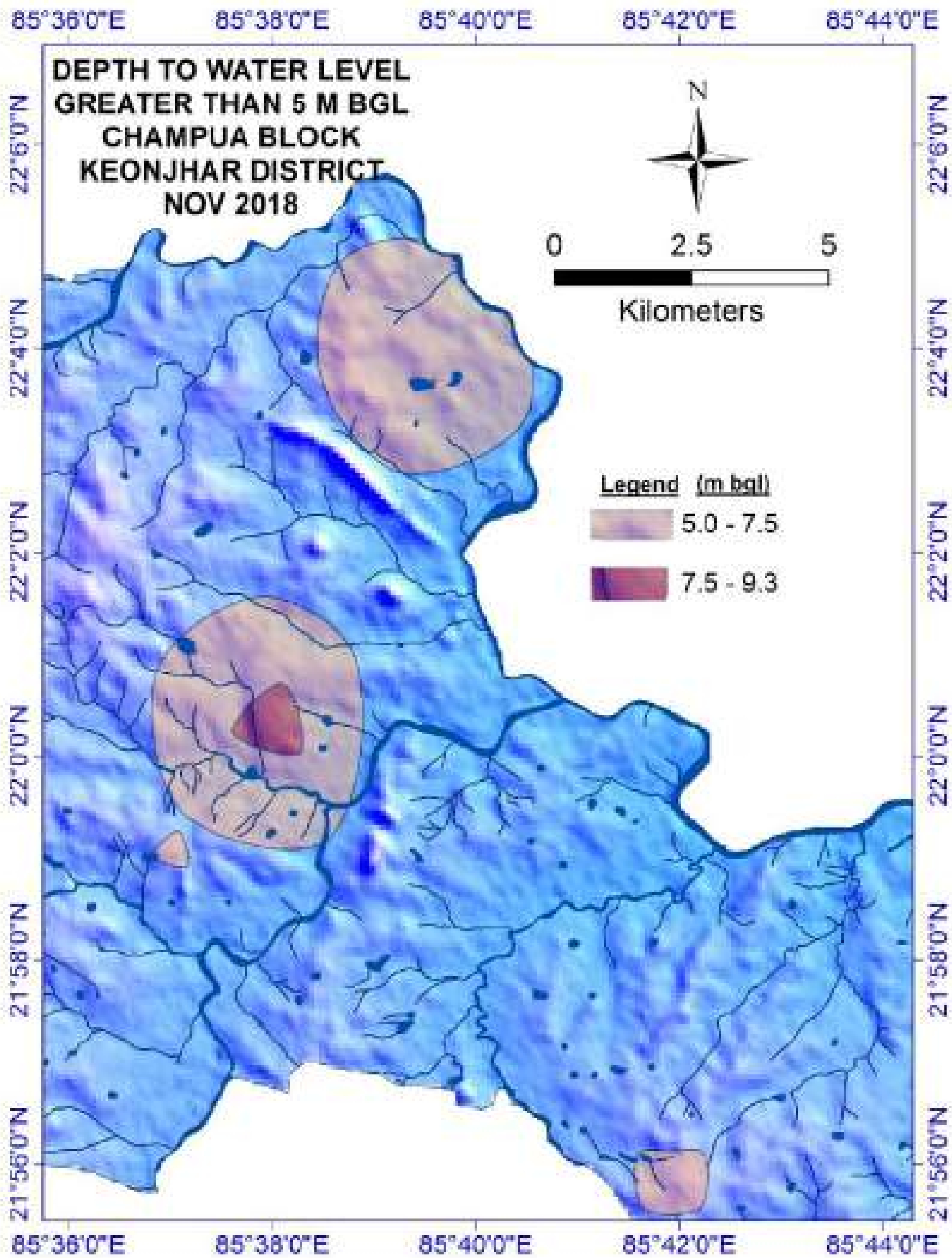

GROUND WATER POTENTAL ZONES
CHAMPUA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°35'0"E
85°40'0"E
85°45'0"E
22°5'0"N
22°0'0"N
21°55'0"N
21°50'0"N
Legend
Low
Moderate
Good
Very good
Major drainage/
water body

PLATE – 3.15


DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
CHAMPUA BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0
2.5
5
Kilometers
Legend (m bgl)
5.0 - 7.5
7.5 - 9.3
85°36'0"E
85°38'0"E
85°40'0"E
85°42'0"E
85°44'0"E
22°6'0"N
22°4'0"N
22°2'0"N
22°0'0"N
21°58'0"N
21°56'0"N

PART II BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

4.0 GHASIPURA BLOCK

4.1 Salient information

Location, area and demography

Location (Plate 4.1)	85^0 55' - 86^0 15' E longitude 21^0 00' – 21^0 17'' N latitude
Area	410 sq. km
No. of Gram Panchayats	22
No. of villages	164
Population (Census 2011)	1,48,554 (rural)
Literacy	68.64%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1448.7 mm
Monsoon normal rainfall	1131.2 mm (78% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	29323 Ha
Net sown area (2)	19215 Ha
Area sown more than once (1-2)	10108 Ha
Cropping intensity (%)	152.6 Ha
Area under forest	5742 Ha
Area under wasteland	3231 Ha
Area under other uses	12750 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	12462 Ha *Kharif:* 10448 Ha *Rabi:* 2014 Ha

4.2 Drainage, geomorphology and soil types

The river Baitarani is master drainage in the block flowing along its eastern borders. The Kusei river and other minor streams contribute to its flow. The drainage pattern is dendritic to sub-trellis and parallel in nature. There are several small and large water bodies in the block (Plate 4.2).

A significant part (~35% of total geographic area) of the block is covered by alluvial plain in the south-east. Besides, the pediment and buried pediments in the north and lateritic uplands in the south form the prominent hydro-geomorphic units (Fig 4.1 and Plate 4.3). These units are considered as potential from as far as groundwater occurrenec is concerned. There are several linear basic (dolerite) dykes in the northern half of the block that run in NE-SW direction. The valley fills cover the linear and narrow river valleys. Most of the block area (~90%) possesses land surface slope of <5% (Fig 4.2), except the minor patches in the northern half in the denudational hills and the linear dykes (Plate 4.4). The soil types include the alluvial soil (alfisol), red sandy soil (alfisol) and red lateritic soils (ultisol).

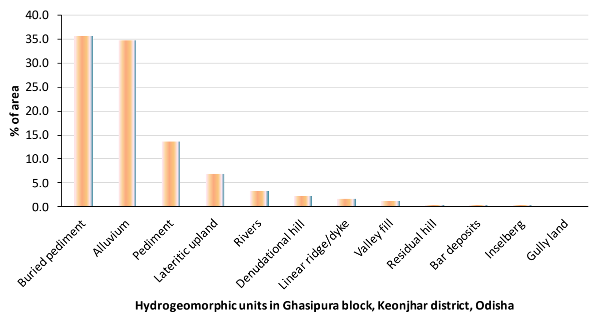


Figure 4.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Ghasipura block.

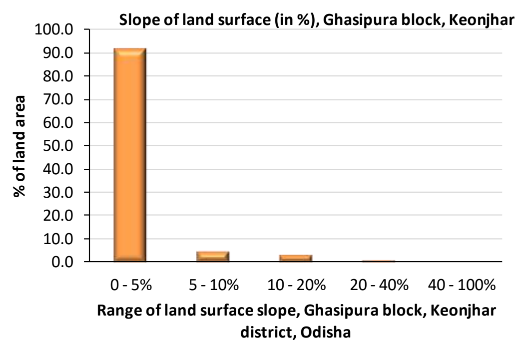


Figure 4.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Ghasipura block, Keonjhar district.

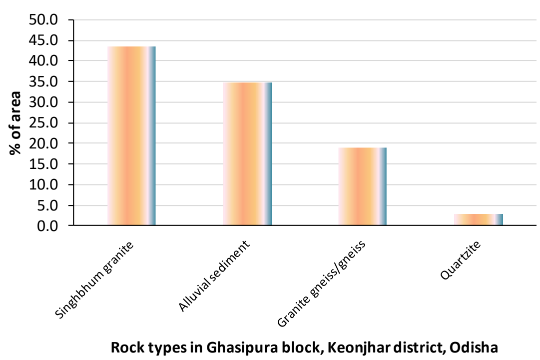


Figure 4.3: Percentage (%) of Ghasipura block area (Keonjhar dist.) covered by various rock types.

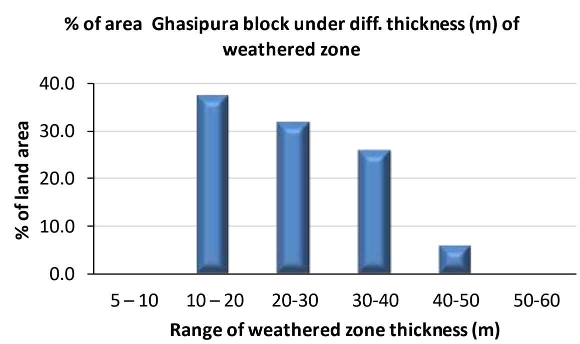


Figure 4.4: Bar diagram depicting the percentage (%) area of Ghasipura block, Keonjhar district falling under different weathered zone thickness (m) ranges.

4.3 Geology

The major geological formations in the block include the Quaternary alluvium, Singhbhum Granite and granites/gneisses. The Singhbhum Granites cover the northern parts (43.6% of block area), whicle the alluvium (covering 34.6% of total area) is found in the east and central parts (Fig 4.3 and Plate 4.5).

4.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories in the hard rock areas of the block, whereas in the alluvium, the intervenning granular zones in the stratigraphic column form the aquifers. The generalized hydrogeological map of the block is presented in Plate 4.6. The Singhbhum Granites posses low to moderate yield potential varying between 3-10 lps, whereas the yield in the alluvium is quite satisfactory in the range of 10-40 lps.

Though, the water levels during pre-monsoon (year 2018) largely varied between 1.0-10 m bgl, a larger part of the block depicted water levels in the range of 2.0-5.0 m bgl (in southern half and western parts), followed by 5.0-7.5 m bgl in the north-eastern parts (Plate 4.7). During the post-monsson period, almost the entire block (except smaller patches in the northern half) depicted water levels <1.0 to 5.0 m bgl, indicating good recharge from rainfall (Plate 4.8). The annual fluctuations in the water levels remained less than 2.0 m in major parts of the block (Plate 4.9).

4.5 Aquifer geometry and characters

The thickness of the weathered regolith overlying the fresh hard rock varies between 5– 50 m (Plate 4.10). It remains within 30-40 m in about 25% of the hard rock area. Another ~30% area is occupied by weathered zones of 20-30 m thick (Fig 4.4). The thick weathered zones form good prospect for groundwater to dug wells and shallow tube wells. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 4.5a-b.

In the block, in general 0-2 sets of fracture zones are encountered in bore wells within the depth of 100 m bgl (1st aquifer system). In major parts, 1-2 sets of fractures are found (Plate 4.11). Beyond this depth in the 2nd aquifer system, the fractures are depleted and in maximum cases, 0-1 sets of fracture zones are encountered during drilling (Plate 4.12). Several bore wells in the block have been drilled which give yield in the range of 2-8 lps. The bore wells in the north yield between 5-8 lps (Plate 4.13). The tube wells in the allubium yield between 10-25 lps in the block.

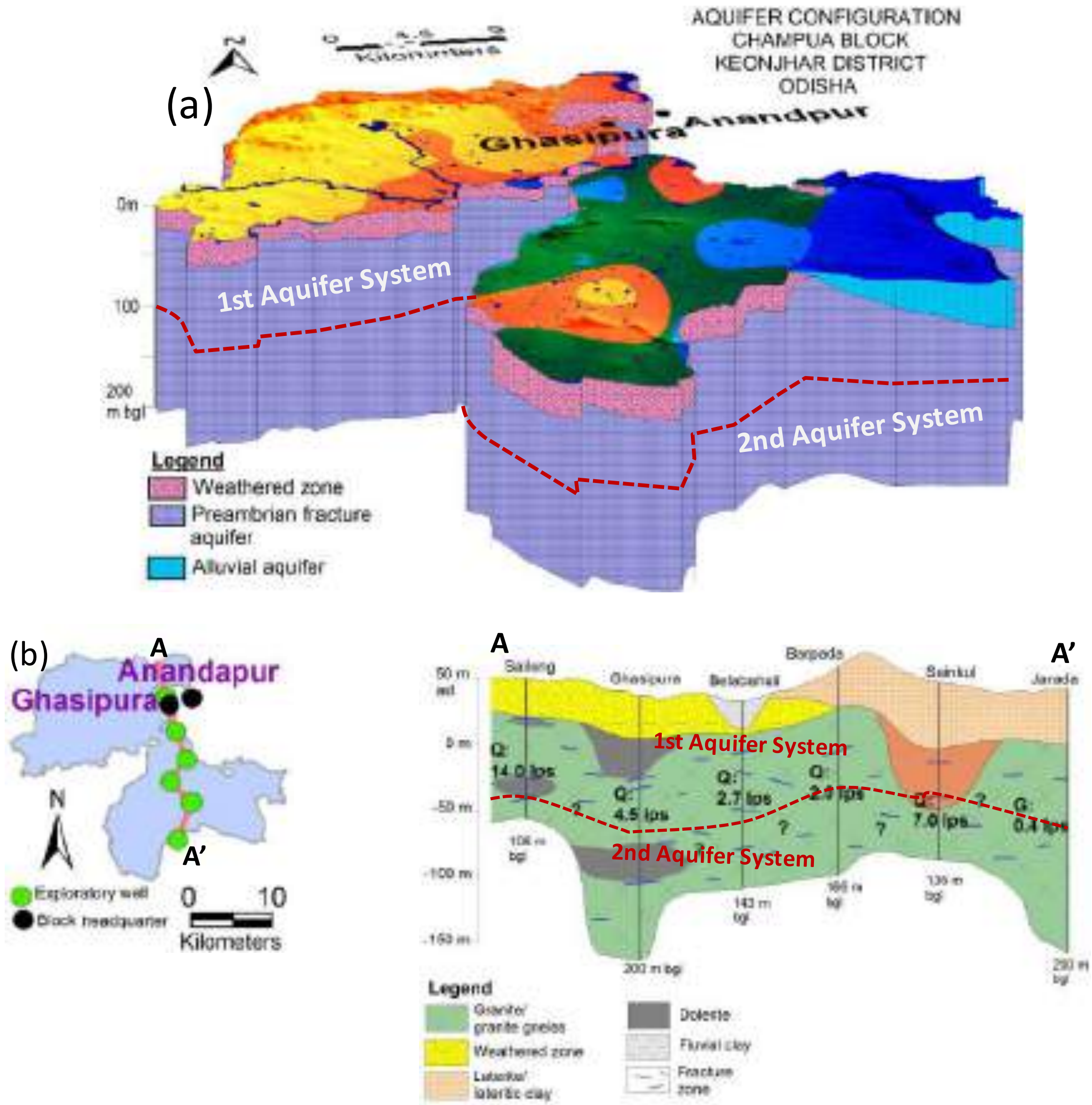


Figure 4.5: 3D aquifer disposition in Ghasipura block, Keonjhar district. (b) 2D hydrogeological transect depicting the aquifer disposition (including the location map) in the block.

4.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered

zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 4.14). The hard rock parts in the north are characterized as good to very potential zones in the context of groundwater. The alluvial areas are delineated as very good groundwater potential zones in the block. Around 65% of the geographical area of the block has been classed as good to very groundwater potential zone (Fig 4.6).

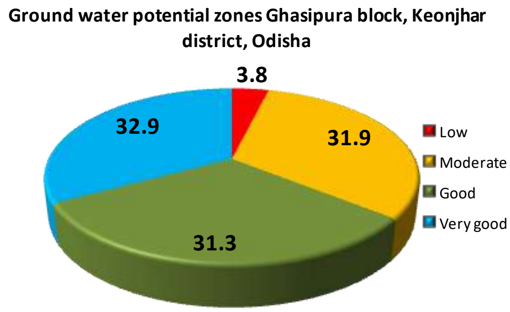


Figure 4.6: Pie diagram depicting the perentage (%) of Ghasipura block, Keonjhar district, Odisha, falling under different groundwater potential zones.

4.7 Ground water quality

Ground water in the block is alkaline in nature (Table 4.1) and pH range of 7.2-8.3. The water is hard to very hard. The mineralization is low to moderate with TDS in the range of 107-833 mg/L (ave.: 363 mg/L). Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly $Ca-HCO_3$ types with Ca^{2+} and HCO_3^- as the principal contributing ions in the groundwater quality (Fig 4.7).

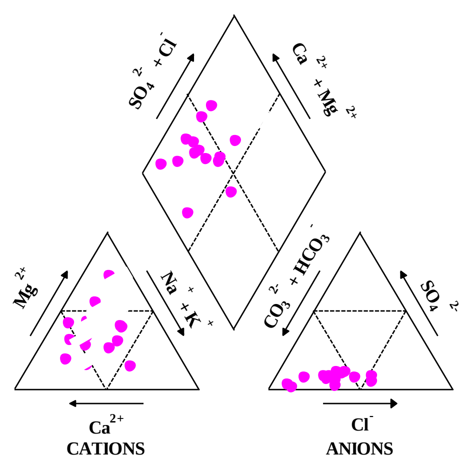


Figure 4.7: The Piper trilinear diagram depicting the groundwater quality in Ghasipura block, Keonjhar district.

Table 4.1: Ground water quality at various locations in Ghasipura block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Ganpur	7.24	220	107	86	64	27	5	9	0.76	0	79	26	2	0.15
Purunabandhagoda	7.8	1720	833	662	465	39	138	58	3.58	0	507	261	55	0.52
Jarak	7.79	400	177	158	166	35	18	7	0.29	0	202	17	2	0.18
Patilo	7.89	1150	607	331	281	77	34	49	83.17	0	342	141	55	0.31
Kanpur	8.05	1440	744	408	437	60	63	119	2.21	0	460	172	67	0.72
Hathisila	7.83	1000	538	202	281	54	16	82	59.6	0	342	108	51	1.04
Rekutia	7.47	280	139	91	78	29	5	19	1.52	0	95	31	7	0.25
Balipala	7.62	580	271	158	253	23	25	46	0.53	0	309	19	7	1.13
Khalapal	7.61	620	295	240	239	33	39	22	1.21	0	292	36	21	0.25
Radhikadeipur	7.37	480	240	168	147	42	15	25	1.2	0	180	50	19	0.17
Balarampur	7.74	835	441.12	235	157	46	29	57.07	34.35	0	191	148	31.2	0.36
Barpada	7.48	320	162.66	135	64	26	17	13.19	1.27	0	78	60	6.2	0.10
Deogaon1	8.27	620	348.45	260	216	60	27	27.1	16.35	0	263	62	24.5	0.14
Kesurdapal	7.53	310	173.93	150	108	38	13	10.8	2.33	0	132	34	9.8	0.17
Min.:	**7.24**	**220**	**107**	**86**	**64**	**23**	**5**	**7**	**0.29**	**0**	**78**	**17**	**2**	**0.10**
Max.:	**8.27**	**1720**	**833**	**662**	**465**	**77**	**138**	**119**	**83.17**	**0**	**507**	**261**	**67**	**1.13**
Average	**7.7**	**712.5**	**362.7**	**234.6**	**211.1**	**42.1**	**31.7**	**38.9**	**14.9**	**0.0**	**248.0**	**83.2**	**25.6**	**0.4**

4.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 4.2-4.4. The net dynamic groundwater available is 6128.6 Ham and the stage of groundwater development stands at 45.3%. Net resource available for future irrigation needs stands at 3317.5 Ham (Fig 4.8). The instorage/static groundwater resource component of 10120.8 Ham (Table 4.3) comes from the 1st aquifer system within 100 m bgl with a major portion of it lying in the alluvial area. The total groundwater available in the block stands at 16253.1 Ham.

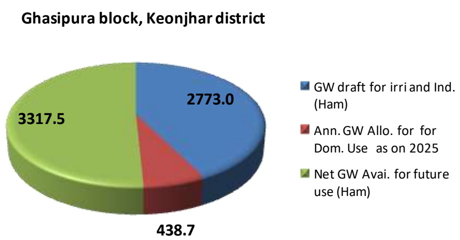


Figure 4.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Ghasipura block, Keonjhar district, Odisha.

Table 4.2: Salient information on annual dynamic groundwater resources, Ghasipura block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	6128.6
2. Irrigation draft (Ham)	2365.1
3. Industrial draft (Ham)	7.2
4. Domestic draft (Ham)	400.7
5. Total draft (Ham)	2773.0
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	438.7
7. Net groundwater available for future use (Ham)	3317.5
8. Stage of groundwater extraction (%)	45.3

Table 4.3: Total groundwater resoure available in the Ghasipura block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	6128.6
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	10120.8
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	3.6
	Block total	**16253.1**

4.9 Aquifer management plan

The existing stage of groundwater development of 45.3% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction

structures as estimated in Table 4.4 (205 bore wells/dug-cum-bore wells and 1739 dug wells) are required to be constructed to develop the available additional resource of 3317.5 Ham. It can help in creating additional irrigation potential for 1175.3 Ha (Table 4.5).

Only around 28.29 km^2 area in the block showed post-monsoon depth to water levels >5.0 m bgl (Plate 4.15; Table 4.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 2.97 MCM of water (Table 4.7) can be recharged by the help additional 6- percolations ponds, 3-subsurface dykes, 3-nala/contour bunds and 6-check dams (Table 4.8) with a total cost of 1.93 crores (Table 4.9).

Table 4.4: Number of additional feasible groundwater abstraction structures in Ghasipura block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	6128.6
2	Stage of GW deve. (%)	45.3
3	Present GW draft (Ham)	2773
4	Ground water draft at 60% stage of deve. (Ham)	3677.1
5	Addi. water to be deve. (Ham)	904.1
6	Addi. no of BW/ dug-cum-bore wells feasible in each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	205
7	Addi. no. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	1739

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 4.5: Irrigation potential likely to be created in Ghasipura block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	45.3
2	Surplus GW avai. for 60% stage of deve. (Ham)	904.1
3	Irri, Pot. likely to be created for Paddy (Ha)	723.3
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	226
5	Irri. Pot. likely to be created for veg. (Ha)	226
6	Proj. area to be Irri. (ha)	1175.3

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 4.6: Areas in Ghasipura block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Ghasipura	27.19	1.10	28.29

Table 4.7: Estimation of volume of water required for artificial recharge to groundwater in Ghasipura block, Keonjhar district.

Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to reharge (MCM)
Ghasipura	410.00	28.29	6.5	3.5	99.02	2.97

Table 4.8: Number of feasible structures in Ghasipura block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (MCM)	No of different freasible structures			
		Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
Ghasipura	2.97	6	3	3	6

Table 4.9: Estimation of cost of artificial recharge structures in Ghasipura block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Ghasipura	1.19	0.30	0.15	0.30	1.93

PLATE – 4.1

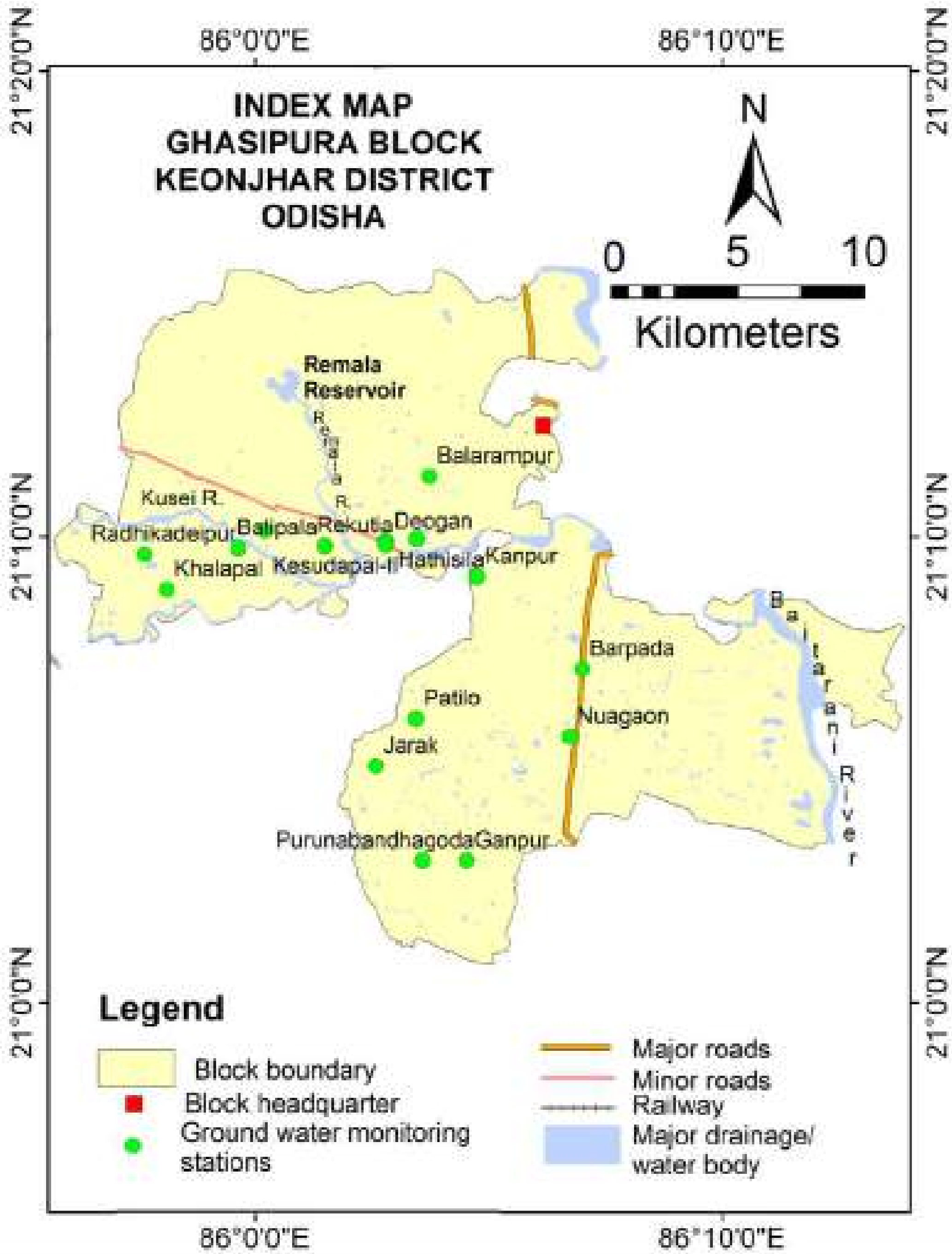

INDEX MAP
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5
10
Kilometers
86°0'0"E
86°10'0"E
21°20'0"N
21°10'0"N
21°0'0"N
Remala Reservoir
Remala R.
Kusei R.
Balarampur
Radhikadeipur
Balipala
Rekutia
Deogan
Khalapal
Kesudapal-II
Hathisila
Kanpur
Barpada
Patilo
Nuagaon
Jarak
Purunabandhagoda
Ganpur
Baitarani River
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body

PLATE – 4.2

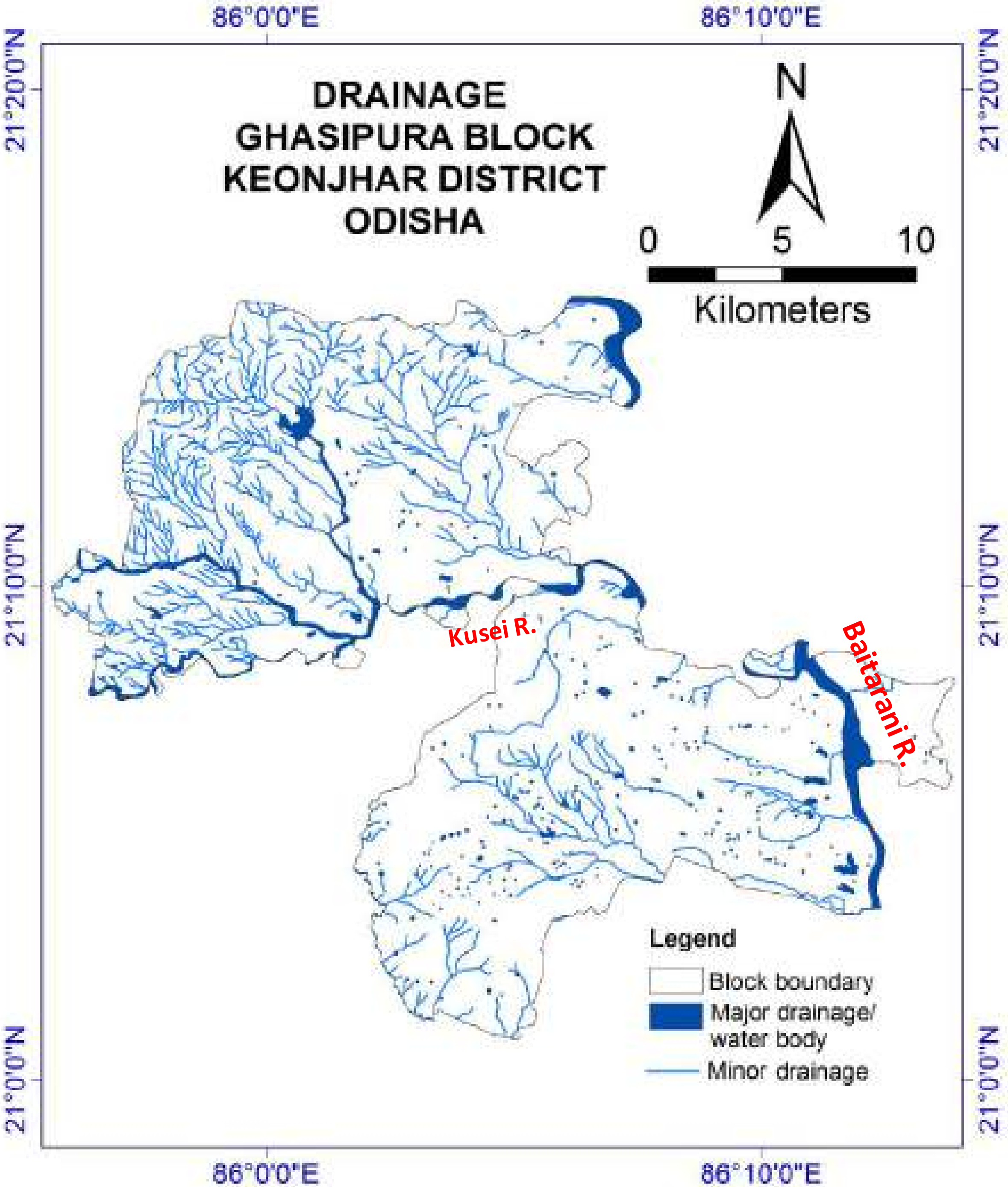

86°0'0"E
86°10'0"E
21°20'0"N
21°10'0"N
21°0'0"N
DRAINAGE
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5
10
Kilometers
Kusei R.
Baitarani R.
Legend
Block boundary
Major drainage/ water body
Minor drainage

PLATE – 4.3

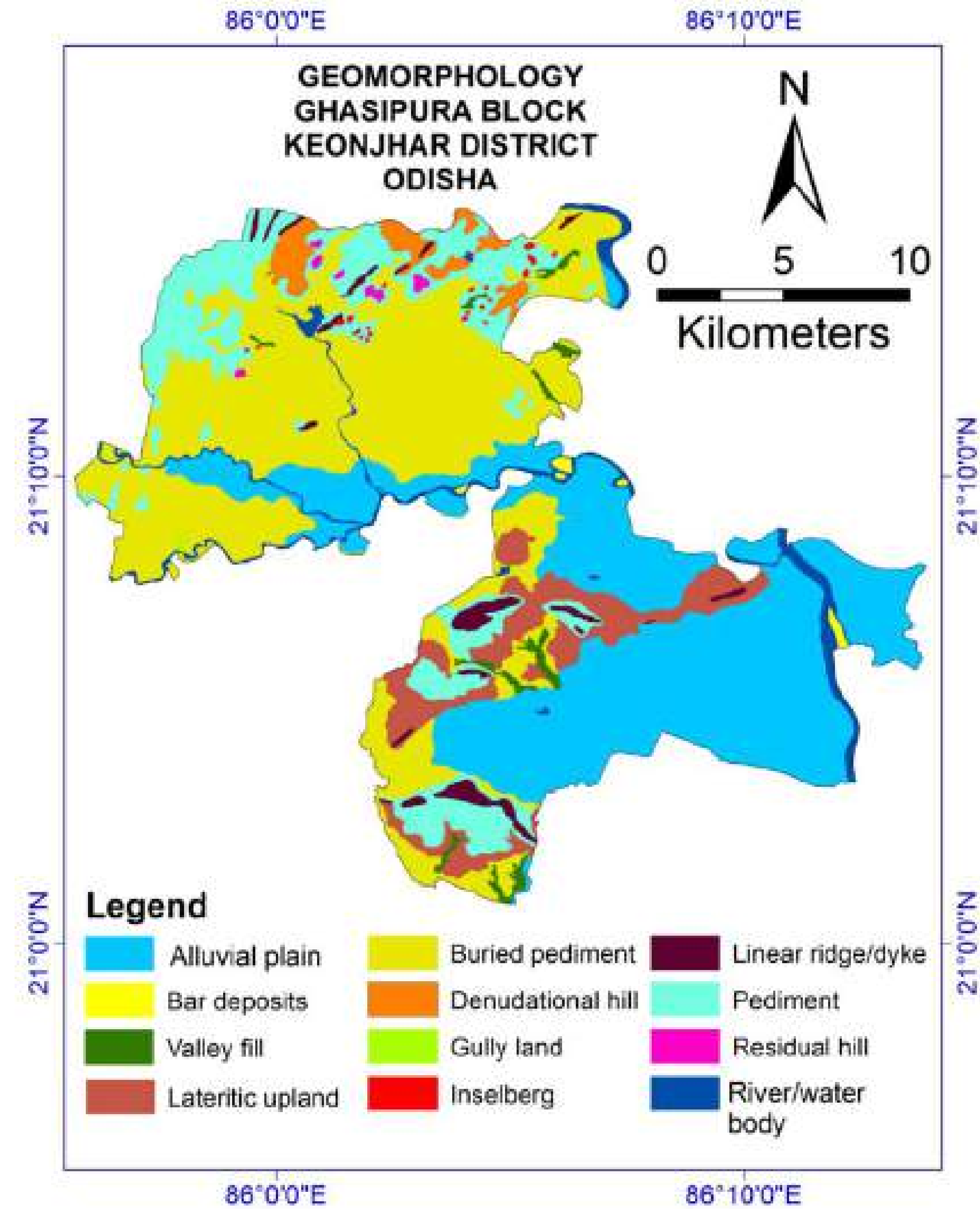

86°0'0"E
86°10'0"E
GEOMORPHOLOGY
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
21°10'0"N
21°0'0"N
Legend
Alluvial plain
Bar deposits
Valley fill
Lateritic upland
Buried pediment
Denudational hill
Gully land
Inselberg
Linear ridge/dyke
Pediment
Residual hill
River/water body

PLATE – 4.4

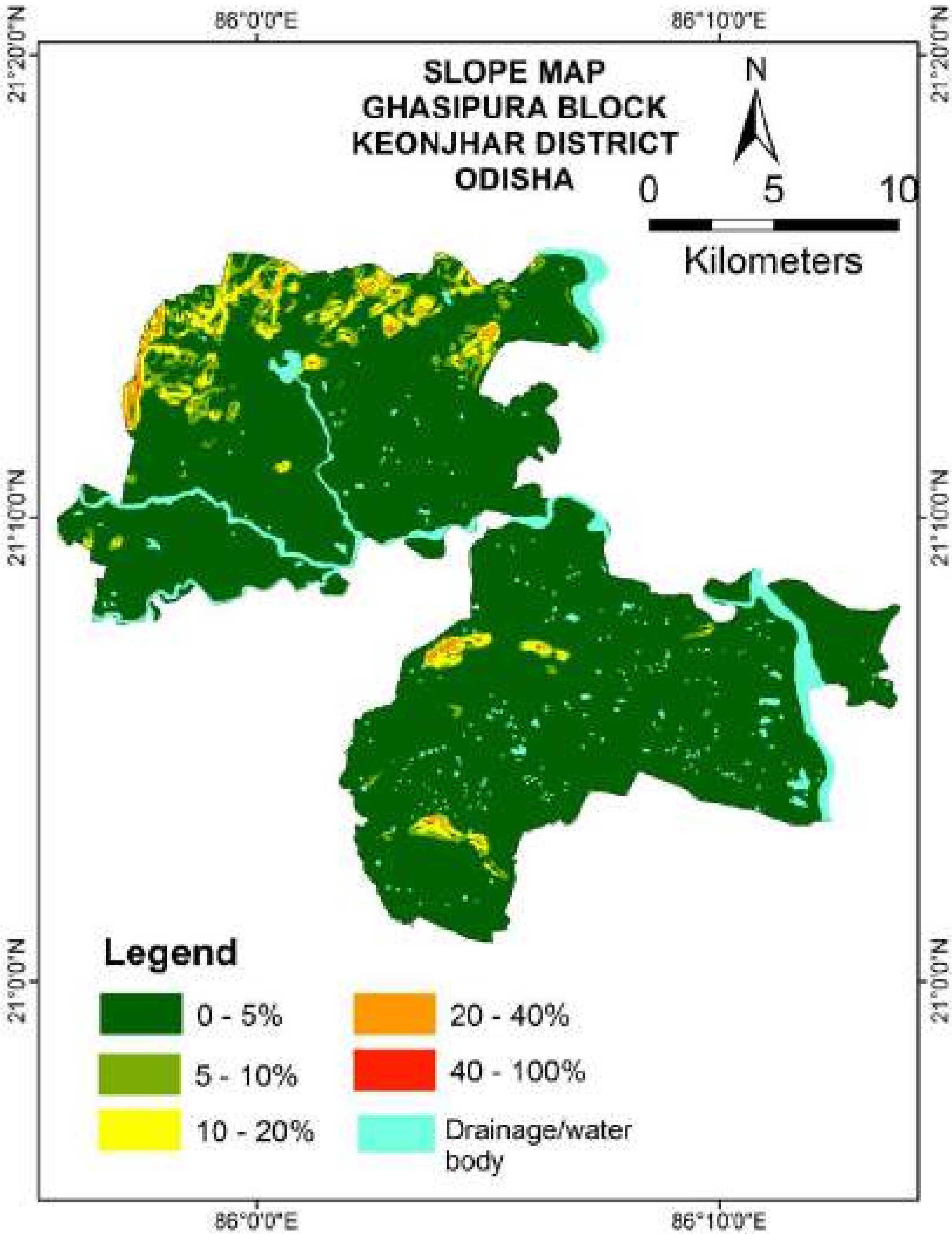

SLOPE MAP
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
86°0'0"E
86°10'0"E
21°20'0"N
21°10'0"N
21°0'0"N
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 4.5

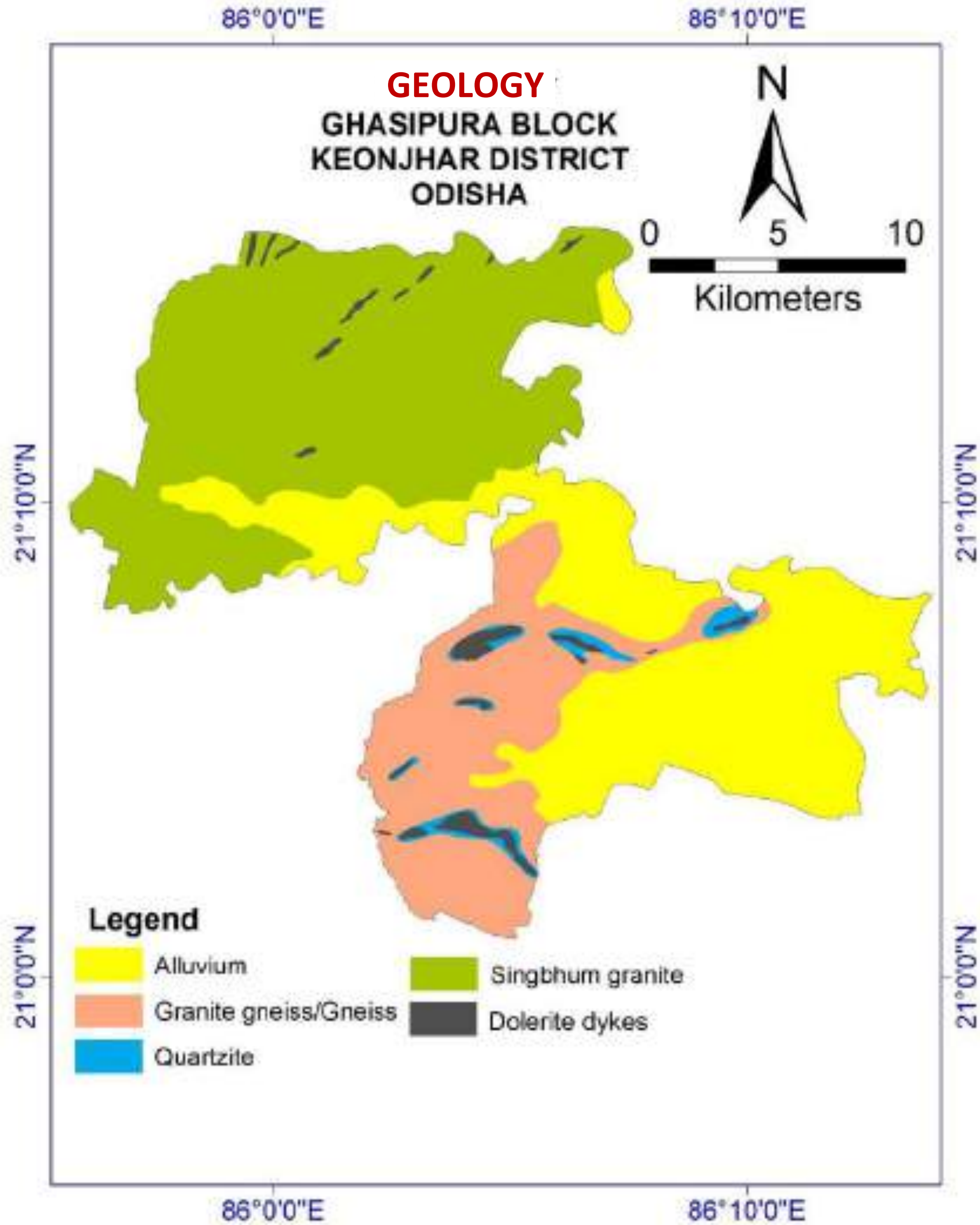
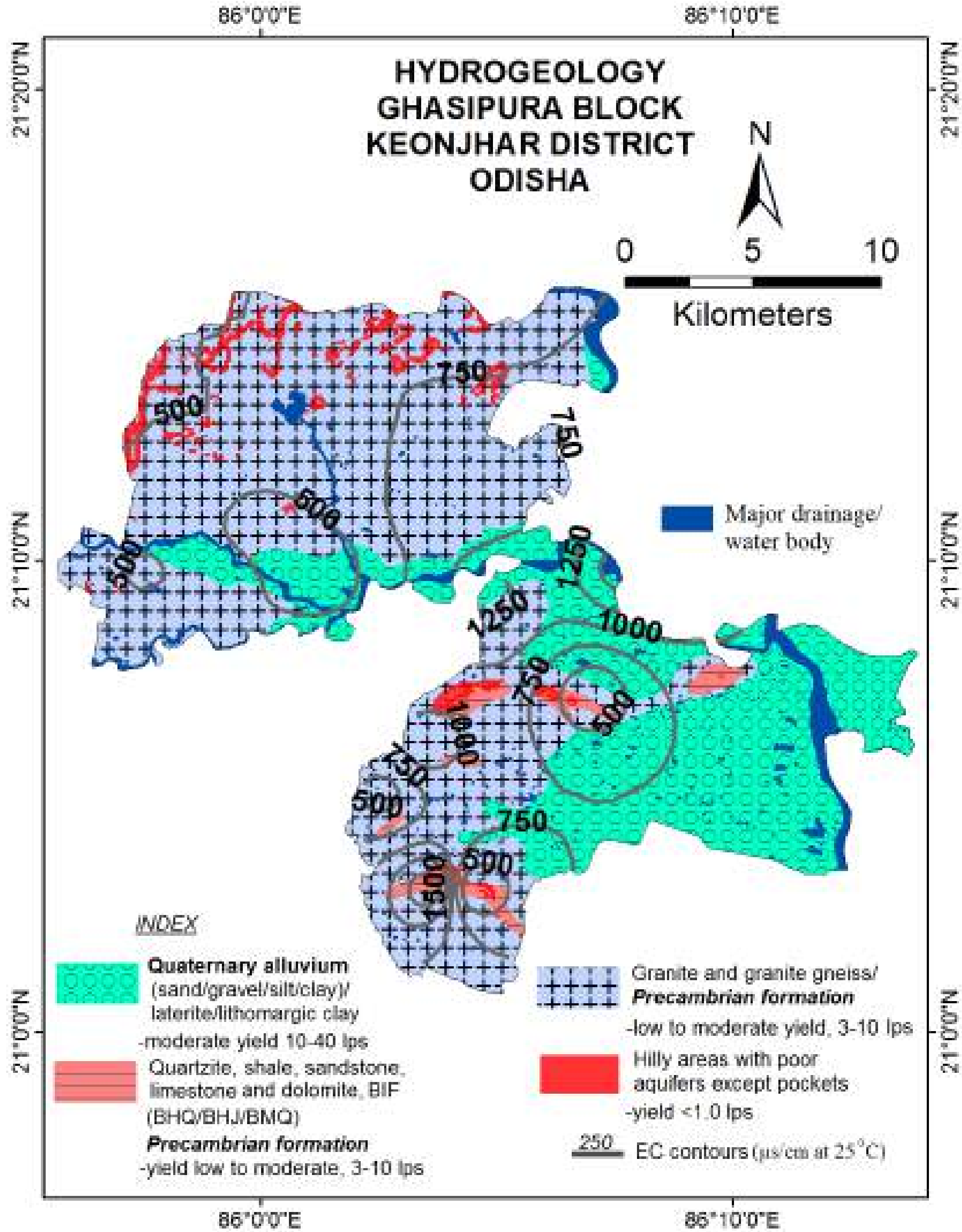
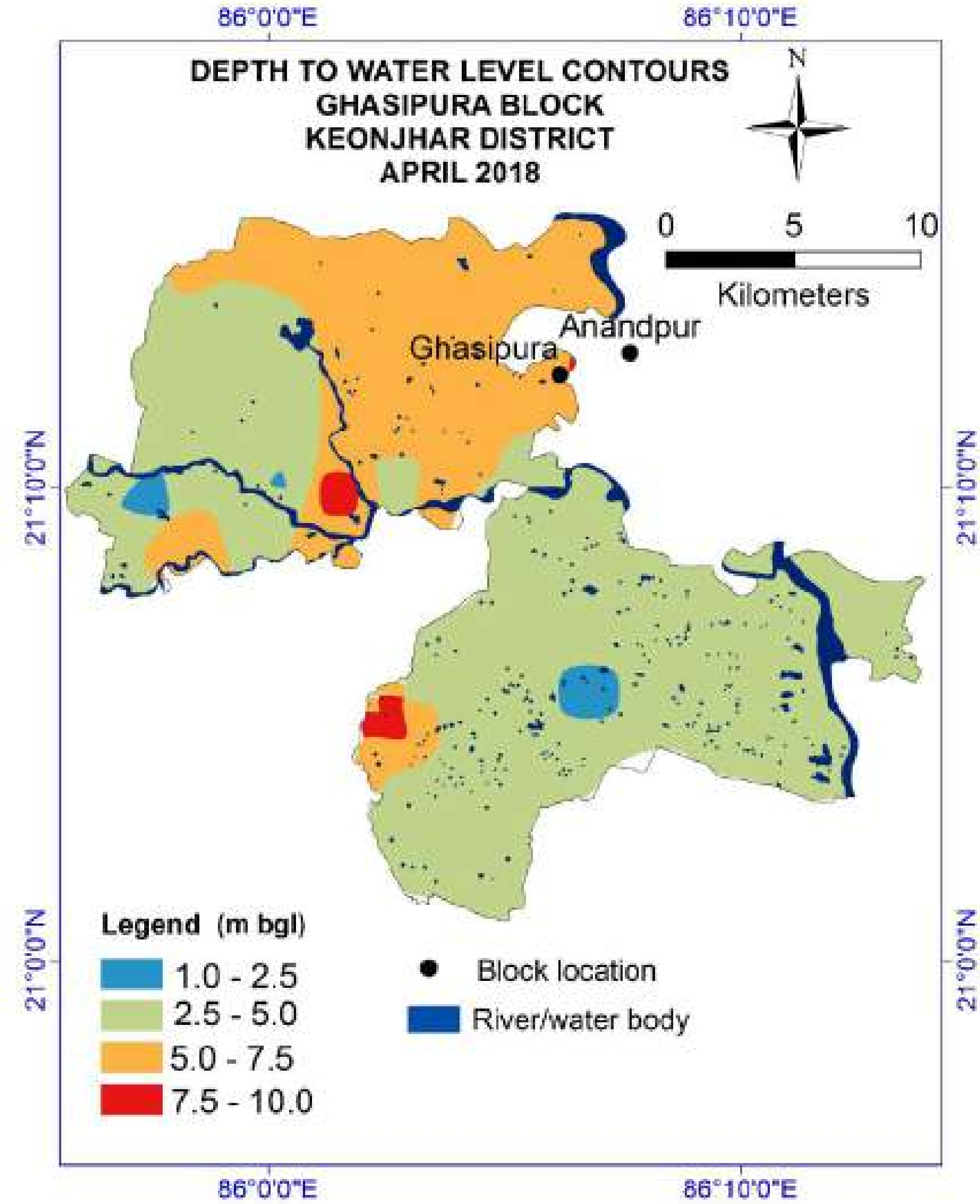

GEOLOGY
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5
10
Kilometers
86°0'0"E
86°10'0"E
21°10'0"N
21°0'0"N
Legend
Alluvium
Granite gneiss/Gneiss
Quartzite
Singbhum granite
Dolerite dykes

PLATE – 4.6



HYDROGEOLOGY
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
86°0'0"E
86°10'0"E
21°20'0"N
21°10'0"N
21°0'0"N
750
500
1250
1000
1500
Major drainage/ water body
INDEX
Quaternary alluvium (sand/gravel/silt/clay)/ laterite/lithomargic clay -moderate yield 10-40 lps
Quartzite, shale, sandstone, limestone and dolomite, BIF (BHQ/BHJ/BMQ) Precambrian formation -yield low to moderate, 3-10 lps
Granite and granite gneiss/ Precambrian formation -low to moderate yield, 3-10 lps
Hilly areas with poor aquifers except pockets -yield <1.0 lps
250 EC contours (µs/cm at 25°C)

PLATE – 4.7



86°0'0"E
86°10'0"E
DEPTH TO WATER LEVEL CONTOURS
GHASIPURA BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0
5
10
Kilometers
Anandpur
Ghasipura
21°10'0"N
21°0'0"N
Legend (m bgl)
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
Block location
River/water body

PLATE – 4.8

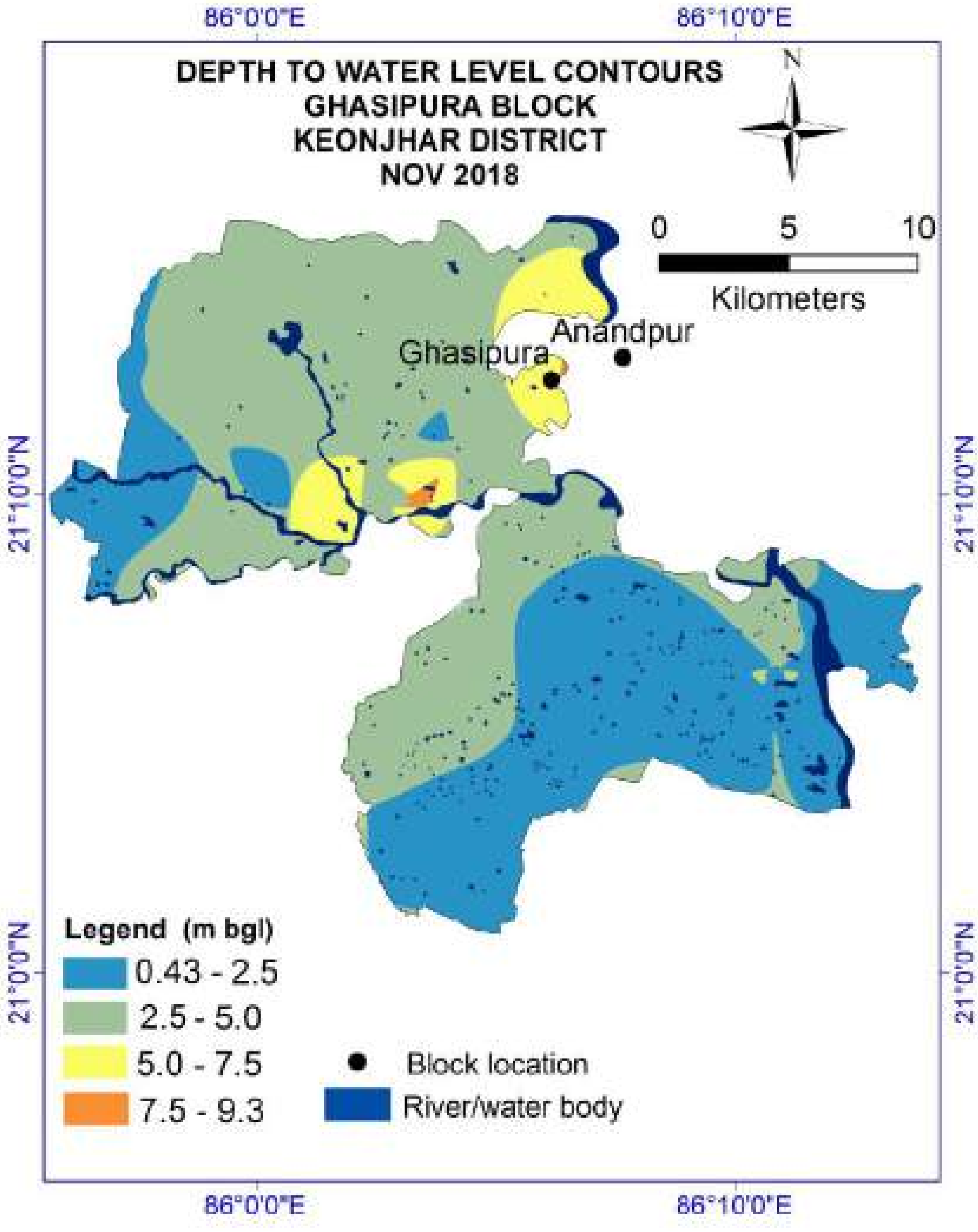

DEPTH TO WATER LEVEL CONTOURS
GHASIPURA BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0
5
10
Kilometers
Anandpur
Ghasipura
86°0'0"E
86°10'0"E
21°10'0"N
21°0'0"N
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
River/water body

PLATE – 4.9

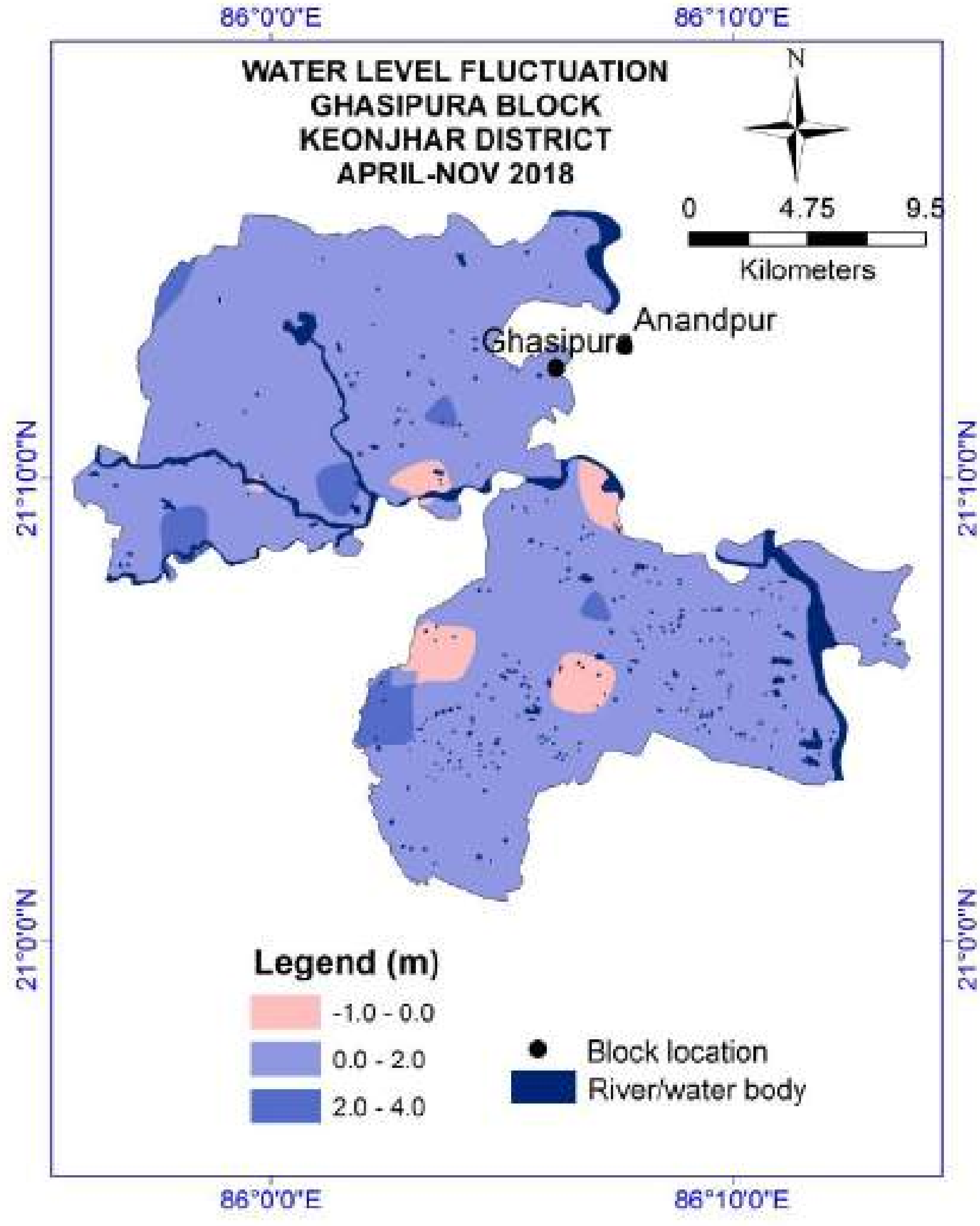

86°0'0"E
86°10'0"E
WATER LEVEL FLUCTUATION
GHASIPURA BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0
4.75
9.5
Kilometers
Anandpur
Ghasipura
21°10'0"N
21°0'0"N
Legend (m)
-1.0 - 0.0
0.0 - 2.0
2.0 - 4.0
Block location
River/water body

PLATE – 4.10

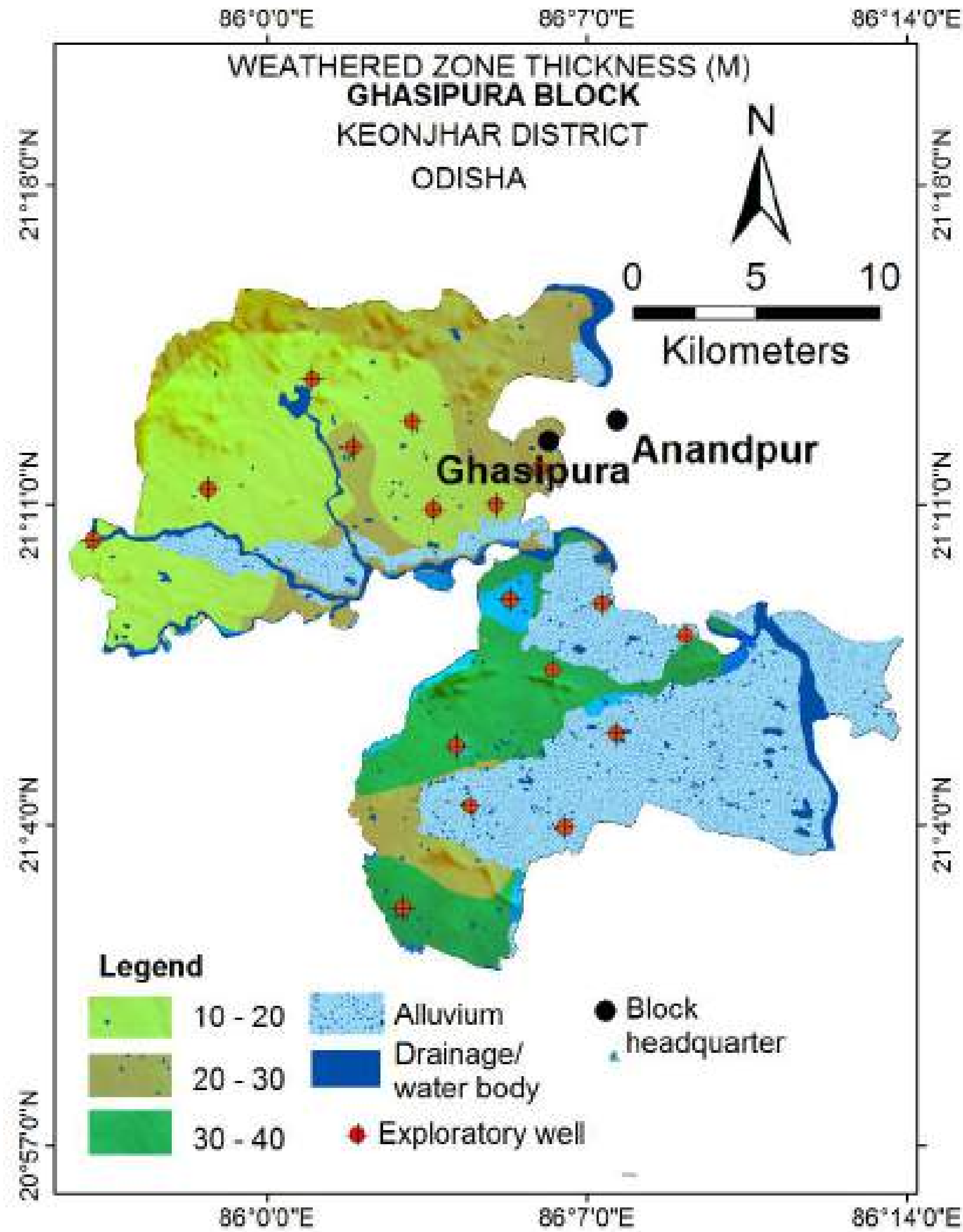

WEATHERED ZONE THICKNESS (M)
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
Ghasipura
Anandpur
86°0'0"E
86°7'0"E
86°14'0"E
21°18'0"N
21°11'0"N
21°4'0"N
20°57'0"N
Legend
10 - 20
20 - 30
30 - 40
Alluvium
Drainage/ water body
Exploratory well
Block headquarter

PLATE – 4.11

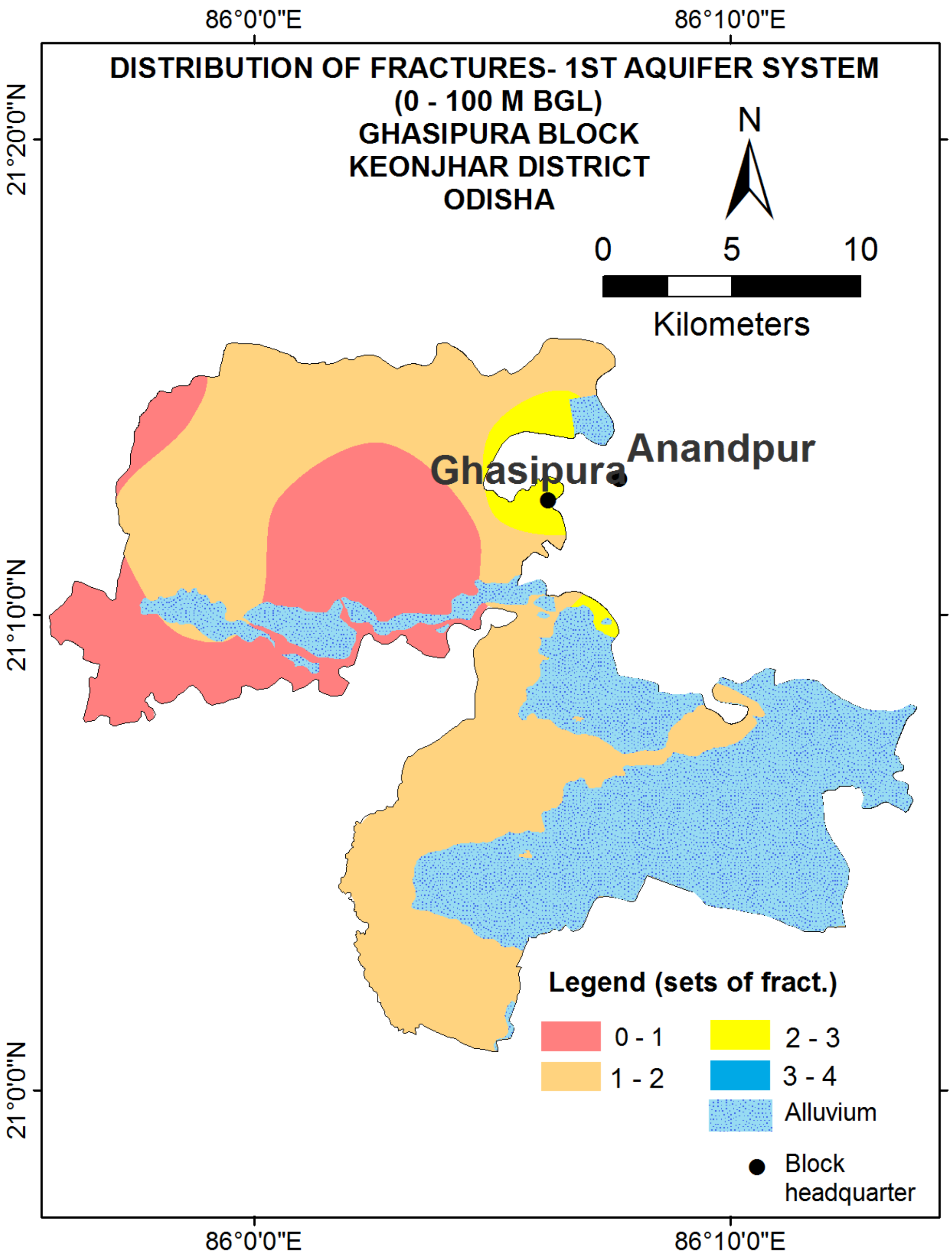

86°0'0"E
86°10'0"E
21°20'0"N
21°10'0"N
21°0'0"N
DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5
10
Kilometers
Ghasipura
Anandpur
Legend (sets of fract.)
0 - 1
1 - 2
2 - 3
3 - 4
Alluvium
Block headquarter

PLATE – 4.12

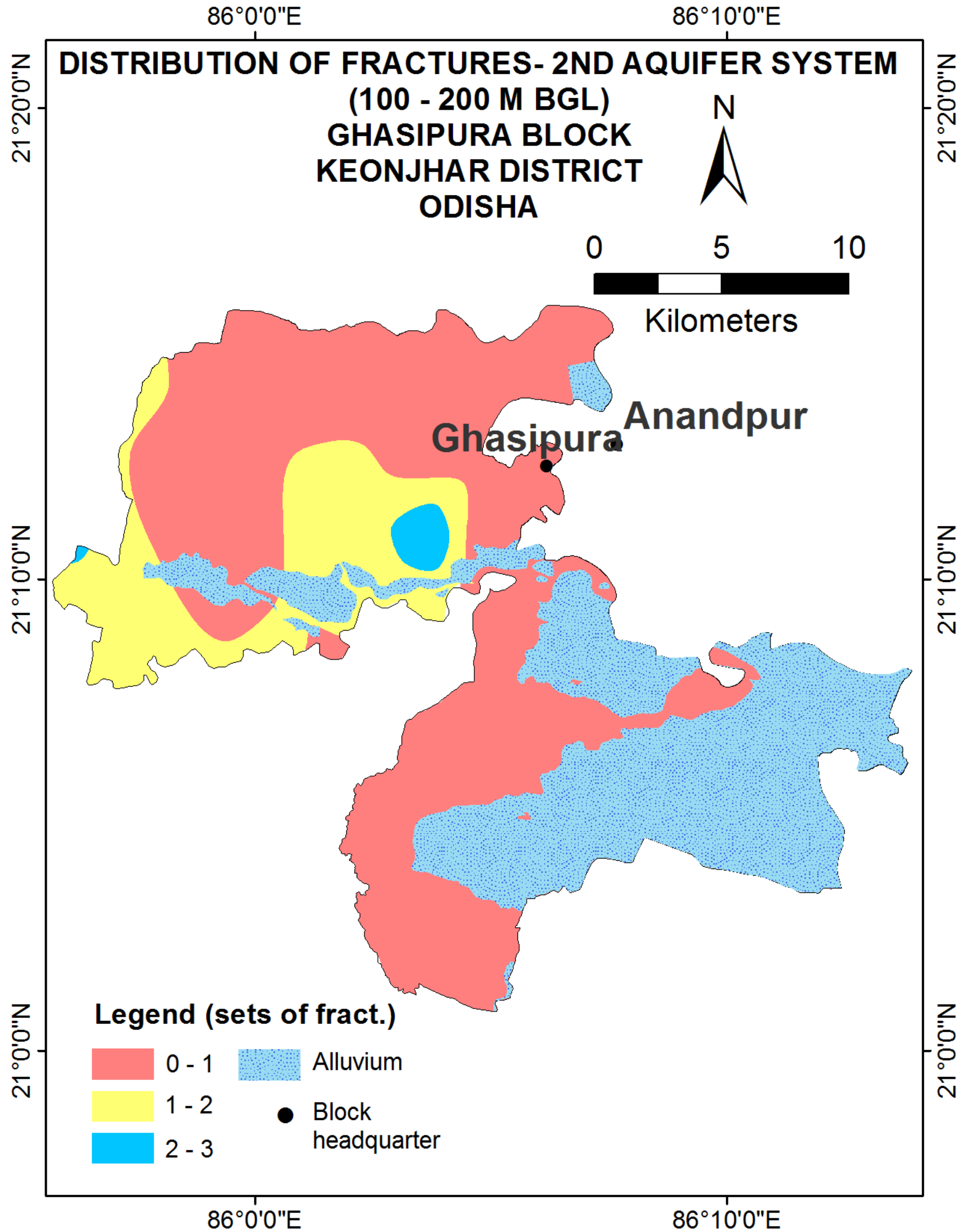
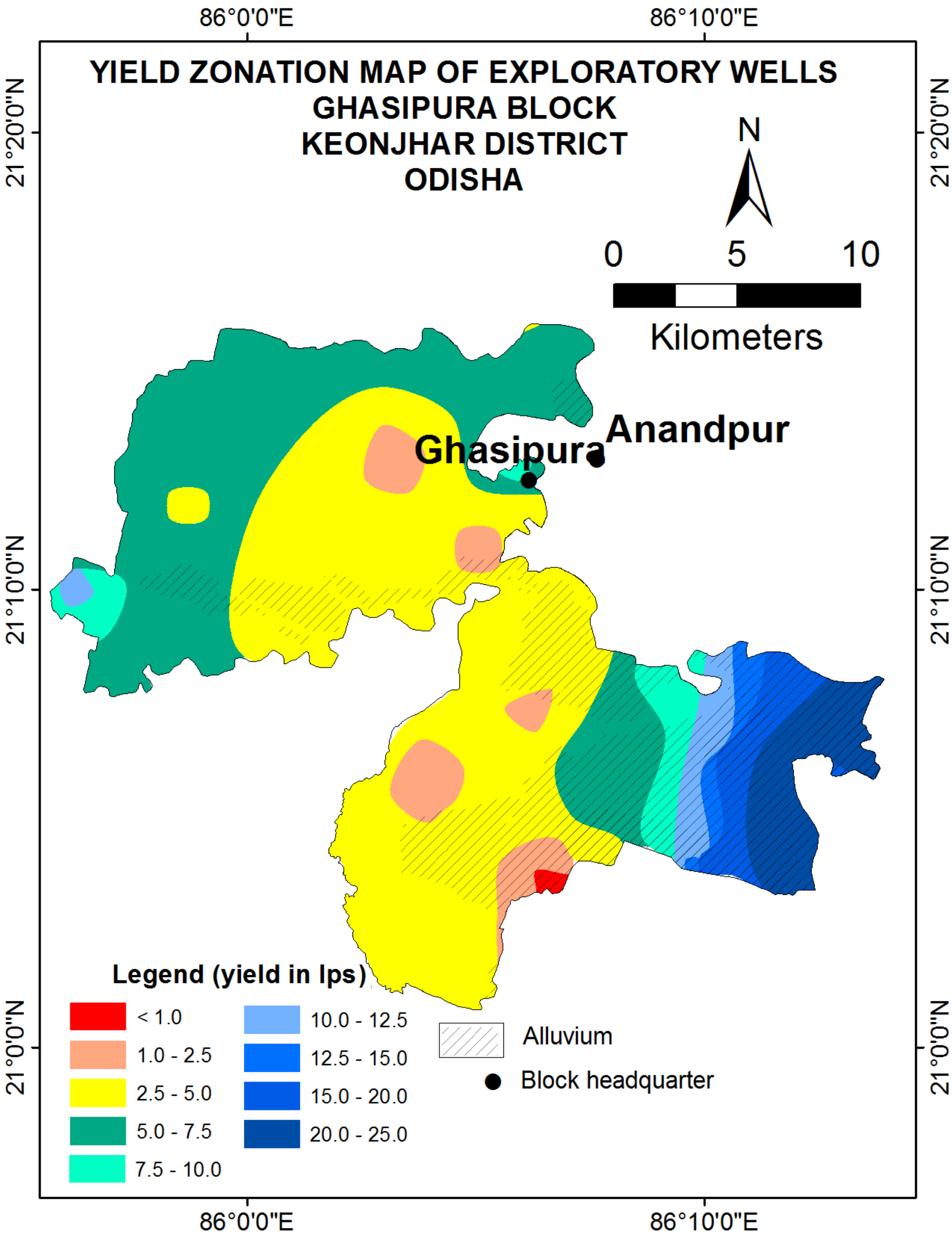
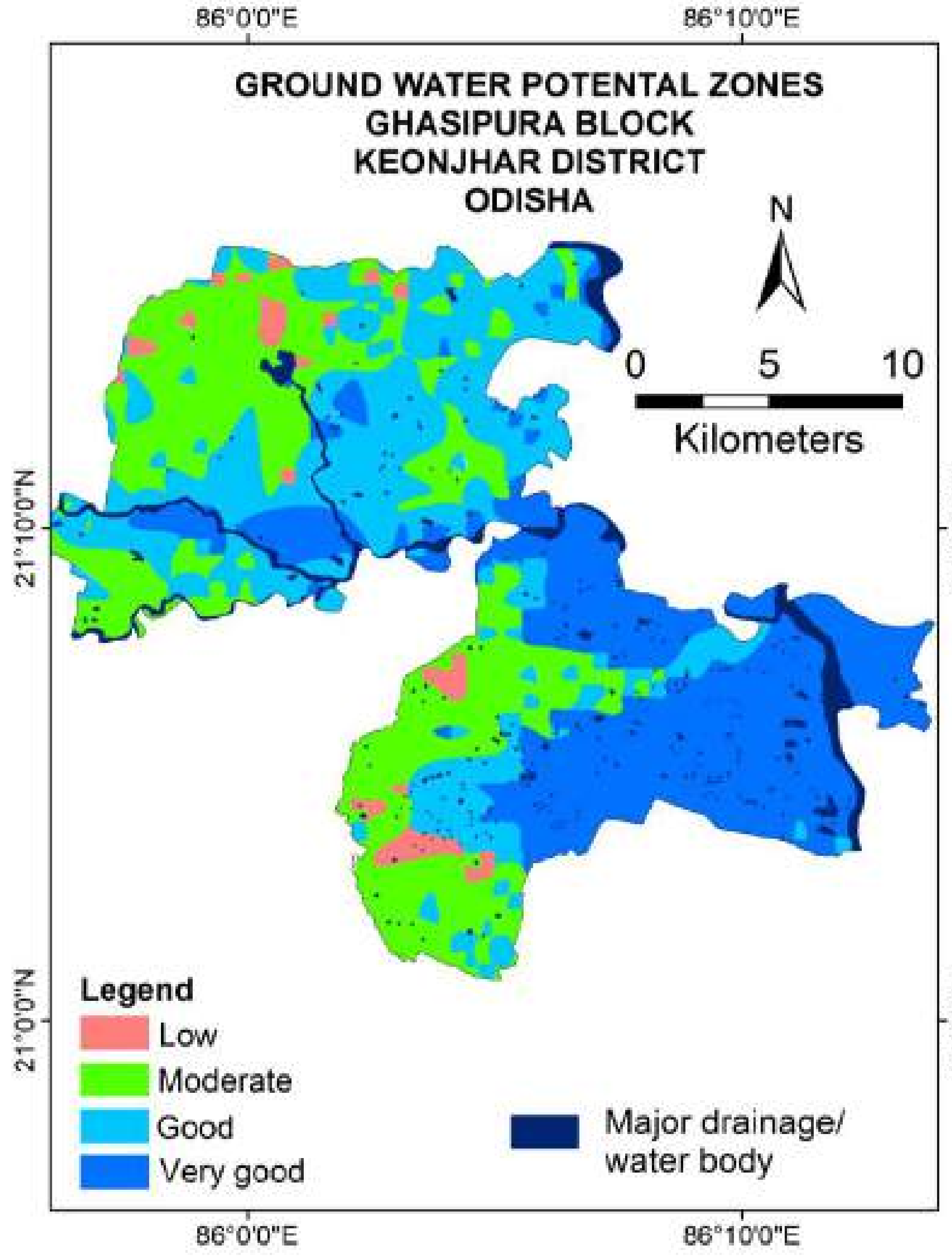

DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
Anandpur
Ghasipura
86°0'0"E
86°10'0"E
21°20'0"N
21°10'0"N
21°0'0"N
Legend (sets of fract.)
0 - 1
1 - 2
2 - 3
Alluvium
Block headquarter

PLATE – 4.13



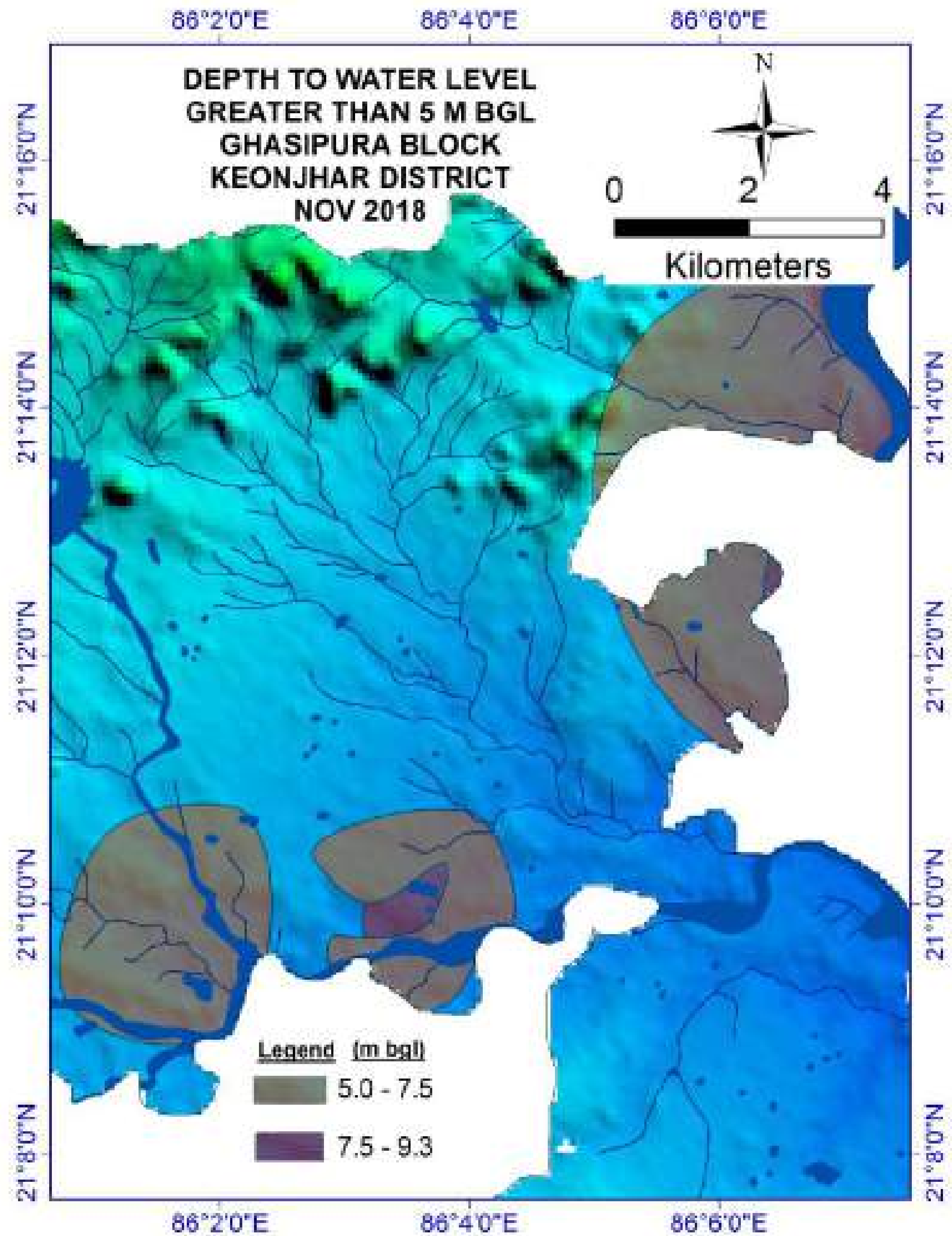
YIELD ZONATION MAP OF EXPLORATORY WELLS
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
86°0'0"E
86°10'0"E
21°20'0"N
21°10'0"N
21°0'0"N
N
0
5
10
Kilometers
Ghasipura
Anandpur
Legend (yield in lps)
< 1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
12.5 - 15.0
15.0 - 20.0
20.0 - 25.0
Alluvium
Block headquarter

PLATE – 4.14



86°0'0"E
86°10'0"E
GROUND WATER POTENTAL ZONES
GHASIPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
21°10'0"N
21°0'0"N
Legend
Low
Moderate
Good
Very good
Major drainage/
water body

PLATE – 4.15


DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
GHASIPURA BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0
2
4
Kilometers
86°2'0"E
86°4'0"E
86°6'0"E
21°16'0"N
21°14'0"N
21°12'0"N
21°10'0"N
21°8'0"N
Legend (m bgl)
5.0 - 7.5
7.5 - 9.3

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

5.0 GHATGAON BLOCK

5.1 Salient information

Location, area and demography

Location (Plate 5.1)	85^0 38' - 86^0 00' E longitude 21^0 20' – 21^0 38'' N latitude
Area	613 sq. km
No. of Gram Panchayats	26
No. of villages	142
Population (Census 2011)	1,18,307 (rural)
Literacy	52.3%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1766.1 mm
Monsoon normal rainfall	1327.7 mm (75% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	27522 Ha
Net sown area (2)	18686 Ha
Area sown more than once (1-2)	8836 Ha
Cropping intensity (%)	147.3 Ha
Area under forest	36600 Ha
Area under wasteland	1276 Ha
Area under other uses	17536 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	11058 Ha *Kharif:* 6785 Ha *Rabi:* 4273 Ha

5.2 Drainage, geomorphology and soil types

The Baitarani River forms the master drainage and flows in the eastern side of the block. The Sita River and upper reaches of Musal River take the run off to Baitarani and join on its right bank. The drainage pattern is sub-dendritic to sub-trellis and parallel in nature (Plate 5.2). The drainage patterns are controlled by linear dykes and other structural lineations.

Major part of the block is occupied by hydro-geomorphic units like pediments, buried pediment and valley fills (together make ~75% of block area) which are considered as suitable for groundwater occurrence. A significant part (~22% of the area) in the east and central portions are covered by denudational hills which are not suitable for groundwater occerrence (Fig 5.1 and Plate 5.3). There are swarms of linear basic (dolerite) dykes that traverse the block NE-SW and NW-SE directions. Most of the block area (~82%) is characterized by land surface slope of <5% (Fig 5.2), except the patches in the denudational hills and dykes where it exceeds 20% slope (Plate 5.4). The soil types are predominantly red red sandy (alfisol), red loamy (alfisol) and red and yellow types (ultisol).

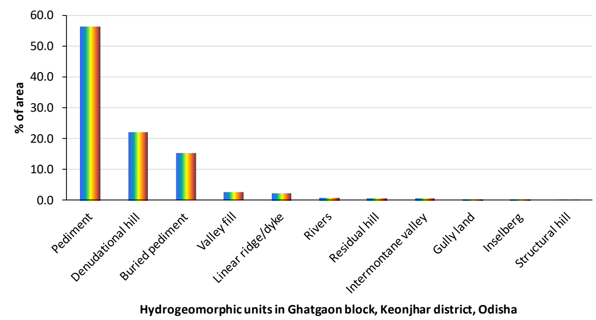


Figure 5.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Ghatgaon block.

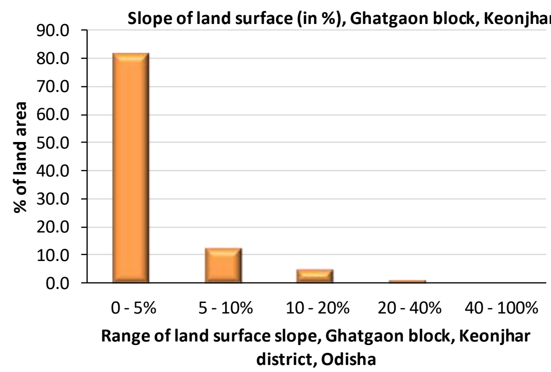


Figure 5.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Ghatgaon block, Keonjhar district.

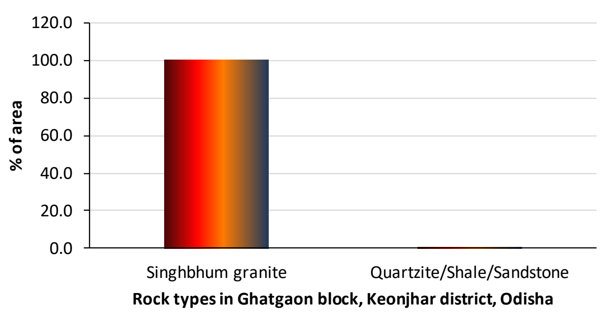


Figure 5.3: Percentage (%) of Ghatgaon block area (Keonjhar dist.) covered by various rock types.

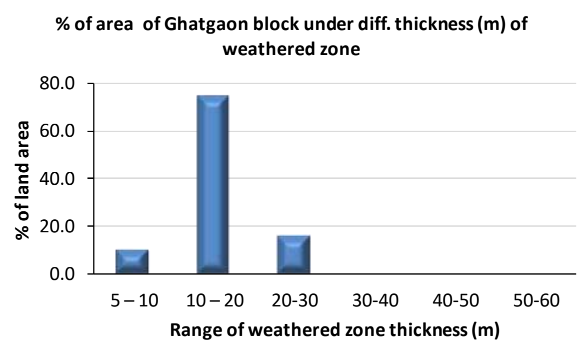


Figure 5.4: Bar diagram depicting the percentage (%) area of Ghatgaon block, Keonjhar district falling under different weathered zone thickness (m) ranges.

5.3 Geology

Almost thye entire block (99.9%) is occupied by Singhbhum Granites of Precambrian age. These rocks have been traversed by several linear basic dykes that run in NE-SW and NW-SE directions (Fig 5.3 and Plate 5.5).

5.4 Hydrogeology

The weathered residumm in the Singhbhum Granites at shallow depth and the fracture zones at deeper depths form groundwater repositories in the block. The generalized hydrogeological map of the block is presented in Plate 5.6. The Singhbhum Granites possess low to moderate yield potential varying between 3-10 lps. The dykes also in many instances play roles if groundwater occurrence. The linear dykes in transverse direction obstruct the groundwater flow and help in accumulation of groundwater in the secondary porosities in the country rock.

Though, the water levels during pre-monsoon (year 2018) in certain limited patches were recorded <5.0-10.0 m bgl, in major parts of the block it remained >5.0 m bgl in the range of 5.0-12.5 m bgl (Plate 5.7). During the post-monsson period, however, almost the entire block (except smaller patches in the northern half) depicted water levels <5.0 m bgl, indicating good recharge from rainfall (Plate 5.8). The annual fluctuations in the water levels remained in the range of 1.0-4.0 m (Plate 5.9).

5.5 Aquifer geometry and characters

The thickness of the weathered regolith in major parts of the block (~75% of area) is moderate varying between 10-20 m only. Only in limited patches it exceeds 20 m and goes up to 40 m (Plate 5.10; Fig 5.4). The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 5.5a-b.

In major parts of the block, only 0-1 sets of fracture zones are encountered in bore wells within the depth of 100 m bgl (1st aquifer system). Towards west, 1-2 sets of fractures are found (Plate 5.11). Within 100-200 m depth (2nd aquifer system), 0-1 sets of fractures are observed in major parts. Towards south, 1-3 sets fracture zones have been observed during drilling (Plate 5.12). In major cases, the wells yielded 2-5 lps of water, in some cases reaching up to 10 lps.

Yield less than 1.0 lps has been observed in some wells in north-western and south-eastern parts of the block (Plate 5.13).

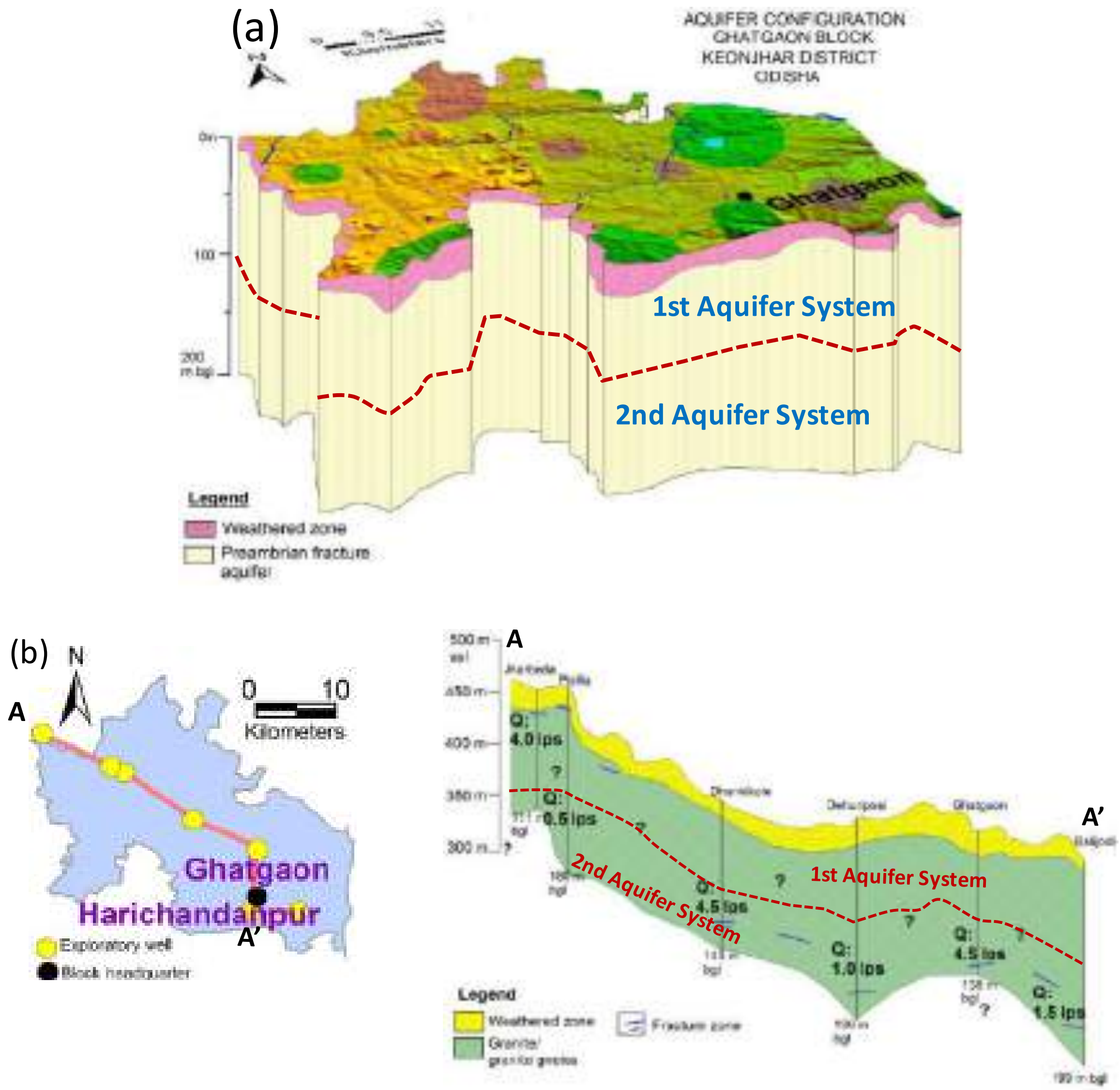


Figure 5.5: 3D aquifer disposition in Ghatgaon block, Keonjhar district. (2D hydrogeological transect (including its location) depicting the aquifer disposition in the block.

5.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 5.14). The good and very groundwater potential zones in the block have been delineated in the central and eastern parts, which cover ~40% of the geographical area (Fig 5.6).

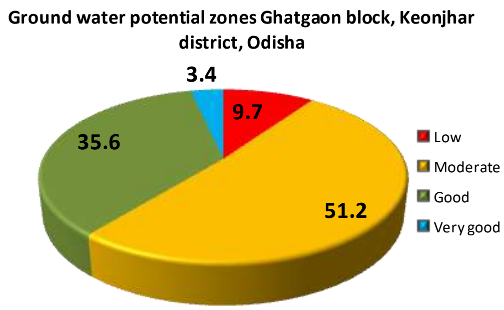


Figure 5.6: Pie diagram depicting the perentage (%) of Ghatgaon block, Keonjhar district, Odisha, falling under different groundwater potential zones.

5.7 Ground water quality

Ground water in the block is alkaline in nature (Table 5.1) and pH range of 7.3-8.5. The water is moderately hard to very hard. The mineralization is low to moderate with TDS in the range of 70-625 mg/L (ave.: 211 mg/L). Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly Ca-HCO_3 and Ca- HCO_3-Cl types with Ca^{2+} and HCO_3^- as the principal contributing ions in the groundwater quality (Fig 5.7).

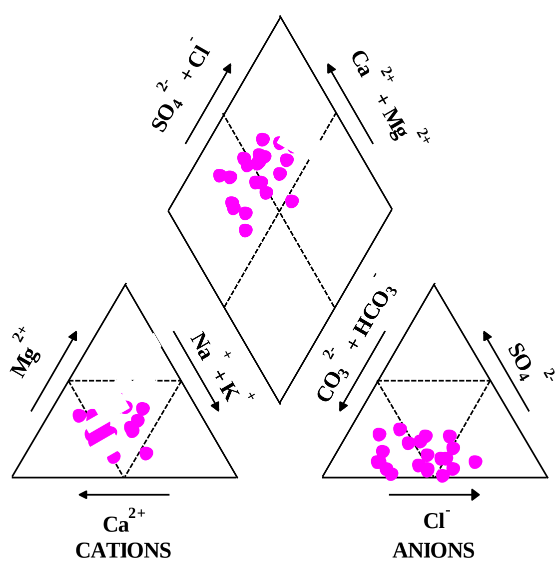


Figure 5.7: The Piper trilinear diagram depicting the groundwater quality in Ghatgaon block, Keonjhar district.

Table 5.1: Ground water quality at various locations in Ghatgaon block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Binajhari	7.29	230	109	91	74	23	8	7	1.09	0	90	24	1	0.06
Dhangardiha	7.46	300	162	96	78	29	6	23	4.49	0	95	50	4	0.08
Balipokhari	7.52	620	309	197	221	39	25	39	3.27	0	269	50	21	0.89
Masinabilla	7.73	270	146	77	35	26	3	21	6.84	0	43	59	9	0.08
Dehuriposhi	8.13	260	125	91	81	26	7	16	1.71	0	99	23	4	0.11
Nalabila	7.6	140	70	50	25	9	7	5	5.52	0	31	26	2	0.09
Bankapatuli	8.48	430	227	127	141	40	7	31	6.88	6	160	33	25	0.8
Jharbeda	7.94	230	115	59	35	15	6	20	1.46	0	43	38	14	0.19
Pichora	8.24	290	156	100	76	29	7	9	11.34	0	92	23	32	0.31
Pandapada	8.5	1110	625	245	242	73	15	116	30.2	12	271	197	47	0.15
Dhangardiha	7.89	320	173	100	51	27	8	20	6.2	0	62	51	30	0.06
Barhatipura	8.41	370	183	100	126	16	14	27	7.86	9	136	28	12	0.22
Nushriposhi	8.4	430	223	159	136	38	15	18	1.44	6	154	23	44	0.32
Santrapur	8.09	300	164	100	61	31	6	13	13.72	0	74	36	28	0.14
Mahulagadia	8.4	460	247	150	106	46	9	22	11.22	6	117	56	39	0.33
Gondsila	8.36	480	252	173	126	44	15	18	7.94	18	117	51	39	0.31
Dhangardiha	7.83	175	110.5	60	54	14	6	16.8	3.4	0	66	34	3.3	0.113
Gadadharpur	7.46	140	80.02	55	34	14	5	8.9	1.82	0	42	29	0.3	0.092
Ghatgaon	7.9	715	382.47	255	167	70	19	46.18	6.19	0	203	105	34.6	0.165
Melana	7.73	355	205.15	110	74	22	13	27.79	15.36	0	90	67	15	0.115
Patilo	8.08	650	355.66	215	181	40	28	35.66	25.3	0	221	98	18.2	0.207
Min.:	**7.29**	**140**	**70**	**50**	**25**	**9**	**3**	**5**	**1.09**	**0**	**31**	**23**	**0.3**	**0.06**
Max.:	**8.5**	**1110**	**625**	**255**	**242**	**73**	**28**	**116**	**30.2**	**18**	**271**	**197**	**47**	**0.89**
Average	**8.0**	**394.0**	**210.5**	**124.3**	**101.1**	**32.0**	**10.9**	**25.7**	**8.3**	**2.7**	**117.9**	**52.4**	**20.1**	**0.2**

5.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 5.2-5.4. The net dynamic groundwater available is 8975.7 Ham and the stage of groundwater development stands at 20.3%. Net resource available for future irrigation needs stands at 7110.6 Ham (Fig 5.8). The in-storage/static groundwater resource component of 6114.7 Ham (Table 5.3) comes from the 1st aquifer system within 100 m bgl. The total groundwater available in the block stands at 15103.4 Ham.

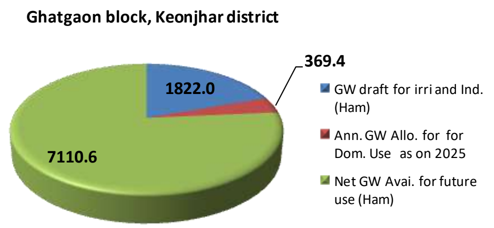


Figure 5.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Ghatgaon block, Keonjhar district, Odisha.

Table 5.2: Salient information on annual dynamic groundwater resources, Ghatgaon block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	8975.7
2. Irrigation draft (Ham)	1471.8
3. Industrial draft (Ham)	23.9
4. Domestic draft (Ham)	326.2
5. Total draft (Ham)	1822.0
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	369.4
7. Net groundwater available for future use (Ham)	7110.6
8. Stage of groundwater extraction (%)	20.3

Table 5.3: Total groundwater resoure available in the Ghatgaon block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	8975.7
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	6114.7
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	13.0
	Block total	**15103.4**

1.1 Aquifer management plan

The existing stage of groundwater development of 20.3% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction

structures as estimated in Table 5.4 (806 bore wells/dug-cum-bore wells and 6853 dug wells) are required to be constructed to develop the available additional resource of 7110.6 Ham. It can help in creating additional irrigation potential for 6236 Ha (Table 5.5).

Around 84.16 km^2 area in the block showed post-monsoon depth to water levels >5.0 m bgl (Plate 5.15; Table 5.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 8.84 MCM of water (Table 5.7) can be recharged by the help additional 18-percolations ponds, 9-subsurface dykes, 9-nala/contour bunds and 18-check dams (Table 5.8) with a total cost of 5.74 crores of rupees (Table 5.9).

Table 5.4: Number of additional feasible groundwater abstraction structures in Ghatgaon block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	8975.7
2	Stage of GW deve. (%)	20.3
3	Present GW draft (Ham)	1822
4	Ground water draft at 60% stage of deve. (Ham)	5385.4
5	Addi. water to be deve. (Ham)	3563.4
6	Addi. no of BW/ dug-cum-bore wells feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	806
7	Addi. no. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	6853

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 5.5: Irrigation potential likely to be created in Ghatgaon block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	20.3
2	Surplus GW avai. for 60% stage of deve. (Ham)	3563.4
3	Irri, Pot. likely to be created for Paddy (Ha)	1781.7
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	1781.7
5	Irri. Pot. likely to be created for veg. (Ha)	2672.6
6	Proj. area to be Irri. (ha)	6236

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 5.6: Areas in Ghatgaon block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Ghatgaon	78.37	5.79	84.16

Table 5.7: Estimation of volume of water required for artificial recharge to groundwater in Ghatgaon block, Keonjhar district.

Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to reharge (MCM)
Ghatgaon	613.00	84.16	6.5	3.5	294.54	8.84

Table 5.8: Number of feasible structures in Ghatgaon block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (MCM)	No of different freasible structures			
		Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
Ghatgaon	8.84	18	9	9	18

Table 5.9: Estimation of cost of artificial recharge structures in Ghatgaon block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Ghatgaon	3.53	0.88	0.44	0.88	5.74

PLATE – 5.1

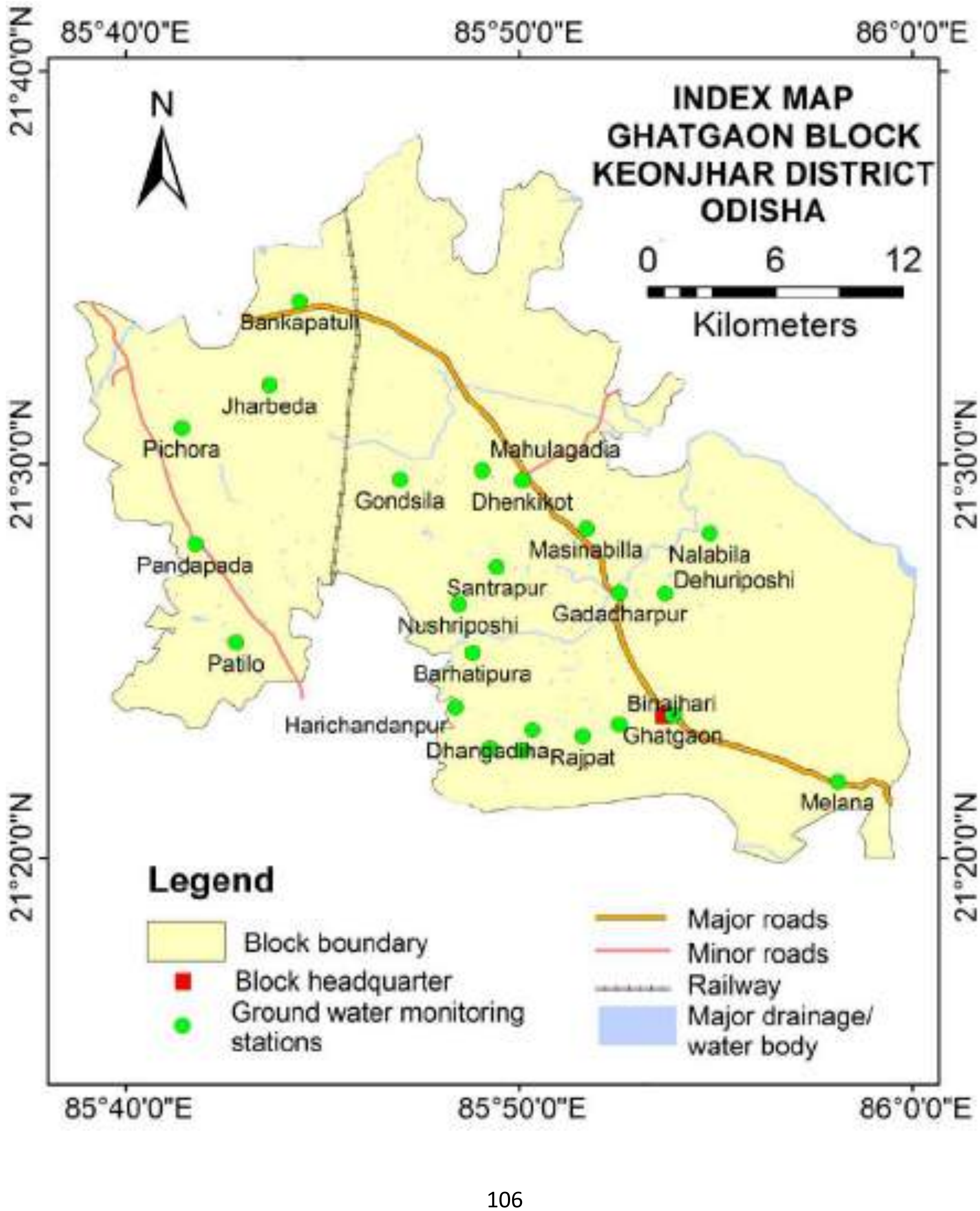

85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
N
INDEX MAP
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
0 6 12
Kilometers
Bankapatuli
Jharbeda
Pichora
Gondsila
Mahulagadia
Dhenkikot
Masinabilla
Nalabila
Dehuriposhi
Pandapada
Santrapur
Gadadharpur
Nushriposhi
Patilo
Barhatipura
Binajhari
Harichandanpur
Ghatgaon
Dhangadiha
Rajpat
Melana
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body

PLATE – 5.2

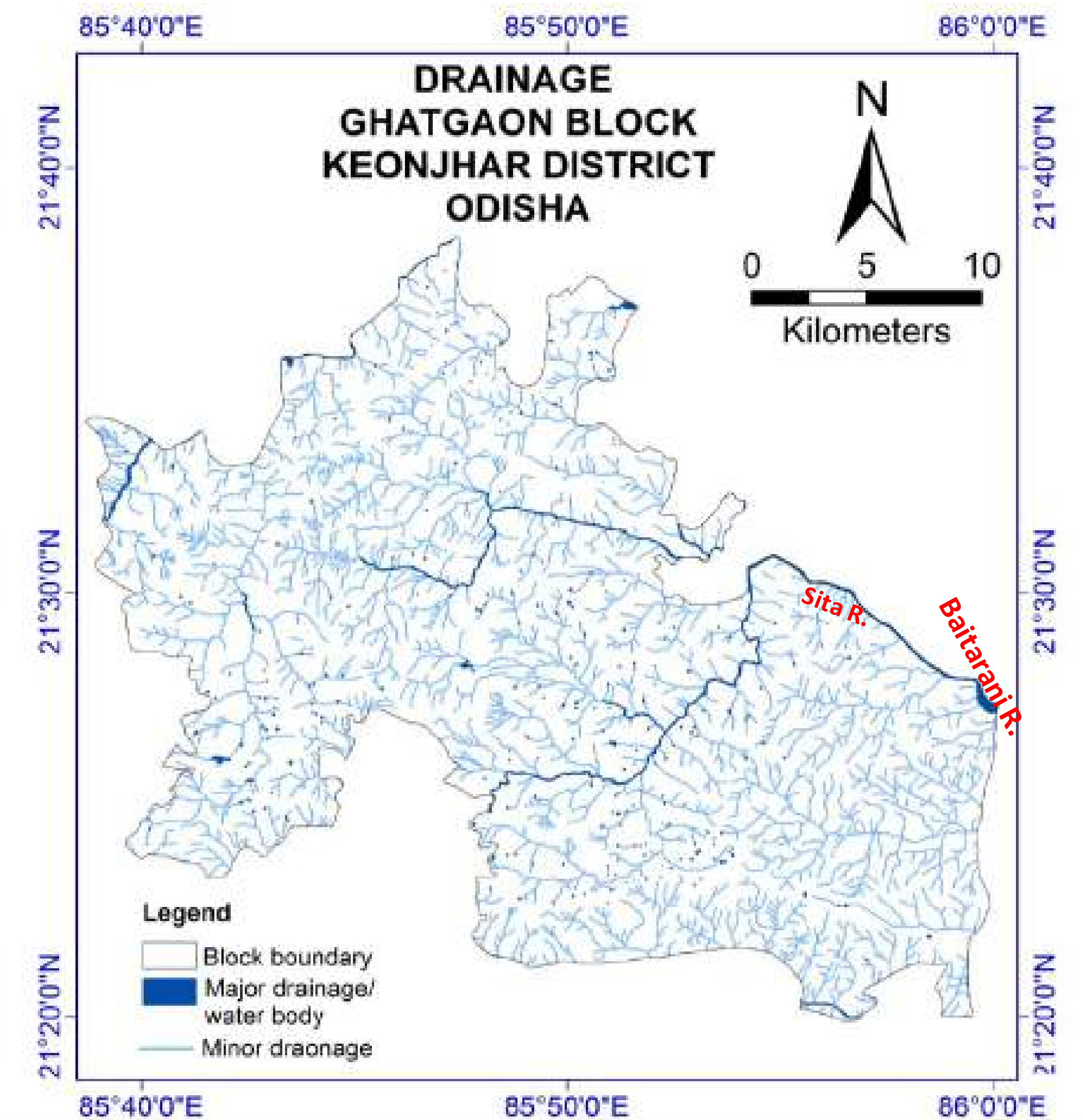

DRAINAGE
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5
10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
Sita R.
Baitarani R.
Legend
Block boundary
Major drainage/ water body
Minor draonage

PLATE – 5.3

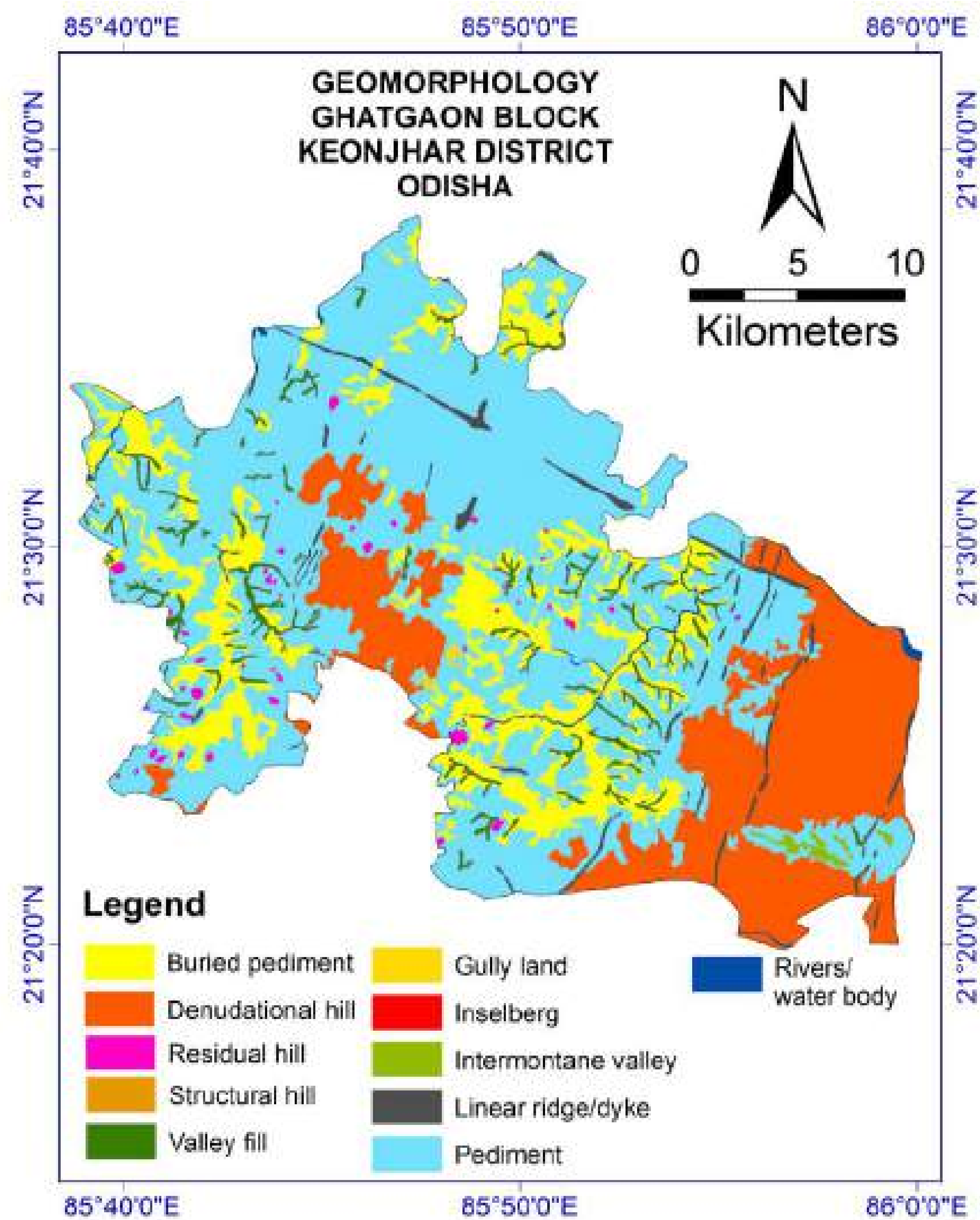

GEOMORPHOLOGY
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
Legend
Buried pediment
Denudational hill
Residual hill
Structural hill
Valley fill
Gully land
Inselberg
Intermontane valley
Linear ridge/dyke
Pediment
Rivers/ water body

PLATE – 5.4

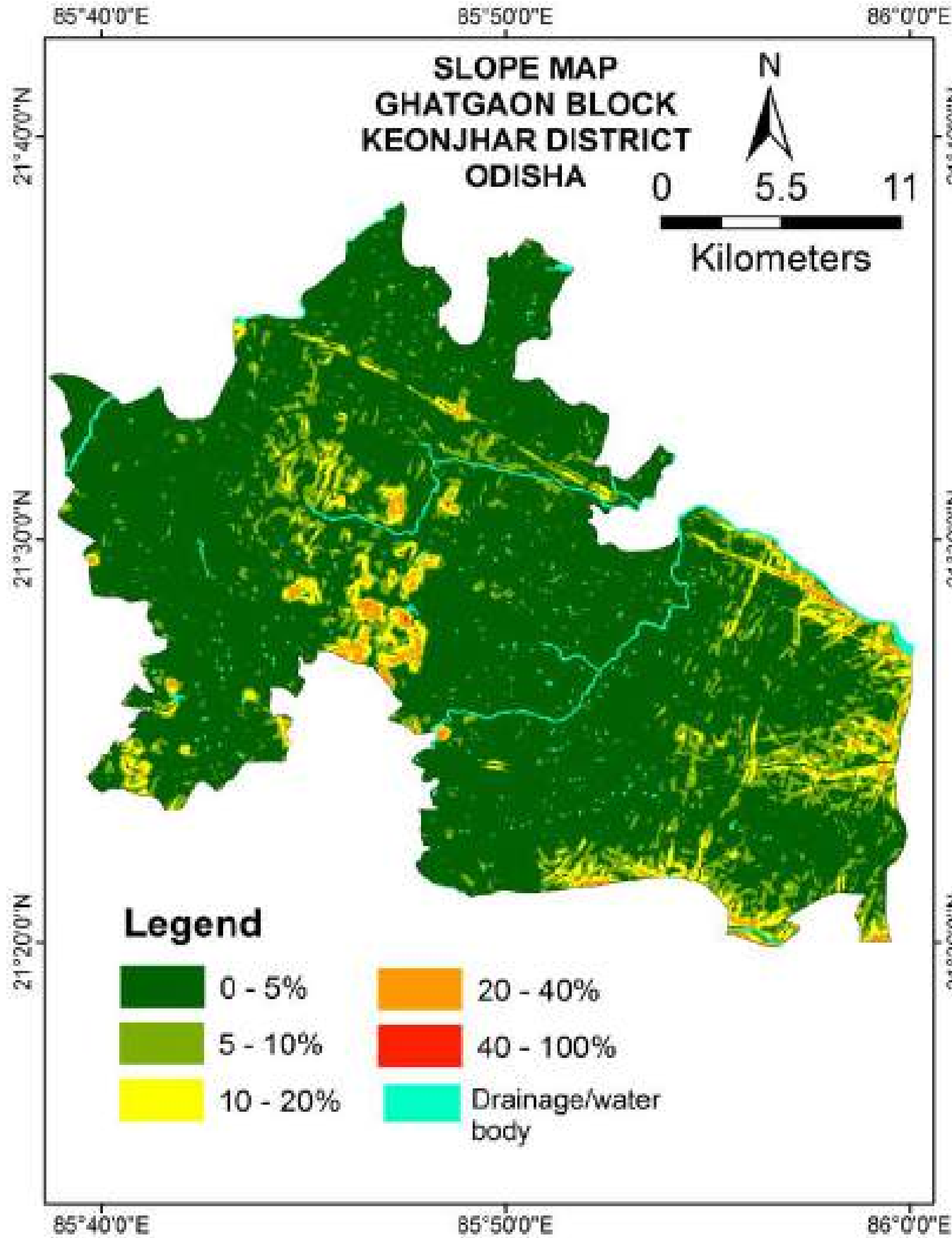

SLOPE MAP
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5.5
11
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 5.5

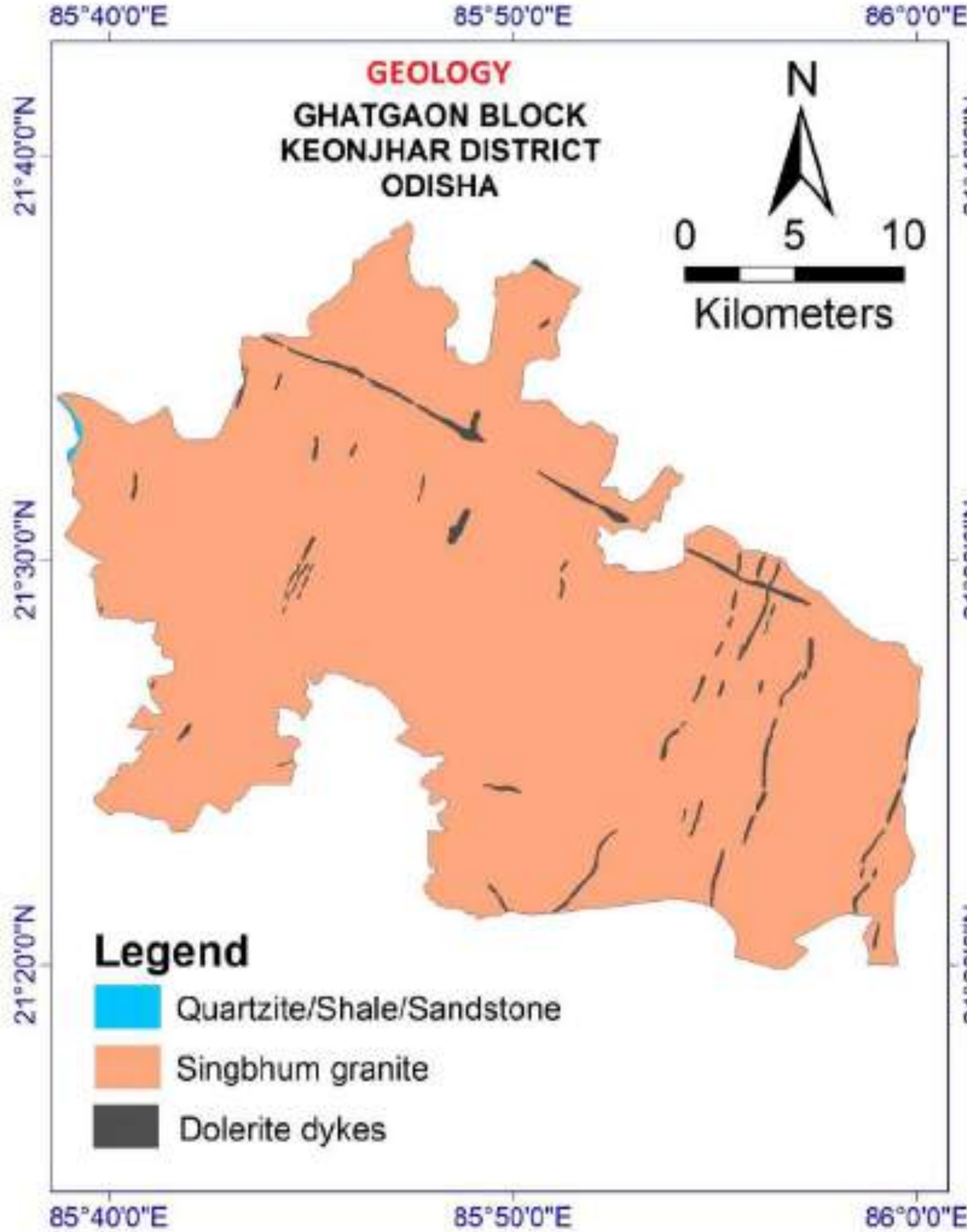
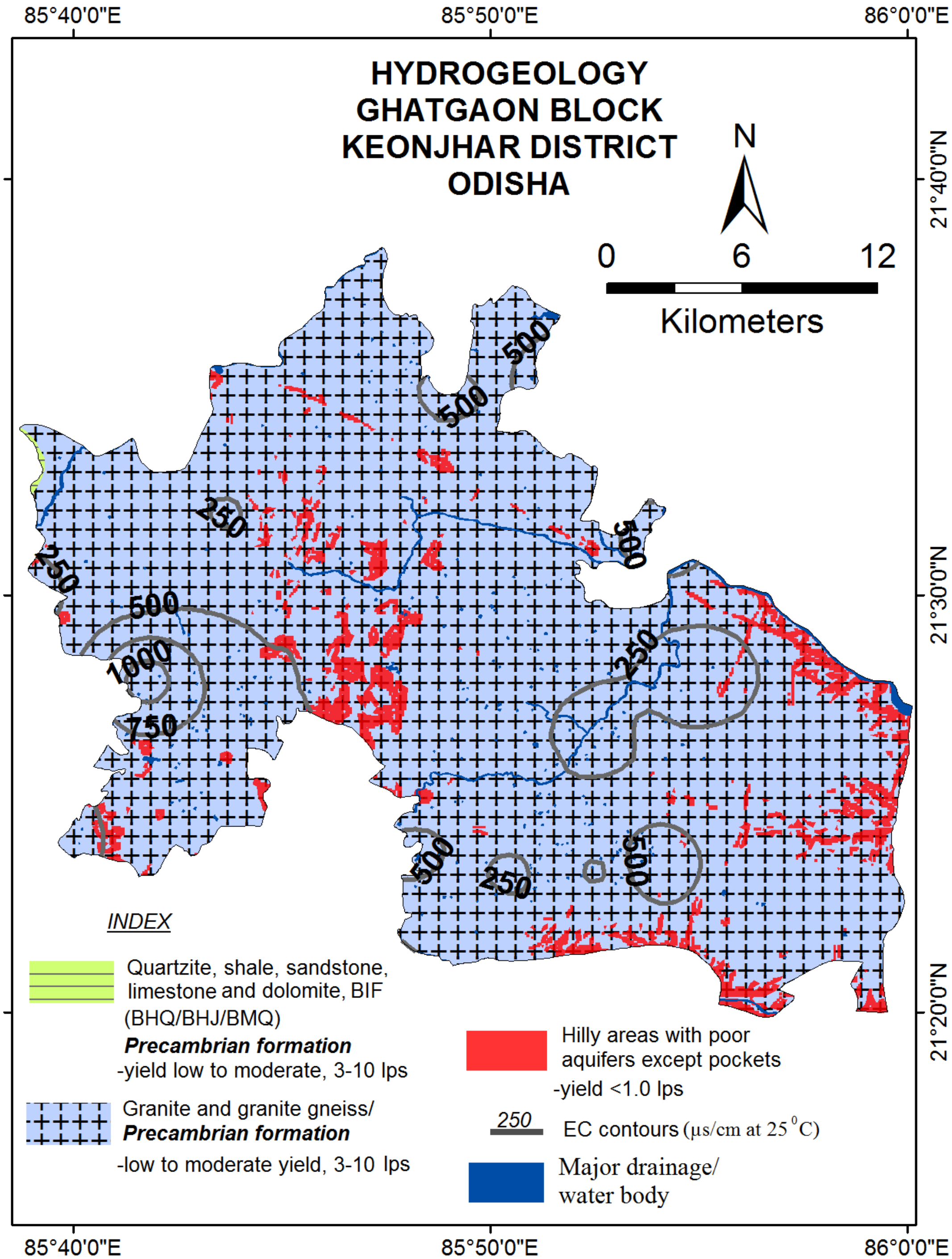

GEOLOGY
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
Legend
Quartzite/Shale/Sandstone
Singbhum granite
Dolerite dykes

PLATE – 5.6



HYDROGEOLOGY
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
500
250
1000
750
INDEX
Quartzite, shale, sandstone, limestone and dolomite, BIF (BHQ/BHJ/BMQ)
Precambrian formation
-yield low to moderate, 3-10 lps
Granite and granite gneiss/
Precambrian formation
-low to moderate yield, 3-10 lps
Hilly areas with poor aquifers except pockets
-yield <1.0 lps
250 EC contours (μs/cm at 25 °C)
Major drainage/ water body

PLATE – 5.7

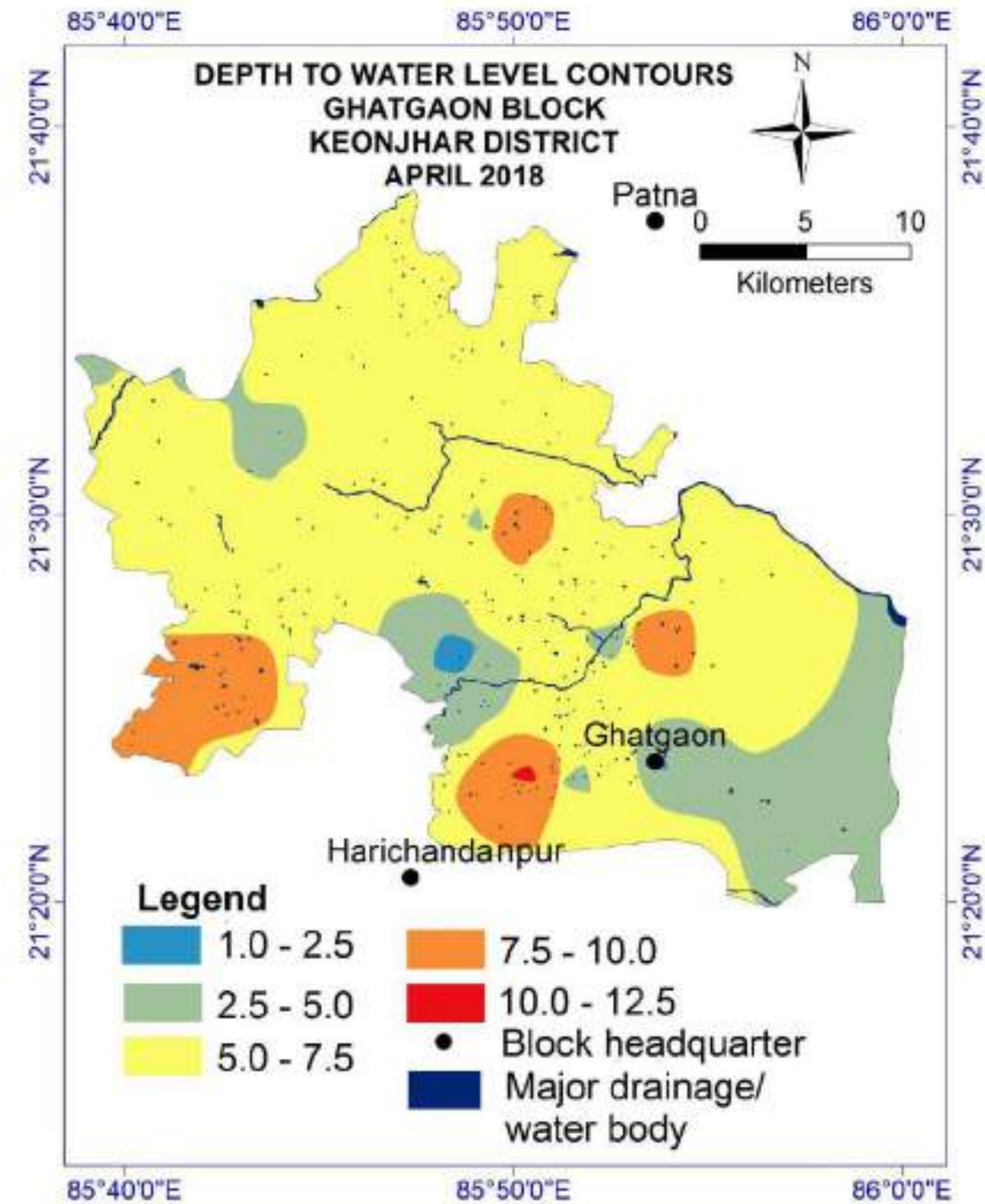

85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
DEPTH TO WATER LEVEL CONTOURS
GHATGAON BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
Patna
0 5 10
Kilometers
Ghatgaon
Harichandanpur
Legend
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
Block headquarter
Major drainage/ water body

PLATE – 5.8

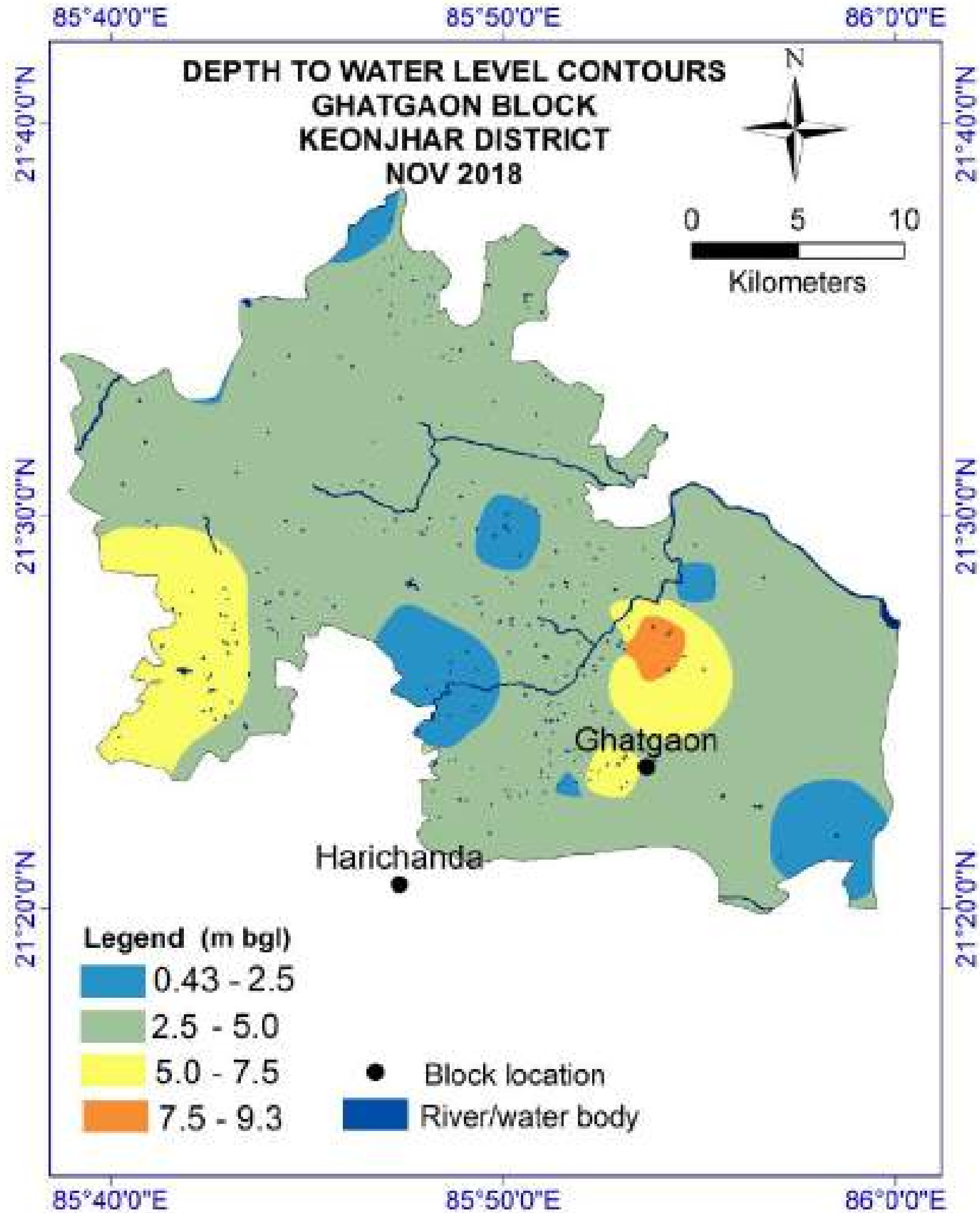

DEPTH TO WATER LEVEL CONTOURS
GHATGAON BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0
5
10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
Ghatgaon
Harichanda
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
River/water body

PLATE – 5.9

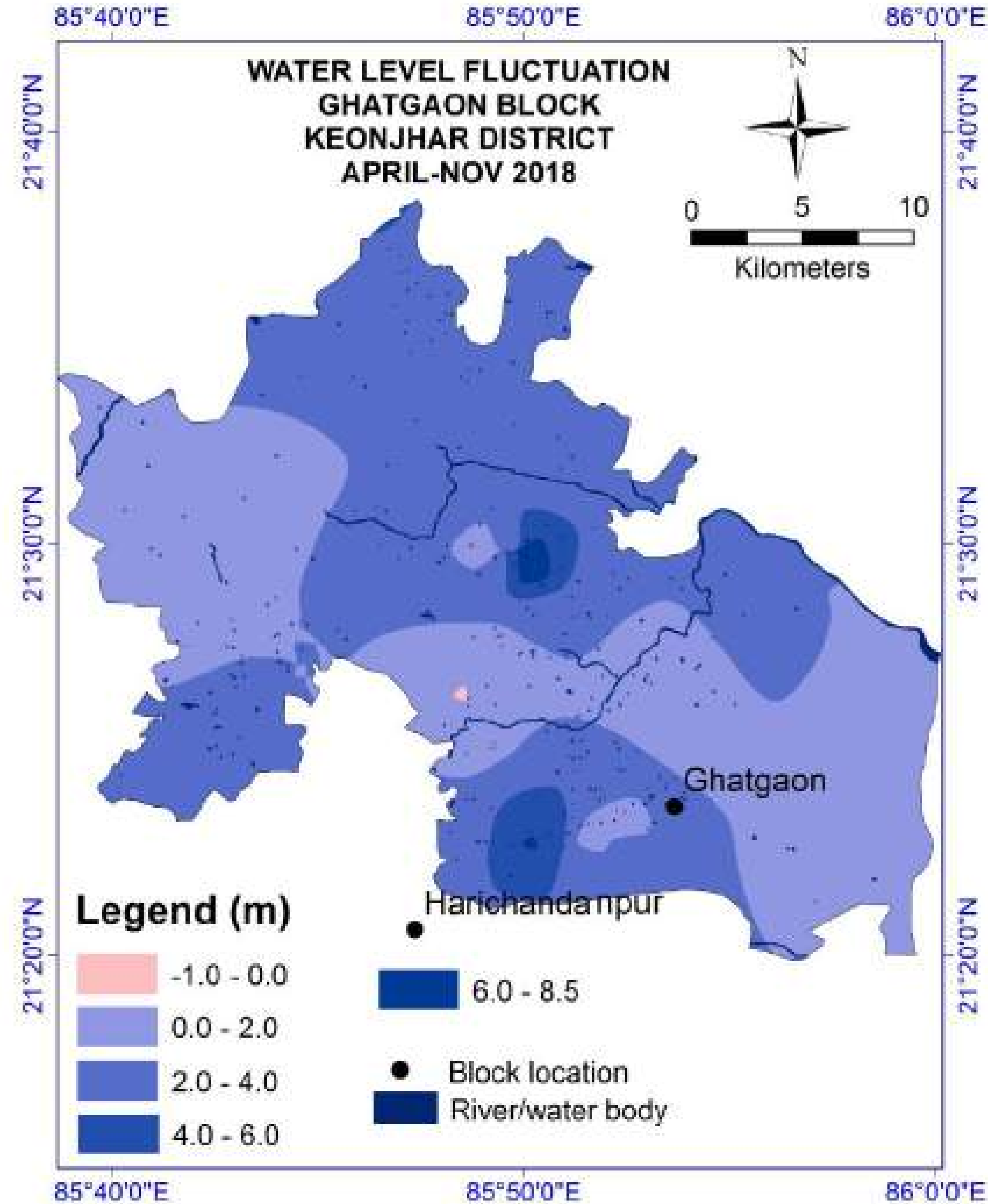

WATER LEVEL FLUCTUATION
GHATGAON BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0 5 10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
Ghatgaon
Harichandanpur
Legend (m)
-1.0 - 0.0
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
6.0 - 8.5
Block location
River/water body

PLATE – 5.10

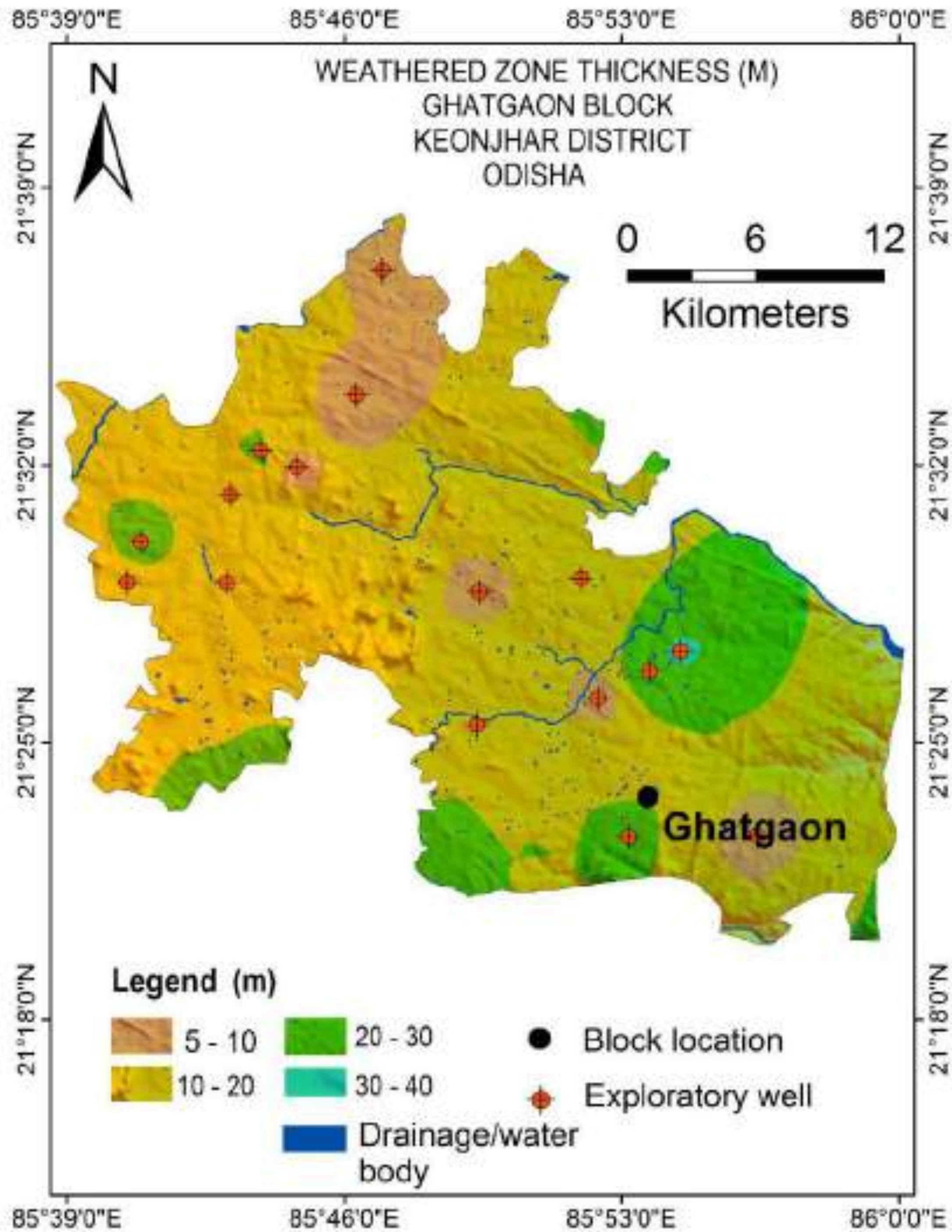

85°39'0"E
85°46'0"E
85°53'0"E
86°0'0"E
21°39'0"N
21°32'0"N
21°25'0"N
21°18'0"N
N
WEATHERED ZONE THICKNESS (M)
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
0 6 12
Kilometers
Ghatgaon
Legend (m)
5 - 10
10 - 20
20 - 30
30 - 40
Drainage/water body
Block location
Exploratory well

PLATE – 5.11

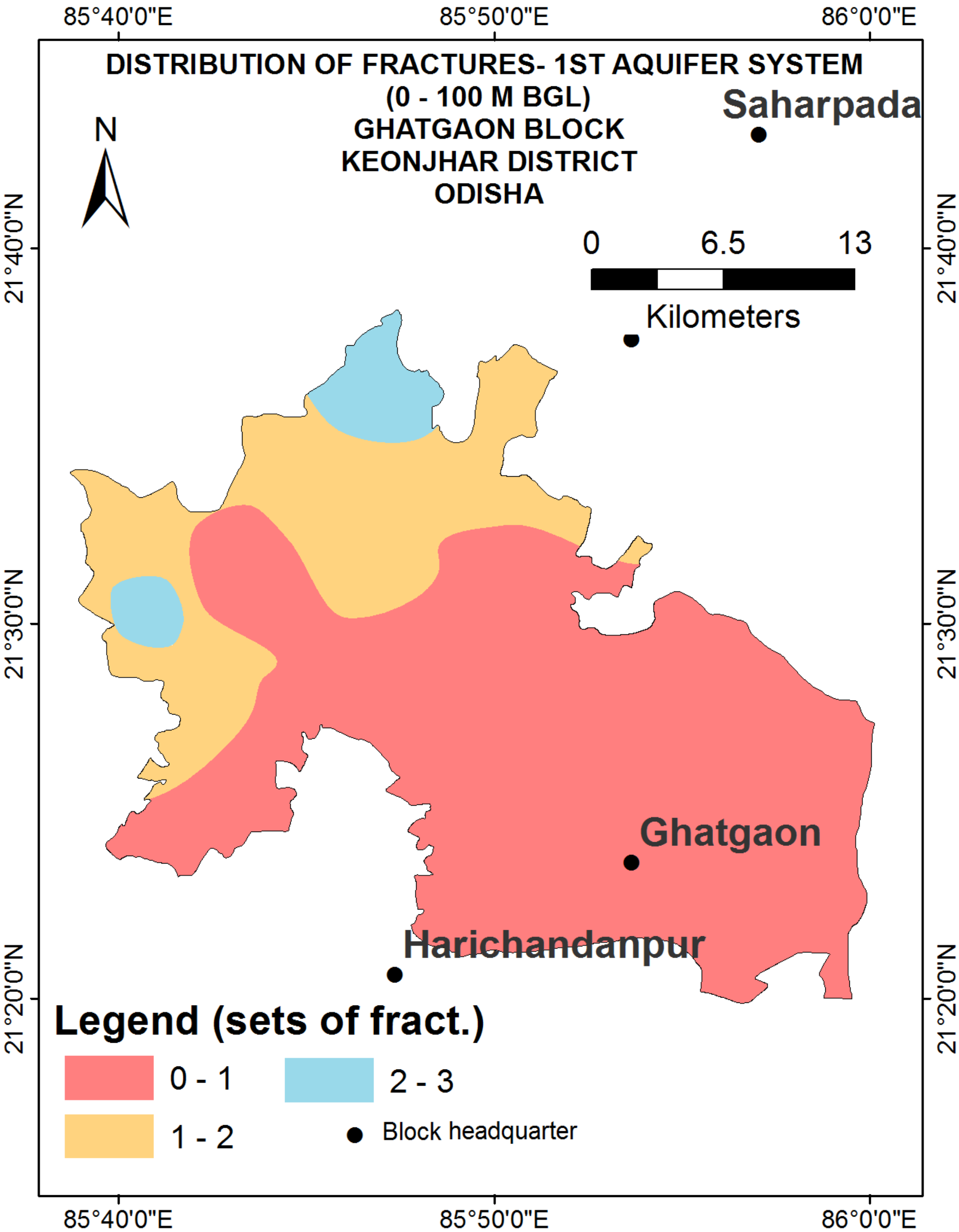
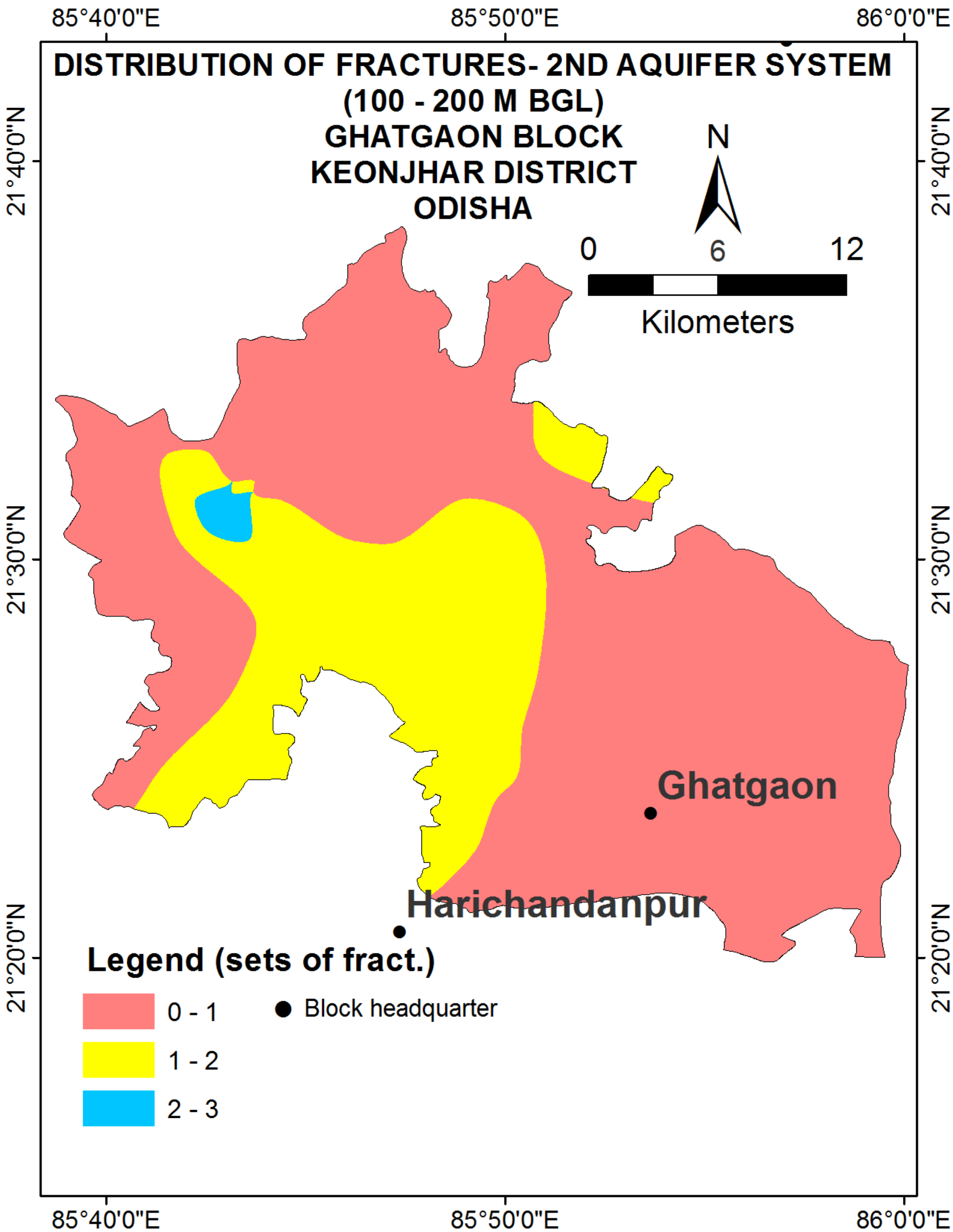

DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
N
0
6.5
13
Kilometers
Saharpada
Ghatgaon
Harichandanpur
Legend (sets of fract.)
0 - 1
2 - 3
1 - 2
Block headquarter

PLATE – 5.12



85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
Ghatgaon
Harichandanpur
Legend (sets of fract.)
0 - 1
1 - 2
2 - 3
Block headquarter

PLATE – 5.13

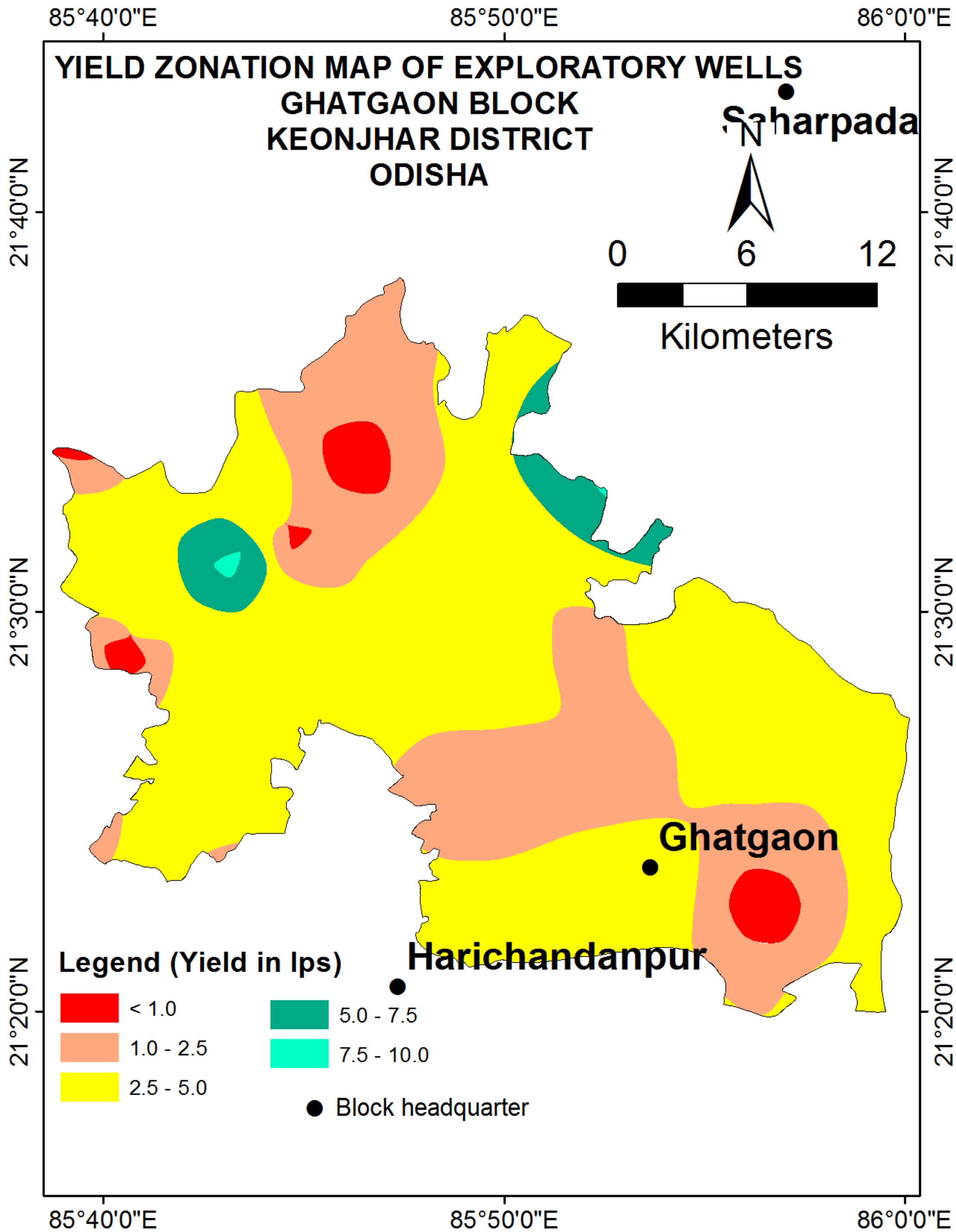

85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
YIELD ZONATION MAP OF EXPLORATORY WELLS
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
Saharpada
N
0
6
12
Kilometers
Ghatgaon
Harichandanpur
Legend (Yield in lps)
< 1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
Block headquarter

PLATE – 5.14

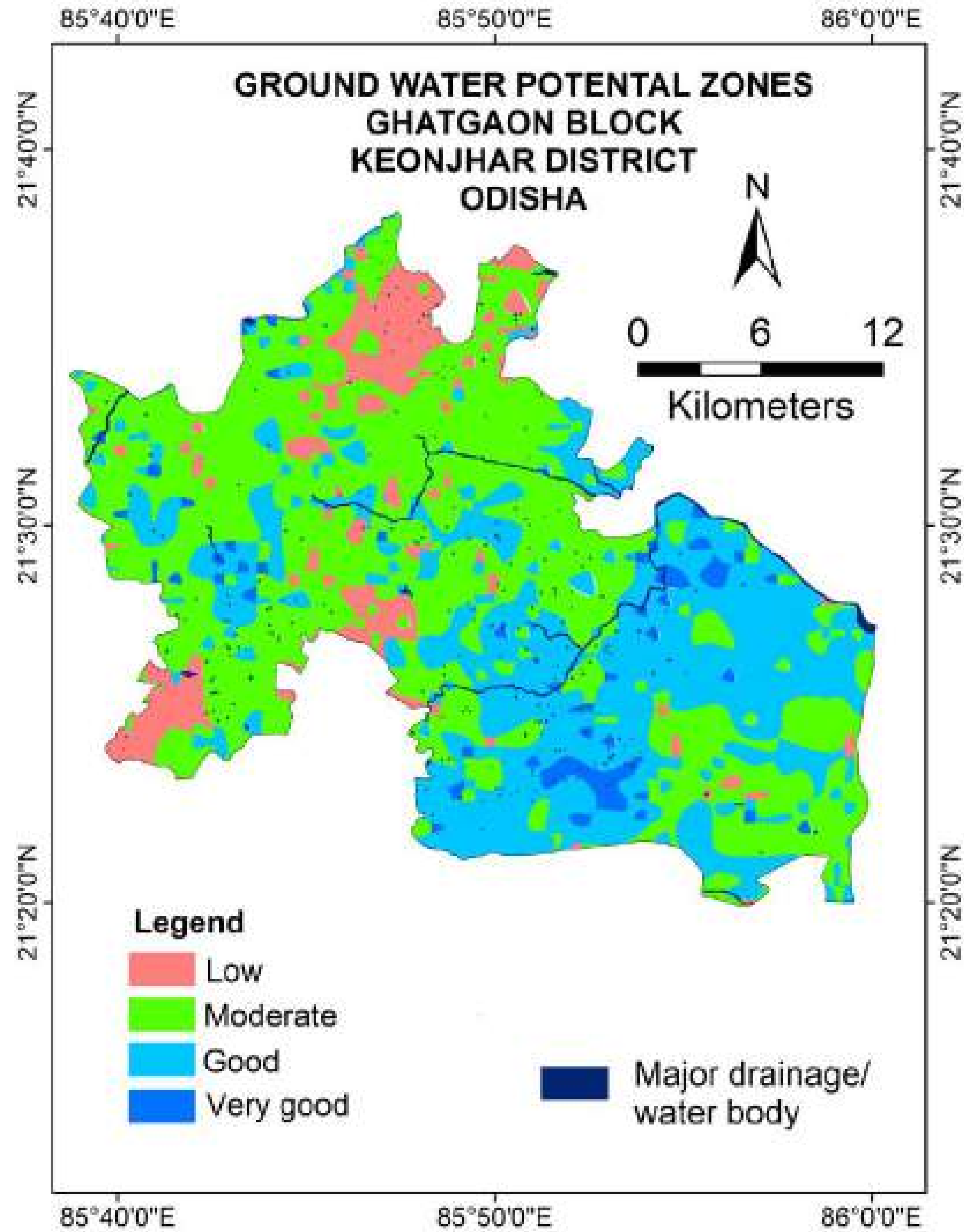
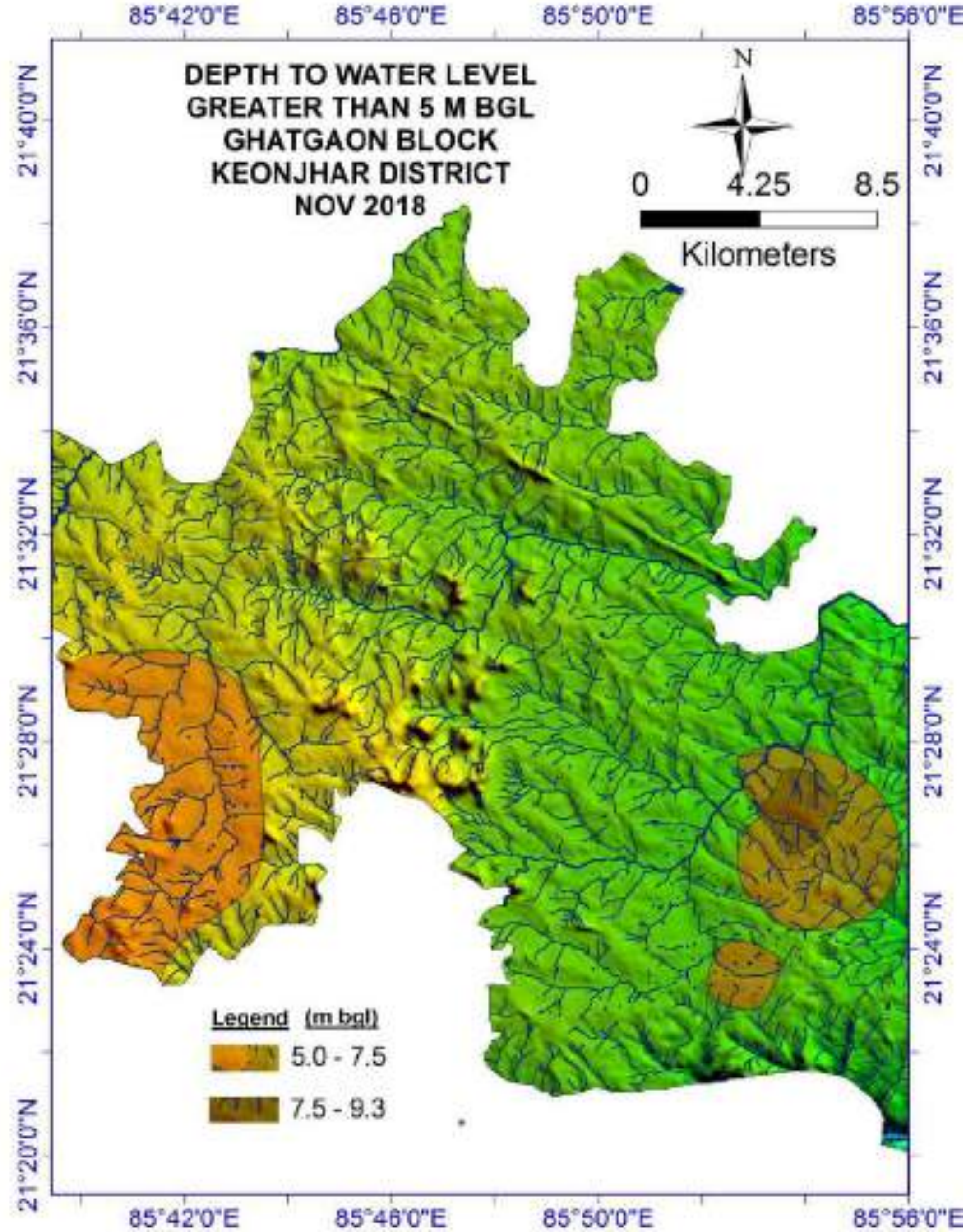

85°40'0"E
85°50'0"E
86°0'0"E
21°40'0"N
21°30'0"N
21°20'0"N
GROUND WATER POTENTAL ZONES
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
Legend
Low
Moderate
Good
Very good
Major drainage/
water body

PLATE – 5.15



DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
GHATGAON BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 4.25 8.5
Kilometers
Legend (m bgl)
5.0 - 7.5
7.5 - 9.3
85°42'0"E
85°46'0"E
85°50'0"E
85°56'0"E
21°40'0"N
21°36'0"N
21°32'0"N
21°28'0"N
21°24'0"N
21°20'0"N

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

2.0 HARICHANDANPUR BLOCK

2.1 Salient information

Location, area and demography

Location (Plate 6.1)	85^0 33' - 86^0 00' E longitude 21^0 05' – 21^0 34'' N latitude
Area	782 sq. km
No. of Gram Panchayats	25
No. of villages	219
Population (Census 2011)	1,42,150 (rural) *Rural:* 1,38,085 *Urban:* 4065
Literacy	52.75%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1154.8 mm
Monsoon normal rainfall	863.2 mm (75% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	33794 Ha
Net sown area (2)	24114 Ha
Area sown more than once (1-2)	9680 Ha
Cropping intensity (%)	140.1 Ha
Area under forest	45402 Ha
Area under wasteland	1852 Ha
Area under other uses	18403 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	8341 Ha *Kharif:* 5475 Ha *Rabi:* 2866 Ha

2.2 Drainage, geomorphology and soil types

The rivers in the block flow northerly, north-easterly to south-easterly to join the regional major drainage the Baitarani River that flows in the eastern side of the block. The rivers draining the block include the Musal, Kusei and Kanjhari. The drainage pattern is sub-dendritic to sub-trellis and sub-parallel in nature (Plate 6.2).

Except the northern/north-eastern and southern/south-western parts, where the structural hills (covering ~20% of area) and denudational hills (covering ~9% of area) are observed, the rest of the block is predominantly covered by pediments, buried pediments, valley fills and intermontane valleys (Fig 6.1 and Plate 6.3). These units (combine area of ~63% of block area) are considered as suitable for groundwater occurrence. There are also several linear basic (dolerite) dykes that traverse the country rock in NE-SW and NW-SE directions. Except the hilly tracts, major parts of the block (~63%) possesses land surface slope of <5% (Plate 6.4; Fig 6.2). The soil types include the red sandy (alfisol), red loamy (alfisol), red and yellow (ultisol) and red gravelly soils (ultisol).

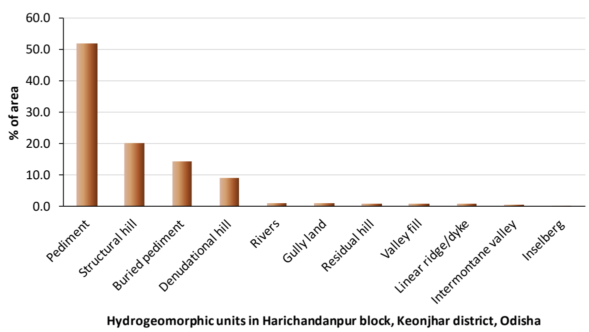


Figure 6.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Harichandanpur block.

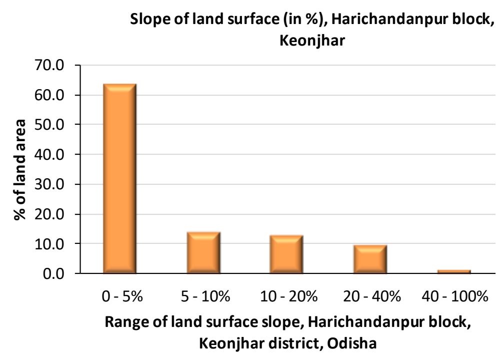


Figure 6.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Harichandanpur block, Keonjhar district.

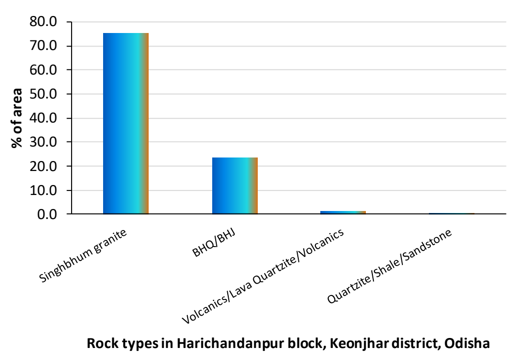


Figure 6.3: Percentage (%) of Harichandanpur block area (Keonjhar dist.) covered by various rock types.

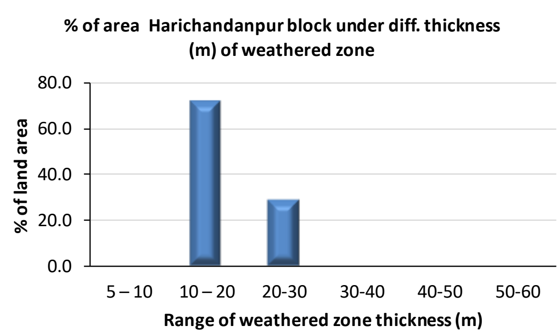


Figure 6.4: Bar diagram depicting the percentage (%) area of Harichandanpur block falling under different weathered zone thickness (m) ranges.

2.3 Geology

The Singhbhum Granite of Precambrian age cover ~75% of the block area, while another 23% is occupied by Banded Iron Formations (BHQ/BHJ). A smaller portion in west is covered by volcanics suite of rocks (Fig 6.3 and Plate 6.5).

2.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories. The generalized hydrogeological map of the block is presented in Plate 6.6. The Singhbhum Granites and the BIF formations possess low to moderate yield potential varying between 3-10 lps.

During pre-monsoon (year 2018) measurement, except the patches in the east and north, major parts of the block depicted water levels >5.0 m bgl (Plate 6.7). During the post-monsson period, except the western parts, major parts depicted water levels <5.0 m bgl, indicating good recharge from rainfall (Plate 6.8). The annual fluctuations in the water levels remained between 1.0-4.0 m in major parts of the block (Plate 6.9).

2.5 Aquifer geometry and characters

The thickness of the weathered regolith in major parts of the block (~72% of area) is moderate varying between 10-20 m only. Only in limited patches it exceeds 20 m and goes up to 30 m (Plate 6.10; Fig 6.4). The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 6.5a-b.

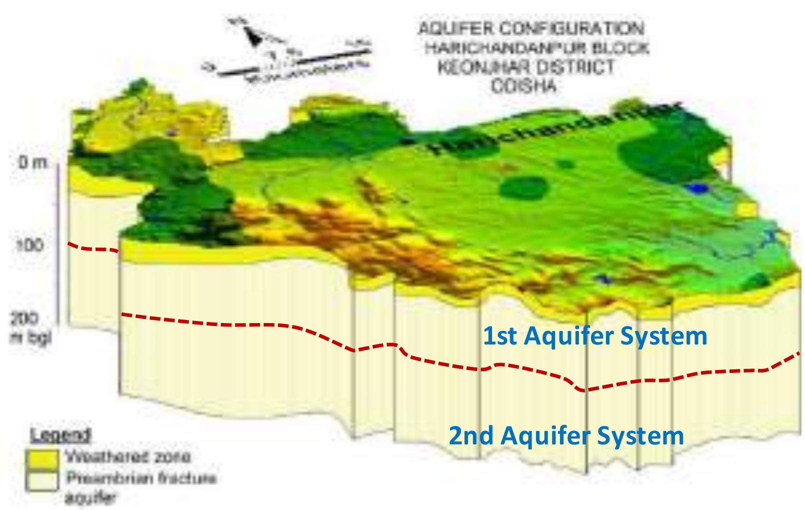


Figure 6.5: (a) 3D aquifer disposition in Harichandanpur block, Keonjhar district.

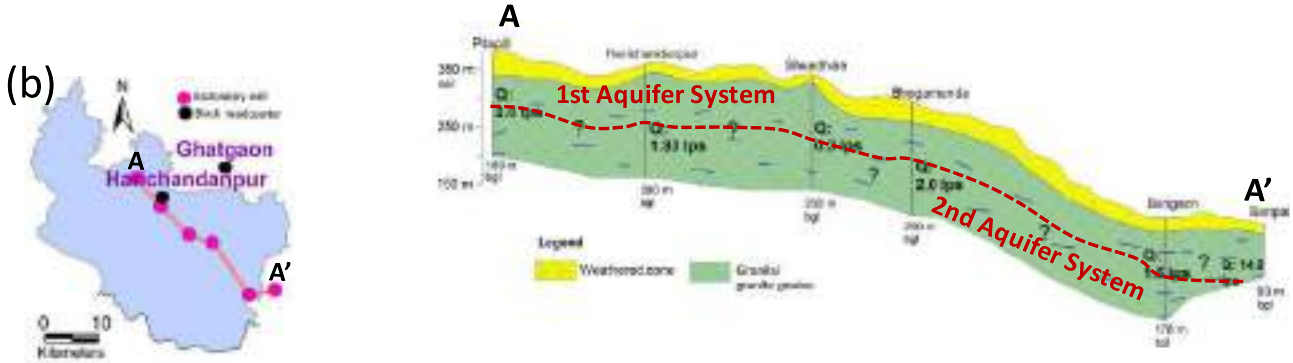


Figure 6.5 contd: (b) 2D hydrogeological transect (including its location) depicting the aquifer disposition in the block.

In the block, in general 0-1 sets of fracture zones are encountered in bore wells within the depth of 100 m bgl (1st aquifer system), except patches where up to 2 sets of fractures are observed (Plate 6.11). Similarly in the 2nd aquifer system (100-200 m bgl), 0-1 sets of fracture zones are encountered except the patches where up to 3 sets of fractures are encountered during drilling (Plate 6.12). In major cases, the bore wells yielded in the range of 1-5 lps of water. In patches in the east and north, it increases up to 10 lps.

2.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 6.14). The hard rock parts in the north are characterized as good to very potential zones in the context of groundwater. The alluvial areas are delineated as very good groundwater potential zones in the block. Around 65% of the geographical area of the block has been classed as good to very groundwater potential zone (Fig 6.6).

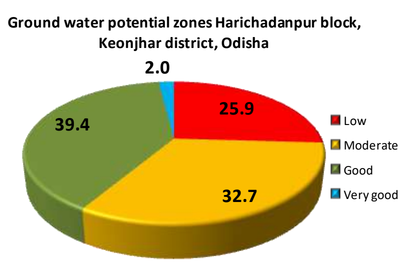


Figure 6.6: Pie diagram depicting the perentage (%) of Harichandanpur block, Keonjhar district, Odisha, falling under different groundwater potential zones.

2.7 Ground water quality

Ground water in the block is alkaline in nature (Table 6.1) and pH range of 6.7-8.72. The water is moderately hard to very hard. The mineralization is low to moderate with TDS in the range of 67-381 mg/L (ave.: 220 mg/L). Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly Ca-HCO_3 and Ca- HCO_3-Cl types with Ca^{2+} and HCO_3^- as the principal contributing ions in the groundwater quality (Fig 6.7).

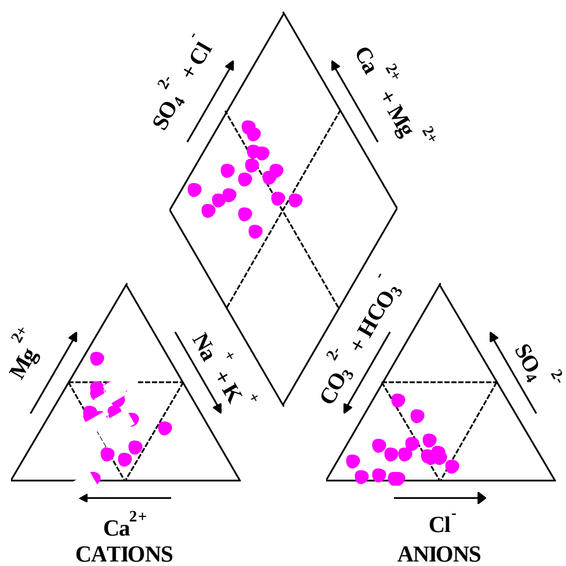


Figure 6.7: The Piper trilinear diagram depicting the groundwater quality in Harichandanpur block, Keonjhar district.

2.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 6.2-6.4. The net dynamic groundwater available is 8219.8 Ham and the stage of groundwater development stands at 30.4%. Net resource available for future irrigation needs stands at 5666.1 Ham (Fig 6.8). The instorage/static groundwater resource component of 7957.9 Ham (Table 6.3) comes from the 1st aquifer system within 100 m bgl with a major portion of it lying in the alluvial area. The total groundwater available in the block stands at 16194.6 Ham.

Table 6.1: Ground water quality at various locations in Harichandanpur block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Duarsuni	8.3	330	165.19	122	129	29	12	15	5.1	0	141	35	0	0.22
Bogamunda	6.7	120	81.59	36	31	14	0	8.1	2.3	0	34	5	22	0.16
Kamalangi	7.418	480	239	187	97	46	18	20	1.66	0	118	67	29	0.13
Revana Palaspa	7.28	350	165	130	143	31	13	11	4.5	0	174	19	1	0.20
Bamhanipal	7.55	550	260	197	207	33	28	24	0.89	0	253	45	5	0.20
Sagadapata	7.94	180	89	59	51	11	8	10	0.86	0	62	18	10	0.30
Jamjodi	8.55	600	322	186	202	60	9	48	1.78	12	222	33	49	0.48
Manpur	8.72	800	365	336	323	46	54	12	0.81	3	388	20	33	0.25
Panasia	8.35	510	259	164	146	26	24	15	20.88	6	130	46	38	0.16
Burhakhaman	7.87	120	67	36	25	7	4	7	4.54	0	31	10	18	0.15
Kalapat	8.38	480	258	155	106	33	18	17	20.92	3	123	61	44	0.28
Pithagola	8.42	700	381	141	141	24	20	46	57.2	0	173	128	19	0.26
Songiri	8.1	250	123	59	56	16	4	18	7.9	0	68	31	12	0.11
Kadua	8.34	280	138	105	96	20	13	9	1.21	3	93	20	15	0.11
Baxibarigaon	8.12	160	97.58	50	64	16	2	17.8	0.68	0	78	22	0.1	1.05
Bhagamunda	7.83	715	350.75	285	152	52	38	23.34	1.51	0	185	110	33.4	0.45
Harichandanpur	8.15	725	377.26	285	167	46	41	31.38	17.98	0	203	103	36.4	0.19
Min.:	**6.7**	**120**	**67**	**36**	**25**	**7**	**0**	**7**	**0.68**	**0**	**31**	**5**	**0**	**0.11**
Max.:	**8.72**	**800**	**381**	**336**	**323**	**60**	**54**	**48**	**57.2**	**12**	**388**	**128**	**49**	**1.05**
Average	**8.0**	**432.4**	**219.9**	**149.0**	**125.6**	**30.0**	**18.0**	**19.6**	**8.9**	**1.6**	**145.6**	**45.5**	**21.5**	**0.3**

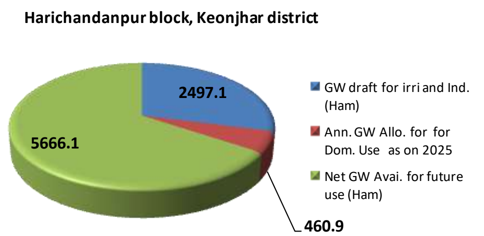


Figure 6.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Harichandanpur block, Keonjhar district, Odisha.

Table 6.2: Salient information on annual dynamic groundwater resources, Harichandanpur block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	8219.8
2. Irrigation draft (Ham)	2058.2
3. Industrial draft (Ham)	34.6
4. Domestic draft (Ham)	404.3
5. Total draft (Ham)	2497.1
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	460.9
7. Net groundwater available for future use (Ham)	5666.1
8. Stage of groundwater extraction (%)	30.4

Table 6.3: Total groundwater resoure available in the Harichandanpur block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	8219.8
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	7957.9
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	16.9
	Block total	**16194.6**

2.9 Aquifer management plan

The existing stage of groundwater development of 30.4% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction structures as estimated in Table 6.4 (551 bore wells/dug-cum-bore wells and 4682 dug wells) are required to be constructed to develop the available additional resource of 2434.8 Ham. It can help in creating additional irrigation potential for 4260.8 Ha (Table 6.5), increasing the present irrigation facility of ~25% to up to ~37%.

*A*round 172.44 km^2 area in the block showed post-monsoon depth to water levels >5.0 m bgl (Plate 6.15; Table 6.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 20.69 MCM of water (Table 6.7) can be recharged by the help additional 41- percolations ponds, 21-subsurface dykes, 21-nala/contour bunds and 41-check dams (Table 6.8) with a total cost of 13.45 crores (Table 6.9).

Table 6.4: Number of additional feasible groundwater abstraction structures in Harichandanpur block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	8219.8
2	Stage of GW deve. (%)	30.4
3	Present GW draft (Ham)	2497.1
4	Ground water draft at 60% stage of deve. (Ham)	4931.9
5	Addi. water to be deve. (Ham)	2434.8
6	Addi. No of BW/ dug-cum-bore wells feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	551
7	Addi. No. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	4682

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 6.5: Irrigation potential likely to be created in Harichandanpur block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	30.4
2	Surplus GW avai. for 60% stage of deve. (Ham)	2434.8
3	Irri, Pot. likely to be created for Paddy (Ha)	1217.4
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	1217.4
5	Irri. Pot. likely to be created for veg. (Ha)	1826.1
6	Proj. area to be Irri. (ha)	4260.8

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 6.6: Areas in Harichandanpur block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Harichandanpur	139.34	33.10	172.44

Table 6.7: Estimation of volume of water required for artificial recharge to groundwater in Harichandanpur block, Keonjhar district.

Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to reharge (MCM)
Harichandanpur	782.00	172.44	7	4	689.76	20.69

Table 6.8: Number of feasible structures in Harichandanpur block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (MCM)	No of different freasible structures			
		Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
Harichandanpur	20.69	41	21	21	41

Table 6.9: Estimation of cost of artificial recharge structures in Harichandanpur block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Harichandanpur	8.28	2.07	1.03	2.07	13.45

PLATE – 6.1

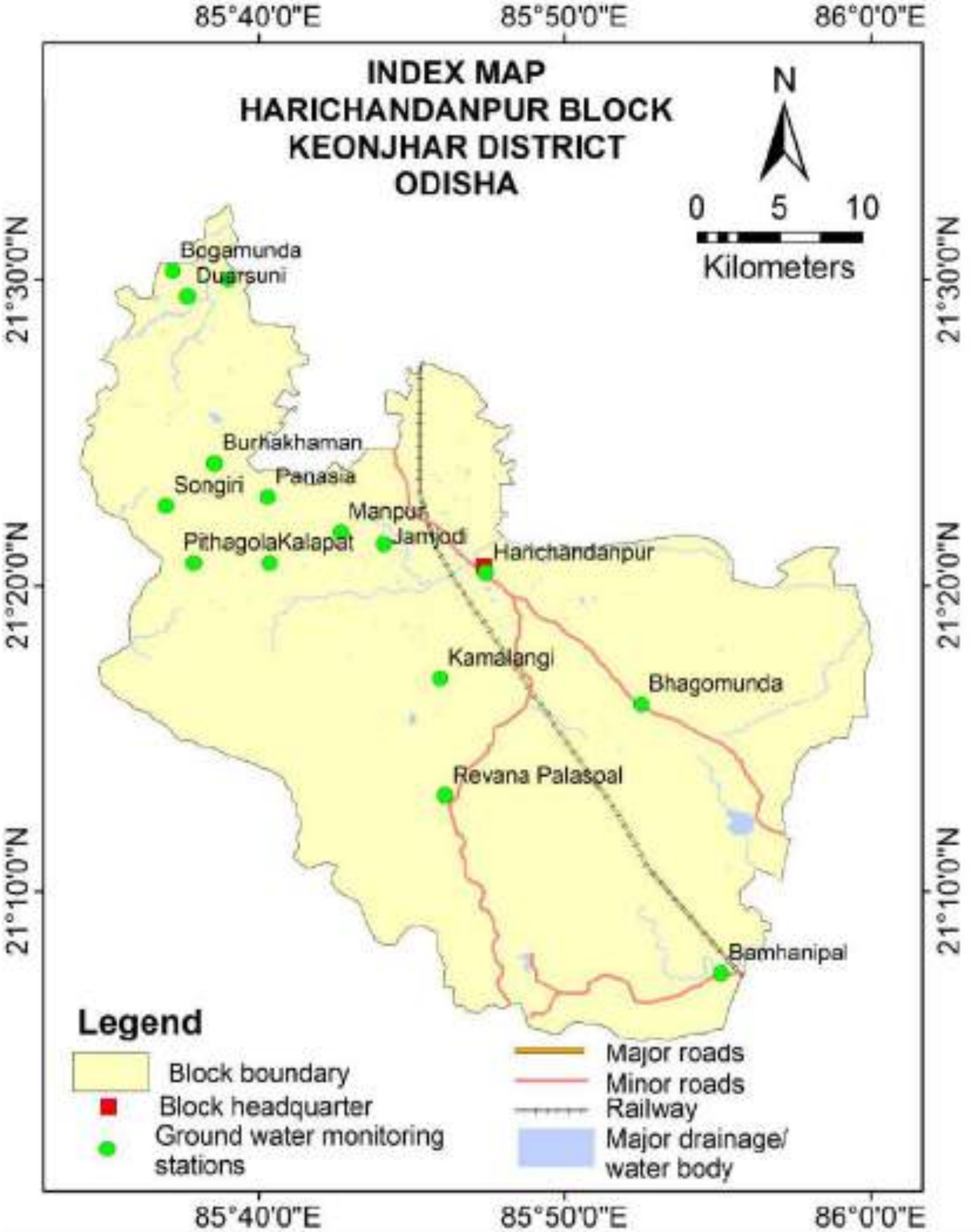

INDEX MAP
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
Bogamunda
Duarsuni
Burhakhaman
Songiri
Panasia
Manpur
Pithagola
Kalapat
Jamjodi
Harichandanpur
Kamalangi
Bhagomunda
Revana Palasoal
Bamhanipal
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body

PLATE – 6.2

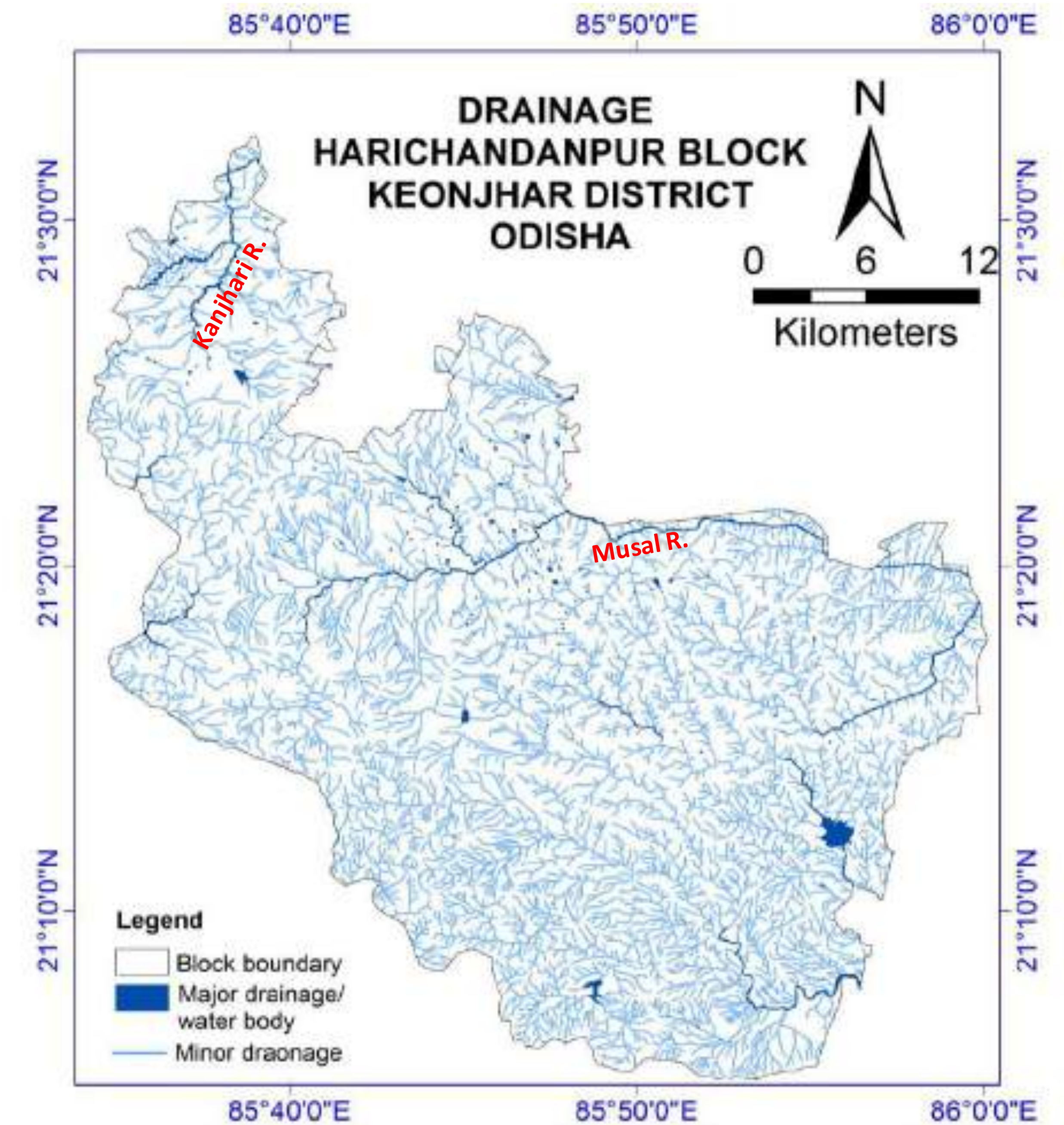

DRAINAGE
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
Kanjhari R.
Musal R.
Legend
Block boundary
Major drainage/ water body
Minor draonage

PLATE – 6.3

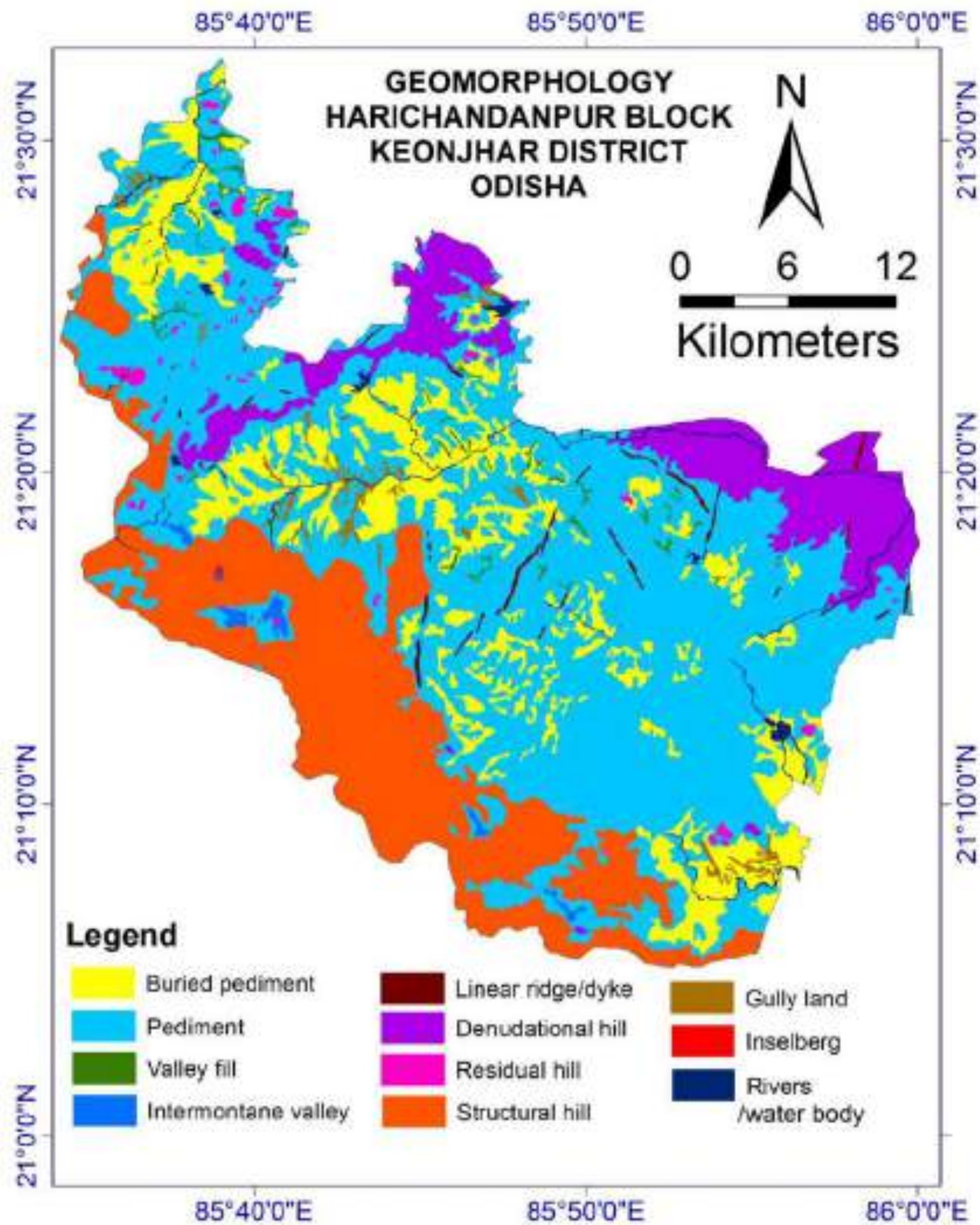

GEOMORPHOLOGY
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend
Buried pediment
Pediment
Valley fill
Intermontane valley
Linear ridge/dyke
Denudational hill
Residual hill
Structural hill
Gully land
Inselberg
Rivers
/water body

PLATE – 6.4

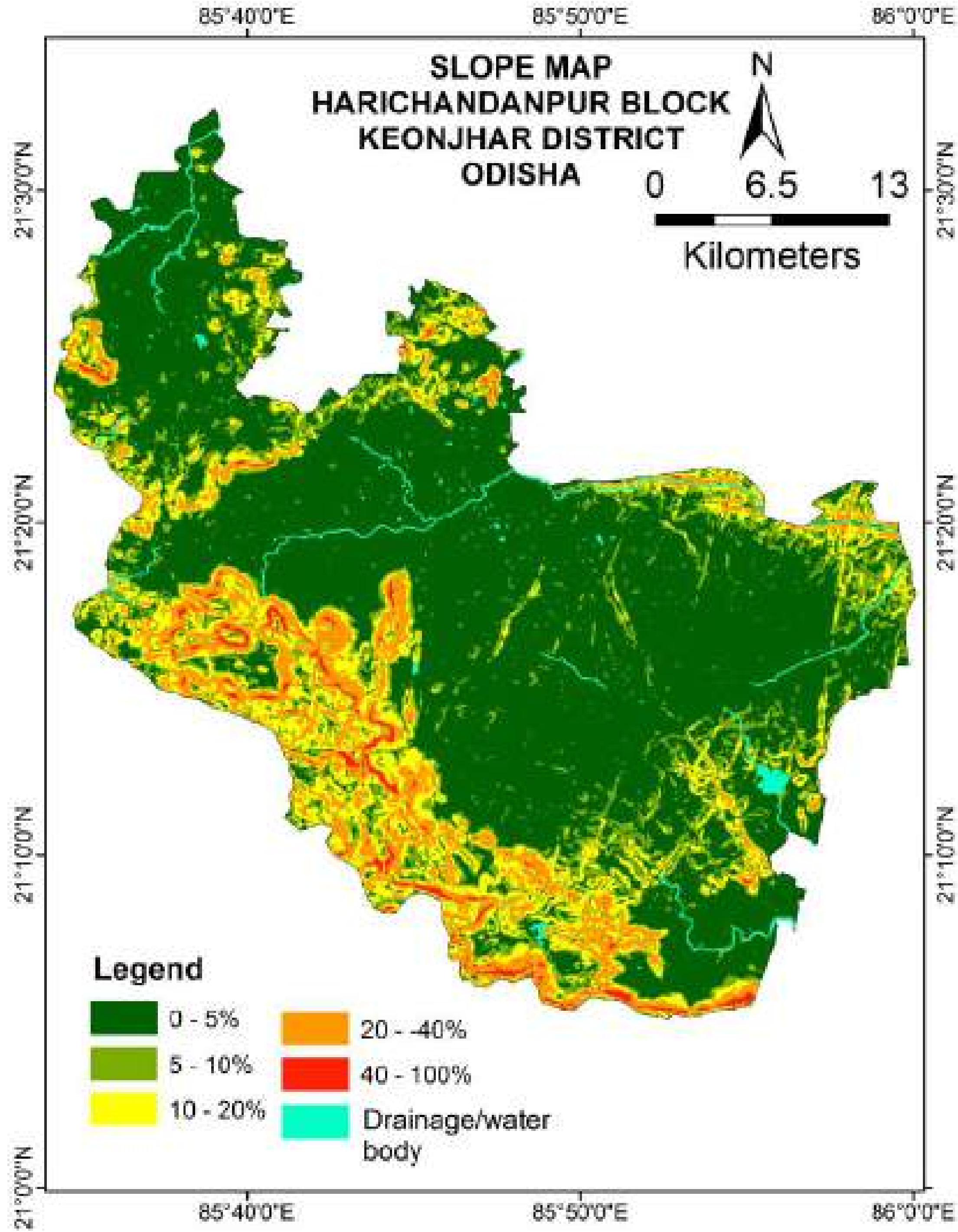

SLOPE MAP
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6.5 13
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 6.5

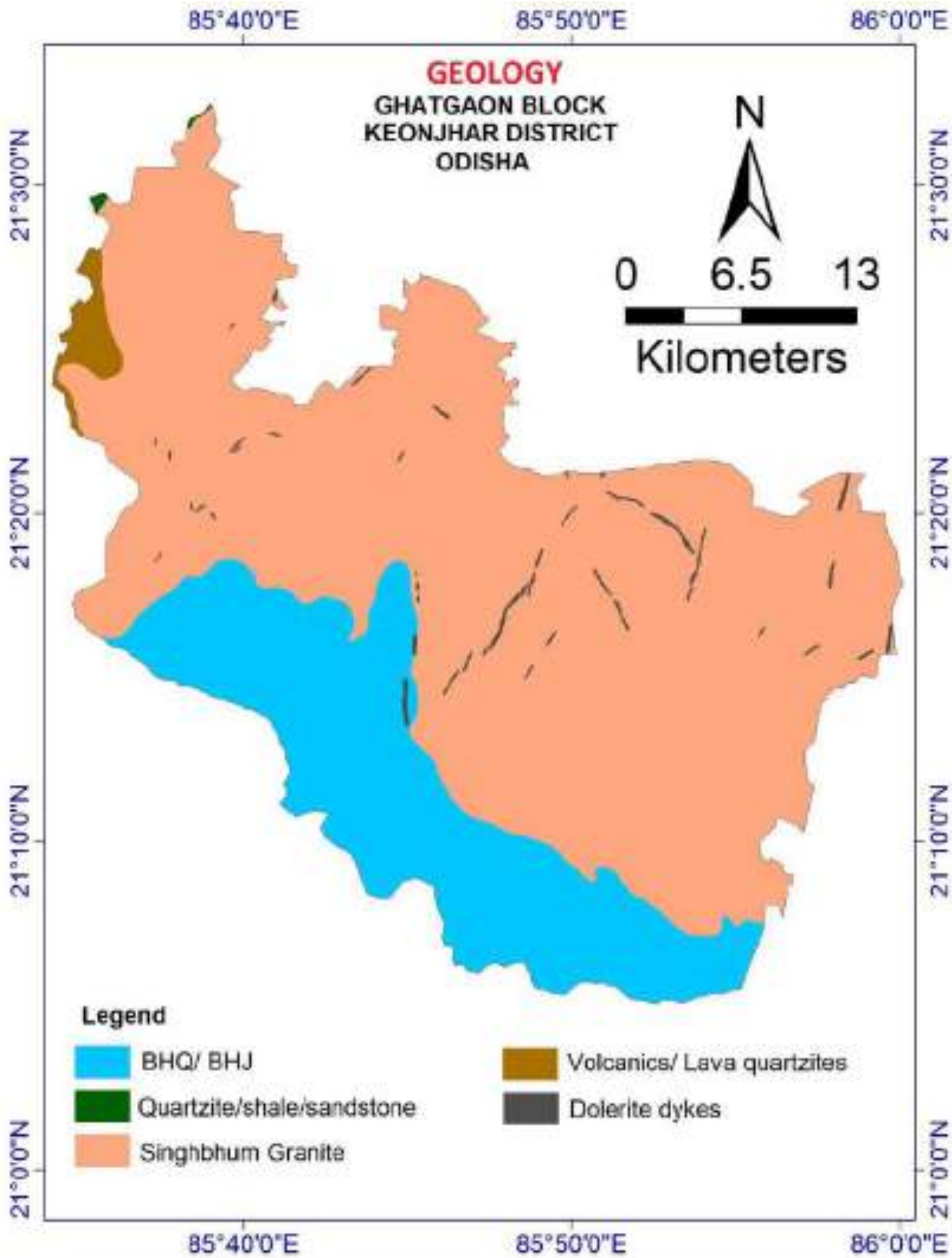

GEOLOGY
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6.5
13
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend
BHQ/ BHJ
Quartzite/shale/sandstone
Singhbhum Granite
Volcanics/ Lava quartzites
Dolerite dykes

PLATE – 6.6

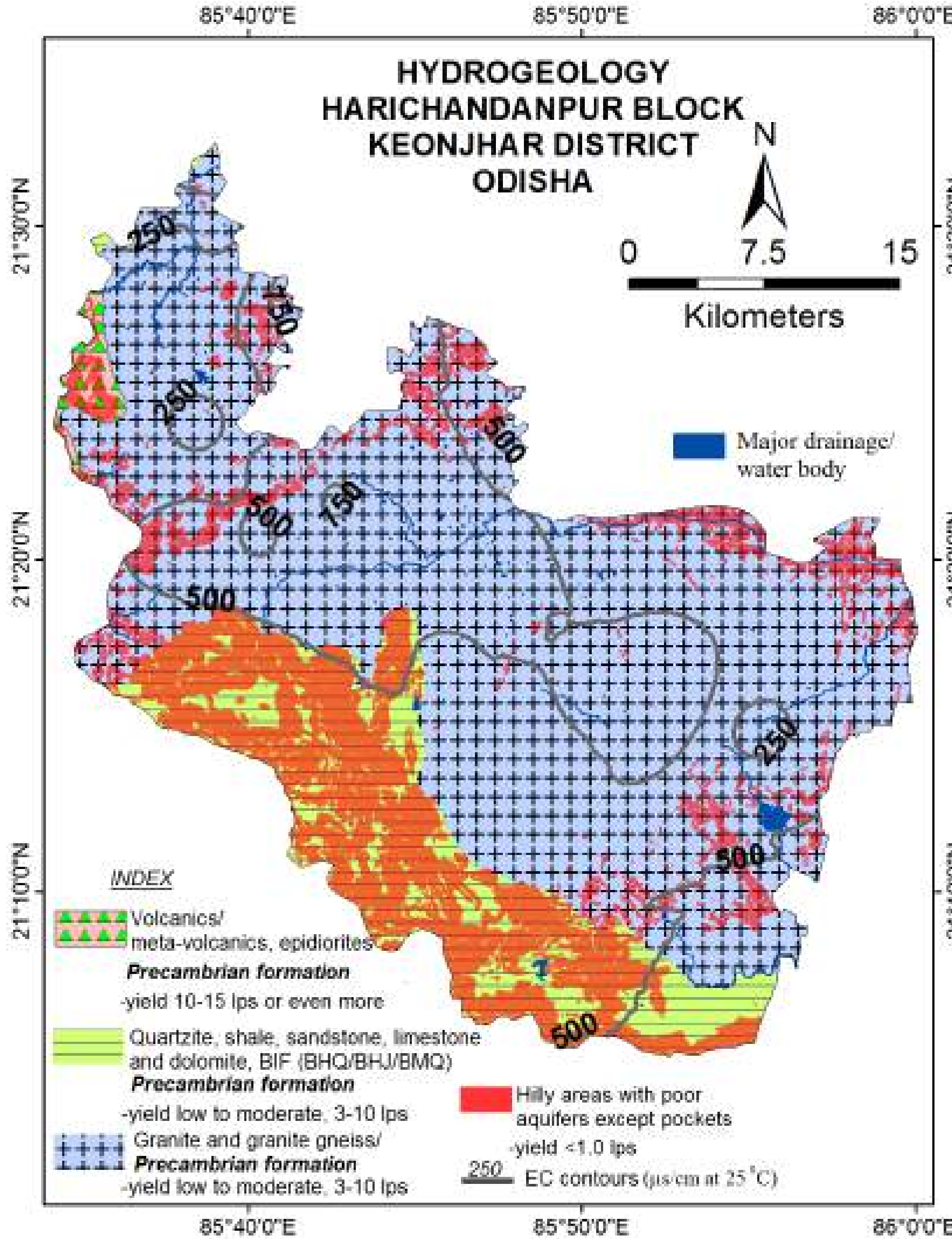

HYDROGEOLOGY
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 7.5 15
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
250
750
500
Major drainage/ water body
INDEX
Volcanics/ meta-volcanics, epidiorites
Precambrian formation
-yield 10-15 lps or even more
Quartzite, shale, sandstone, limestone and dolomite, BIF (BHQ/BHJ/BMQ)
Precambrian formation
-yield low to moderate, 3-10 lps
Granite and granite gneiss/
Precambrian formation
-yield low to moderate, 3-10 lps
Hilly areas with poor aquifers except pockets
-yield <1.0 lps
250 EC contours (µs/cm at 25 °C)

PLATE – 6.7

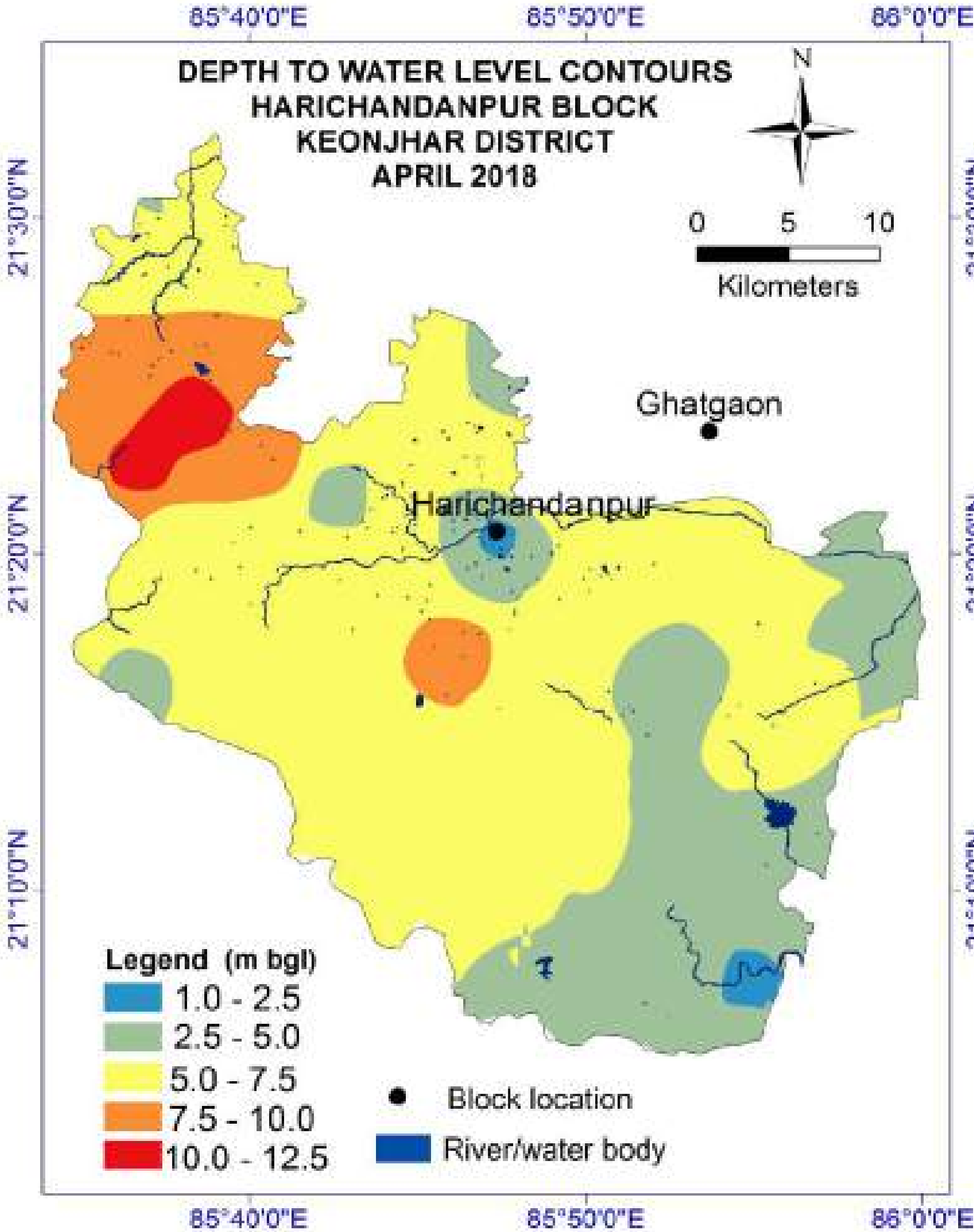

DEPTH TO WATER LEVEL CONTOURS
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0 5 10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
Ghatgaon
Harichandanpur
Legend (m bgl)
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
Block location
River/water body

PLATE – 6.8

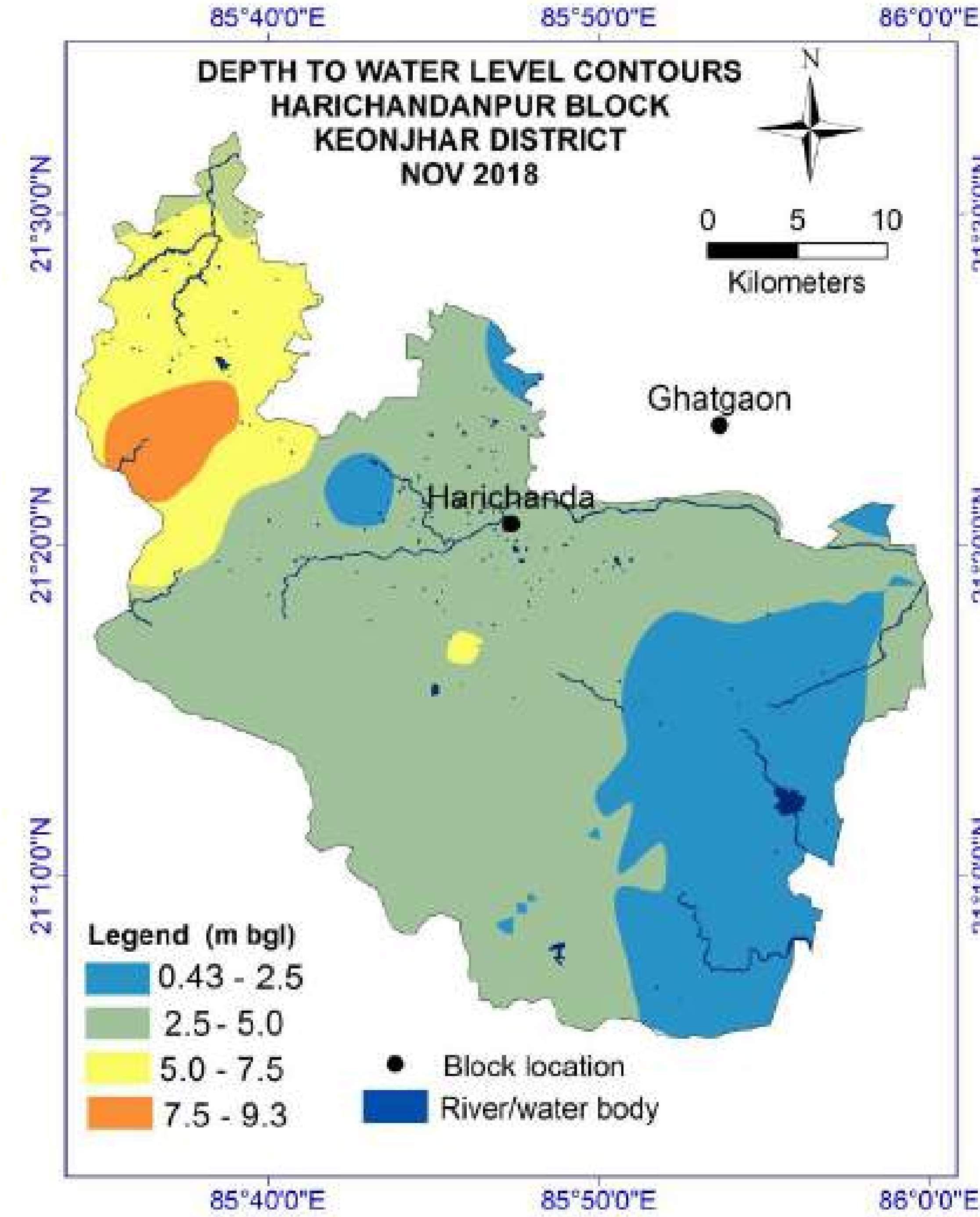

DEPTH TO WATER LEVEL CONTOURS
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 5 10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
Ghatgaon
Harichanda
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
River/water body

PLATE – 6.9

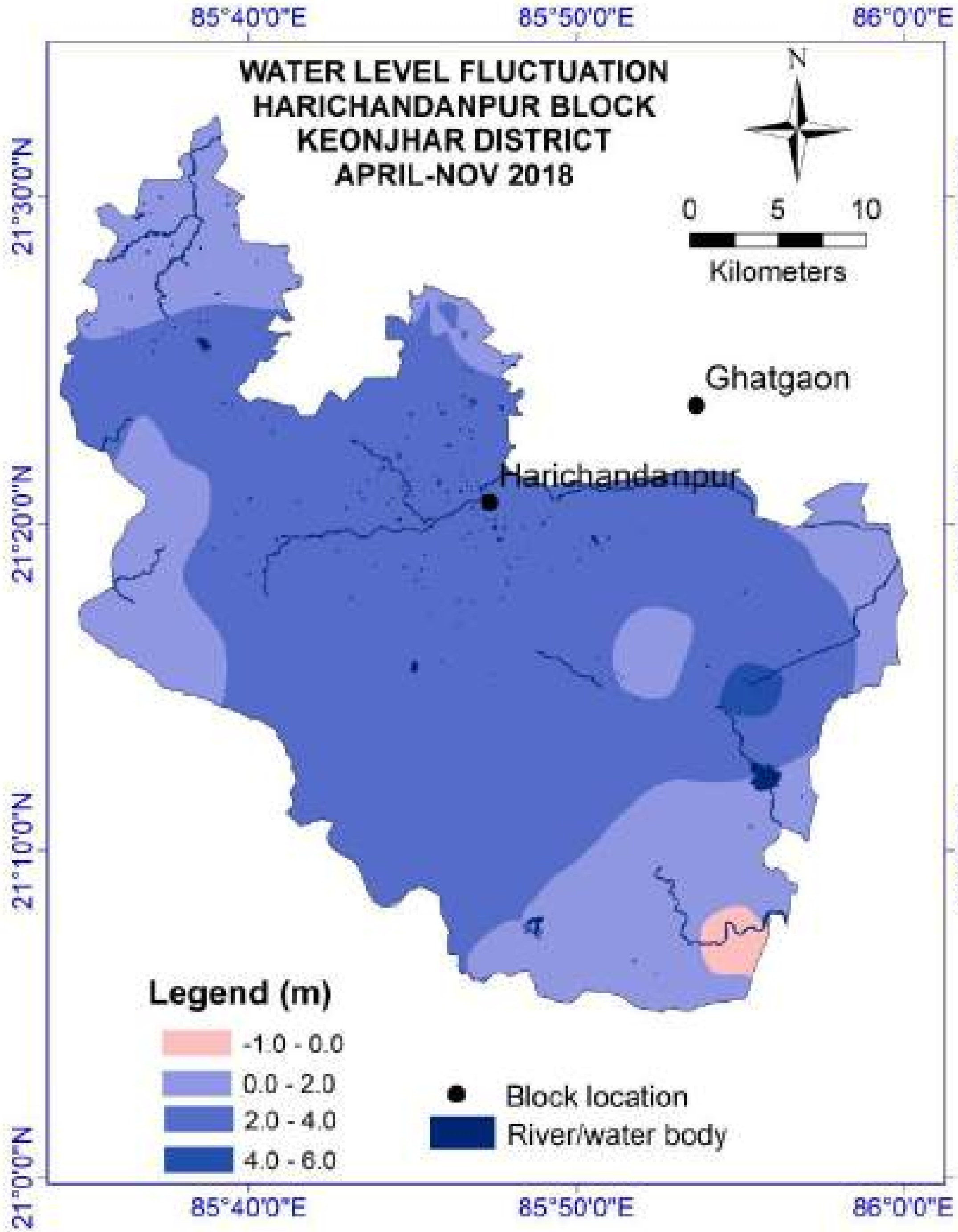

WATER LEVEL FLUCTUATION
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0 5 10
Kilometers
Ghatgaon
Harichandanpur
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend (m)
-1.0 - 0.0
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
Block location
River/water body

PLATE – 6.10

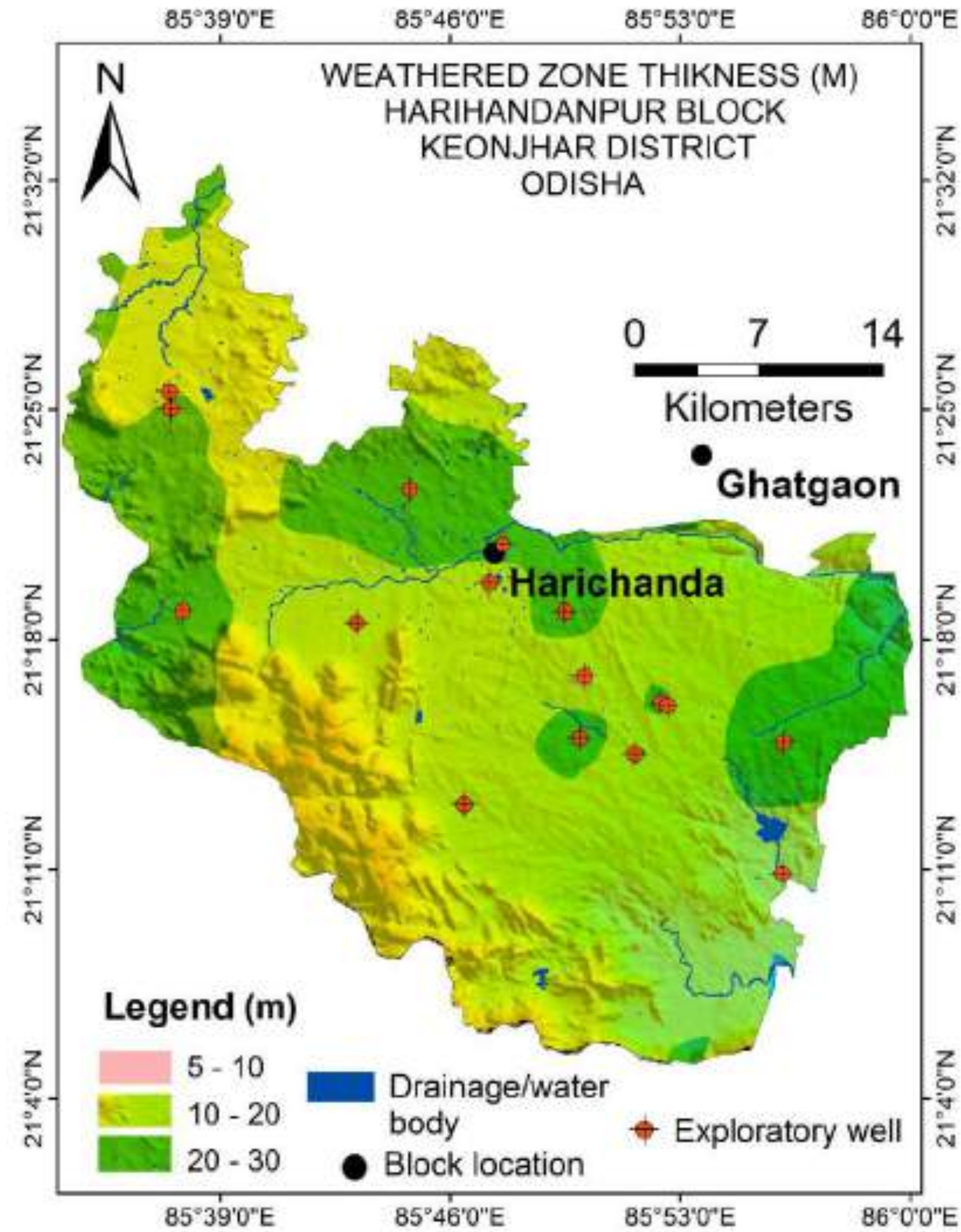

WEATHERED ZONE THIKNESS (M)
HARIHANDANPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 7 14
Kilometers
Ghatgaon
Harichanda
Legend (m)
5 - 10
10 - 20
20 - 30
Drainage/water body
Block location
Exploratory well
85°39'0"E
85°46'0"E
85°53'0"E
86°0'0"E
21°32'0"N
21°25'0"N
21°18'0"N
21°11'0"N
21°4'0"N

PLATE – 6.11

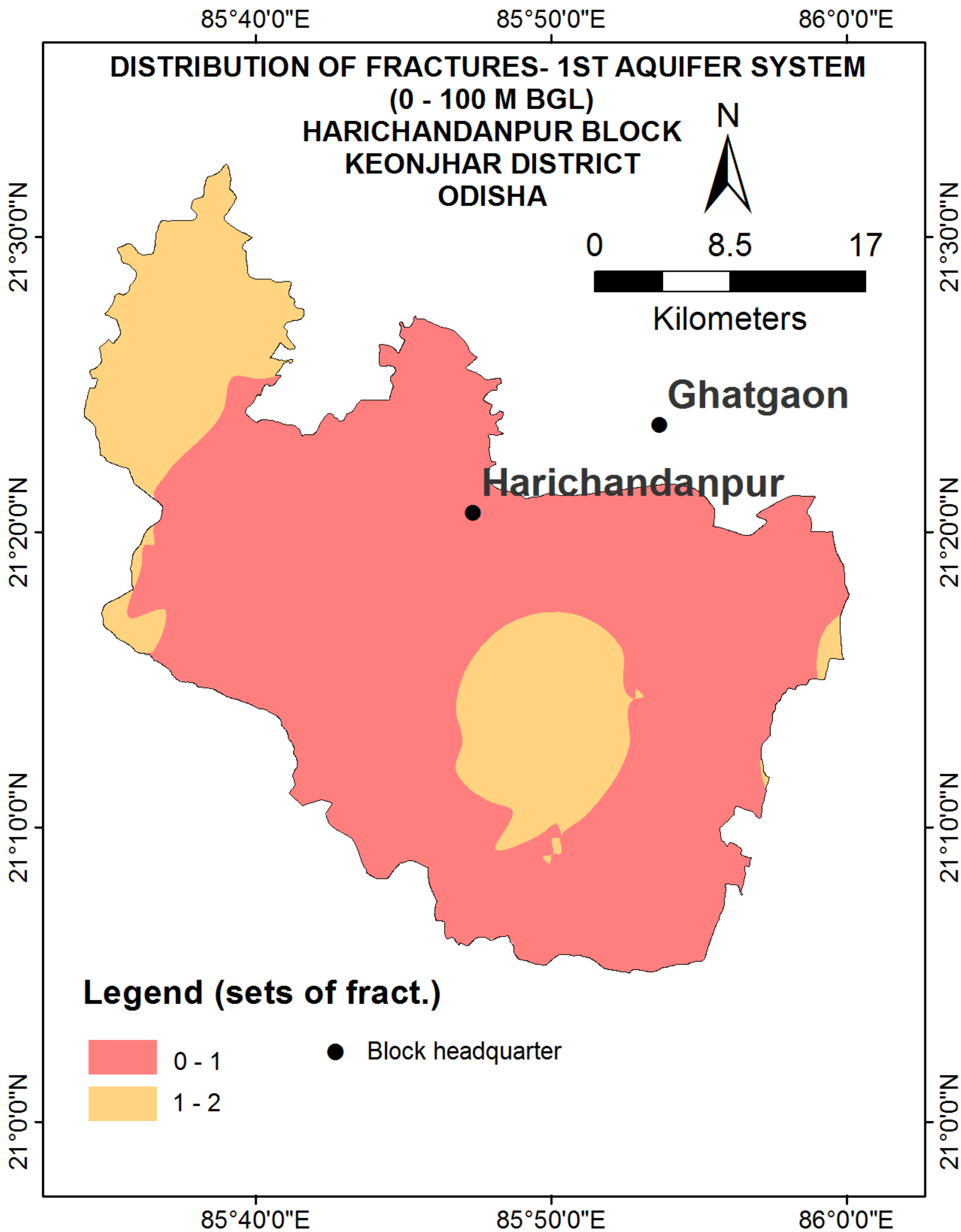

85°40'0"E
85°50'0"E
86°0'0"E
DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
8.5
17
Kilometers
Ghatgaon
Harichandanpur
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend (sets of fract.)
0 - 1
1 - 2
Block headquarter

PLATE – 6.12

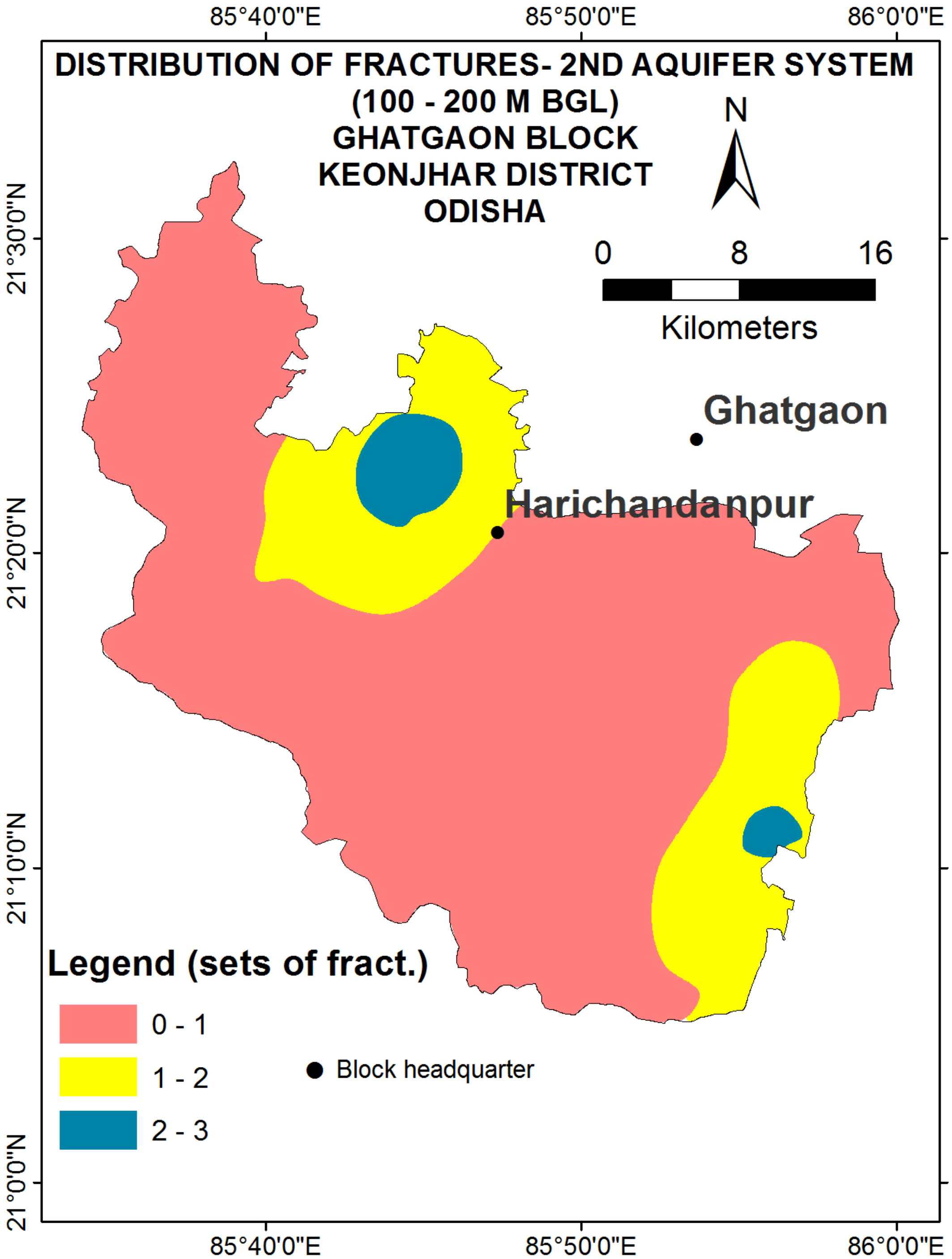

85°40'0"E
85°50'0"E
86°0'0"E
DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
GHATGAON BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
8
16
Kilometers
Ghatgaon
Harichandanpur
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend (sets of fract.)
0 - 1
1 - 2
2 - 3
Block headquarter

PLATE – 6.13

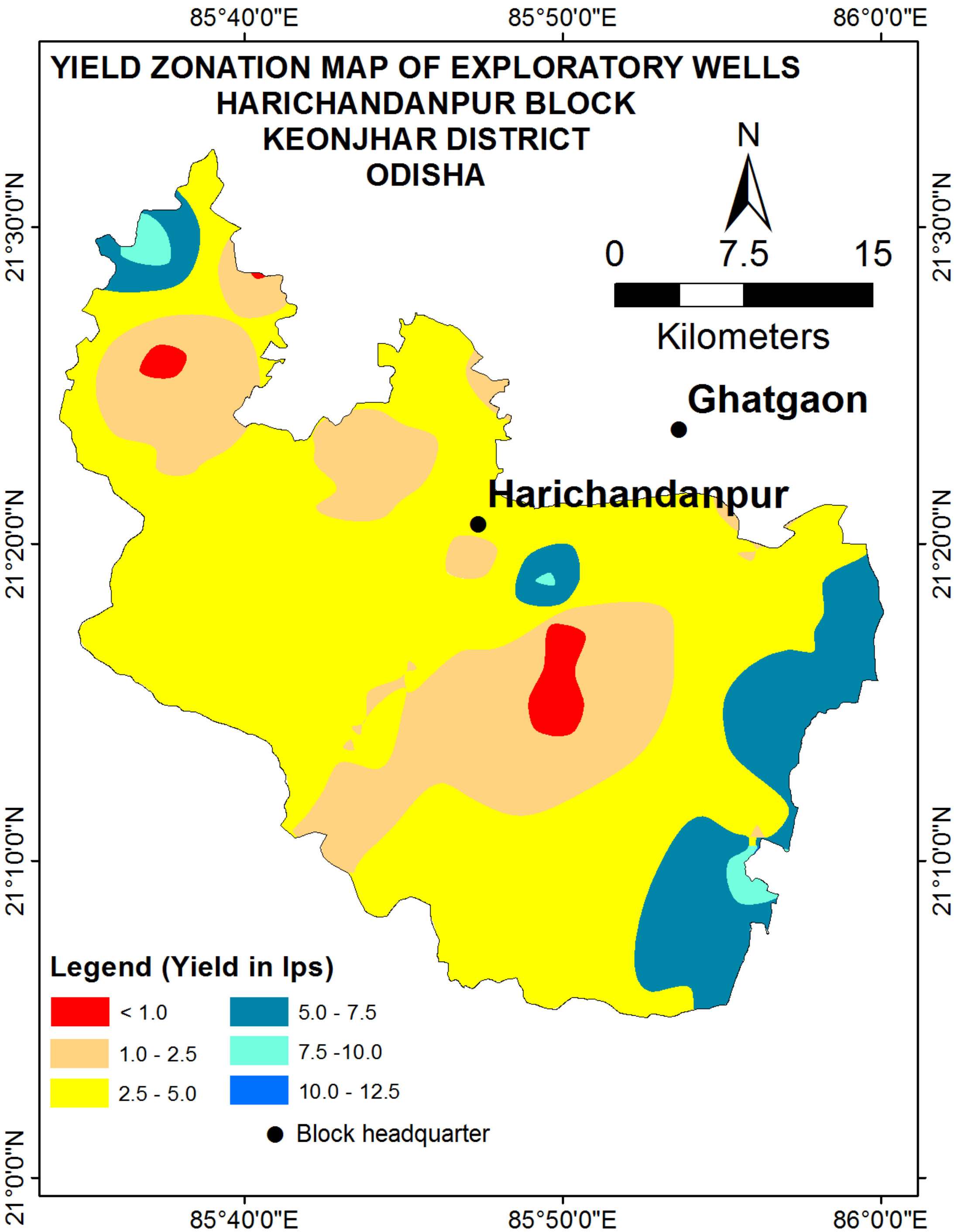

YIELD ZONATION MAP OF EXPLORATORY WELLS
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
7.5
15
Kilometers
Ghatgaon
Harichandanpur
85°40'0"E
85°50'0"E
86°0'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend (Yield in lps)
< 1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 -10.0
10.0 - 12.5
Block headquarter

PLATE – 6.14

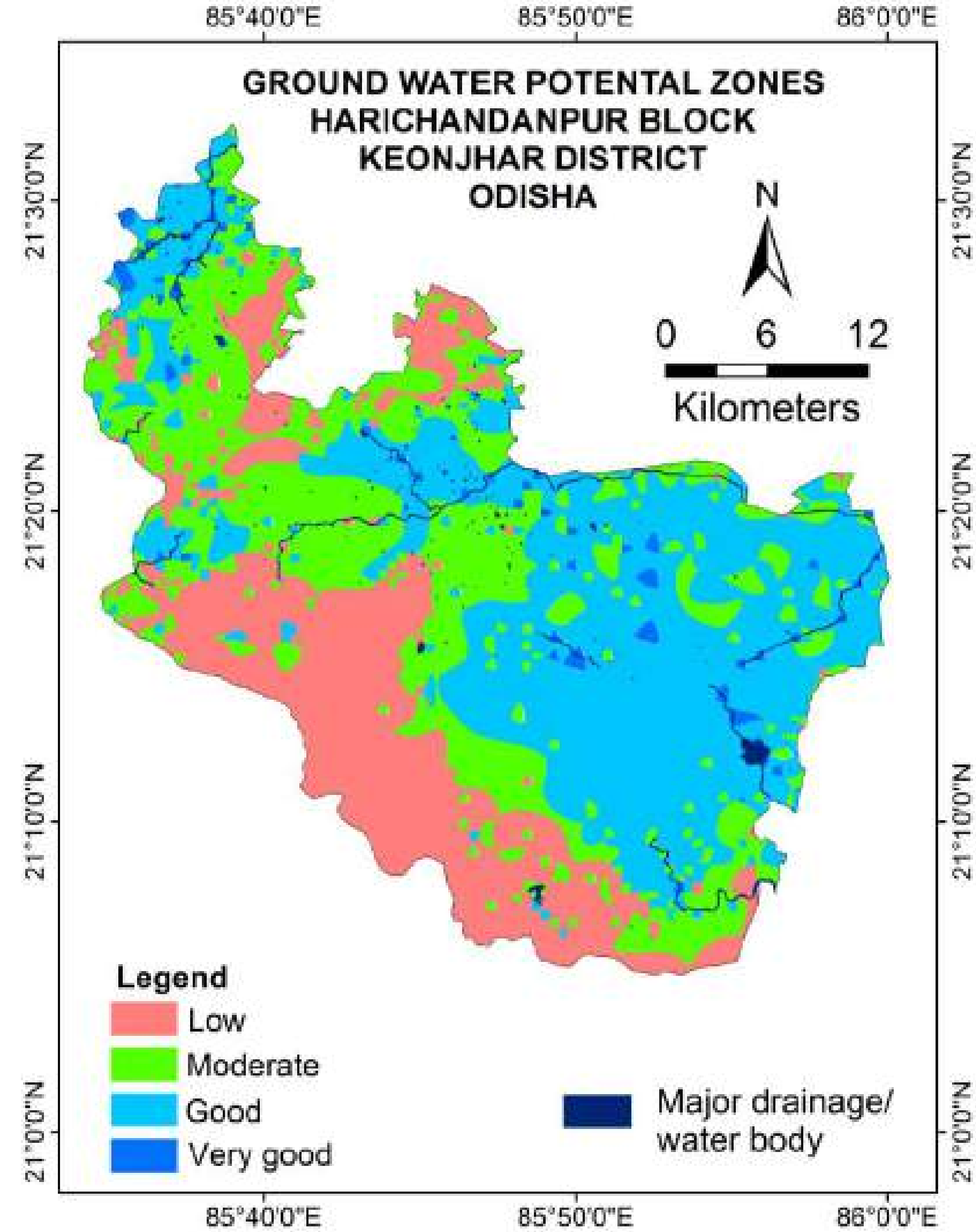
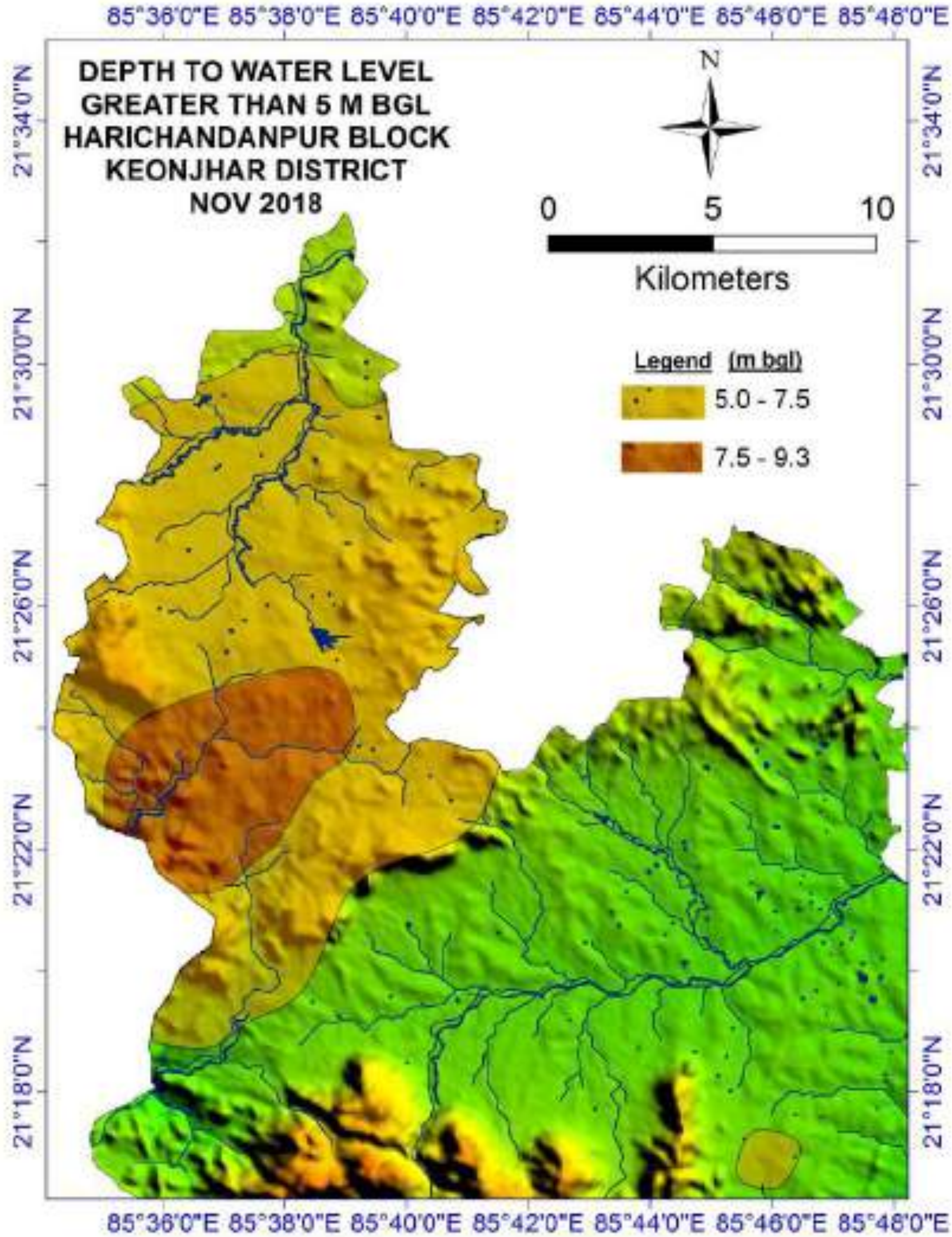

85°40'0"E
85°50'0"E
86°0'0"E
GROUND WATER POTENTAL ZONES
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend
Low
Moderate
Good
Very good
Major drainage/
water body

PLATE – 5.15



DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
HARICHANDANPUR BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 5 10
Kilometers
Legend (m bgl)
5.0 - 7.5
7.5 - 9.3
85°36'0"E 85°38'0"E 85°40'0"E 85°42'0"E 85°44'0"E 85°46'0"E 85°48'0"E
21°34'0"N
21°30'0"N
21°26'0"N
21°22'0"N
21°18'0"N

PART II BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

3.0 HATADIHI BLOCK

3.1 Salient information

Location, area and demography

Location (Plate 7.1)	86^0 10' - 86^0 23' E longitude 21^0 00' – 21^0 23'' N latitude
Area	604 sq. km
No. of Gram Panchayats	31
No. of villages	223
Population (Census 2011)	1,64,629 (rural)
Literacy	70.7%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1117.3 mm
Monsoon normal rainfall	862.5 mm (77.2% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	37788 Ha
Net sown area (2)	27098 Ha
Area sown more than once (1-2)	10690 Ha
Cropping intensity (%)	139.5 Ha
Area under forest	8600 Ha
Area under wasteland	47 Ha
Area under other uses	8743 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	20030 Ha *Kharif:* 15843 Ha *Rabi:* 4189 Ha

3.2 Drainage, geomorphology and soil types

The Baitarani is the major river in the block and flows along its western boundary. The river Salandi is other significant river in the northern parts of the block. The Salandi river and its reservoir in the north attract the local drainage. Some of the drainage lines flowing southward miss in the alluvium, indicating its water absorbing capacity. The existing water bodies near to the Baitarani might be indicating its palaeochannels. The drainage pattern is dendritic to sub-trellis in nature (Plate 7.2).

Around 50% of the geographic area in south is occupied by older alluvial plains. In the north, structural hills which bear low groundwater potential, occupy around 25% of the area. The pediment and buried pediments, considered suitable for groundwater occurrence, cover ~15% of the area in the north (Fig 7.1 and Plate 7.3). The Salandi reservoir that encompasses a significant area in the north may create better groundwater potential in the locality. Around 75% of the block area including the alluvial plains is characterized by land surface slope of <5% (Fig 7.2). Slope exceeds 20% in northern hilly areas (Plate 7.4). The soil types include the alluvial soil (alfisol) and red sandy soil (alfisol).

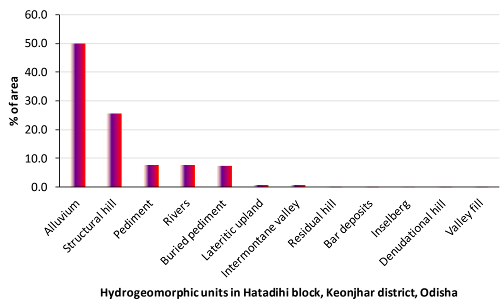


Figure 7.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Hatadihi block.

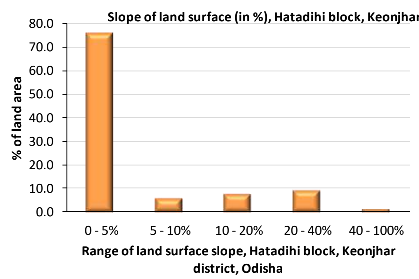


Figure 7.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Hatadihi block, Keonjhar district.

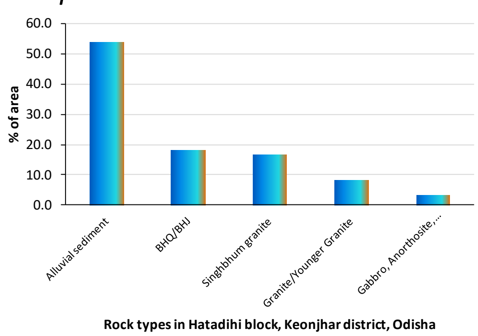


Figure 7.3: Percentage (%) of Hatadihi block area (Keonjhar dist.) covered by various rock types.

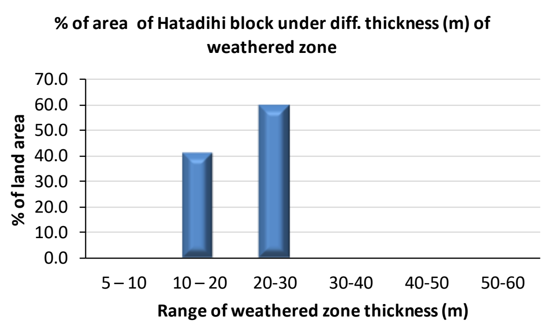


Figure 7.4: Bar diagram depicting the percentage (%) area of Hatadihi block, Keonjhar district falling under different weathered zone thickness (m) ranges.

3.3 Geology

The major geological formations in the block include the Quaternary alluvium, Singhbhum Granite and Banded Iron Formations. Basic-ultra-basic intrusions are found in the Precambrian granitic rocks (Fig 7.3 and Plate 7.5).

3.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories in the hard rock areas of the block, whereas in the alluvium, the intervenning granular zones in the stratigraphic column form the aquifers. The generalized hydrogeological map of the block is presented in Plate 7.7. The Singhbhum Granites posses low to moderate yield potential varying between 3-10 lps, whereas the yield in the alluvium is quite satisfactory in the range of 10-40 lps.

The water levels during the pre-monsoon (year 2018) measurement remained <5.0 m bgl in almost the antire block (Plate 7.7). Water levels <2.5 m bgl were observed close to the Salandi reservoir (downstream). During the post-monsson period, major parts of the block depicted water levels <2.5 m bgl, indicating good recharge from rainfall (Plate 7.8). The annual fluctuations in the water levels remained less than 2.0 m (Plate 7.9). The patches showing water level decline during post-monsoon period might be indicating groundwater withdrawal for irrigation.

3.5 Aquifer geometry and characters

In the northern parts of the block, the thickness of the weathered regolith overlying the fresh hard rock varies between 10-30 m (Plate 7.10) with the major parts in the range of 20-30 m (Fig 7.4). The alluvial thickness in the block goes up to 100 m bgl with around 40% granular zones. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 7.5a-b.

In the block, in general 1-2 sets of fracture zones are encountered within the depth of 100 m bgl (1st aquifer system) (Plate 7.11), whereas in the 2nd aquifer system (100-200 m bgl), 0-1 set of fractures are encountered in bore wells during drilling (Plate 7.12). There is possibility of getting water up to 5 lps in bore wells in the block (Plate 7.13). The tube wells in the alluvium yield between 10-40 lps of water.

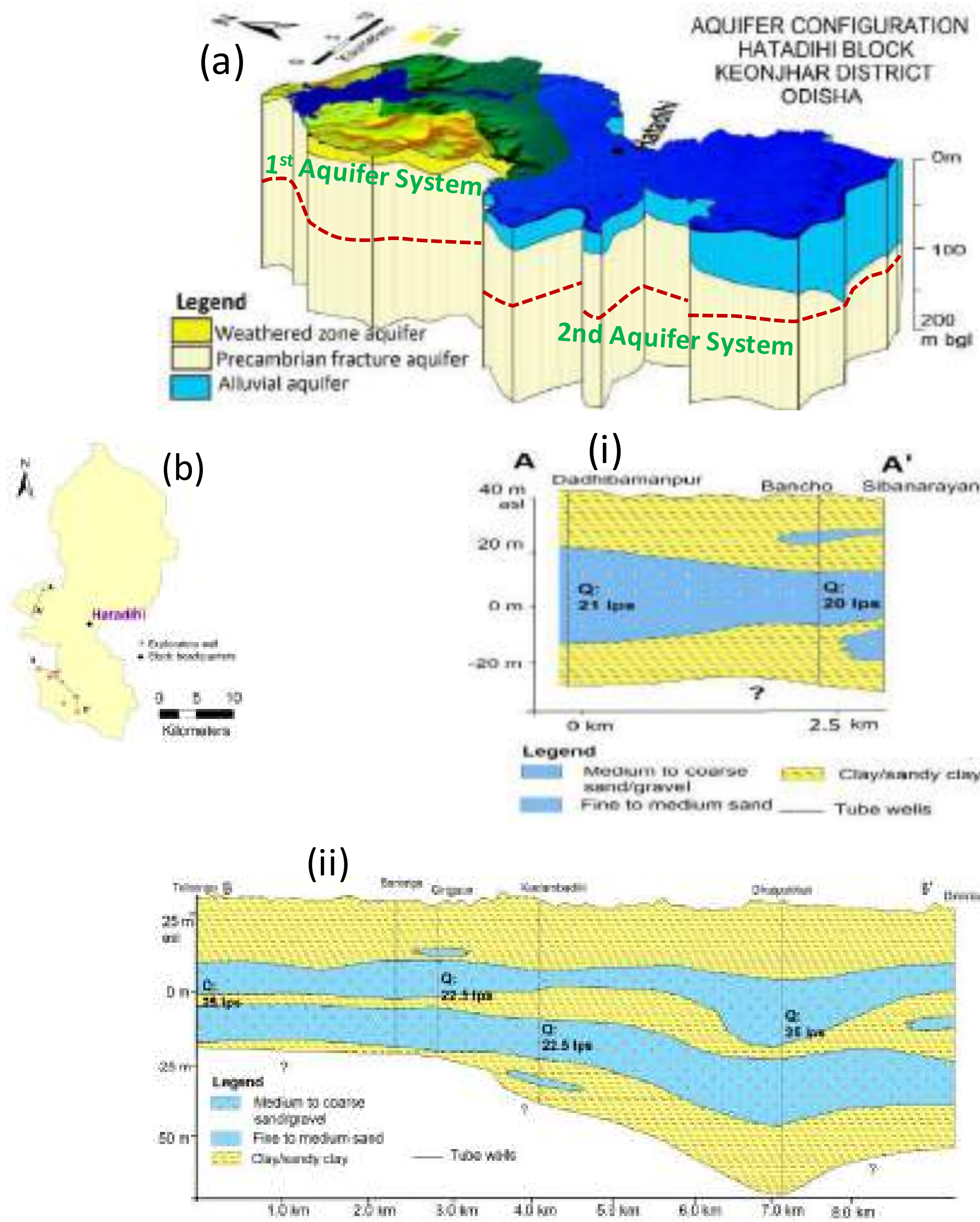


Figure 7.5: (a) 3D aquifer disposition in Hatadihi block, Keonjhar district. (b) (i)-(ii) 2D hydrogeological transects (including their location) A-A' and B-B' depicting the aquifer disposition in the block.

3.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered

zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 7.14). The hard rock parts in the north have been delineated as low to moderate groundwater potential zones. The good to very good potential zones (~63% of the area) are located in the alluvial parts of the block (Fig 7.6).

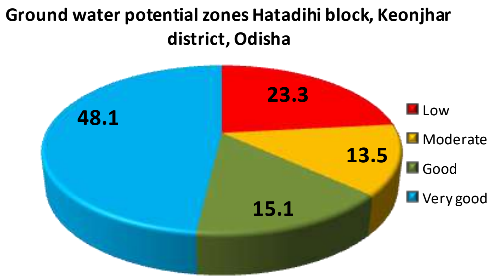


Figure 7.6: Pie diagram depicting the perentage (%) of Hatadihi block, Keonjhar district, Odisha, falling under different groundwater potential zones.

3.7 Ground water quality

Ground water in the block is alkaline in nature (Table 7.1) and pH range of 7.2-8.3. The water is moderately hard to very hard. The mineralization is low to moderate with TDS in the range of 129-822 mg/L (ave.: 315 mg/L). Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly Ca-HCO_3 types (Fig 7.7).

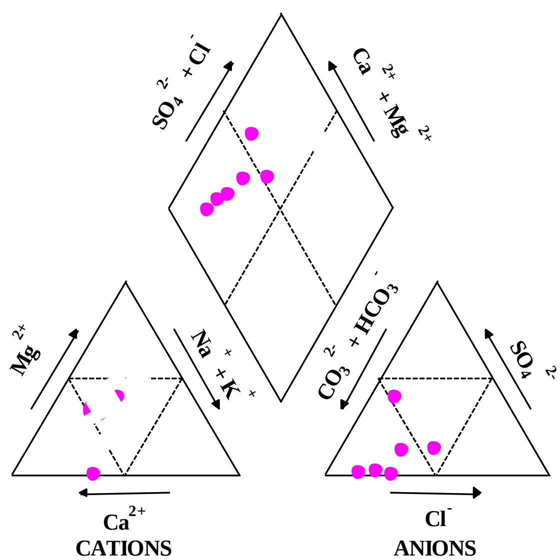


Figure 7.7: The Piper trilinear diagram depicting the groundwater quality in Hatadihi block, Keonjhar district.

Table 7.1: Ground water quality at various locations in Hatadihi block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Saralapasi	7.63	330	161	144	124	48	6	6	2.59	0	152	17	7	0.12
Barigan	8.1	1440	822	346	373	69	42	61	176.2	0	455	182	69	0.41
Soso	7.71	390	193	149	133	35	15	6	19.98	0	163	19	18	0.19
Dhenka	7.68	260	129	96	78	27	7	13	3.12	0	95	26	7	0.11
Nuasahi	7.78	510	270.13	195	167	52	16	32.37	1.06	0	203	48	19.2	0.228
Min.:	**7.63**	**260**	**129**	**96**	**78**	**27**	**6**	**6**	**1.06**	**0**	**95**	**17**	**7**	**0.11**
Max.:	**8.1**	**1440**	**822**	**346**	**373**	**69**	**42**	**61**	**176.2**	**0**	**455**	**182**	**69**	**0.41**
Average	**7.8**	**586.0**	**315.0**	**186.0**	**175.0**	**46.2**	**17.2**	**23.7**	**40.6**	**0.0**	**213.6**	**58.4**	**24.0**	**0.2**

3.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 7.2-7.4. The net dynamic groundwater available is 5879.6 Ham and the stage of groundwater development stands at 49.9%. Net resource available for future irrigation needs stands at 2888.6 Ham (Fig 7.8). The instorage/static groundwater resource component of 8008.6 Ham (Table 7.3) comes from the 1st aquifer system within 100 m bgl with a major portion of it lying in the alluvial area. The total groundwater available in the block stands at 13892.3 Ham.

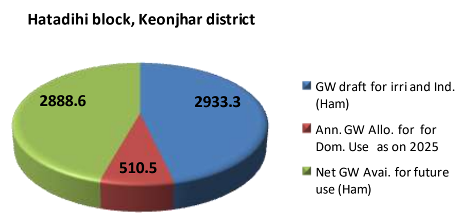


Figure 7.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Hatadihi block, Keonjhar district, Odisha.

Table 7.2: Salient information on annual dynamic groundwater resources, Hatadihi block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	5879.6
2. Irrigation draft (Ham)	2430.3
3. Industrial draft (Ham)	50.2
4. Domestic draft (Ham)	452.7
5. Total draft (Ham)	2933.3
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	510.5
7. Net groundwater available for future use (Ham)	2888.6
8. Stage of groundwater extraction (%)	49.9

Table 7.3: Total groundwater resoure available in the Hatadihi block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	5879.6
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	8008.6
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	4.1
	Block total	**13892.3**

3.9 Aquifer management plan

The existing stage of groundwater development of 49.9% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction

structures as estimated in Table 7.4 (135 bore wells/dug-cum-bore wells and 1143 dug wells) are required to be constructed to develop the available additional resource of 594.5 Ham. It can help in creating additional irrigation potential for 772.8 Ha (Table 7.5).

Only around 28.29 km^2 area in the block showed post-monsoon depth to water levels >5.0 m bgl (Plate 7.15; Table 7.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 2.97 MCM of water (Table 7.7) can be recharged by the help additional 6- percolations ponds, 3-subsurface dykes, 3-nala/contour bunds and 6-check dams (Table 7.8) with a total cost of 1.93 crores (Table 7.9).

Table 7.4: Number of additional feasible groundwater abstraction structures in Hatadihi block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	5879.6
2	Stage of GW deve. (%)	49.9
3	Present GW draft (Ham)	2933.3
4	Ground water draft at 60% stage of deve. (Ham)	3527.8
5	Addi. water to be deve. (Ham)	594.5
6	Addi. No of BW/ dug-cum-bore wells feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	135
7	Addi. No. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	1143

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 7.5: Irrigation potential likely to be created in Hatadihi block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	49.9
2	Surplus GW avai. for 60% stage of deve. (Ham)	594.5
3	Irri, Pot. likely to be created for Paddy (Ha)	475.6
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	74.3
5	Irri. Pot. likely to be created for veg. (Ha)	222.9
6	Proj. area to be Irri. (ha)	772.8

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 7.6: Areas in Hatadihi block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Hatadihi	0.0	0.0	0.0

Table 7.7: Estimation of volume of water required for artificial recharge to groundwater in Hatadihi block, Keonjhar district.

Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (mcm)	Total volume of water required to reharge (mcm)
Hatadihi	607.00	0.00	0	0	0.00	0.00

Table 7.8: Number of feasible structures in Hatadihi block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (mcm)	No of different freasible structures			
		Percolation tank (40%) @0.2 mcm	sub-surface dyke (15%) @0.15 mcm	Nala bund/contour bunding (15%) @0.15 mcm	Check dams & weirs (30%) @0.15 mcm
Hatadihi	0.00	0	0	0	0

Table 7.9: Estimation of cost of artificial recharge structures in Hatadihi block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Hatadihi	0.00	0.00	0.00	0.00	0.00

PLATE – 7.1

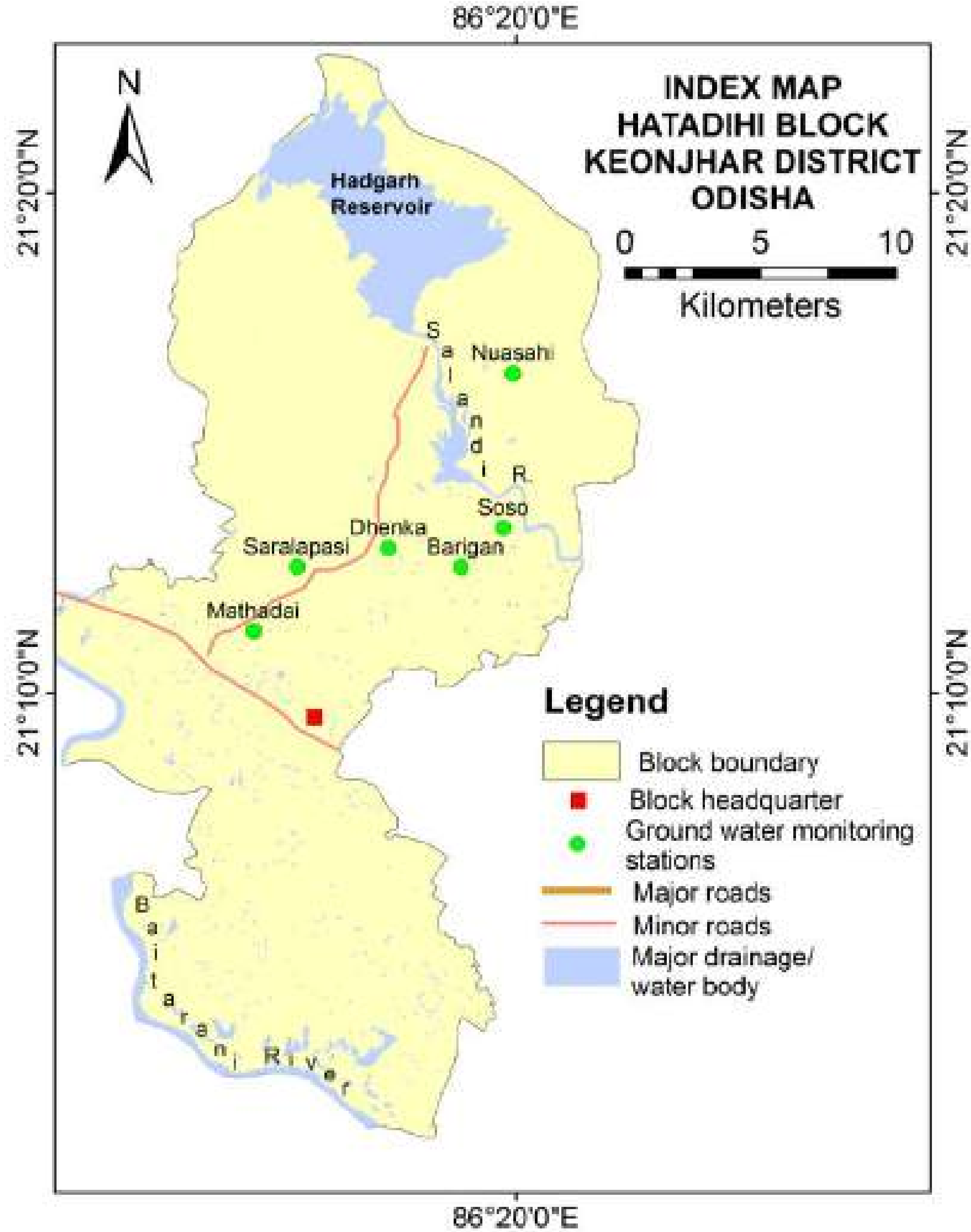

86°20'0"E
N
INDEX MAP
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
0 5 10
Kilometers
21°20'0"N
21°10'0"N
Hadgarh Reservoir
Salandi R.
Nuasahi
Soso
Dhenka
Barigan
Saralapasi
Mathadai
Baitarani River
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Major drainage/ water body

PLATE – 7.2

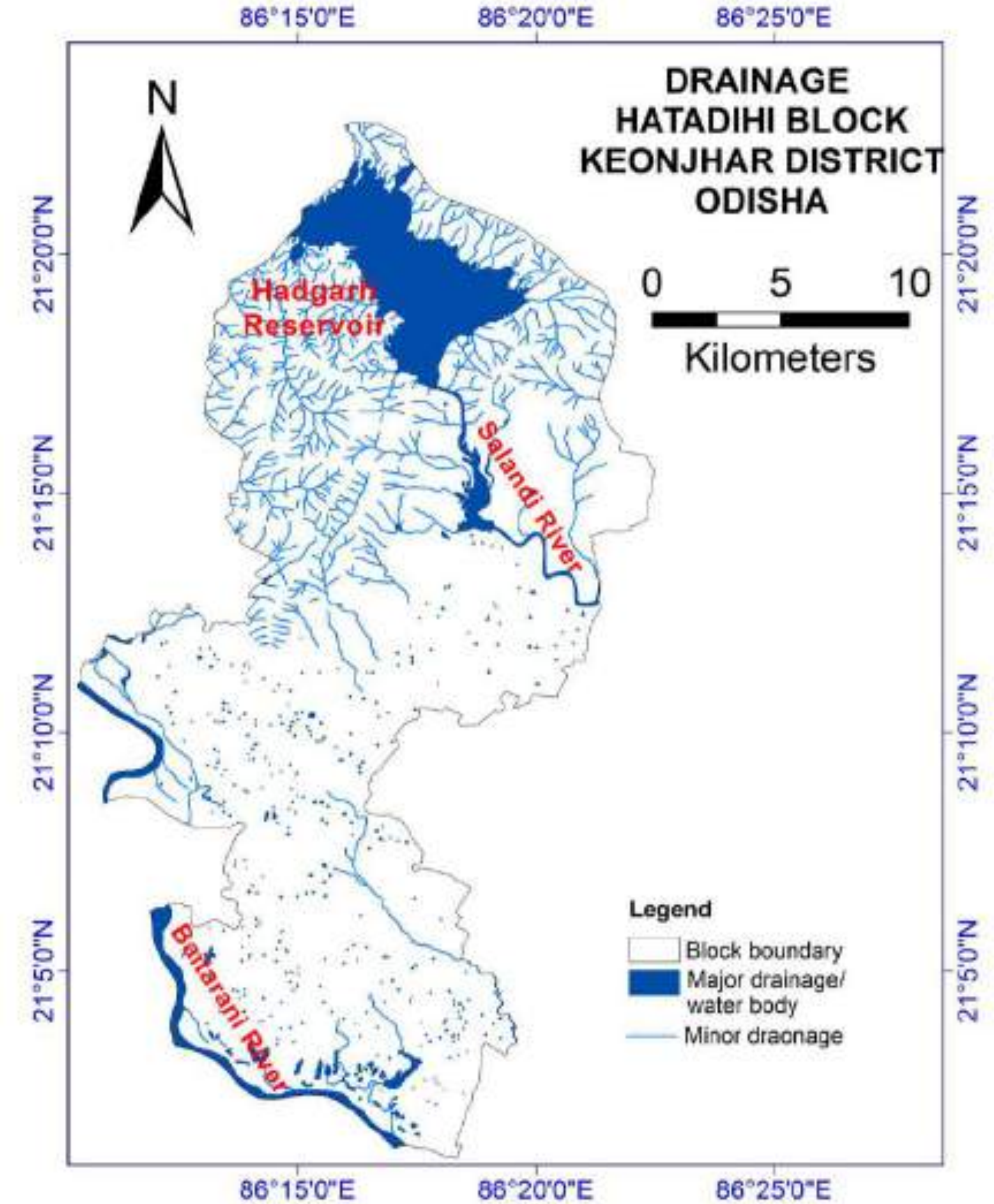

86°15'0"E
86°20'0"E
86°25'0"E
N
DRAINAGE
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
0
5
10
Kilometers
21°20'0"N
21°15'0"N
21°10'0"N
21°5'0"N
Hadgarh Reservoir
Salandi River
Baitarani River
Legend
Block boundary
Major drainage/ water body
Minor draonage

PLATE – 7.3

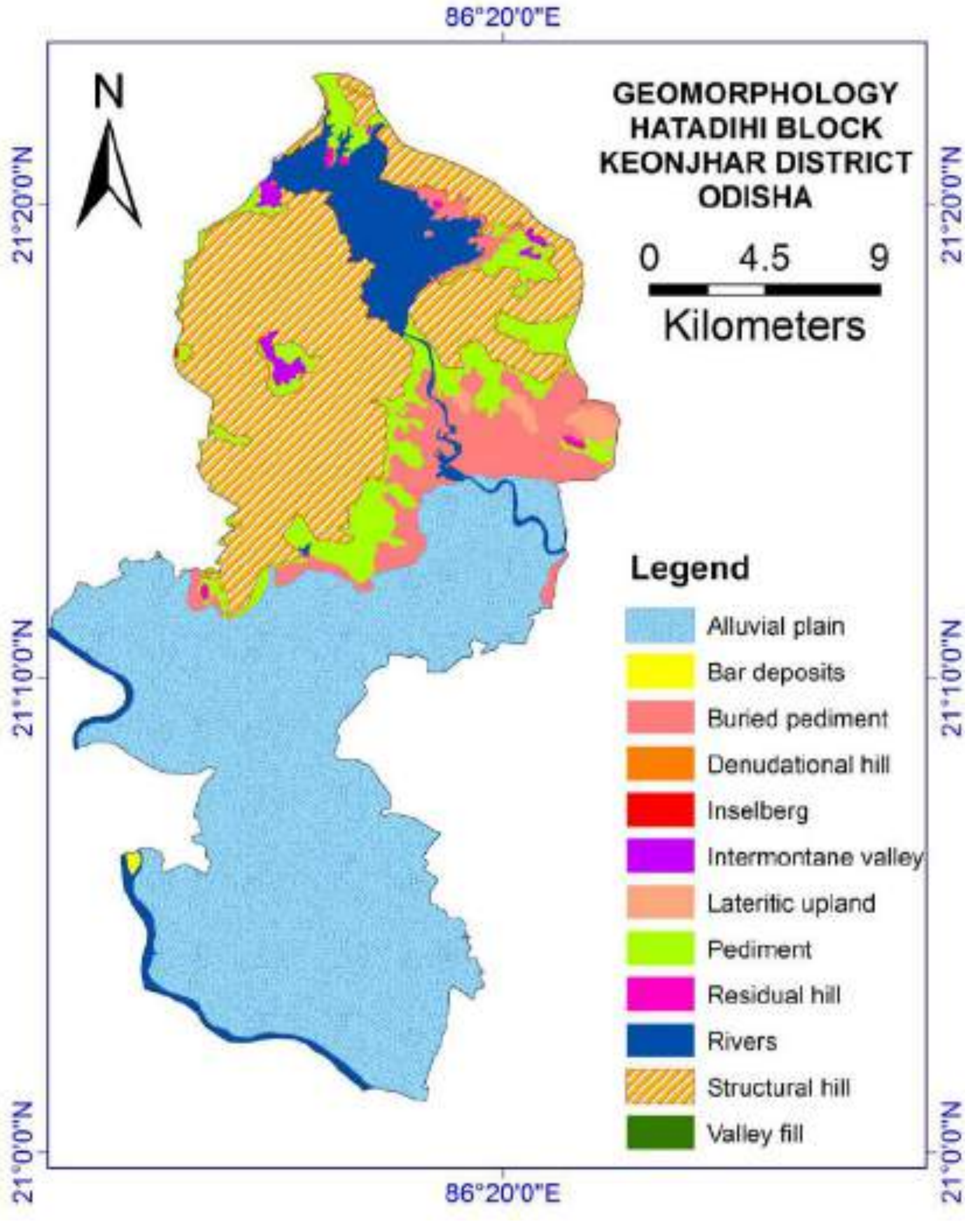

86°20'0"E
21°20'0"N
21°10'0"N
21°0'0"N
N
GEOMORPHOLOGY
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
0 4.5 9
Kilometers
Legend
Alluvial plain
Bar deposits
Buried pediment
Denudational hill
Inselberg
Intermontane valley
Lateritic upland
Pediment
Residual hill
Rivers
Structural hill
Valley fill

PLATE – 7.4

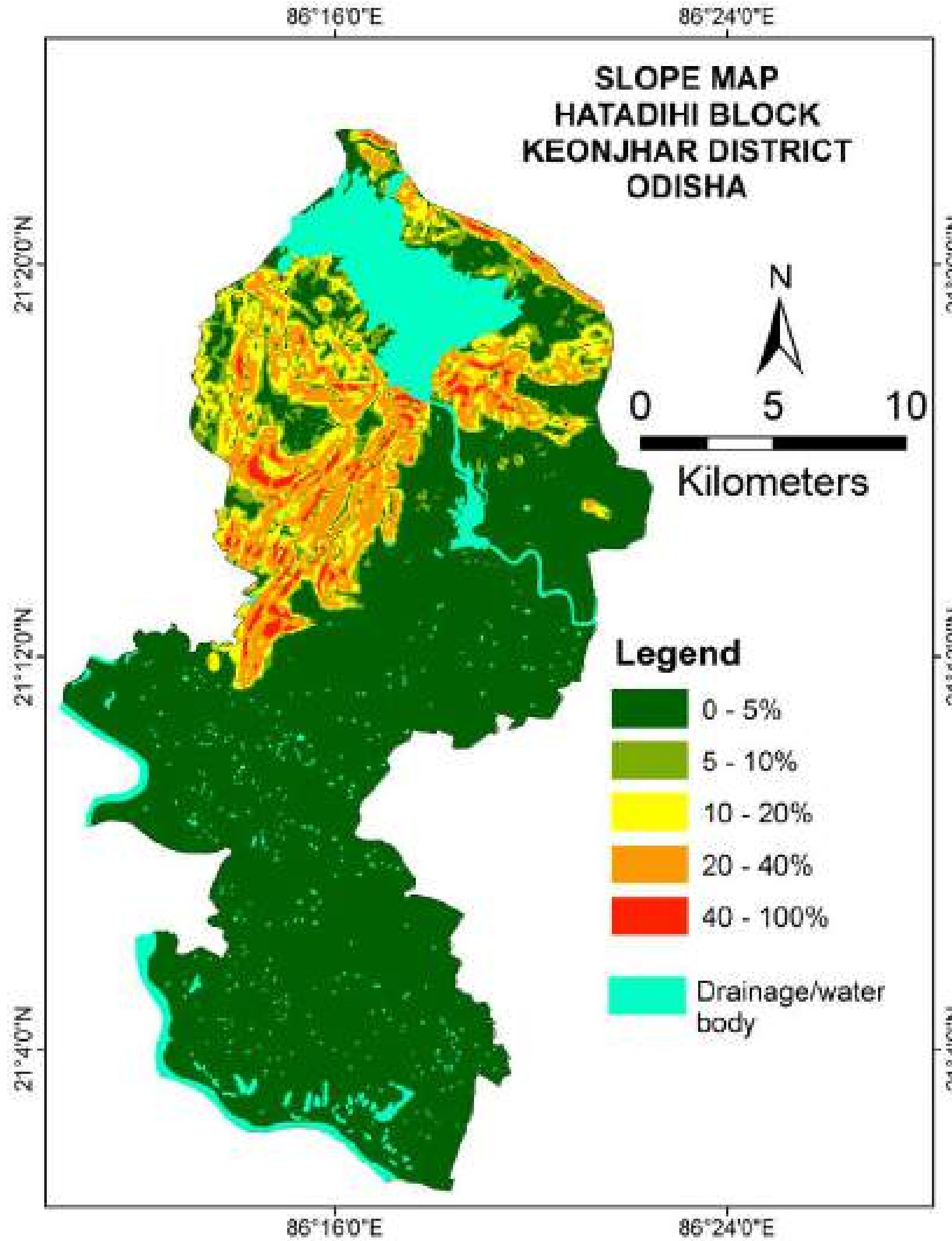

SLOPE MAP
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
86°16'0"E
86°24'0"E
21°20'0"N
21°12'0"N
21°4'0"N
N
0
5
10
Kilometers
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 7.5

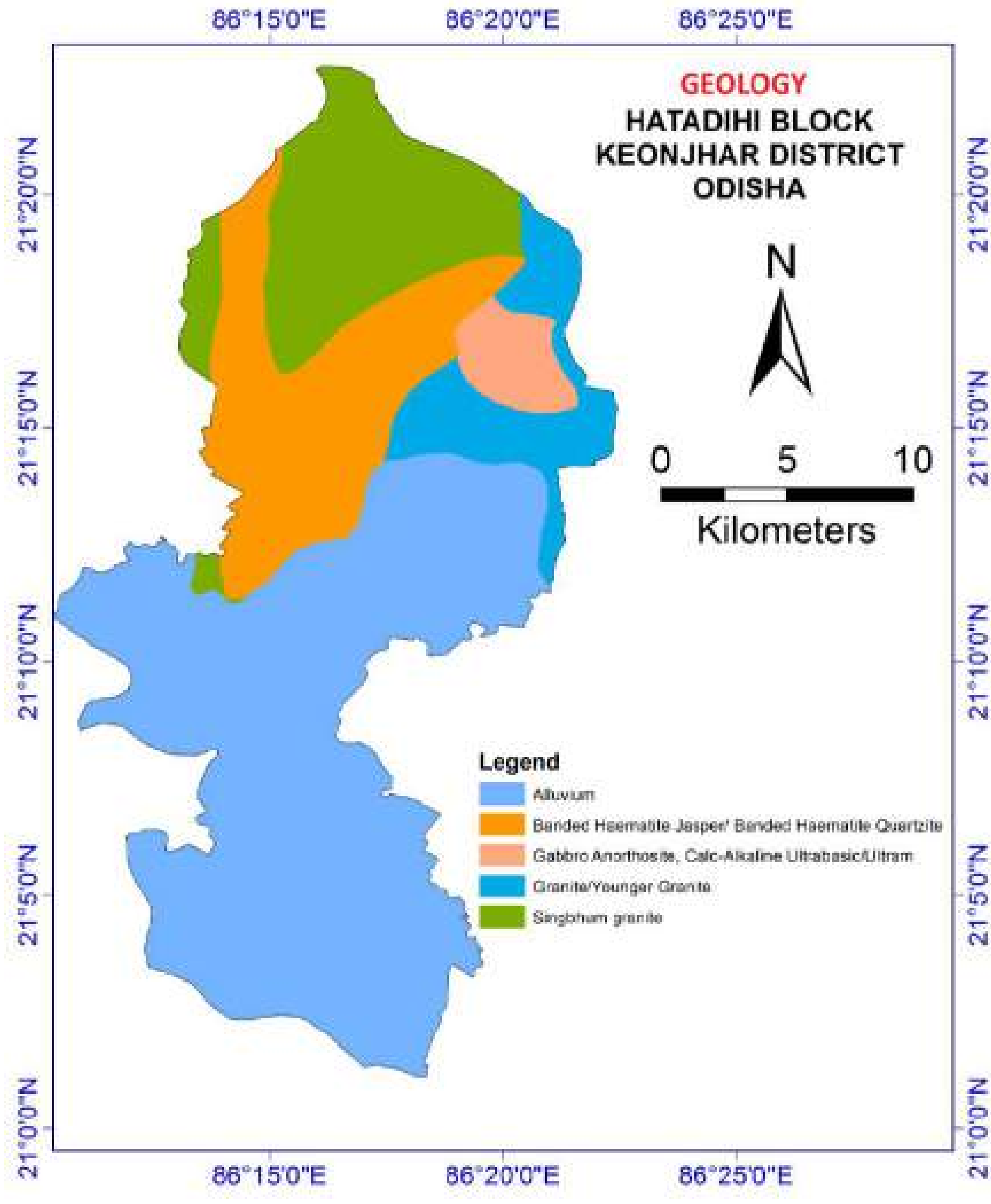

GEOLOGY
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
86°15'0"E
86°20'0"E
86°25'0"E
21°20'0"N
21°15'0"N
21°10'0"N
21°5'0"N
21°0'0"N
Legend
Alluvium
Banded Haematite Jasper/ Banded Haematite Quartzite
Gabbro Anorthosite, Calc-Alkaline Ultrabasic/Ultram
Granite/Younger Granite
Singbhum granite

PLATE – 7.6

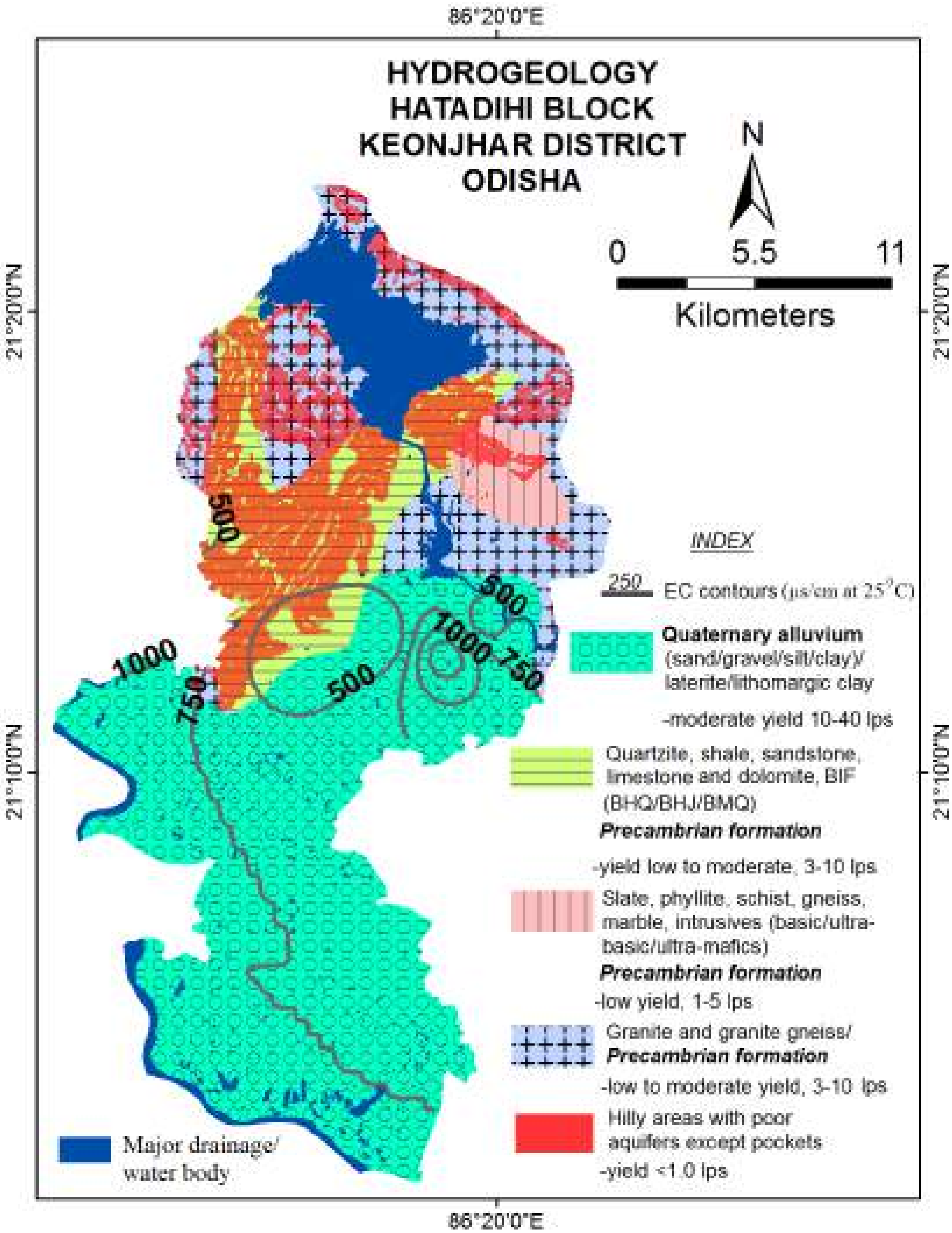
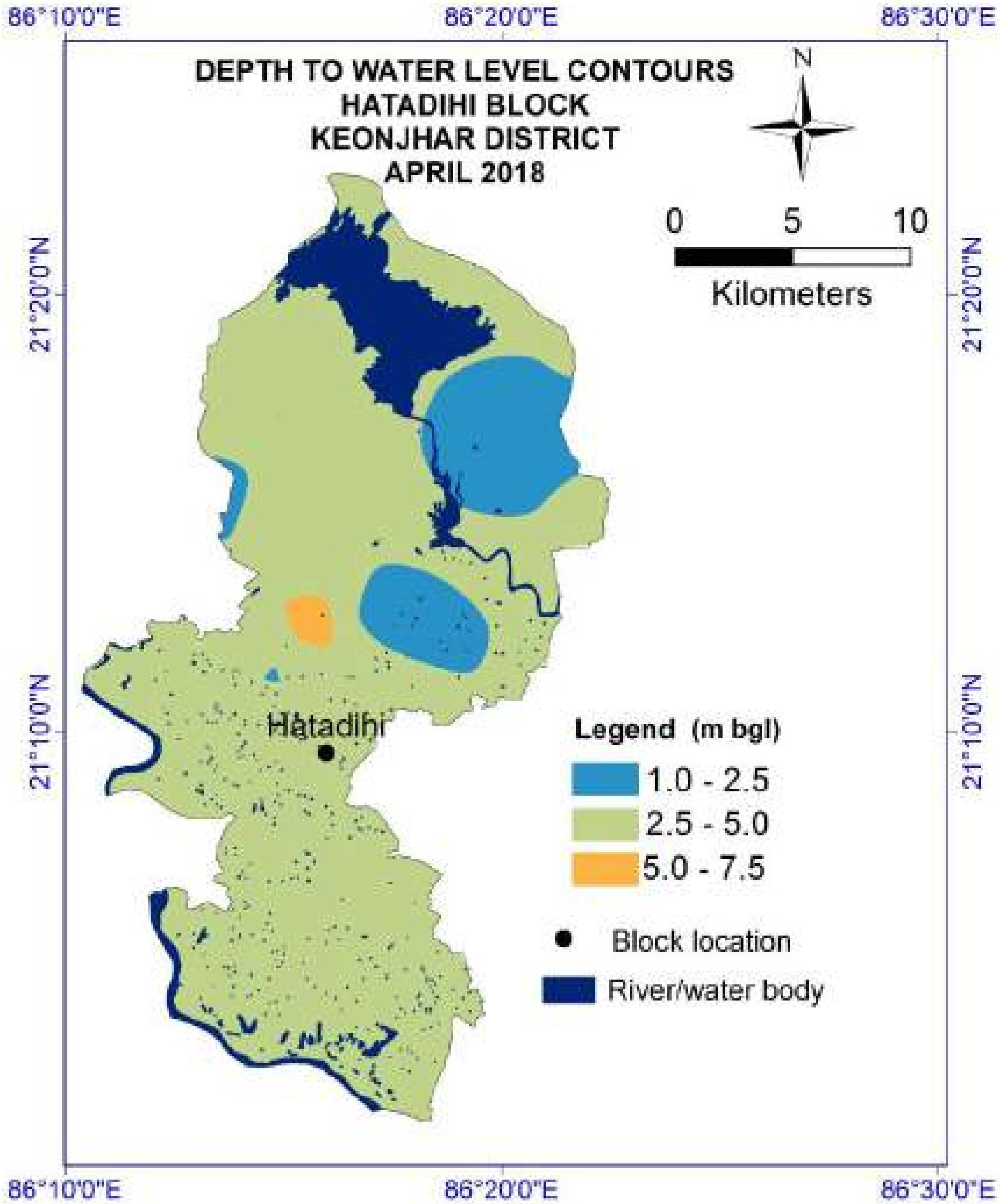

HYDROGEOLOGY
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
86°20'0"E
21°20'0"N
21°10'0"N
N
0 5.5 11
Kilometers
500
1000
750
INDEX
250 EC contours (µs/cm at 25°C)
Quaternary alluvium (sand/gravel/silt/clay)/ laterite/lithomargic clay
-moderate yield 10-40 lps
Quartzite, shale, sandstone, limestone and dolomite, BIF (BHQ/BHJ/BMQ)
Precambrian formation
-yield low to moderate, 3-10 lps
Slate, phyllite, schist, gneiss, marble, intrusives (basic/ultra-basic/ultra-mafics)
Precambrian formation
-low yield, 1-5 lps
Granite and granite gneiss/
Precambrian formation
-low to moderate yield, 3-10 lps
Hilly areas with poor aquifers except pockets
-yield <1.0 lps
Major drainage/ water body

PLATE – 7.7



86°10'0"E
86°20'0"E
86°30'0"E
DEPTH TO WATER LEVEL CONTOURS
HATADIHI BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0 5 10
Kilometers
21°20'0"N
21°10'0"N
Hatadihi
Legend (m bgl)
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
Block location
River/water body

PLATE – 7.8

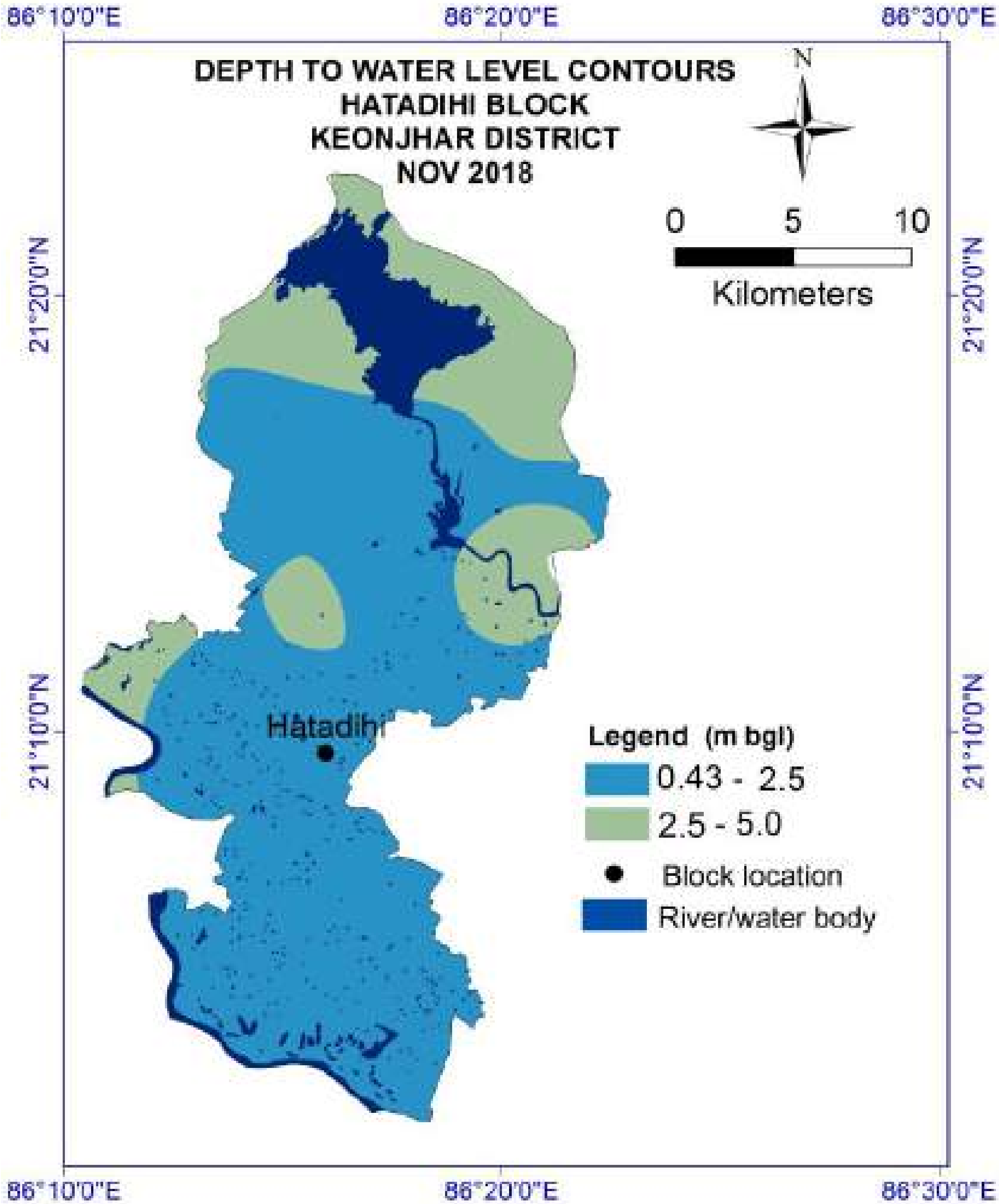

DEPTH TO WATER LEVEL CONTOURS
HATADIHI BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0
5
10
Kilometers
86°10'0"E
86°20'0"E
86°30'0"E
21°20'0"N
21°10'0"N
Hatadihi
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
Block location
River/water body

PLATE – 7.9

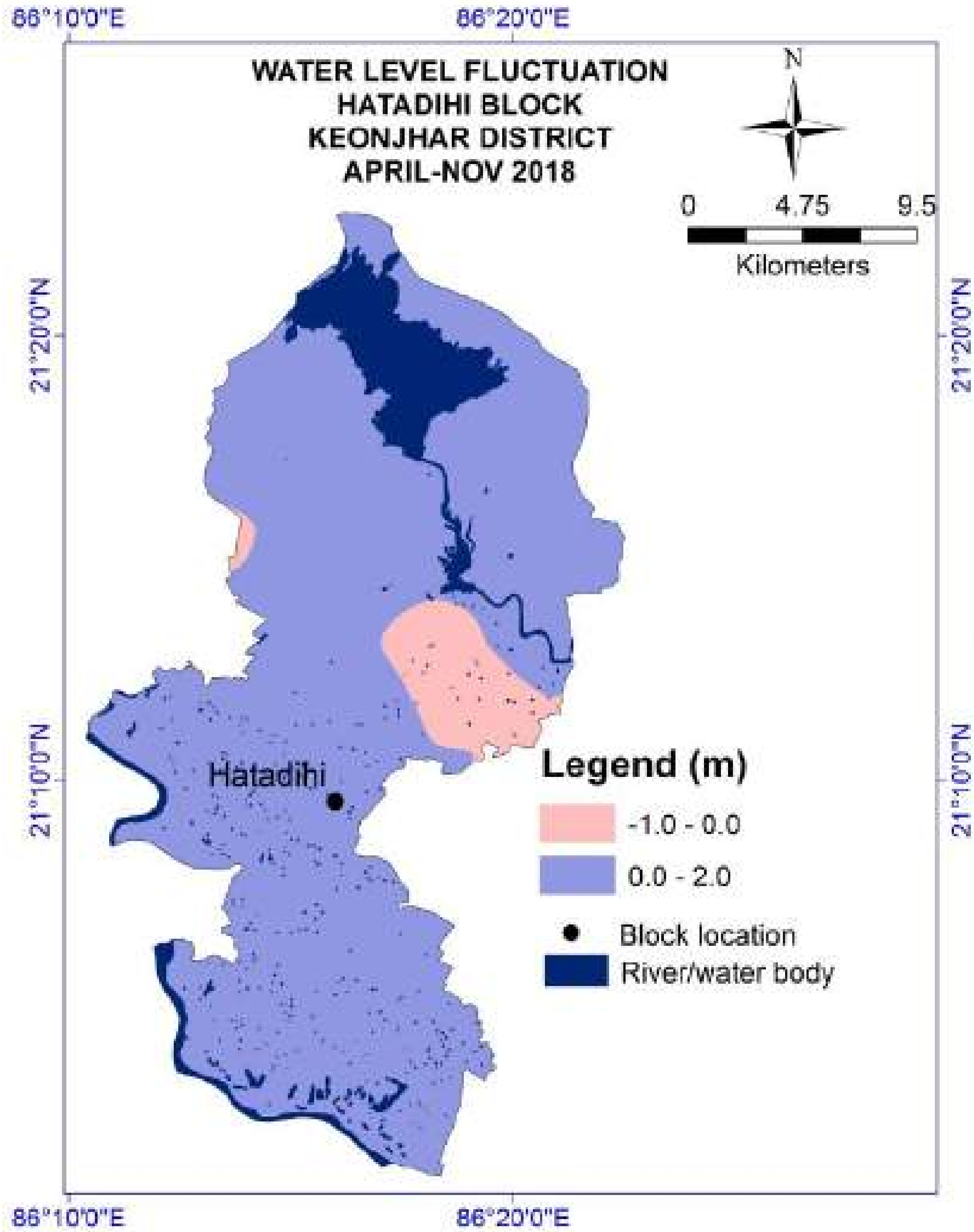

86°10'0"E
86°20'0"E
WATER LEVEL FLUCTUATION
HATADIHI BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0
4.75
9.5
Kilometers
21°20'0"N
21°10'0"N
Hatadihi
Legend (m)
-1.0 - 0.0
0.0 - 2.0
Block location
River/water body

PLATE – 7.10

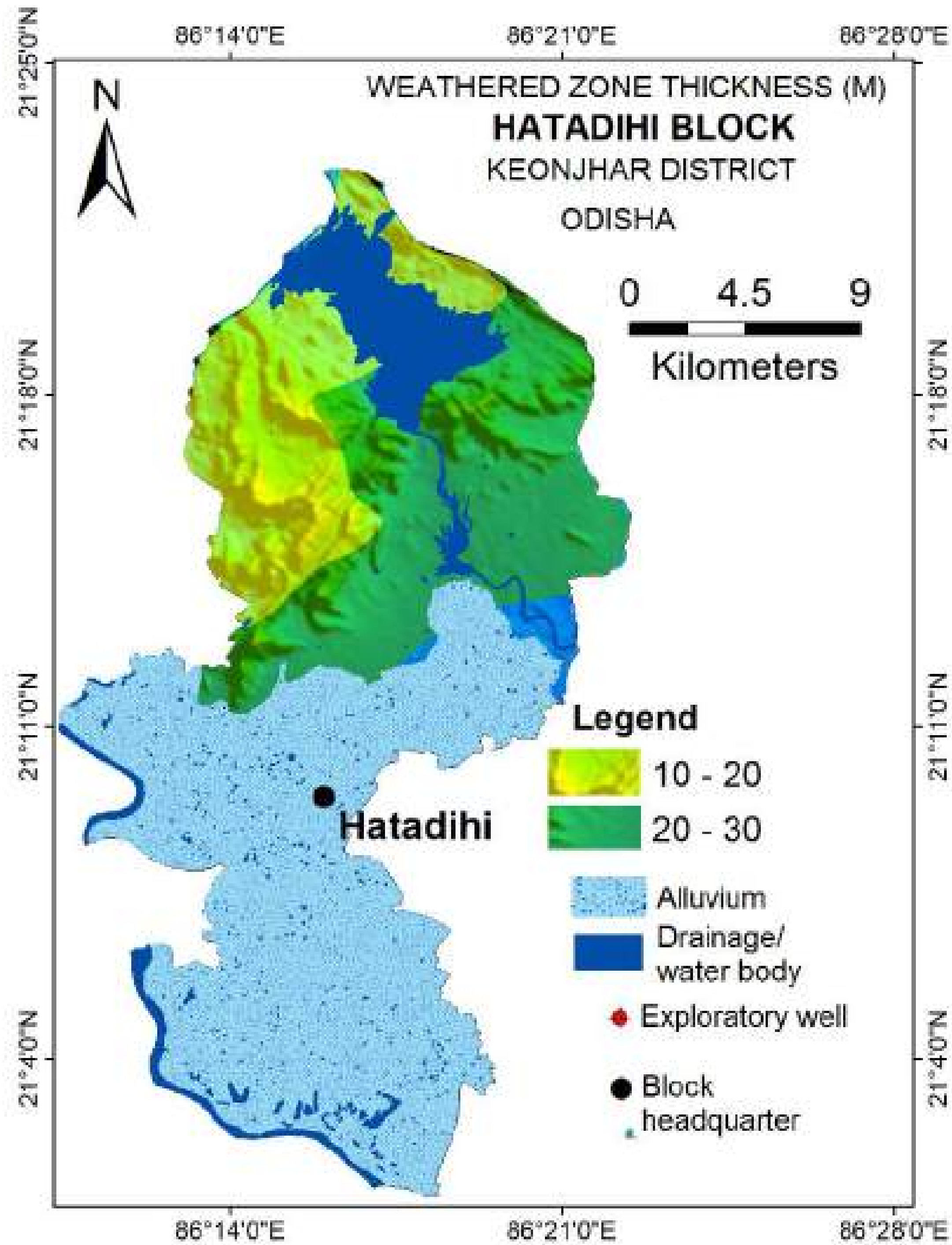

WEATHERED ZONE THICKNESS (M)
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 4.5 9
Kilometers
Legend
10 - 20
20 - 30
Alluvium
Drainage/ water body
Exploratory well
Block headquarter
Hatadihi
86°14'0"E
86°21'0"E
86°28'0"E
21°25'0"N
21°18'0"N
21°11'0"N
21°4'0"N

PLATE – 7.11

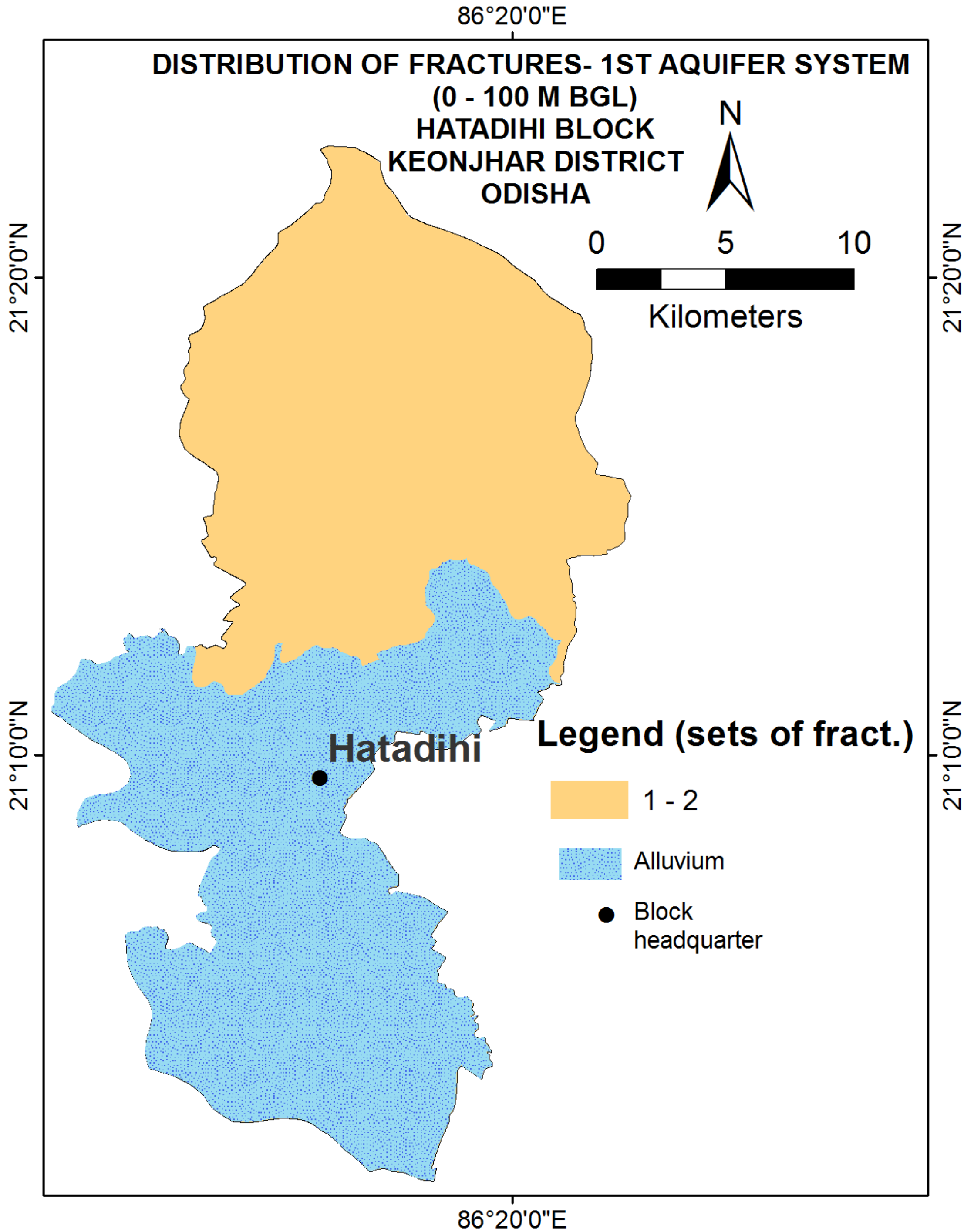

86°20'0"E
DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5
10
Kilometers
21°20'0"N
21°10'0"N
Hatadihi
Legend (sets of fract.)
1 - 2
Alluvium
Block headquarter
86°20'0"E

PLATE – 7.12

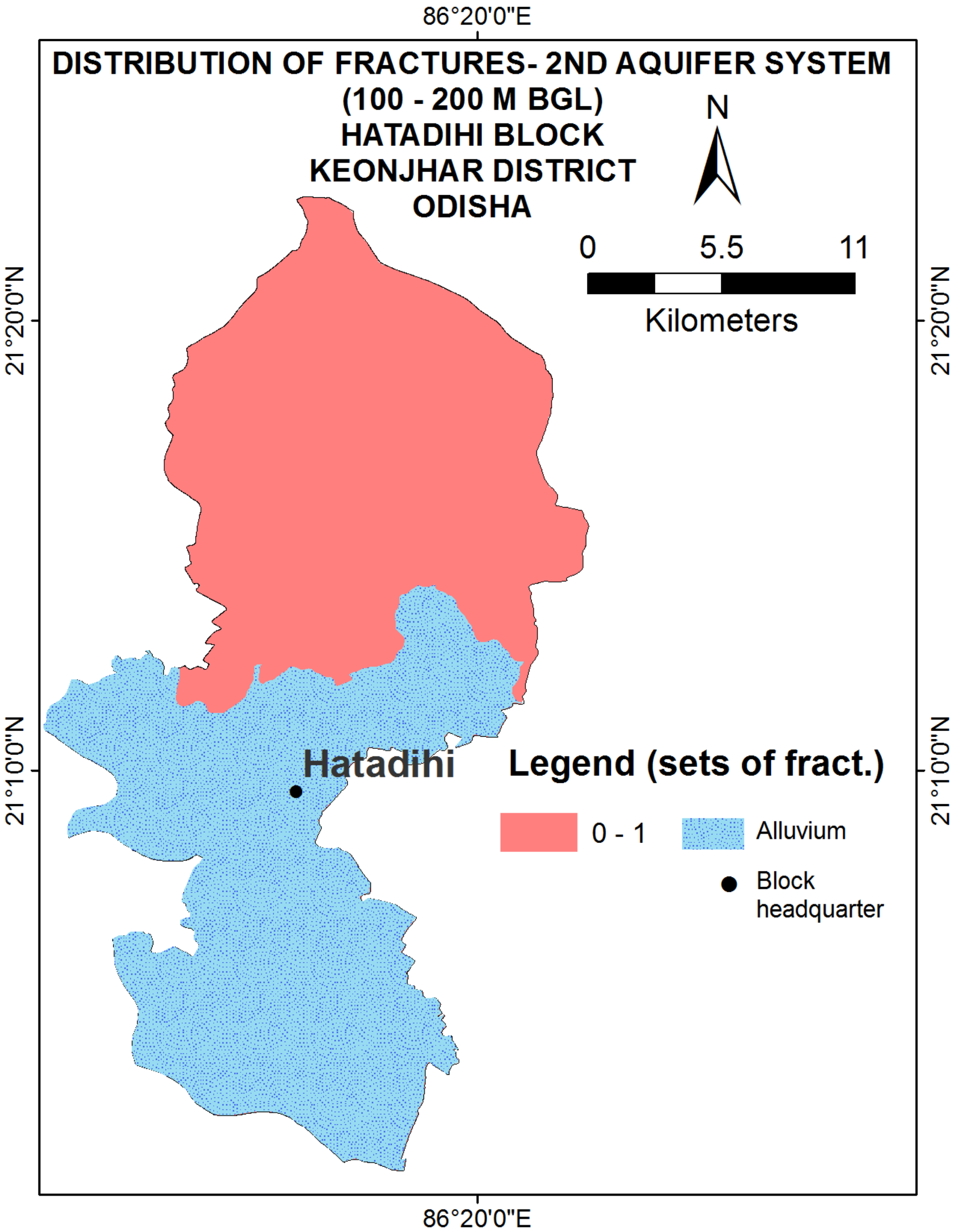

DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5.5
11
Kilometers
86°20'0"E
21°20'0"N
21°10'0"N
Hatadihi
Legend (sets of fract.)
0 - 1
Alluvium
Block
headquarter

PLATE – 7.13

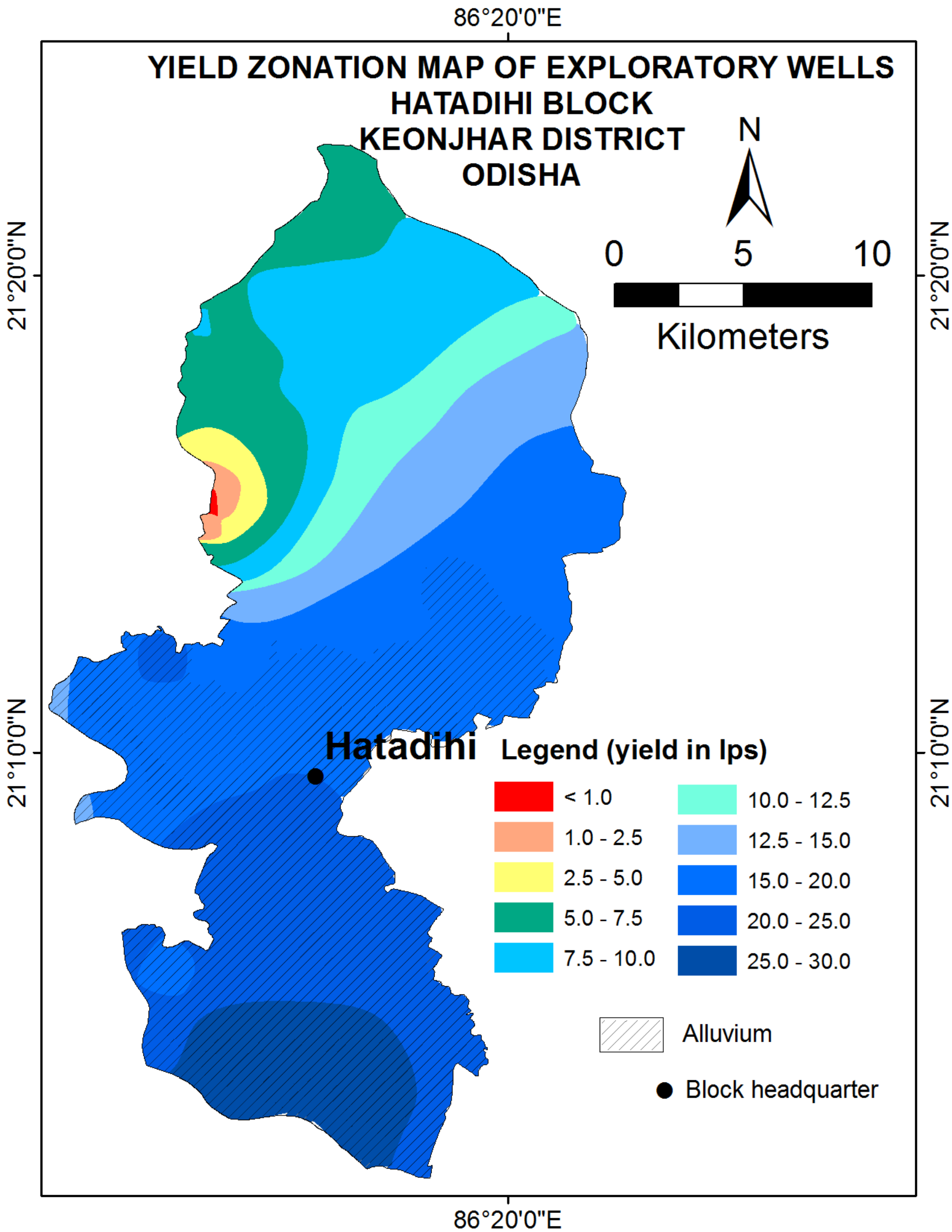
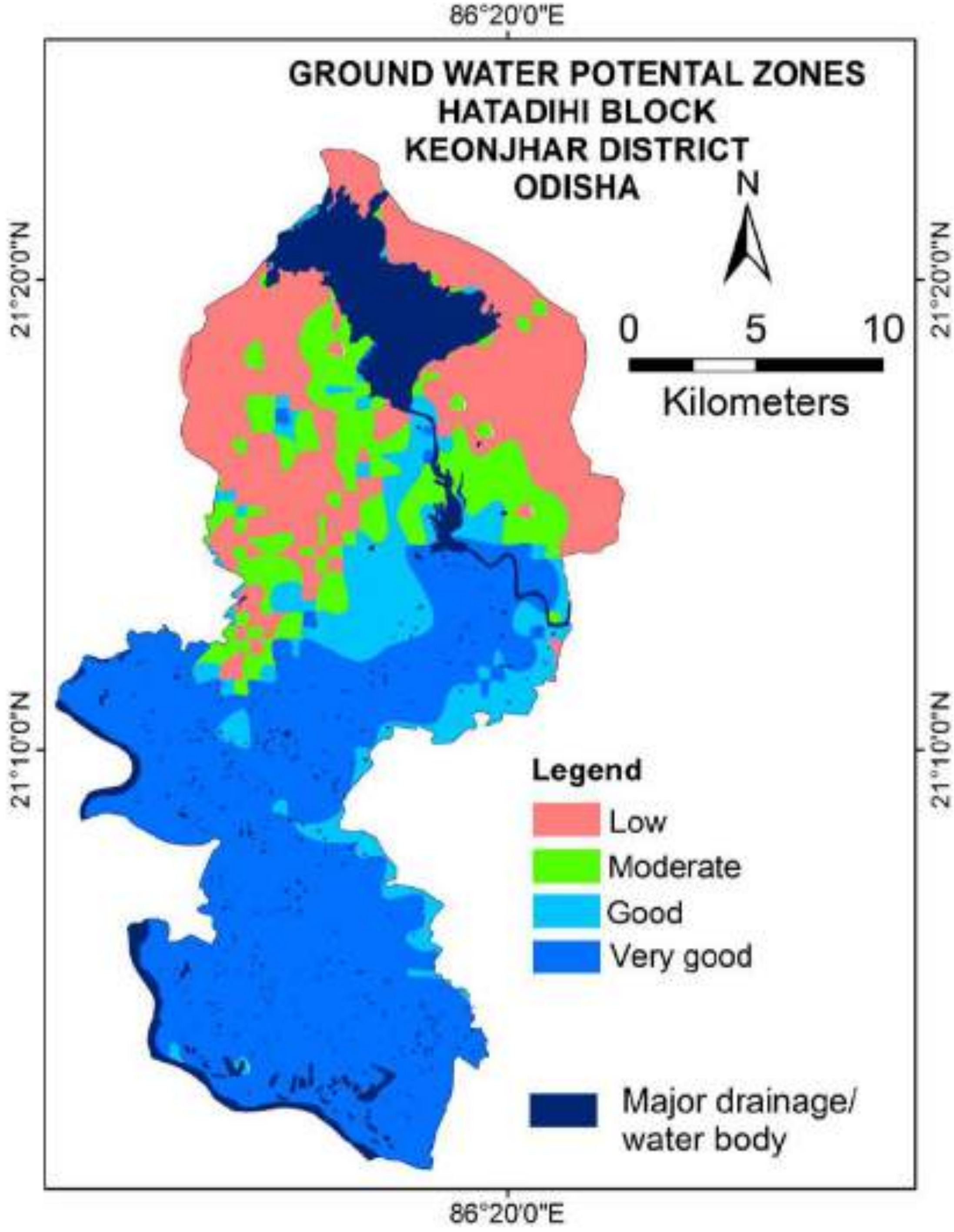

86°20'0"E
YIELD ZONATION MAP OF EXPLORATORY WELLS
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
21°20'0"N
21°10'0"N
Hatadihi
Legend (yield in lps)
< 1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
12.5 - 15.0
15.0 - 20.0
20.0 - 25.0
25.0 - 30.0
Alluvium
Block headquarter
86°20'0"E

PLATE – 7.14


86°20'0"E
GROUND WATER POTENTAL ZONES
HATADIHI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
21°20'0"N
21°10'0"N
Legend
Low
Moderate
Good
Very good
Major drainage/
water body
86°20'0"E

PART II BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

4.0 JHUMPURA BLOCK

4.1 Salient information

Location, area and demography

Location (Plate 8.1)	85^0 21' - 86^0 45' E longitude 21^0 44' – 22^0 00'' N latitude
Area	594 sq. km
No. of Gram Panchayats	22
No. of villages	153
Population (Census 2011)	1,13,149 Rural: 1,07,085 Urban: 6,064
Literacy	53.92%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1240 mm
Monsoon normal rainfall	977 mm (79% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	32441 Ha
Net sown area (2)	24012 Ha
Area sown more than once (1-2)	8429 Ha
Cropping intensity (%)	135.1 Ha
Area under forest	16706 Ha
Area under wasteland	619 Ha
Area under other uses	15320 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	5709 Ha *Kharif:* 3464 Ha *Rabi:* 2245 Ha

4.2 Drainage, geomorphology and soil types

The Baitarani River that enters at the south-west corner leaves the block flowing in the north-east direction. Other rivers that drain the block include the Ardei, Mermeda and

Neorojol, which are tributaries of the river Baitarani. The drainage pattern is dendritic to sub-trellis and in some parts sub-parallel in nature. There are several small water bodies in the Ardei, Mermeda and Neorojol river basins (Plate 8.2).

The western part is predominantly covered by structural hills (~22% of the area) with intervenning intermontane valleys (Plate 8.3). The central and eastern parts are mostly occupied (68% of block area) by pediments, buried pediments and valley fills (Fig 8.1 and Plate 8.3). These units are considered as potential for groundwater occurrence. There are a few linear basic (dolerite) dykes that run in NE-SW and NW-SE directions. Except the parts in the western hills (Plate 8.4), major parts of the block (78% of area) possess land surface slope of <5% (Fig 8.2). The soil types include the red sandy soil (alfisol), red loamy (alfisol) and red and yellow soil types (ultisol).

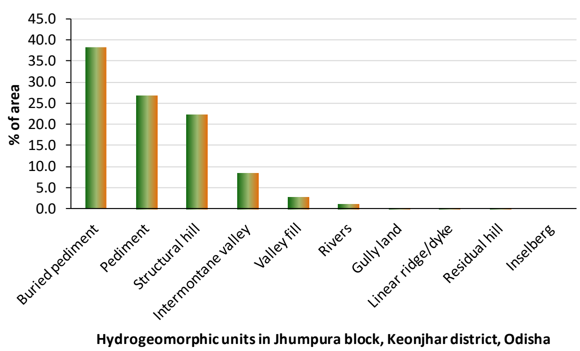


Figure 8.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Jhumpura block.

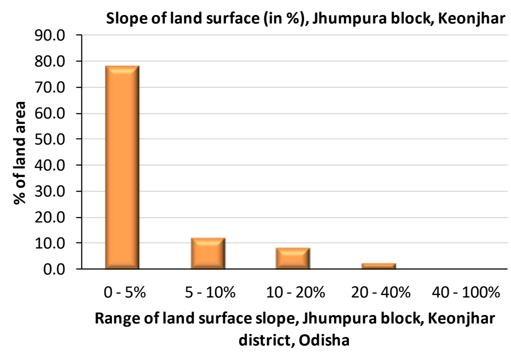


Figure 8.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Jhumpura block, Keonjhar district.

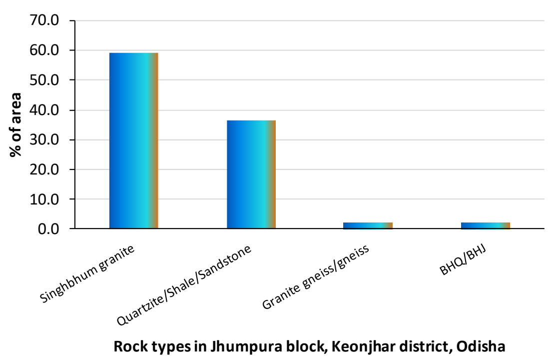


Figure 8.3: Percentage (%) of Jhumpura block area (Keonjhar dist.) covered by various rock types.

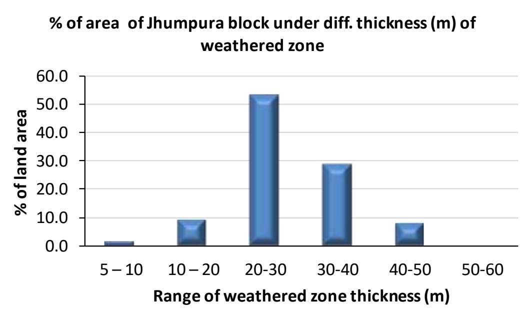


Figure 8.4: Bar diagram depicting the percentage (%) area of Jhumpura block, Keonjhar district falling under different weathered zone thickness (m) ranges.

4.3 Geology

The Singhbhum Granites occupy around 60% of the block area. Among others, the quarztites/shales/sandstones form hills in the western parts. Smaller parts in the west and north respectively are occupied by BHQ/BHJ and schists/gneiss kind of rocks (Fig 8.3 and Plate 8.5).

4.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories in the hard rock areas of the block. The generalized hydrogeological map of the block is presented in Plate 8.7. The Singhbhum Granites posses low to moderate yield potential varying between 3-10 lps. The metasedimentaries in the west bear potential of yielding 3-10 lps of water.

The pre-monsoon (year 2018) water levels varied between 1.0-5.0 m bgl in about 50% of the area. In the rest area, deeper water levels in the range of 5.0-10.0 m bgl were observed (Plate 8.7). During the post-monsson period, almost the entire block (except smaller patches) depicted water levels <1.0 to 5.0 m bgl, indicating good recharge from rainfall (Plate 8.8). The water levels fluctuated up to 4.0 m during the year 2018 (Plate 8.9).

4.5 Aquifer geometry and characters

The weathered regolith in the block is 5–50 m thick with the thicker zones lying in the western and eastern parts (Plate 8.10). The 20-30 and 30-40 m thick weathered zones occupy 53% and 29% of the block area respectively (Fig 8.4). The thick weathered zones form good prospect for groundwater to dug wells and shallow tube wells. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 8.5a-b.

In the block, 1-2 sets of fracture zones are encountered in bore wells with increasing incidence towards east and west within the depth of 100 m bgl (1st aquifer system) (Plate 8.11). Beyond this depth in the 2nd aquifer system, the fractures are depleted in the western parts (0-1 sets only). In the eastern parts up to 4 sets of fractures are encountered (Plate 8.12). In majr cases, the bore wells in the block yielded between 1.0-2.5 lps of water. In the south-central parts, it remained in the range of 2.5-5.0 lps (Plate 8.13).

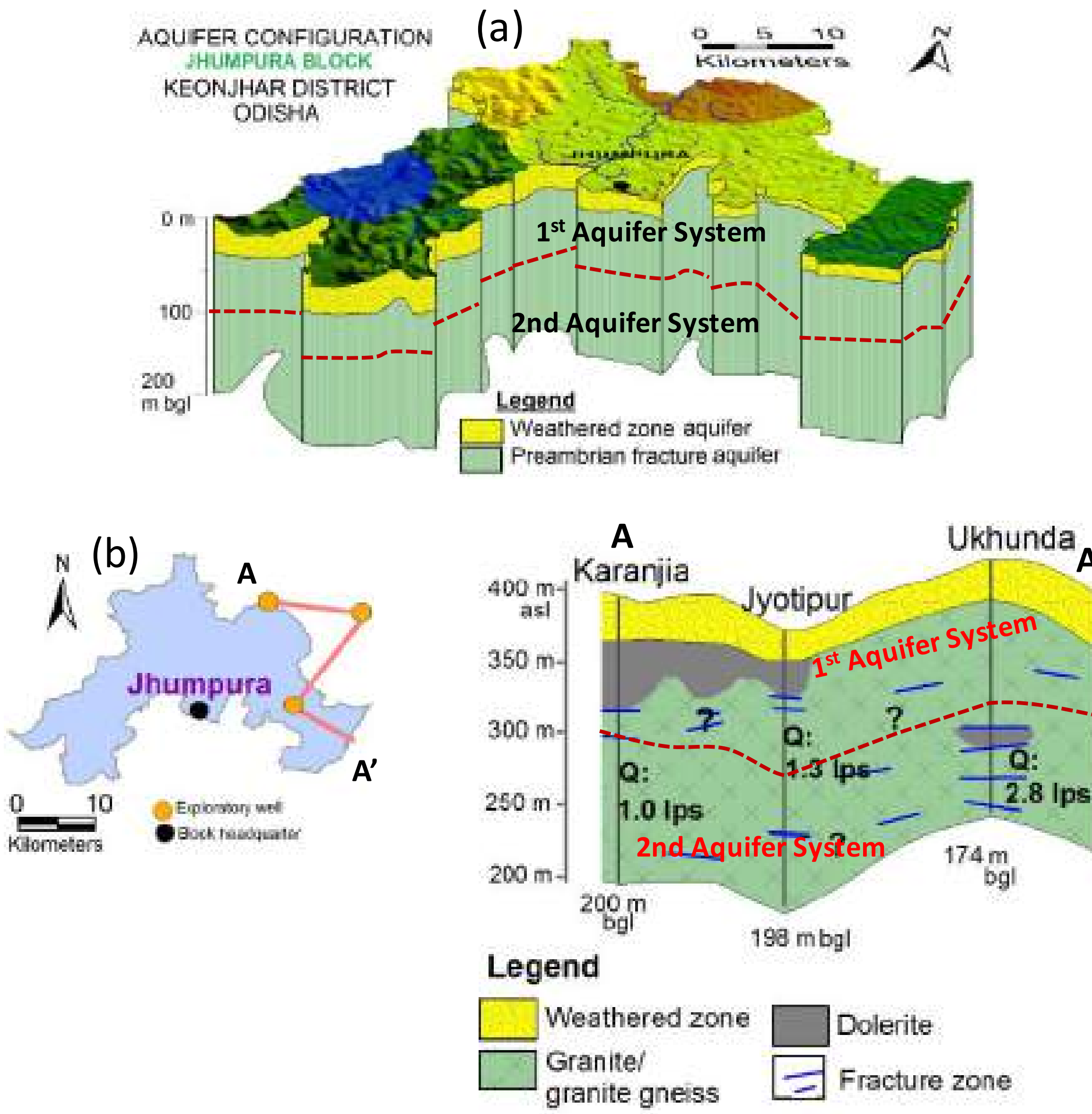


Figure 8.5: (a) 3D aquifer disposition in Jhumpura block, Keonjhar district. (b) 2D hydrogeological transect (including its location) A-A' depicting the aquifer disposition in the block.

4.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 8.14). As per this analysis, a major part of the block has been delineated as having good groundwater potential. The very good potential zones are located in the central and western parts of the block. Both these potential zones make up 66% of the total geographical area of the block (Fig 8.6).

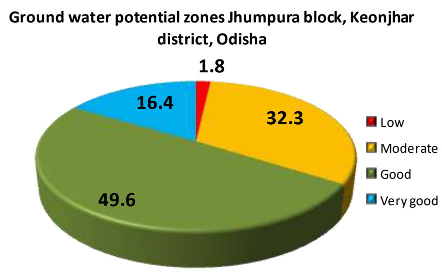


Figure 8.6: Pie diagram depicting the perentage (%) of Jhumpura block, Keonjhar district, Odisha, falling under different groundwater potential zones.

4.7 Ground water quality

Ground water in the block is alkaline in nature (Table 8.1) and pH range of 7.4-8.3. In many cases, the water is soft to moderately hard, though it is hard to very hard in some cases. The mineralization is low to moderate with TDS in the range of 44-257 mg/L (ave.: 156 mg/L). Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly Ca-HCO_3 types (Fig 8.7).

Table 8.1: Ground water quality at various locations in Jhumpura block Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L										
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Badaneuli	8	290	157	117	118	43	2	11.11	2.26	0	129	18	17.54	0.29
Baria	7.93	470	241	168	201	49	11	18.78	17.05	0	219	38	0	0.14
Manima	8.04	240	124	66	108	27	0	21.78	0.85	0	118	15	1.3	0.36
Nardapur	7.5	120	69	31	36	10	1	12.89	0.31	0	39	8	17.2	0.83
Murusuan	8.15	250	132	87	88	29	4	14.02	1.16	0	96	18	19.18	0.18
Balibandha	8.3	500	256	153	196	35	16	37.26	11.27	0	214	50	2.1	0.12
Basantpur	7.4	90	44	36	26	8	4	2	1	0	28	10	5.3	0.88
Rugudisahi	8.3	240	121	92	88	33	2	12	2.3	0	96	25	0	0.16
Unknown	8.2	130	64	56	52	14	5	3.1	1	0	56	10	3.9	0.16
Dhatika	7.8	520	253	230	221	55	22	11	3.4	0	242	43	0	0.21
Chipinda	8.2	170	87	61	52	12	7	10	1.2	0	56	20	9.3	0.13
Nahada	7.8	500	257	189	216	63	7	23.27	8.3	0	236	40	0	0.45
Badaposhi	7.82	420	228	150	123	48	7	25.04	6.95	0	149	55	11.2	0.23
Jhumpura	7.94	260	156	75	59	26	2	29.11	1.17	0	72	60	1.3	0.22
Min.:	**7.4**	**90**	**44**	**31**	**26**	**8**	**0**	**2**	**0.31**	**0**	**28**	**8**	**0**	**0.12**
Max.:	**8.3**	**520**	**257**	**230**	**221**	**63**	**22**	**37.26**	**17.05**	**0**	**242**	**60**	**19.18**	**0.88**
Average	**8.0**	**300.0**	**156**	**107.9**	**113.1**	**32.3**	**6.4**	**16.5**	**4.2**	**0.0**	**125.0**	**29.3**	**6.3**	**0.3**

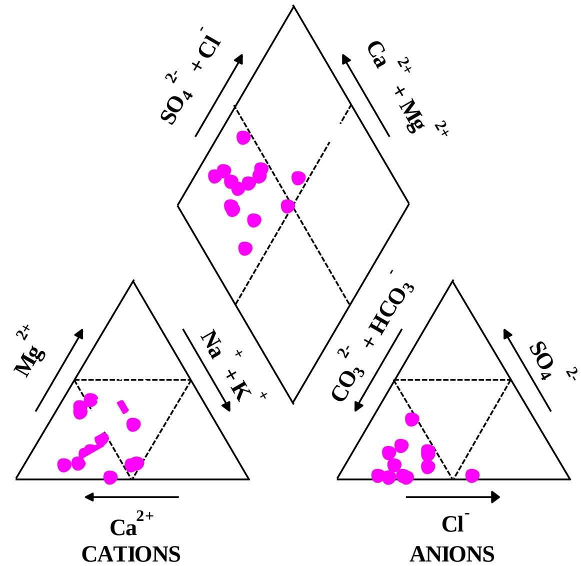


Figure 8.7: The Piper trilinear diagram depicting the groundwater quality in Jhumpura block, Keonjhar district.

4.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 8.2-8.4. The net dynamic groundwater available is 5592.4 Ham and the stage of groundwater development stands at 39.9%. Net resource available for future irrigation needs stands at 3317.9 Ham (Fig 8.8). The instorage/static groundwater resource component of 6657.3 Ham (Table 8.3) comes from the 1st aquifer system within 100 m bgl. The total groundwater available in the block stands at 12259.1 Ham.

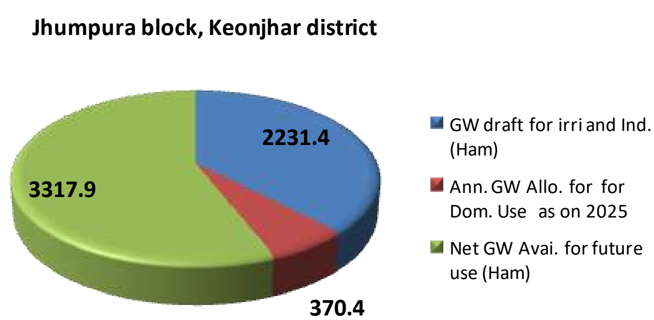


Figure 8.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Jhumpura block, Keonjhar district, Odisha.

Table 8.2: Salient information on annual dynamic groundwater resources, Jhumpura block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	5592.4
2. Irrigation draft (Ham)	1854.6
3. Industrial draft (Ham)	49.4
4. Domestic draft (Ham)	327.4
5. Total draft (Ham)	2231.4
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	370.4
7. Net groundwater available for future use (Ham)	3317.9
8. Stage of groundwater extraction (%)	39.9

Table 8.3: Total groundwater resoure available in the Jhumpura block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	5592.4
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	6657.3
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	9.4
	Block total	**12259.1**

4.9 Aquifer management plan

The existing stage of groundwater development of 45.3% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction structures as estimated in Table 8.4 (254 bore wells/dug-cum-bore wells and 2162 dug wells) are required to be constructed to develop the available additional resource of 1124 Ham. It can help in creating additional irrigation potential for 1967 Ha (Table 8.5).

Only around 26.16 km^2 area in the block showed post-monsoon depth to water levels >5.0 m bgl (Plate 8.15; Table 8.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 2.75 MCM of water (Table 8.7) can be recharged by the help additional 5- percolations ponds, 3-subsurface dykes, 3-nala/contour bunds and 5-check dams (Table 8.8) with a total cost of 1.79 crores (Table 8.9).

Table 8.4: Number of additional feasible groundwater abstraction structures in Jhumpura block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	5592.4
2	Stage of GW deve. (%)	39.9
3	Present GW draft (Ham)	2231.4
4	Ground water draft at 60% stage of deve. (Ham)	3355.4
5	Addi. water to be deve. (Ham)	1124
6	Addi. No of BW/ STW feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	254
7	Addi. No. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	2162

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 8.5: Irrigation potential likely to be created in Jhumpura block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	39.9
2	Surplus GW avai. for 60% stage of deve. (Ham)	1124
3	Irri, Pot. likely to be created for Paddy (Ha)	562
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	843
5	Irri. Pot. likely to be created for veg. (Ha)	562
6	Proj. area to be Irri. (ha)	1967

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 8.6: Areas in Jhumpura block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Jhumpura	24.19	1.97	26.16

Table 8.7: Estimation of volume of water required for artificial recharge to groundwater in Jhumpura block, Keonjhar district.

Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (mcm)	Total volume of water required to reharge (mcm)
Jhumpura	594.00	26.16	6.5	3.5	91.55	2.75

Table 8.8: Number of feasible structures in Jhumpura block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (mcm)	No of different feasible structures			
		Percolation tank (40%) @0.2 mcm	sub-surface dyke (15%) @0.15 mcm	Nala bund/contour bunding (15%) @0.15 mcm	Check dams & weirs (30%) @0.15 mcm
Jhumpura	2.75	5	3	3	5

Table 8.9: Estimation of cost of artificial recharge structures in Jhumpura block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Jhumpura	1.10	0.27	0.14	0.27	1.79

PLATE – 8.1

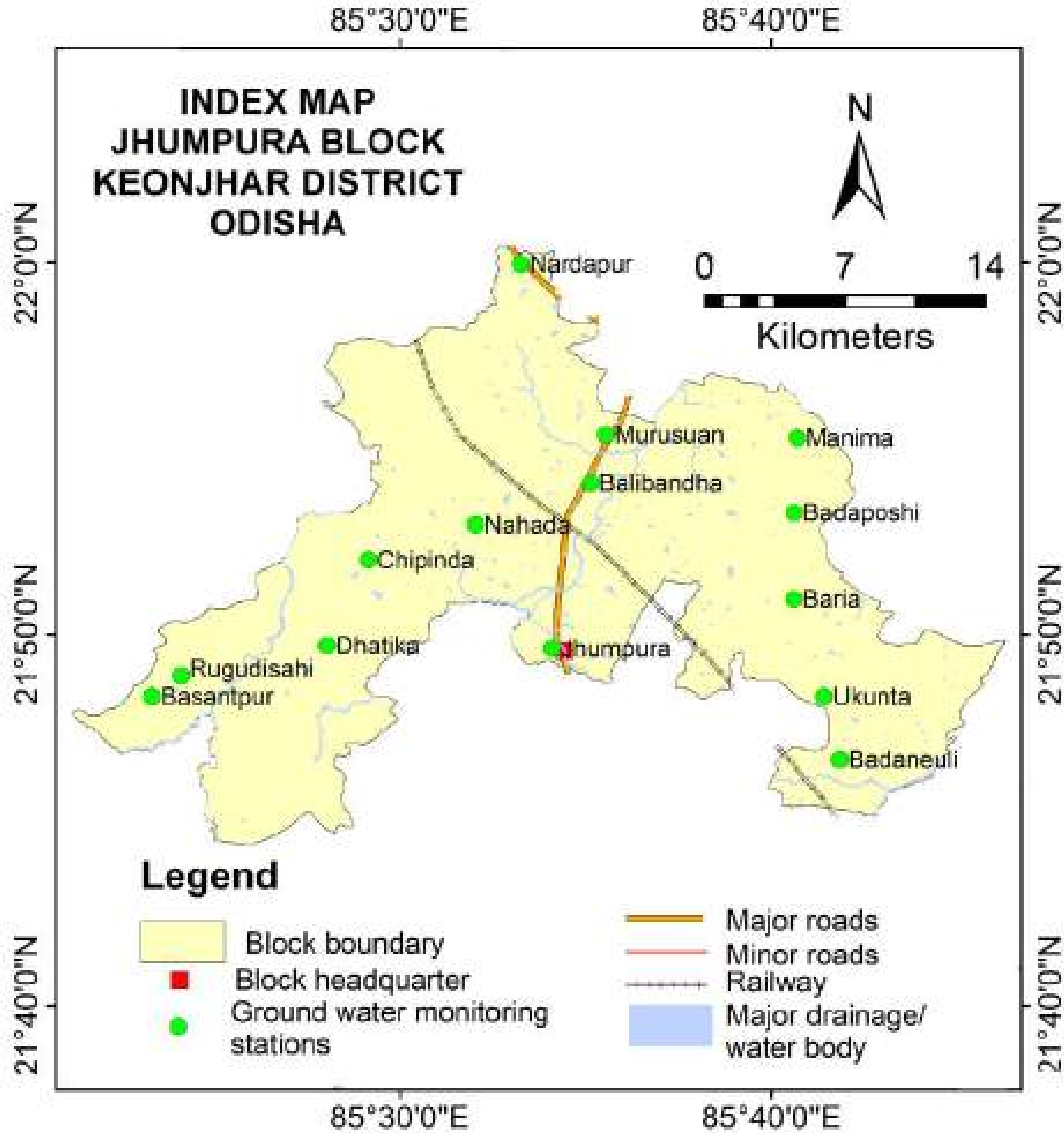

INDEX MAP
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
85°30'0"E
85°40'0"E
22°0'0"N
21°50'0"N
21°40'0"N
N
0
7
14
Kilometers
Nardapur
Murusuan
Manima
Balibandha
Badaposhi
Nahada
Chipinda
Baria
Dhatika
Jhumpura
Rugudisahi
Basantpur
Ukunta
Badaneuli
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body

PLATE – 8.2

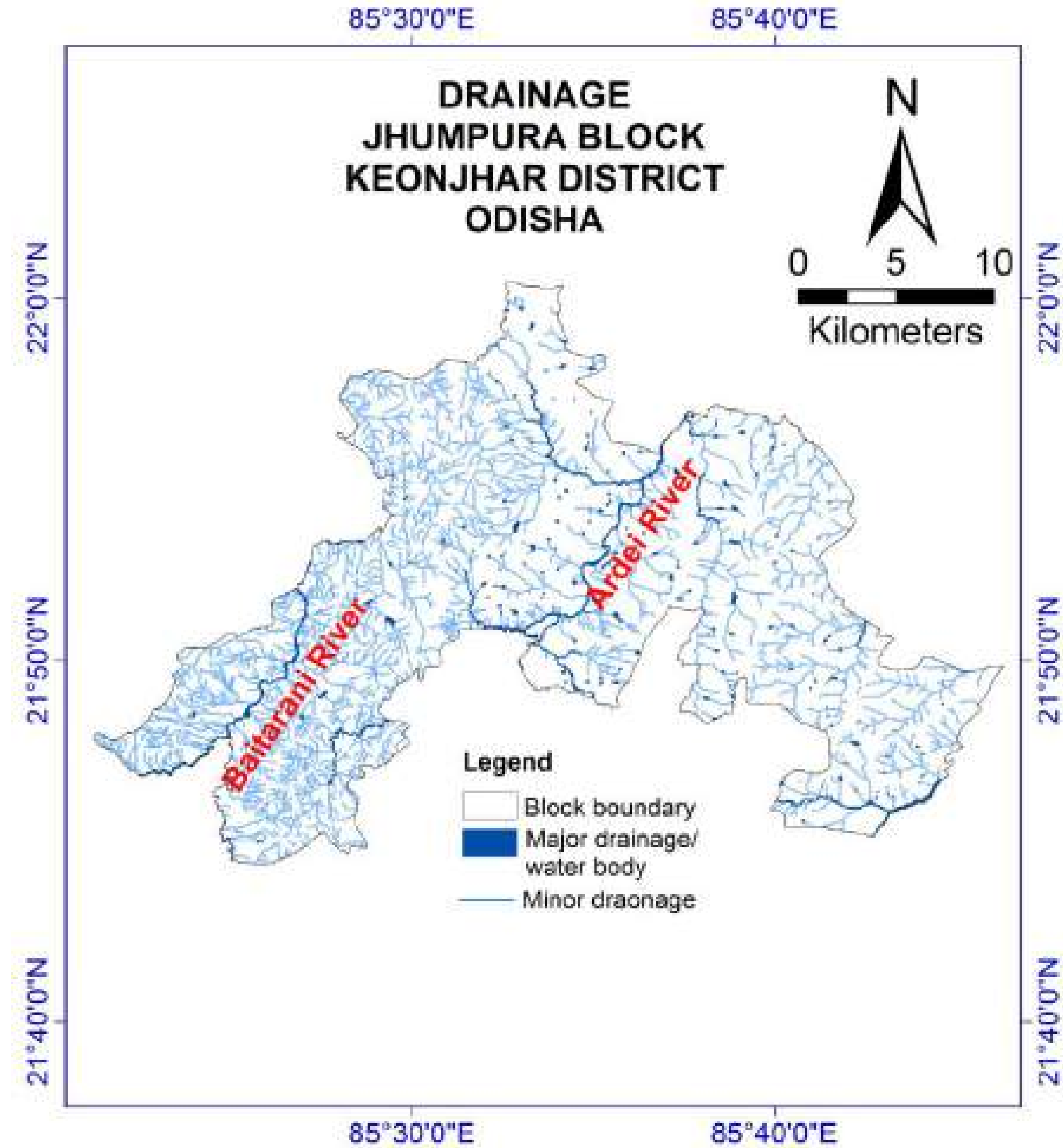

DRAINAGE
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°30'0"E
85°40'0"E
22°0'0"N
21°50'0"N
21°40'0"N
Baitarani River
Ardei River
Legend
Block boundary
Major drainage/ water body
Minor draonage

PLATE – 8.3

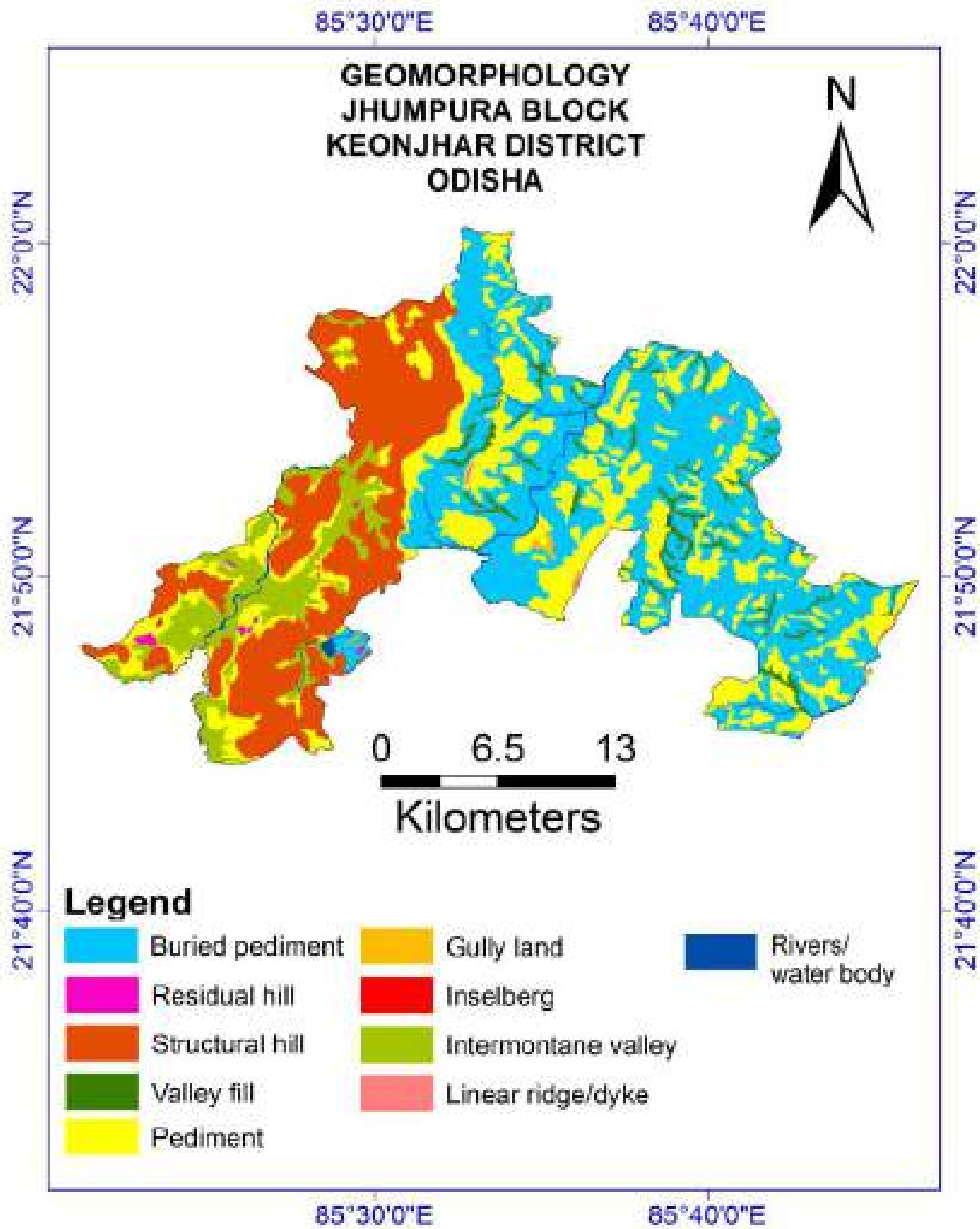

85°30'0"E
85°40'0"E
GEOMORPHOLOGY
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
22°0'0"N
21°50'0"N
21°40'0"N
0
6.5
13
Kilometers
Legend
Buried pediment
Residual hill
Structural hill
Valley fill
Pediment
Gully land
Inselberg
Intermontane valley
Linear ridge/dyke
Rivers/
water body

PLATE – 8.4

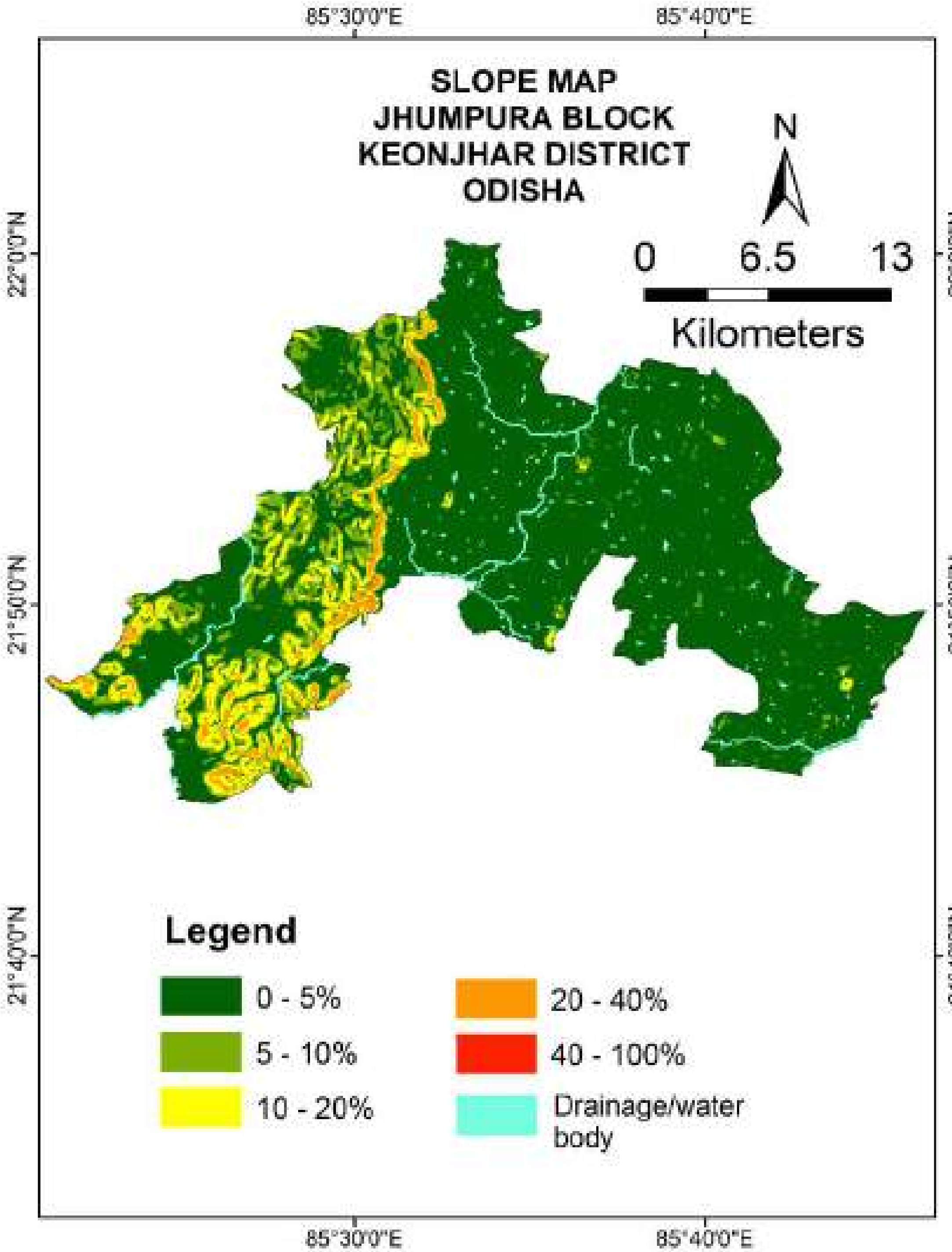

85°30'0"E
85°40'0"E
SLOPE MAP
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6.5
13
Kilometers
22°0'0"N
21°50'0"N
21°40'0"N
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 8.5

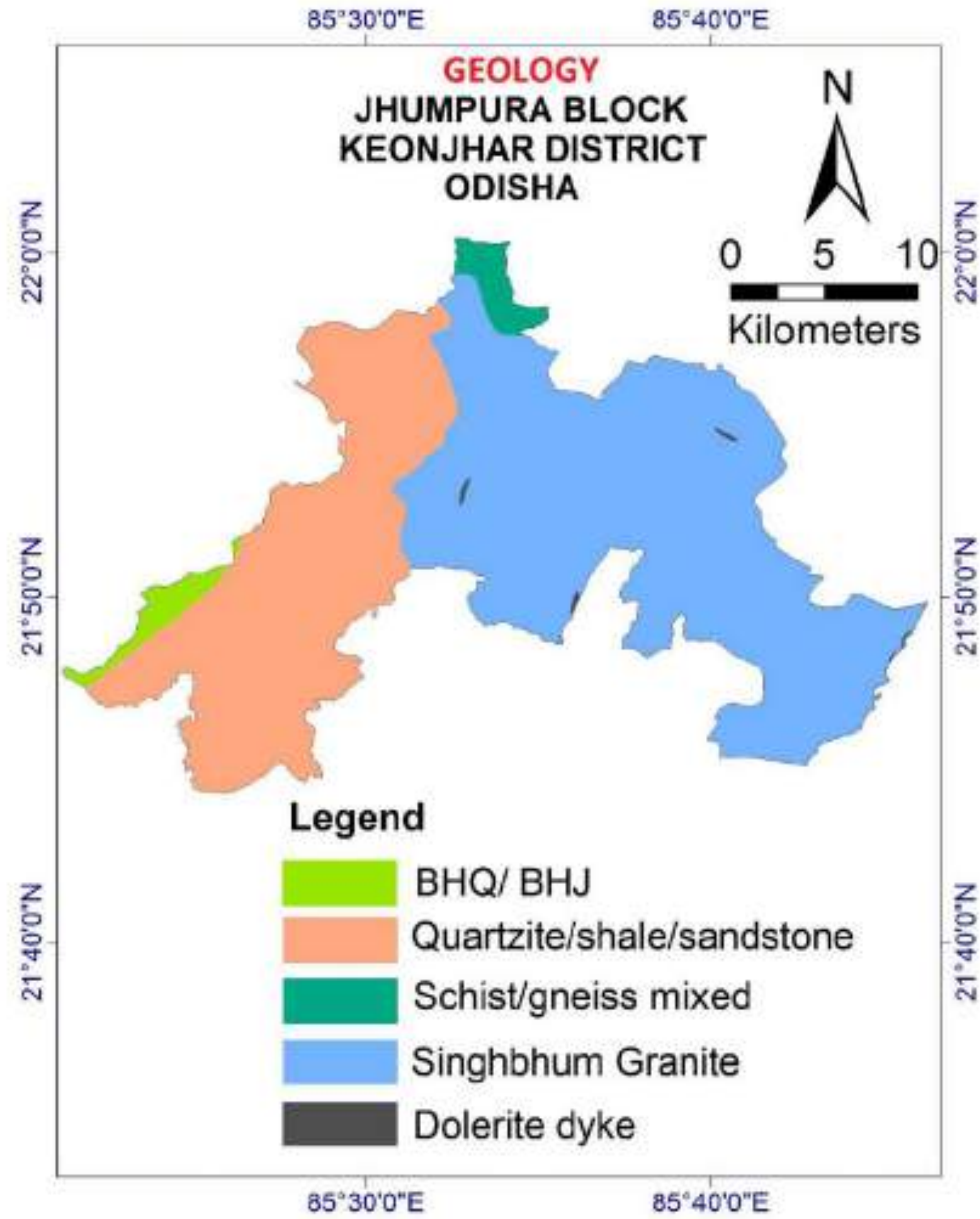

GEOLOGY
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°30'0"E
85°40'0"E
22°0'0"N
21°50'0"N
21°40'0"N
Legend
BHQ/ BHJ
Quartzite/shale/sandstone
Schist/gneiss mixed
Singhbhum Granite
Dolerite dyke

PLATE – 8.6

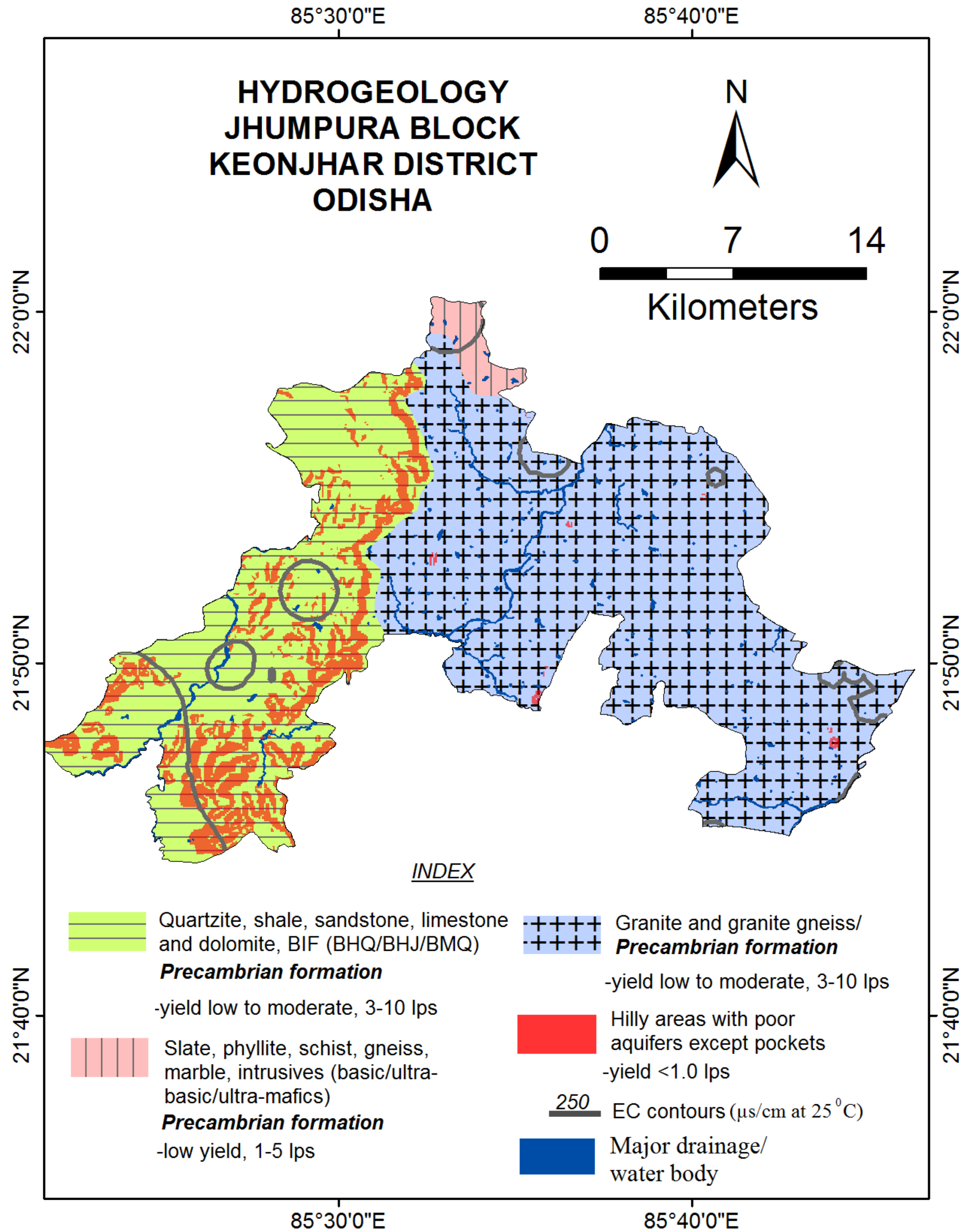

85°30'0"E
85°40'0"E
HYDROGEOLOGY
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
7
14
Kilometers
22°0'0"N
21°50'0"N
21°40'0"N
INDEX
Quartzite, shale, sandstone, limestone and dolomite, BIF (BHQ/BHJ/BMQ)
Precambrian formation
-yield low to moderate, 3-10 lps
Slate, phyllite, schist, gneiss, marble, intrusives (basic/ultra-basic/ultra-mafics)
Precambrian formation
-low yield, 1-5 lps
Granite and granite gneiss/
Precambrian formation
-yield low to moderate, 3-10 lps
Hilly areas with poor aquifers except pockets
-yield <1.0 lps
250
EC contours (µs/cm at 25 °C)
Major drainage/ water body

PLATE – 8.7

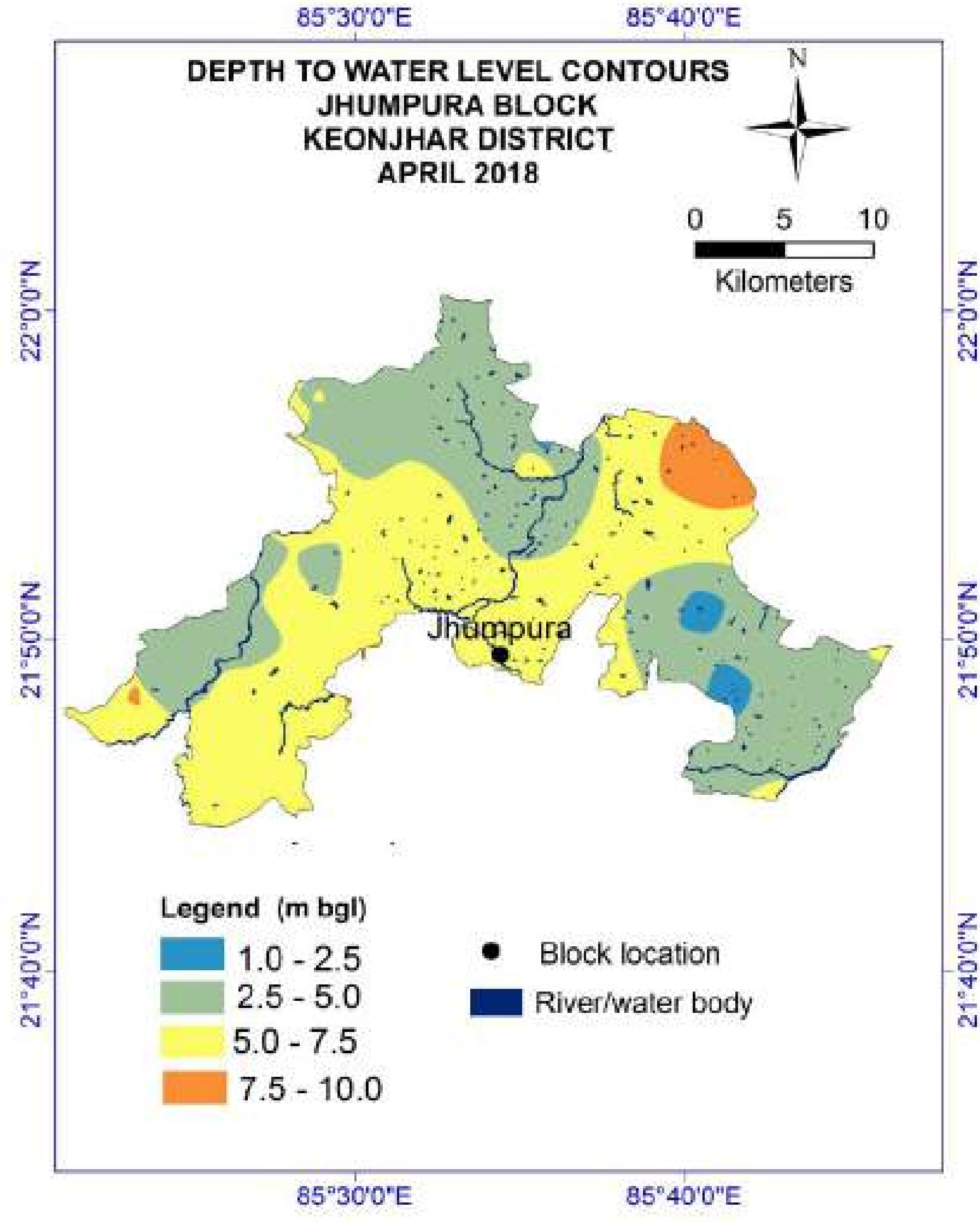
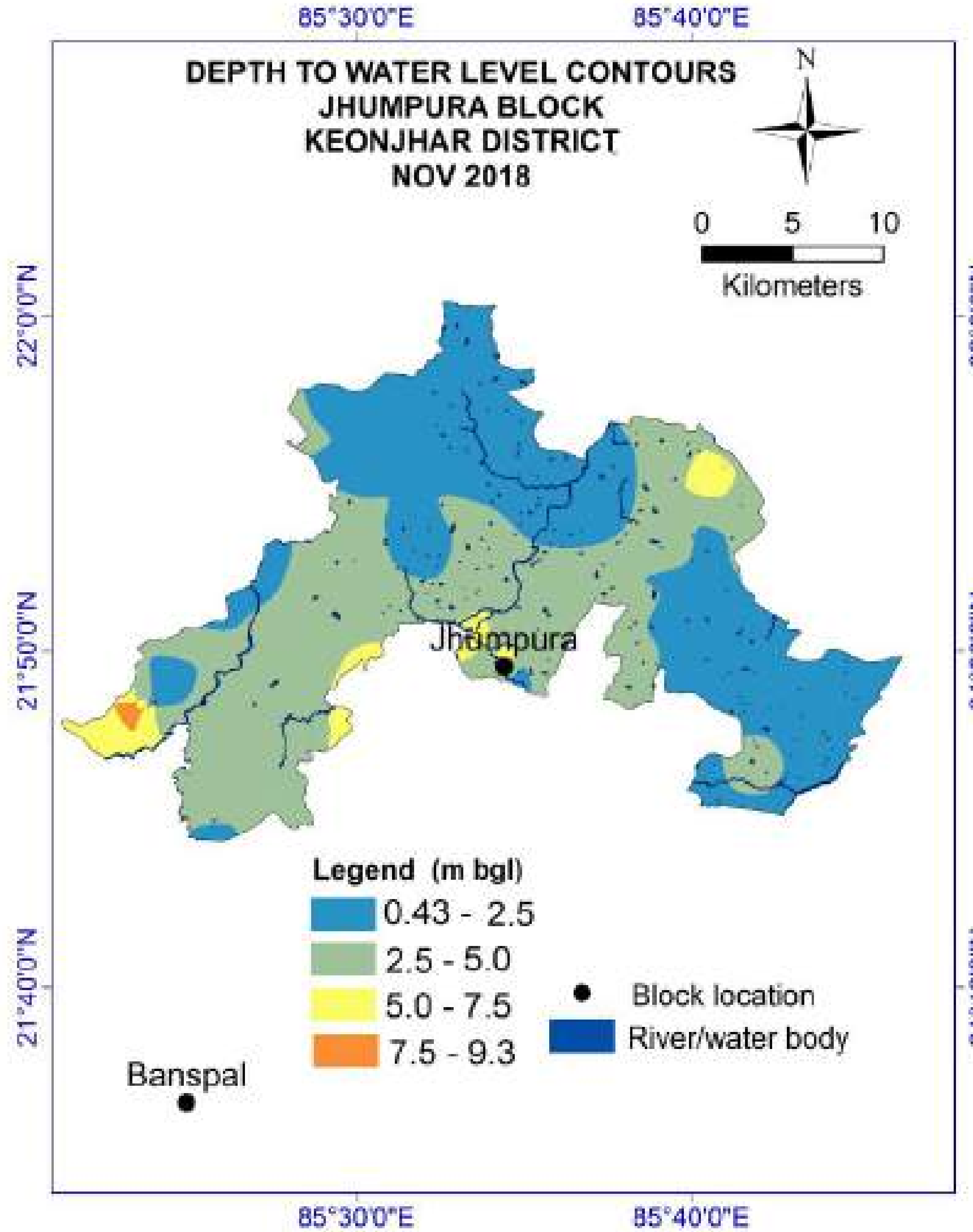

DEPTH TO WATER LEVEL CONTOURS
JHUMPURA BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0 5 10
Kilometers
85°30'0"E
85°40'0"E
22°0'0"N
21°50'0"N
21°40'0"N
Jhumpura
Legend (m bgl)
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
Block location
River/water body

PLATE – 8.8



DEPTH TO WATER LEVEL CONTOURS
JHUMPURA BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0
5
10
Kilometers
85°30'0"E
85°40'0"E
22°0'0"N
21°50'0"N
21°40'0"N
Jhumpura
Banspal
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
River/water body

PLATE – 8.9

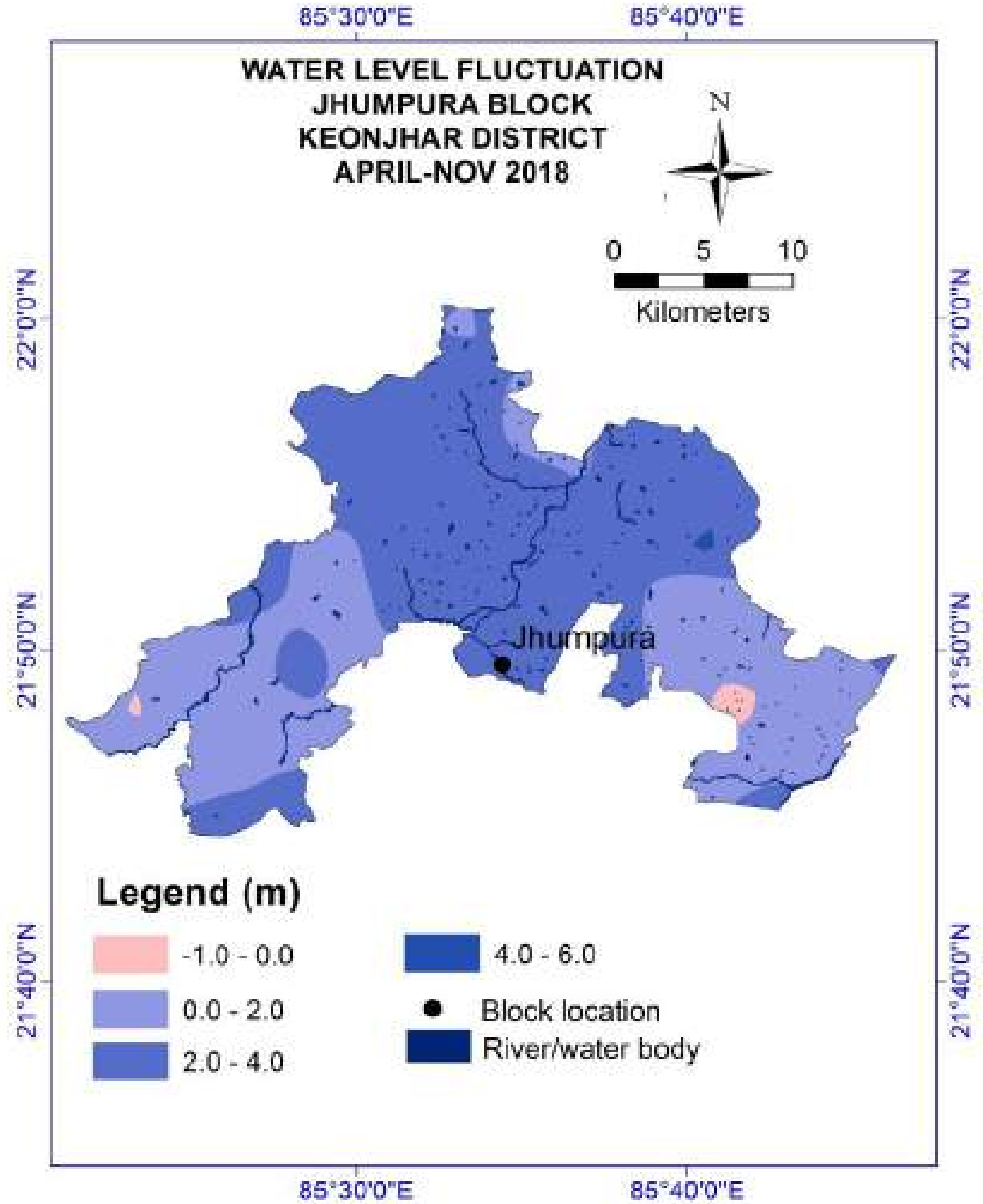

85°30'0"E
85°40'0"E
WATER LEVEL FLUCTUATION
JHUMPURA BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0 5 10
Kilometers
22°0'0"N
21°50'0"N
21°40'0"N
Jhumpura
Legend (m)
-1.0 - 0.0
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
Block location
River/water body

PLATE – 8.10

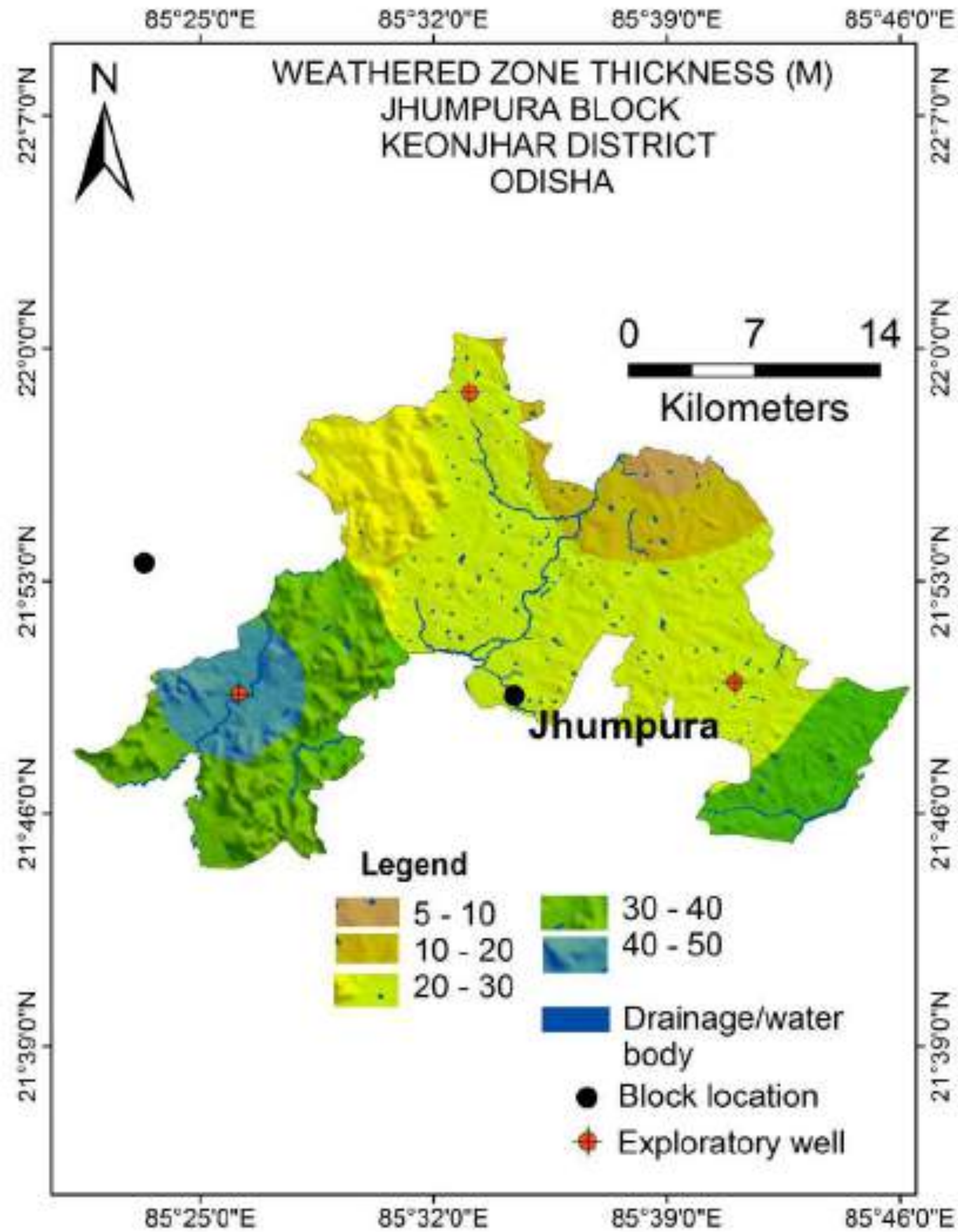

WEATHERED ZONE THICKNESS (M)
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 7 14
Kilometers
Jhumpura
Legend
5 - 10
10 - 20
20 - 30
30 - 40
40 - 50
Drainage/water body
Block location
Exploratory well
85°25'0"E
85°32'0"E
85°39'0"E
85°46'0"E
22°7'0"N
22°0'0"N
21°53'0"N
21°46'0"N
21°39'0"N

PLATE – 8.11

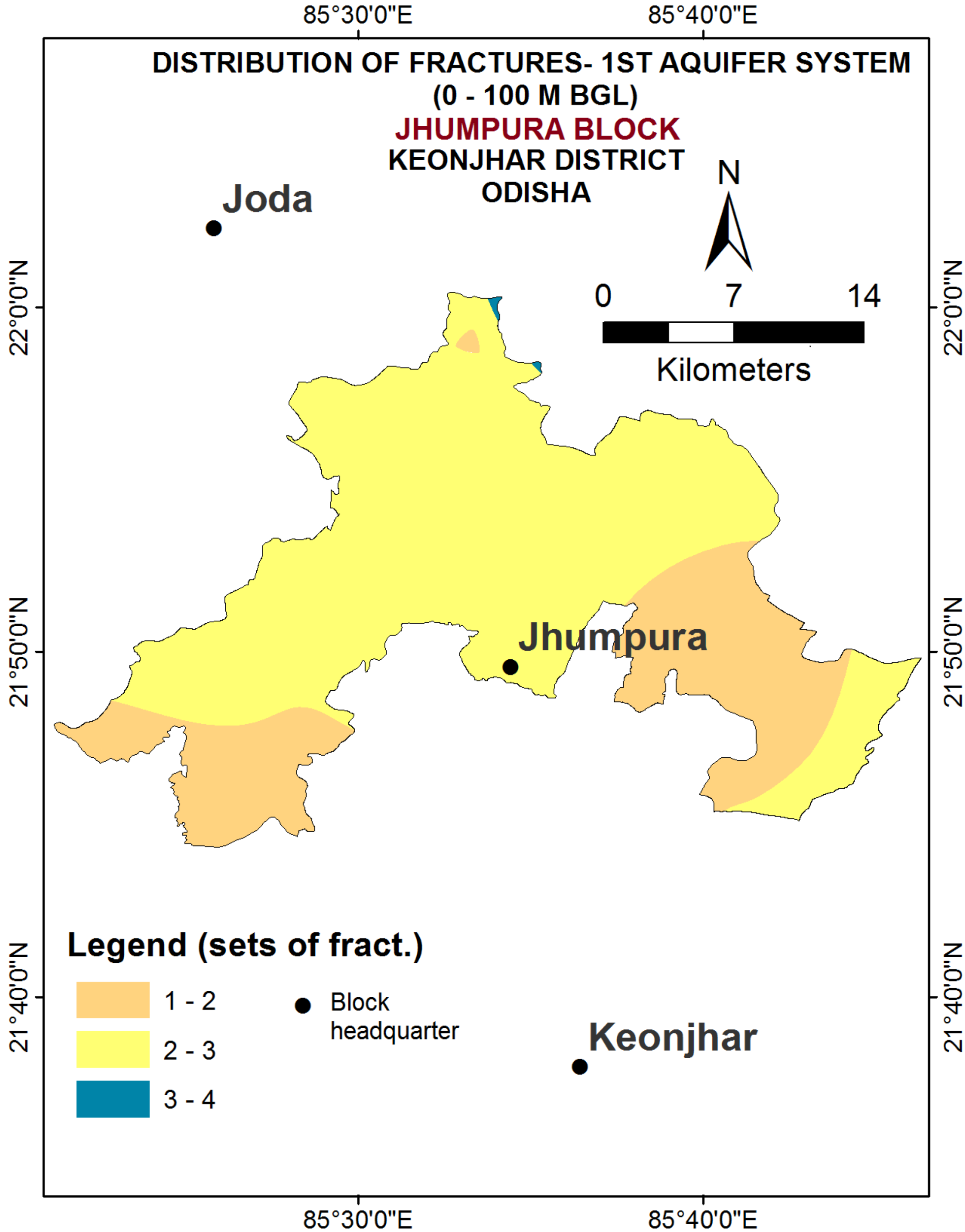

85°30'0"E
85°40'0"E
DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
7
14
Kilometers
Joda
Jhumpura
Keonjhar
22°0'0"N
21°50'0"N
21°40'0"N
Legend (sets of fract.)
1 - 2
2 - 3
3 - 4
Block headquarter

PLATE – 8.12

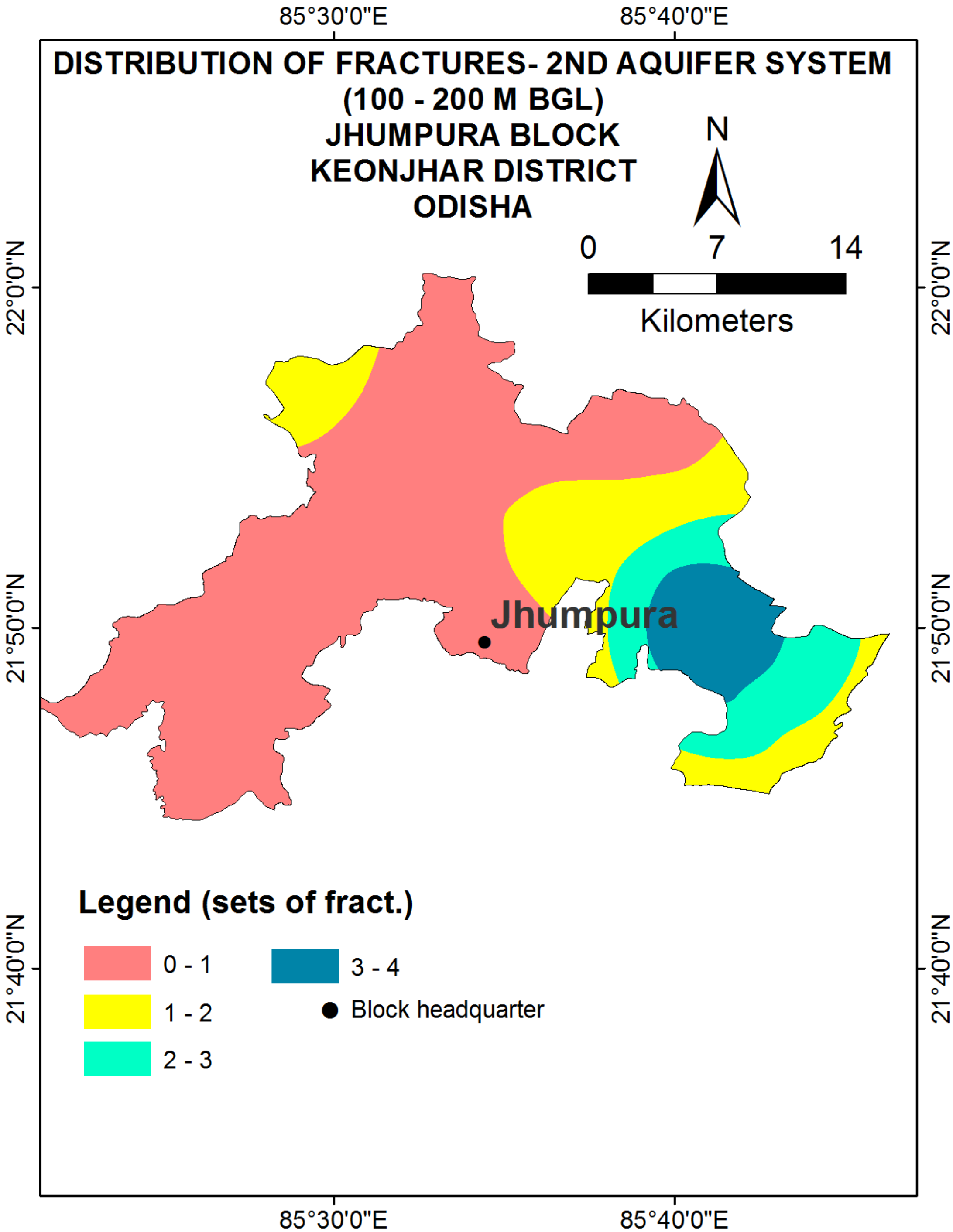

DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
7
14
Kilometers
85°30'0"E
85°40'0"E
22°0'0"N
21°50'0"N
21°40'0"N
Jhumpura
Legend (sets of fract.)
0 - 1
1 - 2
2 - 3
3 - 4
Block headquarter

PLATE – 8.13

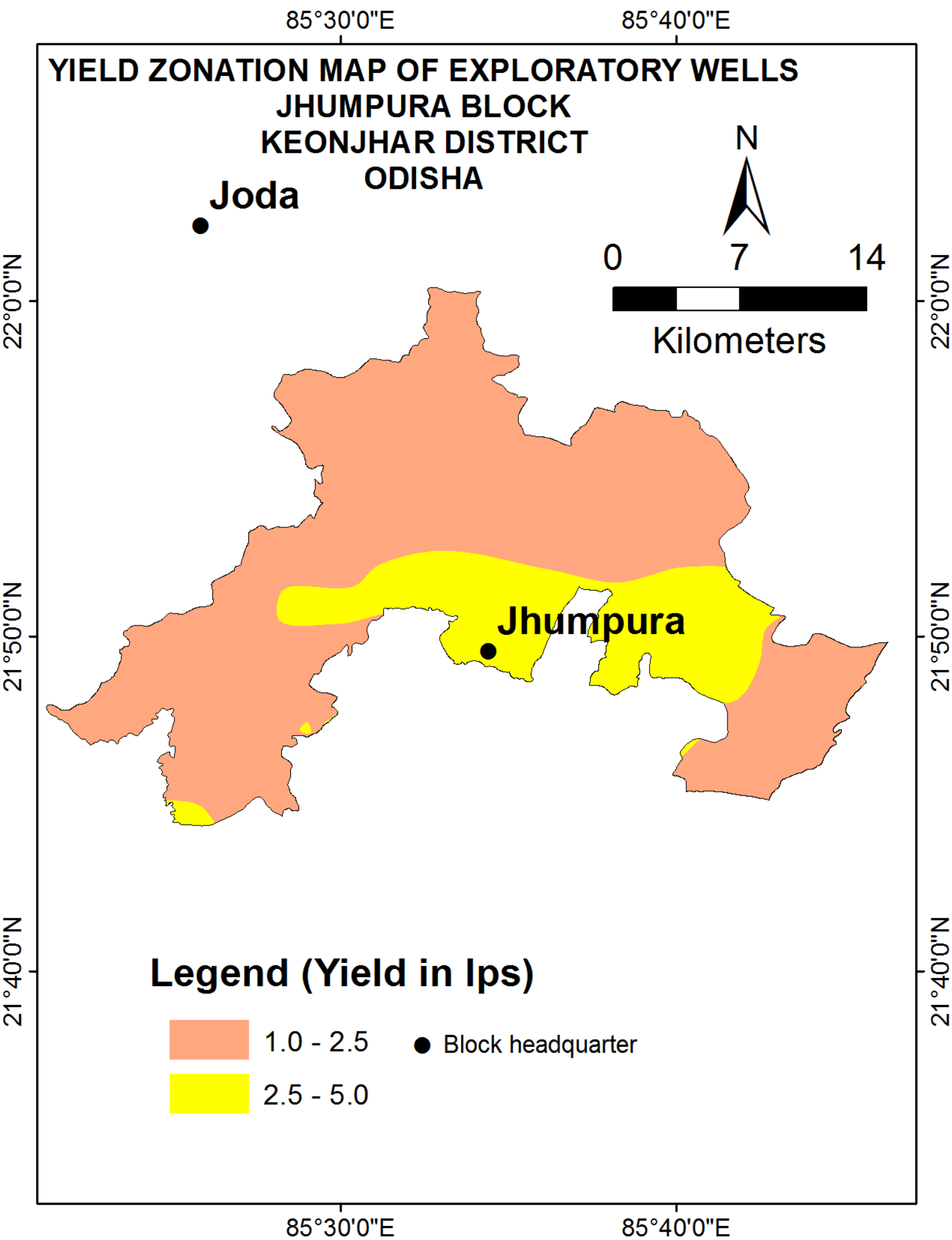

85°30'0"E
85°40'0"E
YIELD ZONATION MAP OF EXPLORATORY WELLS
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
Joda
0
7
14
Kilometers
22°0'0"N
21°50'0"N
21°40'0"N
Jhumpura
Legend (Yield in lps)
1.0 - 2.5
2.5 - 5.0
Block headquarter

PLATE – 8.14

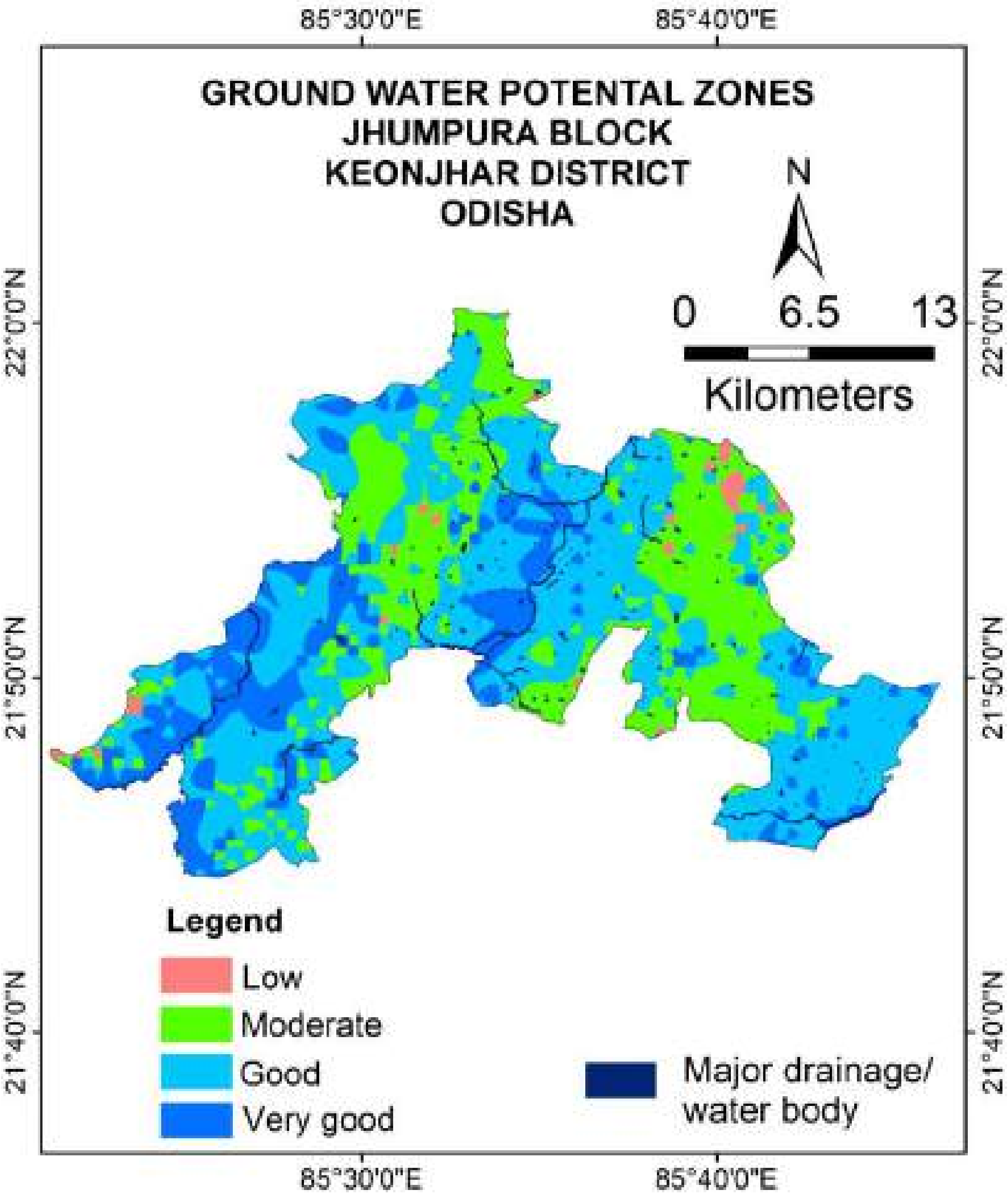
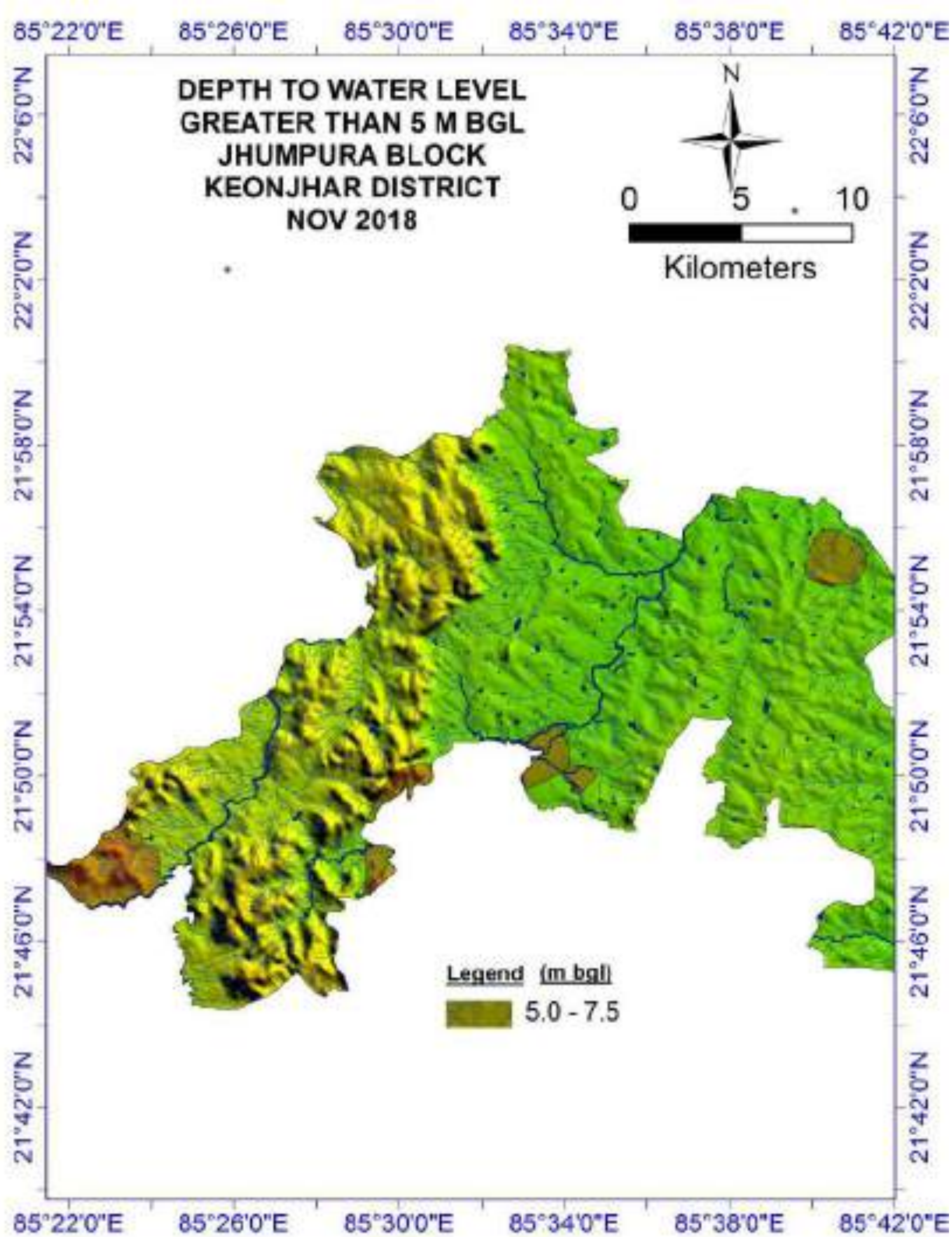

GROUND WATER POTENTAL ZONES
JHUMPURA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6.5 13
Kilometers
85°30'0"E
85°40'0"E
22°0'0"N
21°50'0"N
21°40'0"N
Legend
Low
Moderate
Good
Very good
Major drainage/ water body

PLATE – 8.15


85°22'0"E
85°26'0"E
85°30'0"E
85°34'0"E
85°38'0"E
85°42'0"E
22°6'0"N
22°2'0"N
21°58'0"N
21°54'0"N
21°50'0"N
21°46'0"N
21°42'0"N
DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
JHUMPURA BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 5 10
Kilometers
Legend (m bgl)
5.0 - 7.5

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

5.0 JODA BLOCK

5.1 Salient information

Location, area and demography

Location (Plate 9.1)	85^0 14' - 86^0 35' E longitude 21^0 47' – 22^0 10'' N latitude
Area	727 sq. km
No. of Gram Panchayats	15
No. of villages	120
Population (Census 2011)	1,25,728 Rural: 1,06,538 Urban: 9,190
Literacy	47.27%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1538.5 mm
Monsoon normal rainfall	1205.8 mm (78.4% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	19524 Ha
Net sown area (2)	14351 Ha
Area sown more than once (1-2)	5173 Ha
Cropping intensity (%)	136.1 Ha
Area under forest	14872 Ha
Area under wasteland	1718 Ha
Area under other uses	20959 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	2942 Ha *Kharif:* 1471 Ha *Rabi:* 1471 Ha

5.2 Drainage, geomorphology and soil types

The Baitarani and Karo are the two major rivers that flow in the nortrh-east direction and drain the block. The drainage pattern is dendritic to sub-trellis in nature. The water bodies are less and some of them are found in the Baitarani basin (Plate 9.2).

Major parts of the block (53% of block area) are occupied by structural hills that bear poor groundwater potential. Pediments and intermonatane valleys lie in between the hills. The north-eastern parts of the block are predominated by pediments and buried pediments. The pediments, buried pediments and intermontane valleys, considered as good for groundwater, occupy ~43% of the block area (Fig 9.1 and Plate 9.3). Though, ~30% of the block area in the hills possesses relief >10% (Plate 9.4), the intervenning areas are characterized by slope <10%, which area suitable for groundwater recharge (Fig 9.2). The soil types include red and yellow (ultisol), red sandy (alfisol) and red gravel (ultisol).

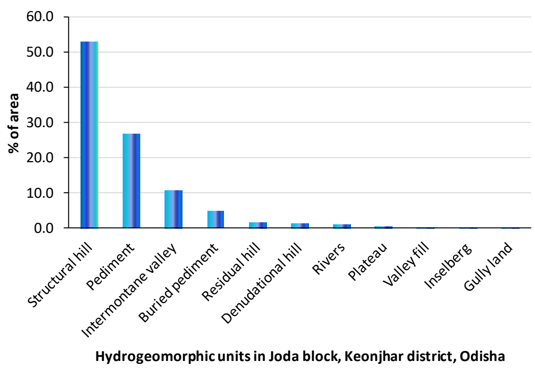


Figure 9.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Joda block.

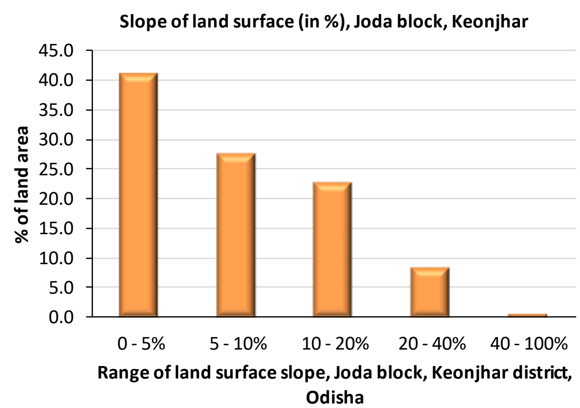


Figure 9.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Joda block, Keonjhar district.

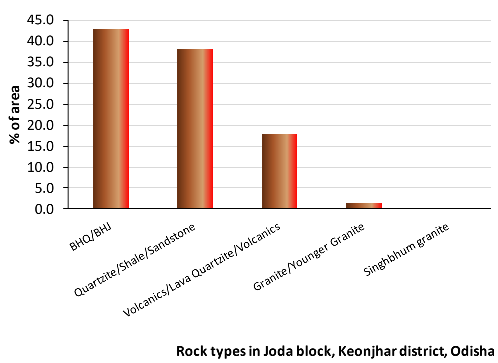


Figure 9.3: Percentage (%) of Joda block area (Keonjhar dist.) covered by various rock types.

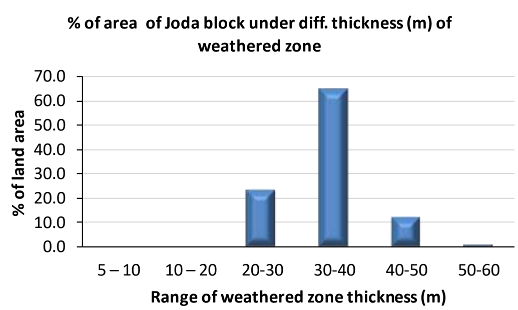


Figure 9.4: Bar diagram depicting the percentage (%) area of Joda block, Keonjhar district falling under different weathered zone thickness (m) ranges.

5.3 Geology

The Banded Iron Formations like BHQ/BHJ (forming hills) and metasediments (quartzite/shale/sandstone) occupy ~80% of the block area. The volcanics, shales and granites occupy the rest area (Fig 9.3 and Plate 9.5).

5.4 Hydrogeology

The weathered residuum in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories in the hard rock areas of the block. The generalized hydrogeological map of the block is presented in Plate 9.7. The Iron Ore series rocks including the variegated shales yield between 3-10 lps of water, whereas the volcanics suite of rocks are promising and yield between 10-15 lps of water.

Except minor patches in the east, almost the entire block depicted water levels >5.0 m bgl during the pre-monsoon of the year 2018 (Plate 9.7). The water levels remained deeper (>7.5 m bgl) in the northern parts of the block which might be reflecting mine-water dewatering (Plate 9.7). During the post-monsoon period, though a major part of the block recovered the water level to <5.0 m bgl, those remained >5.0 m bgl in the northern parts and patches in the west and south (Plate 9.8). The annual fluctuations in the water levels remained largely between 4-6 m in the block (Plate 9.9).

5.5 Aquifer geometry and characters

Except the areas with volcanics and granitic rocks where the weathered zone remains 20-30 m thick, the major part of the block (77% of the area) in the iron ore formations possesses 30-60 m thick weathered zones (Plate 9.10; Fig 9.4). The thick weathered zones form good prospect for groundwater to dug wells and shallow tube wells. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 9.5a-b.

In the block, in major cases 1-3 sets of fracture zones are encountered in bore wells which increase up to 4 sets in the northern parts within the depth of 100 m bgl (1st aquifer system) (Plate 9.11). Beyond this depth in the 2nd aquifer system, 1-2 sets of fractures are observed in the areas occupied by volcanics rocks in the east, whereas in rest of the block 0-1 sets of fractures have been encountered (Plate 9.12). The bore wells both in the volcanics and the BIF formations registered yield between 1-5 lps (Plate 9.13).

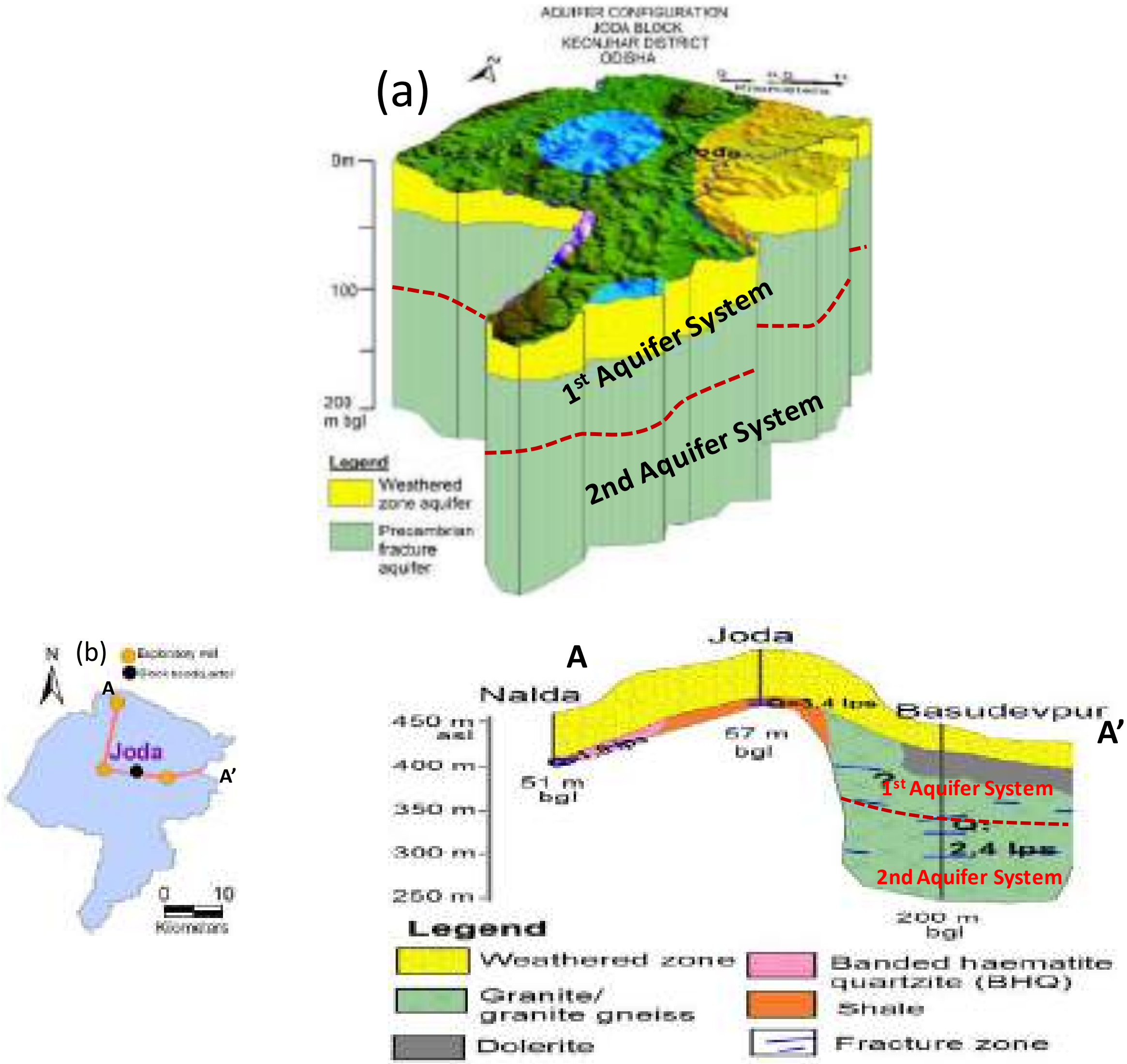


Figure 9.5: (a) 3D aquifer disposition in Joda block, Keonjhar district. (b) 2D hydrogeological transect (including its location) A-A' depicting the aquifer disposition in the block.

5.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 9.14). As per this analysis, 64% of the block area has been delineated as good to very good groundwater potential zones (Fig 9.6). Such areas fall both in the volcanics and BIF rocks.

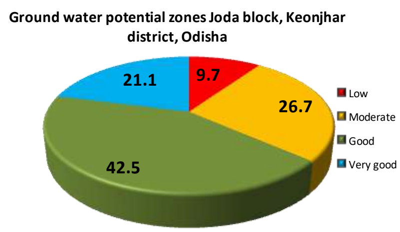


Figure 9.6: Pie diagram depicting the perentage (%) of Joda block, Keonjhar district, Odisha, falling under different groundwater potential zones.

5.7 Ground water quality

Ground water in the block is alkaline in nature (Table 9.1) and pH range of 7.5-8.3. The water is moderately hard to hard. The mineralization is low to moderate with TDS in the range of 66-257 mg/L (ave.: 146 mg/L). Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly Ca-HCO_3 types with Ca^{2+} and HCO_3^- as the principal ions contributing to the groundwater quality (Fig 9.7).

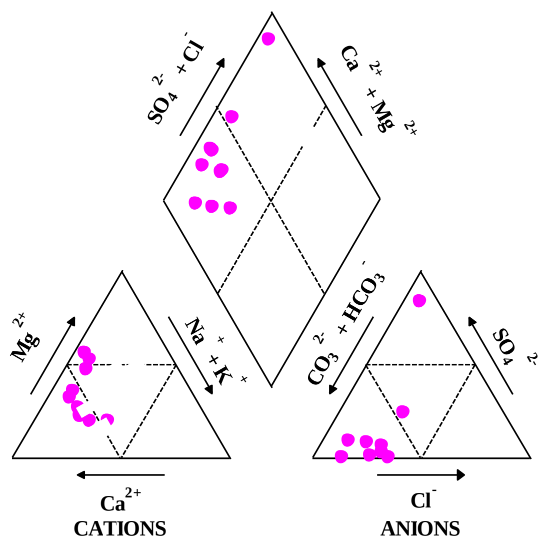


Figure 9.7: The Piper trilinear diagram depicting the groundwater quality in Joda block, Keonjhar district.

Table 9.1: Ground water quality at various locations in Joda block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Kandra	8.25	430	215	138	160	39	10	33.36	1.04	0	174	30	16.1	0.28
Bamebari	8	280	134	112	129	31	9	10	1.8	0	141	13	0	0.16
Nayagarh	8.1	470	257	173	237	51	11	25.31	3.5	0	223	20	19.06	0.49
Bhadrasahi1	8.3	230	115	87	82	25	6	8.5	3.5	0	90	28	0	0.18
Nalda Barbil	7.5	160	76	71	57	12	10	3	1	0	62	20	0	0.13
Soyabali	7.6	110	66	51	5	8	7	1	0.8	0	6	3	43.1	0.18
Bhadrasahi	8.1	215	129	115	93	30	10	5.1	1.77	0	114	24	1.3	0.21
Guali	7.95	180	116	90	74	26	6	8.5	3.09	0	90	24	3.2	0.26
Joda	7.88	265	147	125	64	24	16	5.4	2.96	0	78	29	31	0.21
Rugudi	7.92	360	200	165	127	40	16	3.8	9.84	0	155	41	12.2	0.27
Min.:	**7.5**	**110**	**66**	**51**	**5**	**8**	**6**	**1**	**0.8**	**0**	**6**	**3**	**0**	**0.13**
Max.:	**8.3**	**470**	**257**	**173**	**237**	**51**	**16**	**33.36**	**9.84**	**0**	**223**	**41**	**43.1**	**0.49**
Average	**8.0**	**270.0**	**146**	**113**	**102.8**	**28.6**	**10.1**	**10.4**	**2.9**	**0.0**	**113.3**	**23.2**	**12.6**	**0.2**

5.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 9.2-9.4. The net dynamic groundwater available is 3936.1 Ham and the stage of groundwater development stands at 68.3%. Net resource available for future irrigation needs stands at 1038.5 Ham (Fig 9.8). The instorage/static groundwater resource component of 4961.2 Ham (Table 9.3) comes from the 1st aquifer system within 100 m bgl. The total groundwater available in the block stands at 8908 Ham.

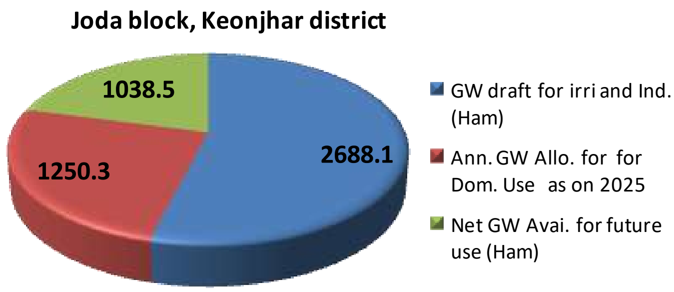


Figure 9.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Joda block, Keonjhar district, Odisha.

Table 9.2: Salient information on annual dynamic groundwater resources, Joda block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	3936.1
2. Irrigation draft (Ham)	1565.7
3. Industrial draft (Ham)	81.6
4. Domestic draft (Ham)	1040.8
5. Total draft (Ham)	2688.1
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	1250.3
7. Net groundwater available for future use (Ham)	1038.5
8. Stage of groundwater extraction (%)	68.3

Table 9.3: Total groundwater resoure available in the Joda block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	3936.1
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	4961.2
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	10.6
	Block total	**8908.0**

5.9 Aquifer management plan

The groundwater development in the block has already reached 68.3% of the annual replenishable resource. Thus, there is little scope left for any further development of the reource. Based on the existing resource potential no additional groundwater abstraction structures are feasible in the block (Table 9.4). Once the stage of development exceeds 70%, the block may come under "Semi-critical" category. Additional irrigation potential can only be created only if the resource base is augmented by means of artificial recharge to groundwater (Table 9.5).

About 246.73 km^2 area in the block (~34% of total area) showed post-monsoon depth to water levels >5.0 m bgl (Plate 9.15; Table 9.6). Artificial recharge to groundwater is urgently required, which should be taken up in the critical areas in order to restore the water level and augment the groundwater resources. A total of 29.61 MCM of water (Table 9.7) can be recharged by the help additional 59- percolations ponds, 30-subsurface dykes, 30-nala/contour bunds and 59-check dams (Table 9.8) with a total cost of 19.25 crores (Table 9.9).

Table 9.4: Number of additional feasible groundwater abstraction structures in Joda block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	3936.1
2	Stage of GW deve. (%)	68.3
3	Present GW draft (Ham)	2688.1
4	Ground water draft at 60% stage of deve. (Ham)	2361.7
5	Addi. water to be deve. (Ham)	*nil*
6	Addi. no of BW/ dug-cum-bore wlls feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	*nil*
7	Addi. no. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	*nil*

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 9.5: Irrigation potential likely to be created in Joda block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	68.3
2	Surplus GW avai. for 60% stage of deve. (Ham)	*nil*
3	Irri, Pot. likely to be created for Paddy (Ha)	*nil*
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	*nil*
5	Irri. Pot. likely to be created for veg. (Ha)	*nil*
6	Proj. area to be Irri. (ha)	*nil*

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 9.6: Areas in Joda block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Joda	232.02	14.71	246.73

Table 9.7: Estimation of volume of water required for artificial recharge to groundwater in Joda block, Keonjhar district.

Name of block	Total area of the block (km^2)	Area identified for artificial recharge (km^2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aqui. Vol. to raise water level to 3 m bgl (MCM)	Tot. vol. of water req. to recharge (MCM)
Joda	727.00	246.73	7	4	986.94	29.61

Table 9.8: Number of feasible structures in Joda block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (MCM)	No of different feasible structures			
		Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
Joda	29.61	59	30	30	59

Table 9.9: Estimation of cost of artificial recharge structures in Joda block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Joda	11.84	2.96	1.48	2.96	19.25

PLATE – 9.1

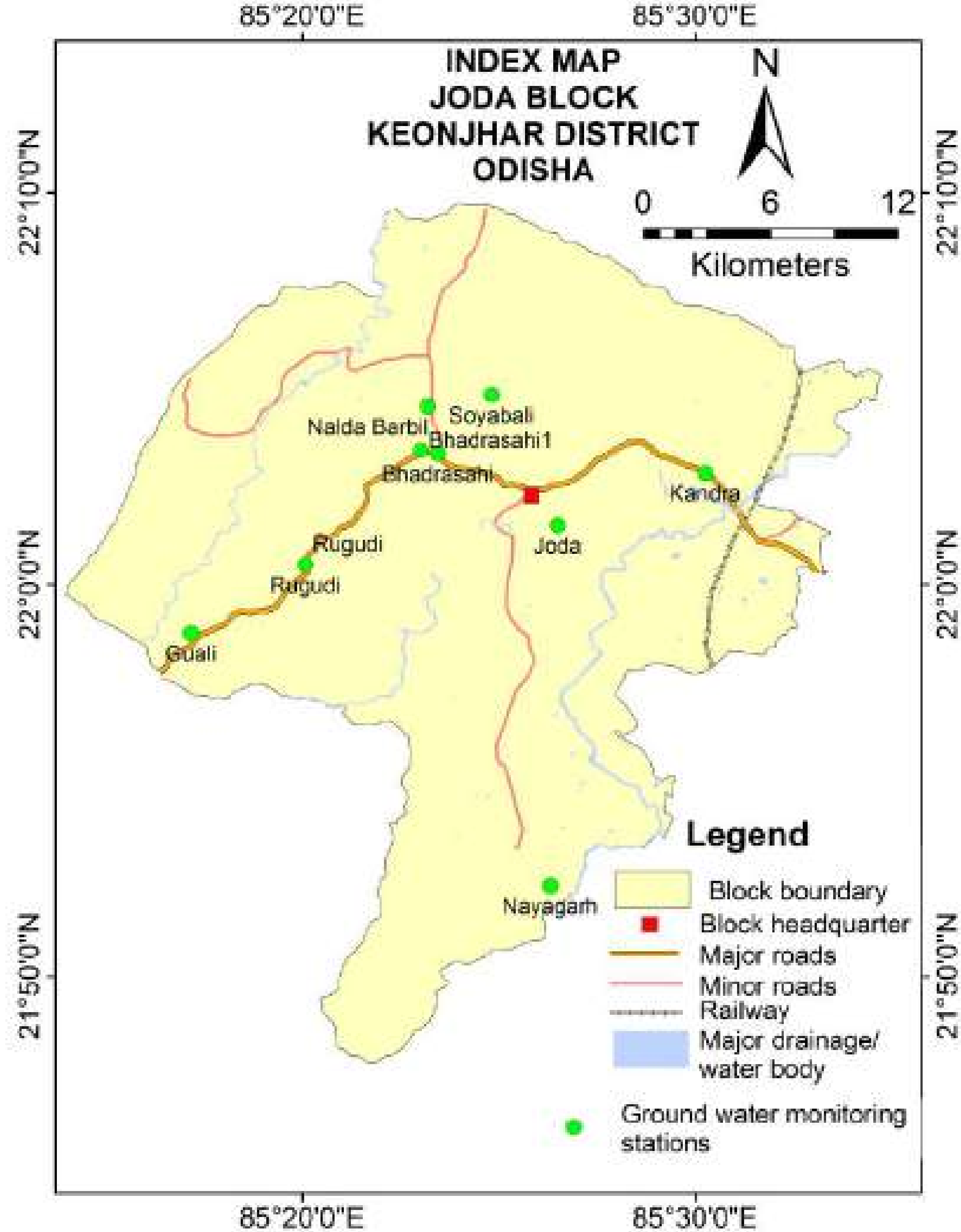

INDEX MAP
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
85°20'0"E
85°30'0"E
22°10'0"N
22°0'0"N
21°50'0"N
Soyabali
Nalda Barbil
Bhadrasahi1
Bhadrasahi
Kandra
Joda
Rugudi
Rugudi
Guali
Nayagarh
Legend
Block boundary
Block headquarter
Major roads
Minor roads
Railway
Major drainage/ water body
Ground water monitoring stations

PLATE – 9.2

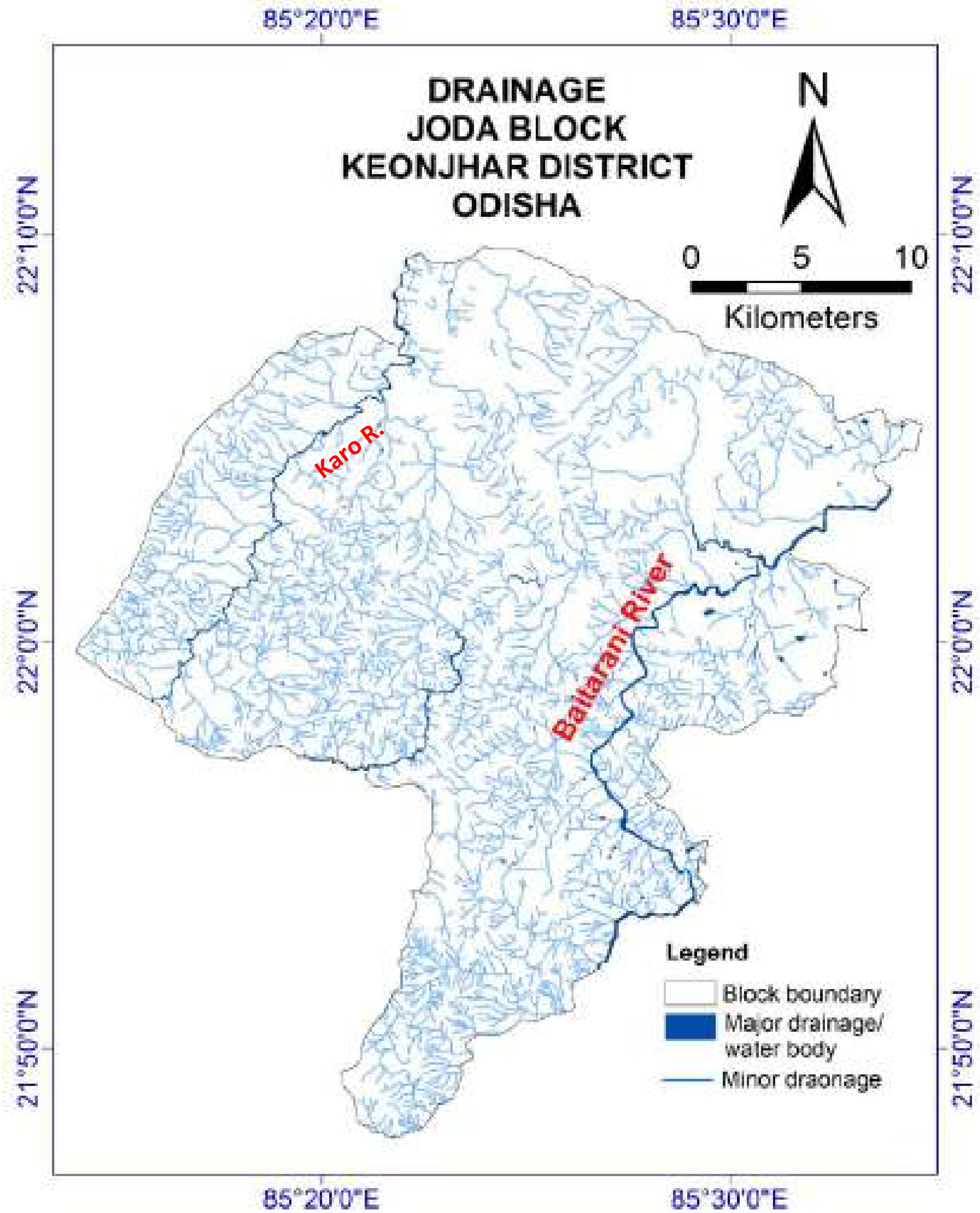

85°20'0"E
85°30'0"E
DRAINAGE
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5
10
Kilometers
22°10'0"N
22°0'0"N
21°50'0"N
Karo R.
Baitarani River
Legend
Block boundary
Major drainage/ water body
Minor draonage

PLATE – 9.3

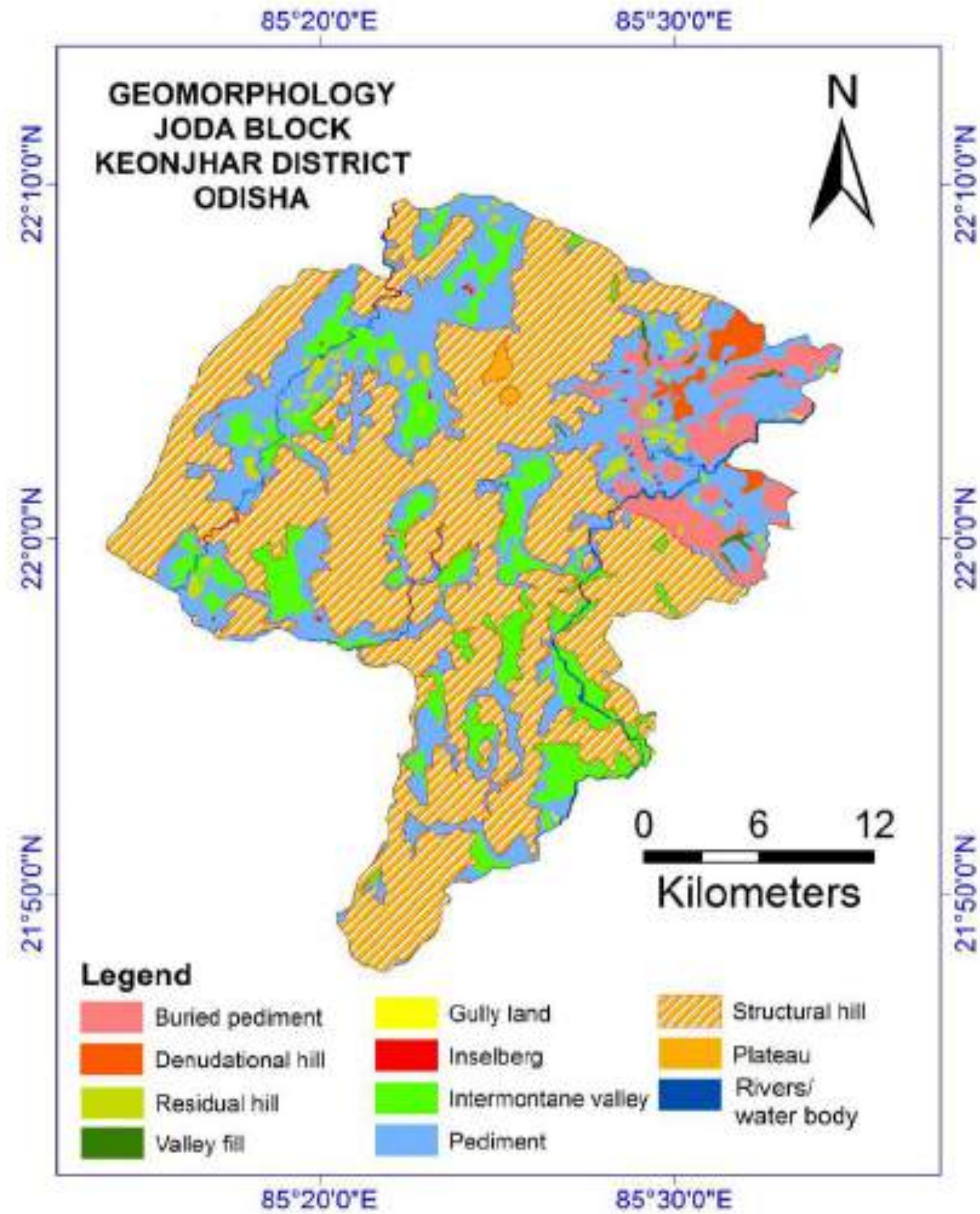

GEOMORPHOLOGY
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
85°20'0"E
85°30'0"E
22°10'0"N
22°0'0"N
21°50'0"N
0
6
12
Kilometers
Legend
Buried pediment
Denudational hill
Residual hill
Valley fill
Gully land
Inselberg
Intermontane valley
Pediment
Structural hill
Plateau
Rivers/
water body

PLATE – 9.4

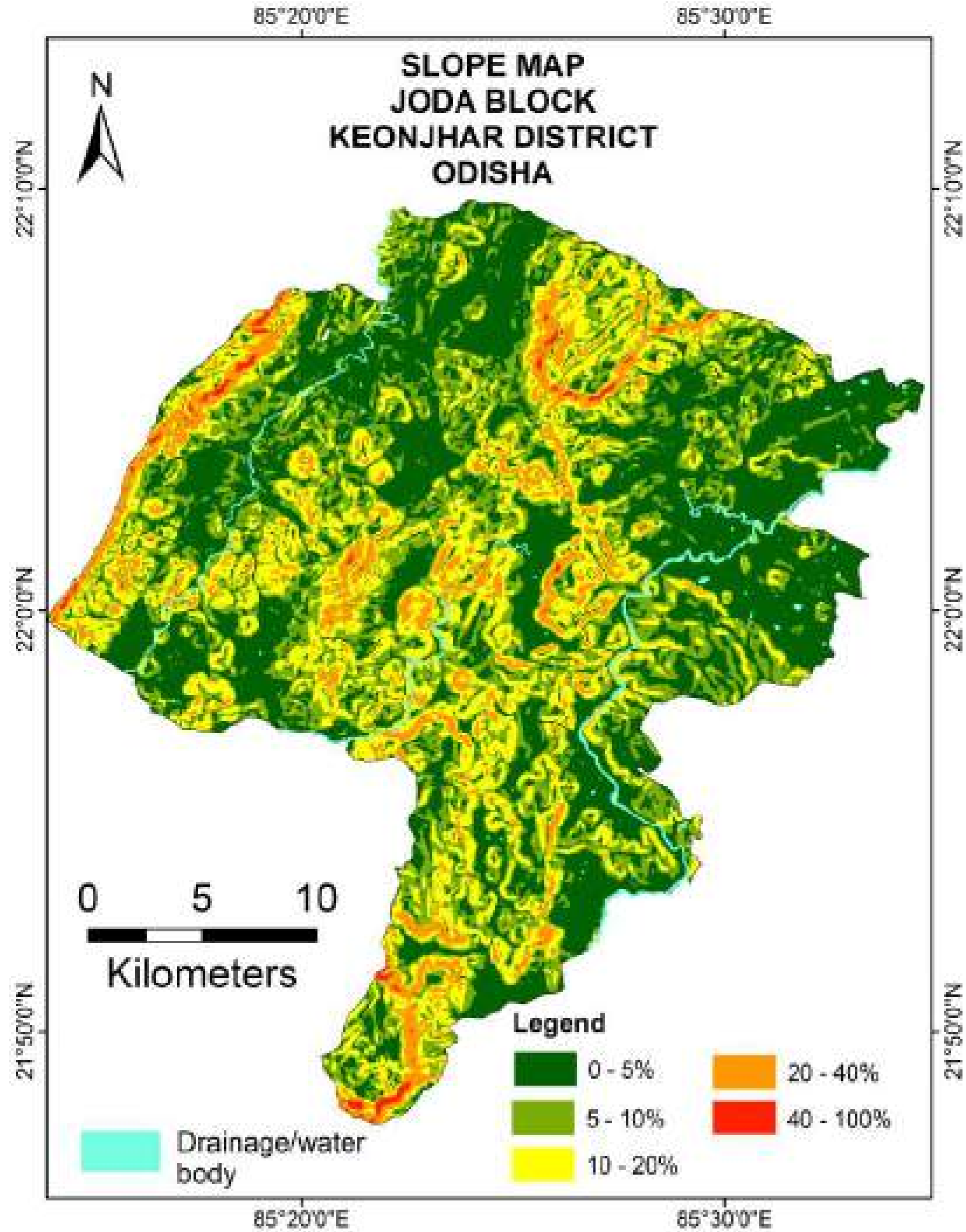

SLOPE MAP
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
85°20'0"E
85°30'0"E
22°10'0"N
22°0'0"N
21°50'0"N
0 5 10
Kilometers
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 9.5

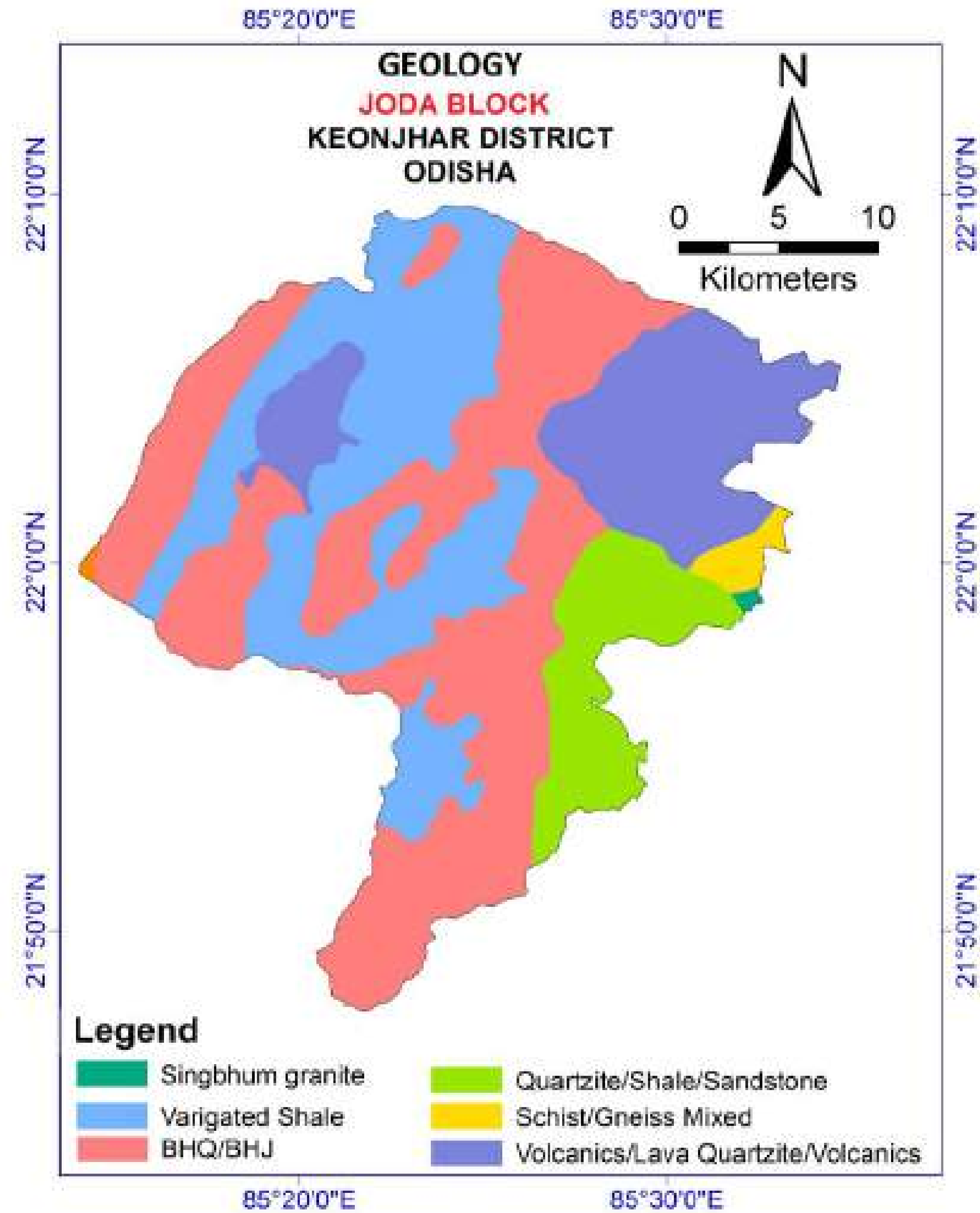

85°20'0"E
85°30'0"E
GEOLOGY
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
22°10'0"N
22°0'0"N
21°50'0"N
Legend
Singbhum granite
Varigated Shale
BHQ/BHJ
Quartzite/Shale/Sandstone
Schist/Gneiss Mixed
Volcanics/Lava Quartzite/Volcanics

PLATE – 9.6

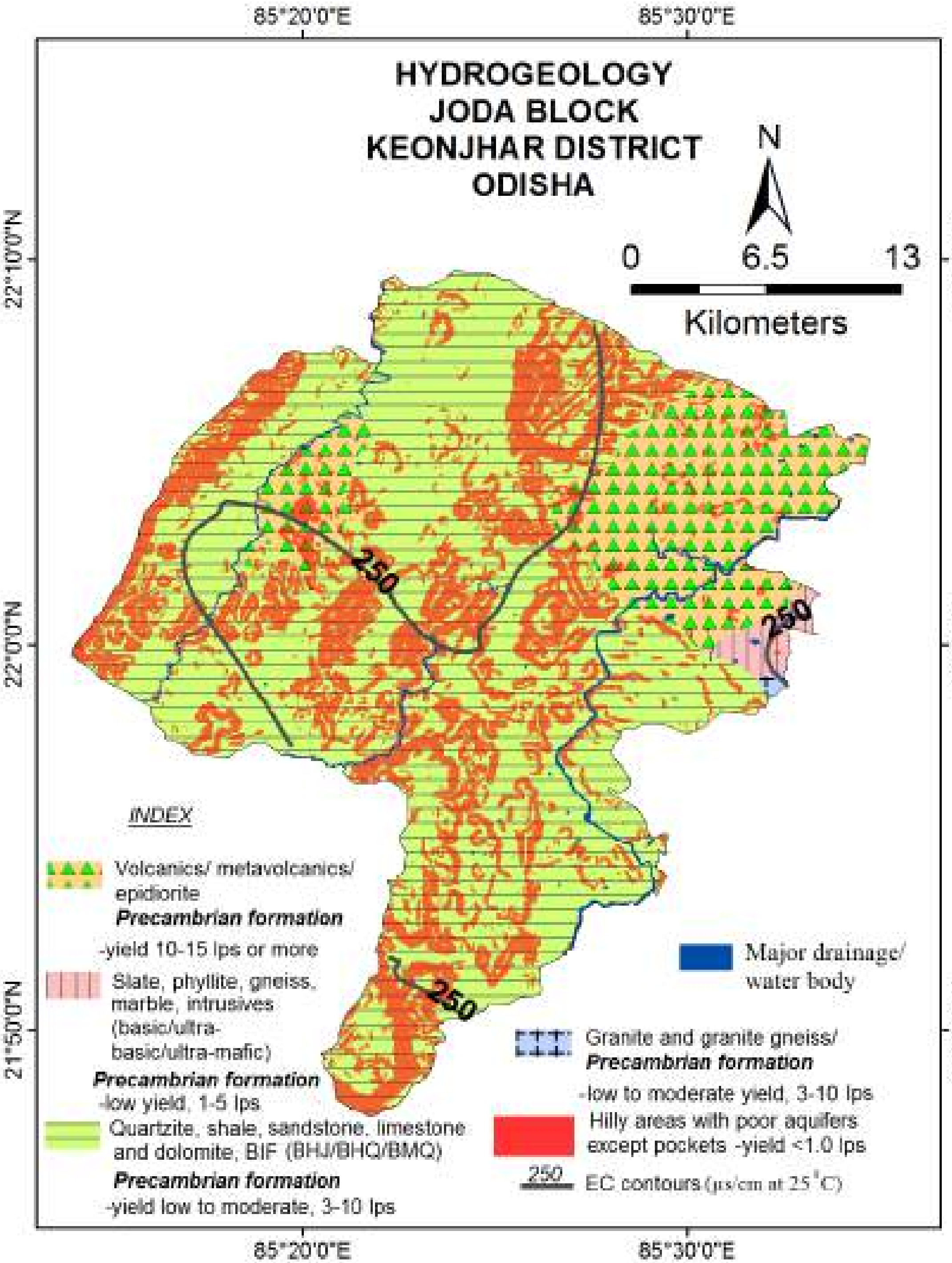

HYDROGEOLOGY
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6.5 13
Kilometers
85°20'0"E
85°30'0"E
22°10'0"N
22°0'0"N
21°50'0"N
250
INDEX
Volcanics/ metavolcanics/ epidiorite
Precambrian formation
-yield 10-15 lps or more
Slate, phyllite, gneiss, marble, intrusives (basic/ultra-basic/ultra-mafic)
Precambrian formation
-low yield, 1-5 lps
Quartzite, shale, sandstone, limestone and dolomite, BIF (BHJ/BHQ/BMQ)
Precambrian formation
-yield low to moderate, 3-10 lps
Major drainage/ water body
Granite and granite gneiss/
Precambrian formation
-low to moderate yield, 3-10 lps
Hilly areas with poor aquifers except pockets -yield <1.0 lps
250 EC contours (μs/cm at 25°C)

PLATE – 9.7

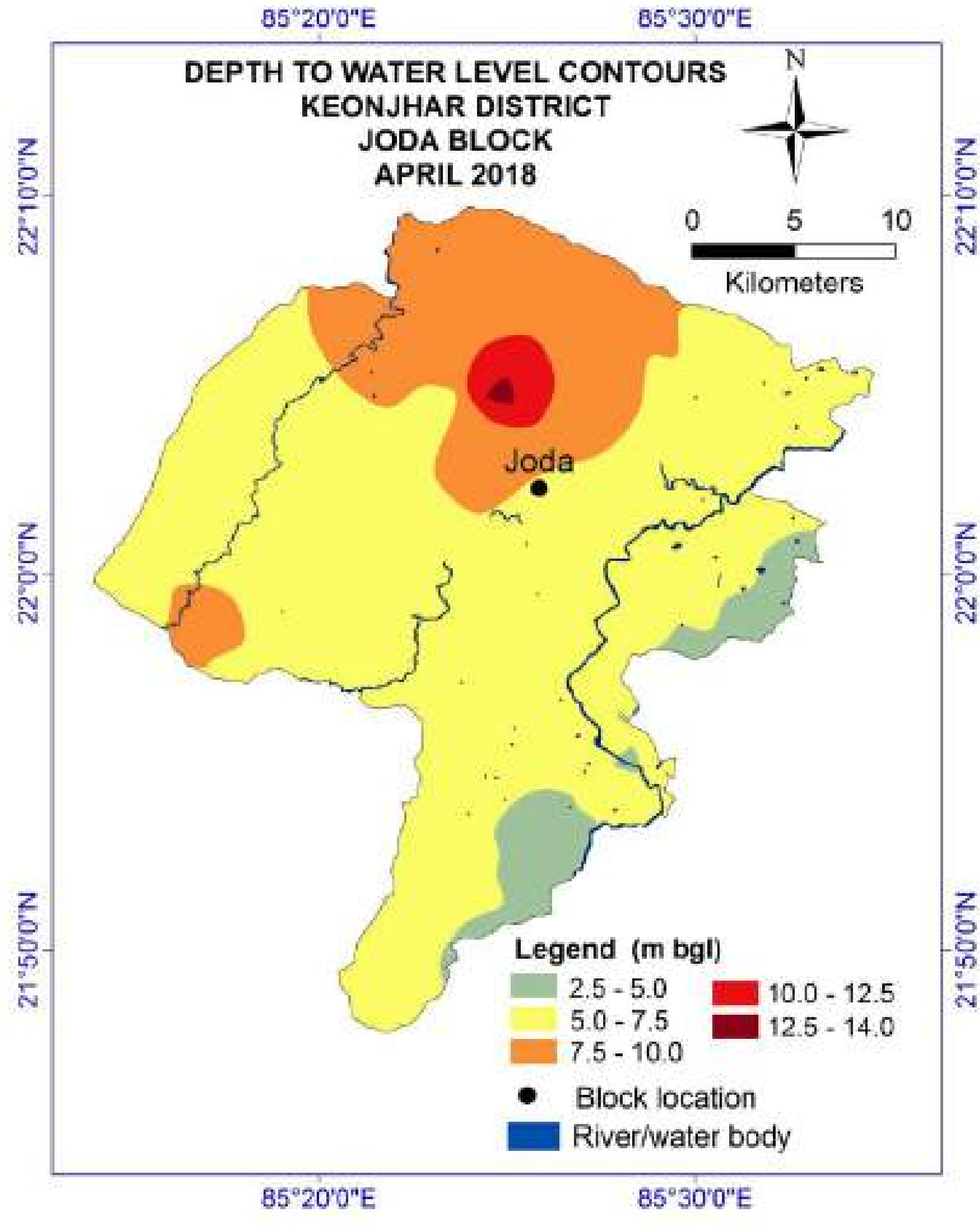
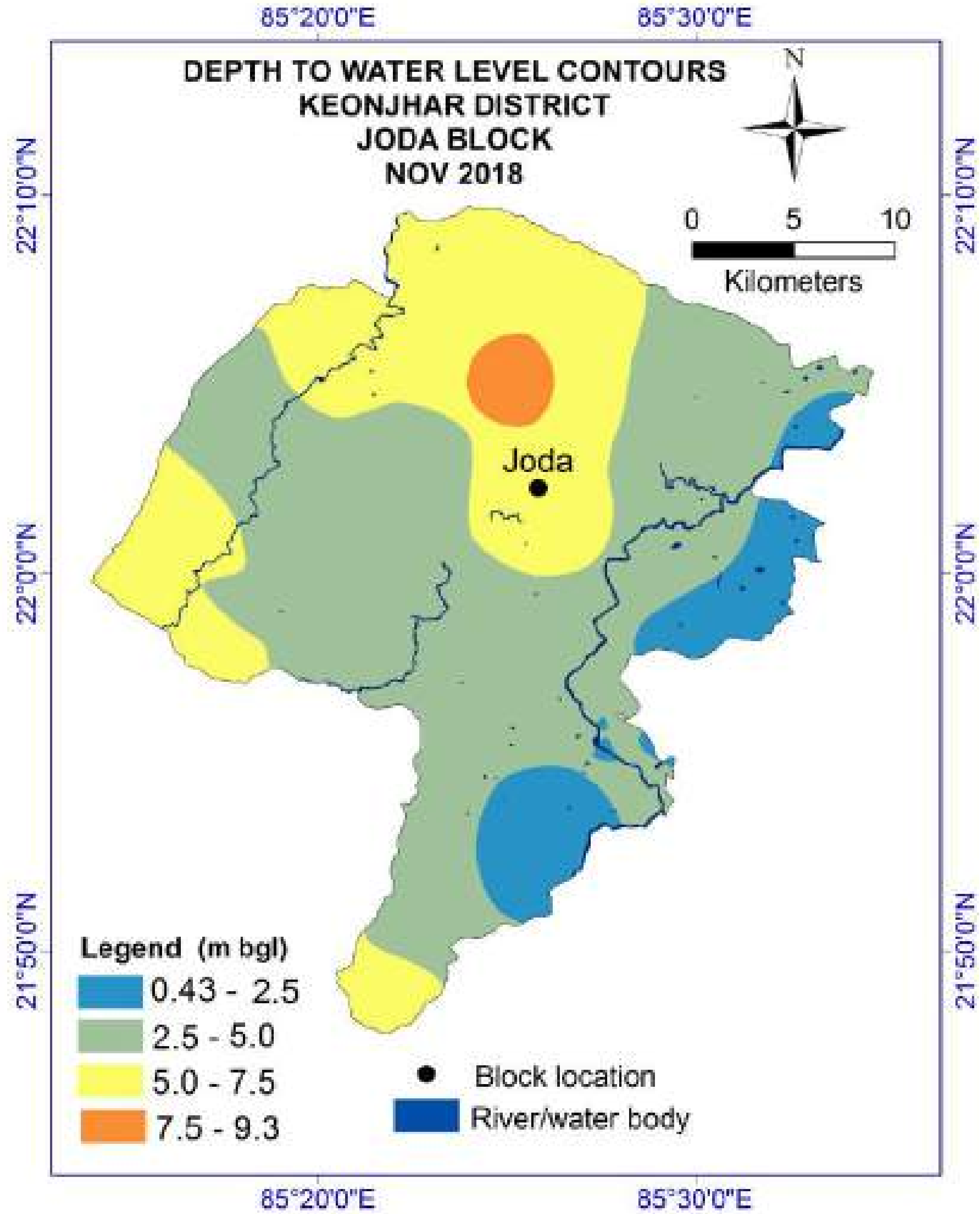

85°20'0"E
85°30'0"E
DEPTH TO WATER LEVEL CONTOURS
KEONJHAR DISTRICT
JODA BLOCK
APRIL 2018
N
0 5 10
Kilometers
22°10'0"N
22°0'0"N
21°50'0"N
Joda
Legend (m bgl)
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
12.5 - 14.0
Block location
River/water body

PLATE – 9.8



85°20'0"E
85°30'0"E
DEPTH TO WATER LEVEL CONTOURS
KEONJHAR DISTRICT
JODA BLOCK
NOV 2018
N
0
5
10
Kilometers
22°10'0"N
22°0'0"N
21°50'0"N
Joda
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
River/water body

PLATE – 9.9

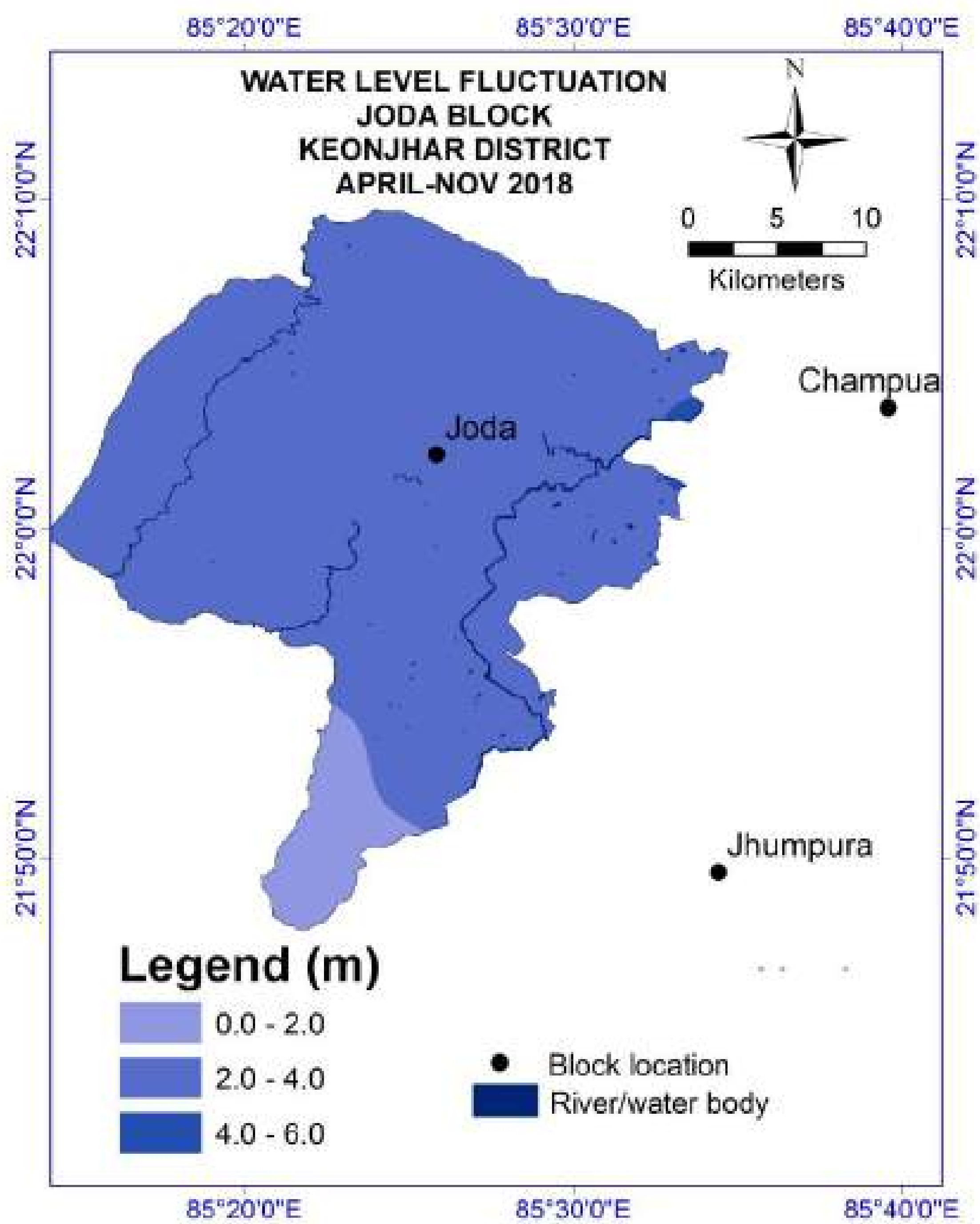

WATER LEVEL FLUCTUATION
JODA BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0 5 10
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
22°10'0"N
22°0'0"N
21°50'0"N
Champua
Joda
Jhumpura
Legend (m)
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
Block location
River/water body

PLATE – 9.10

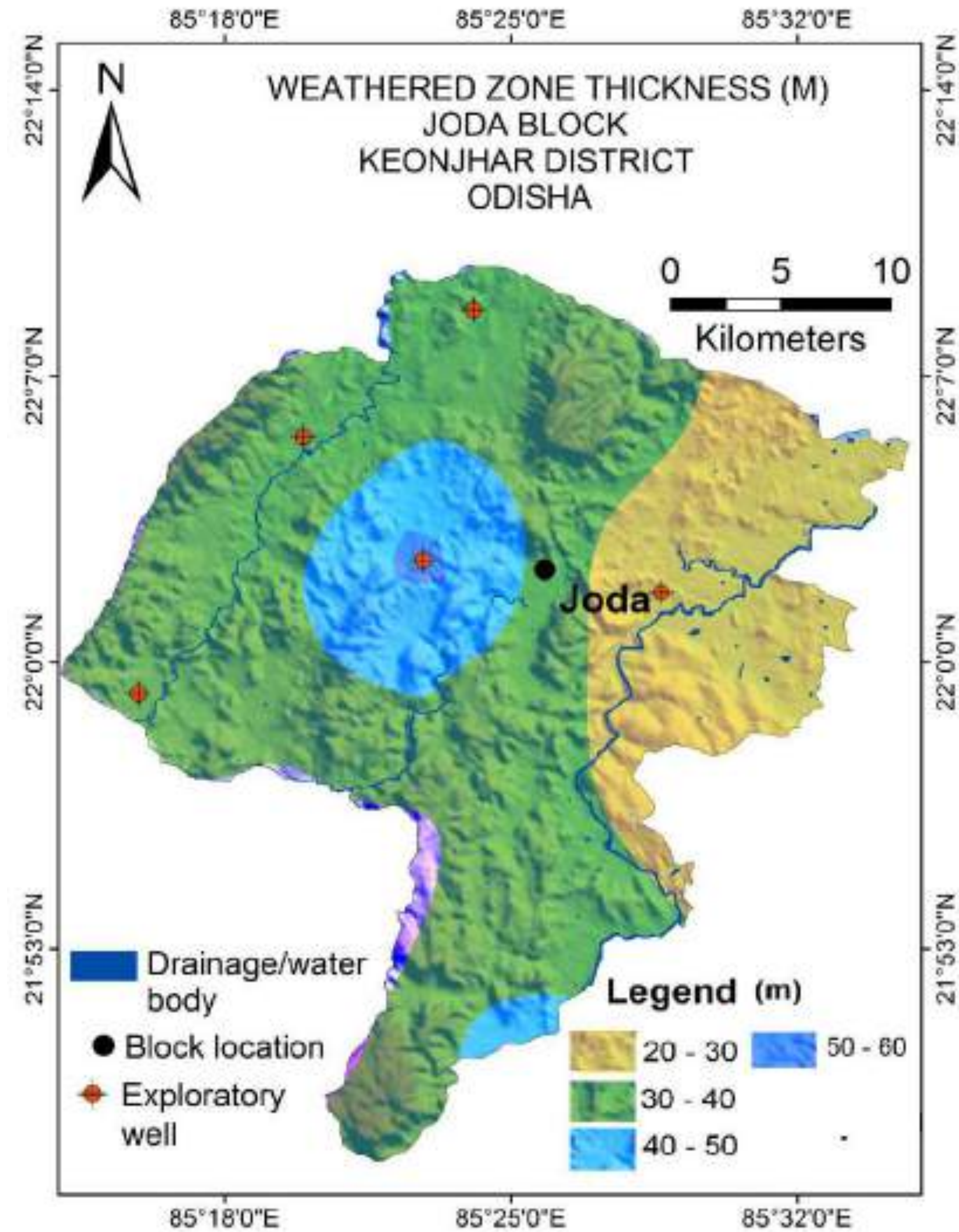

WEATHERED ZONE THICKNESS (M)
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
Joda
Drainage/water body
Block location
Exploratory well
Legend (m)
20 - 30
30 - 40
40 - 50
50 - 60
85°18'0"E
85°25'0"E
85°32'0"E
22°14'0"N
22°7'0"N
22°0'0"N
21°53'0"N

PLATE – 9.11

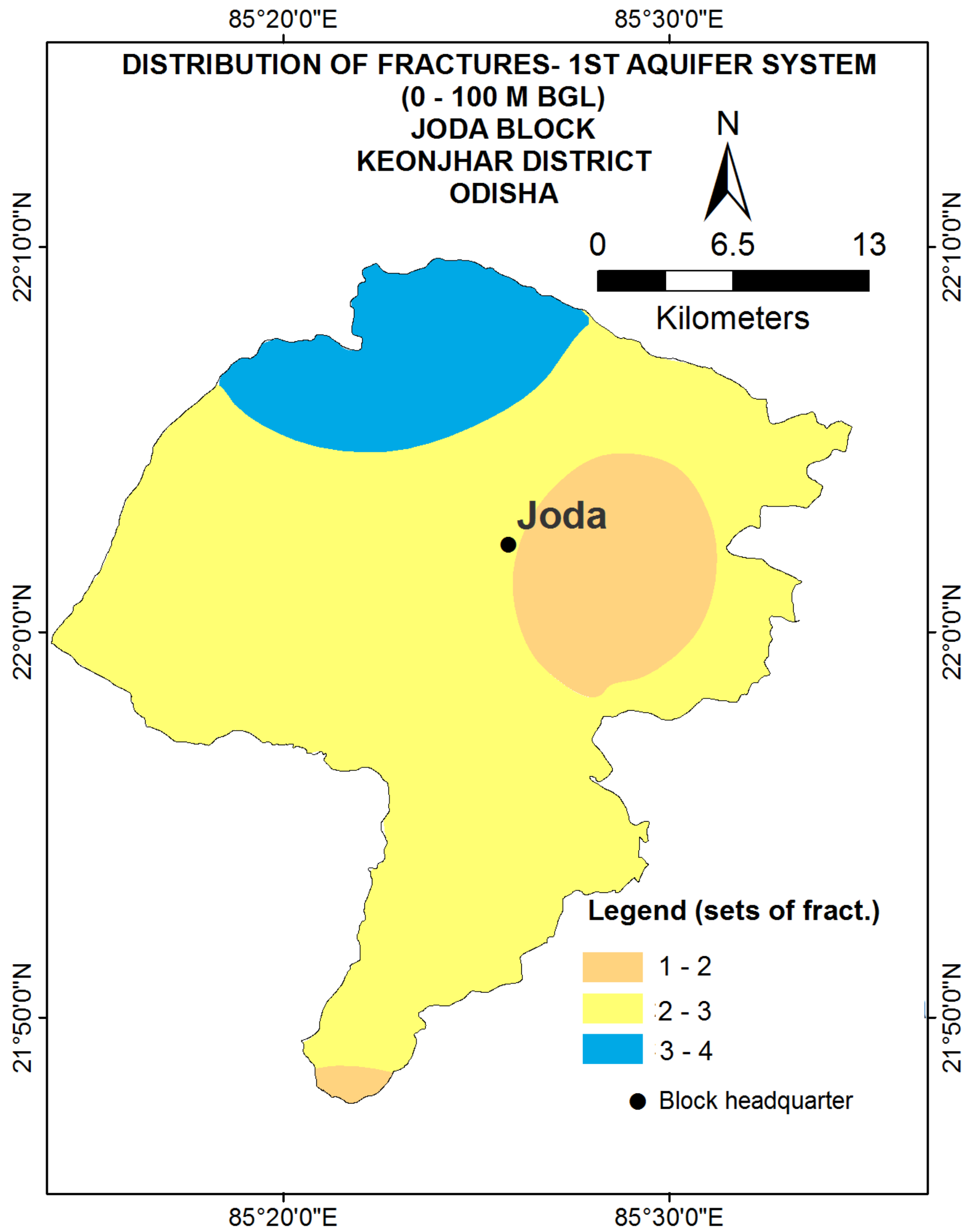

DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6.5
13
Kilometers
Joda
Legend (sets of fract.)
1 - 2
2 - 3
3 - 4
Block headquarter
85°20'0"E
85°30'0"E
22°10'0"N
22°0'0"N
21°50'0"N

PLATE – 9.12

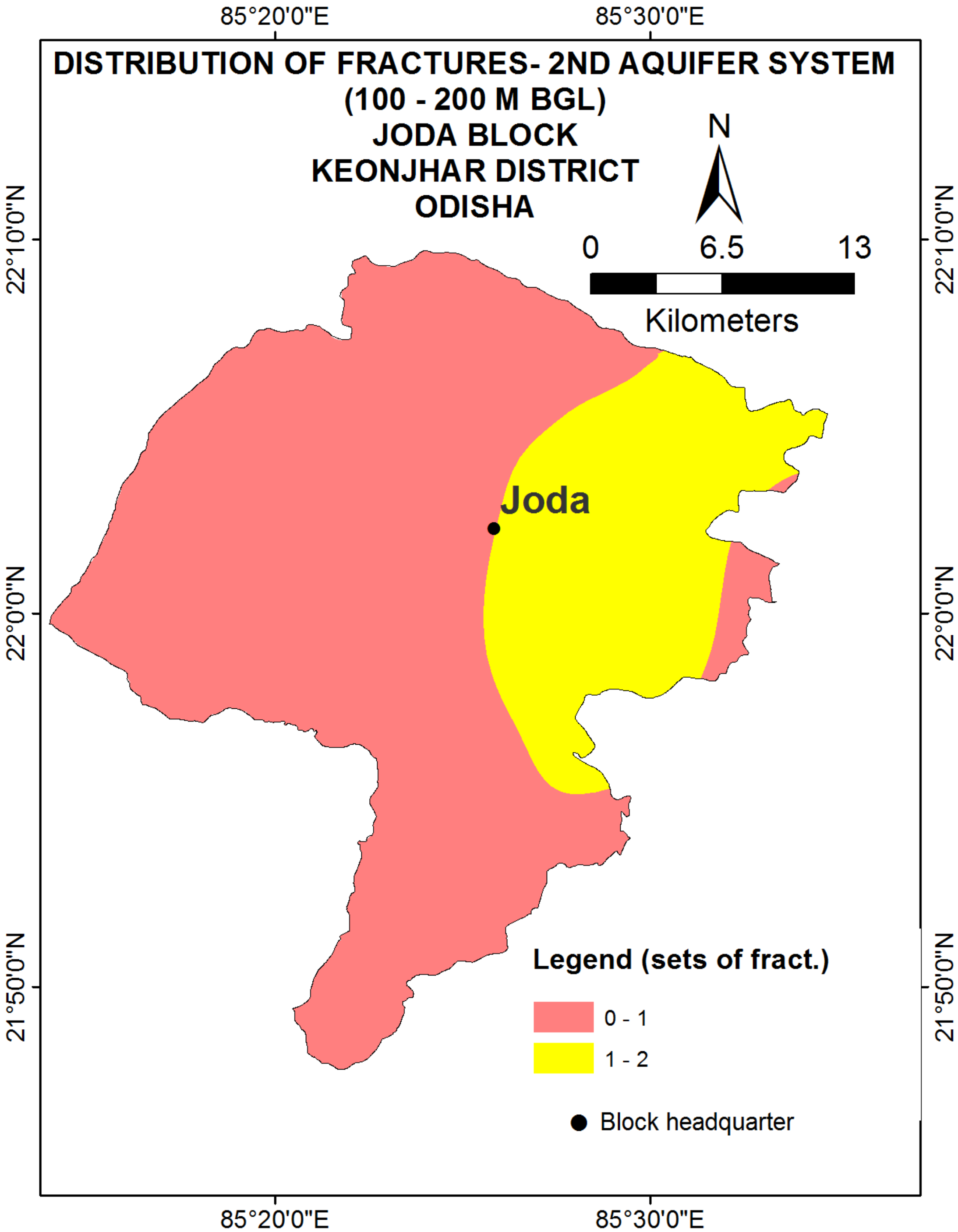
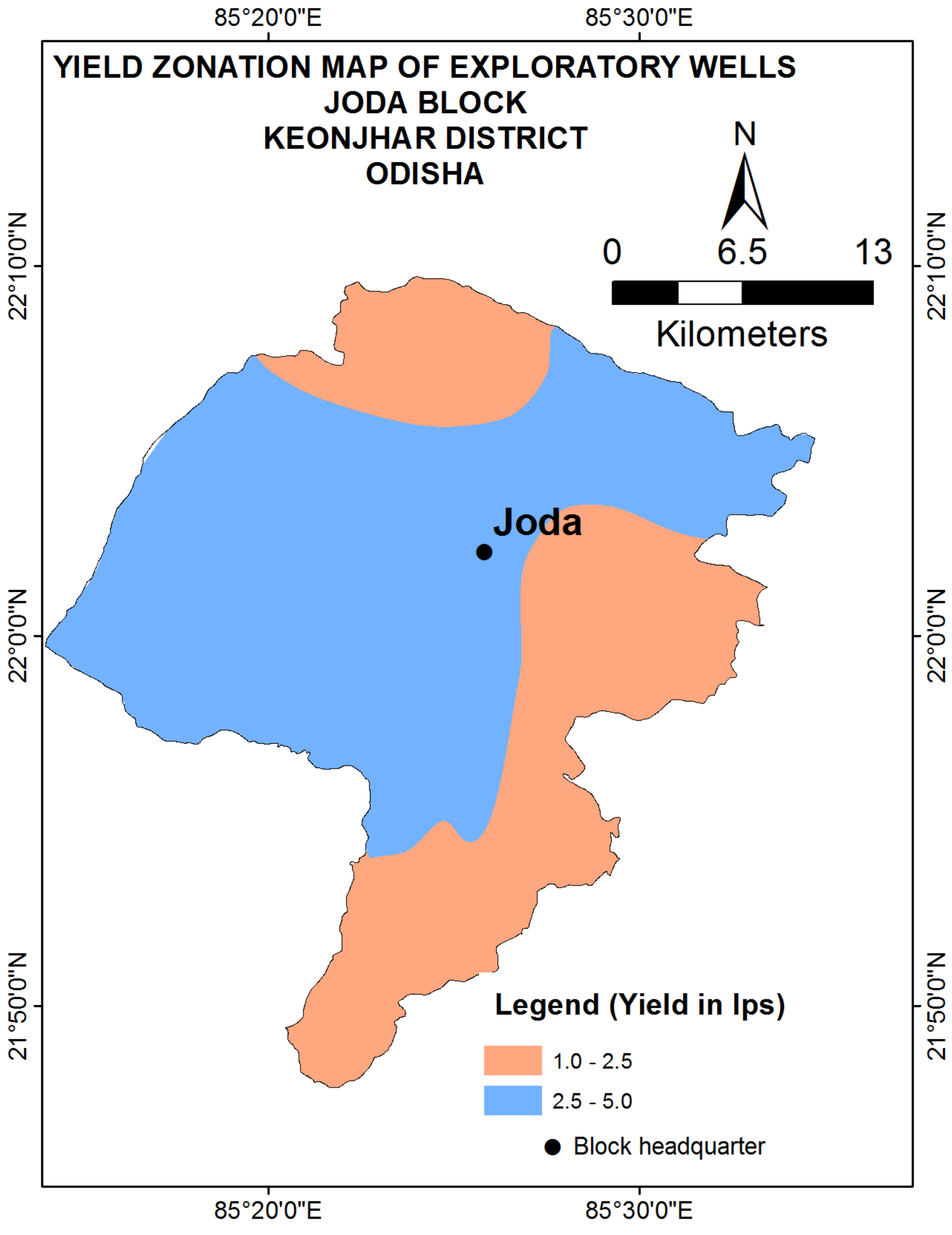

85°20'0"E
85°30'0"E
DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6.5
13
Kilometers
22°10'0"N
22°0'0"N
21°50'0"N
Joda
Legend (sets of fract.)
0 - 1
1 - 2
Block headquarter

PLATE – 9.13



YIELD ZONATION MAP OF EXPLORATORY WELLS
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
85°20'0"E
85°30'0"E
22°10'0"N
22°0'0"N
21°50'0"N
N
0
6.5
13
Kilometers
Joda
Legend (Yield in lps)
1.0 - 2.5
2.5 - 5.0
Block headquarter

PLATE – 9.14

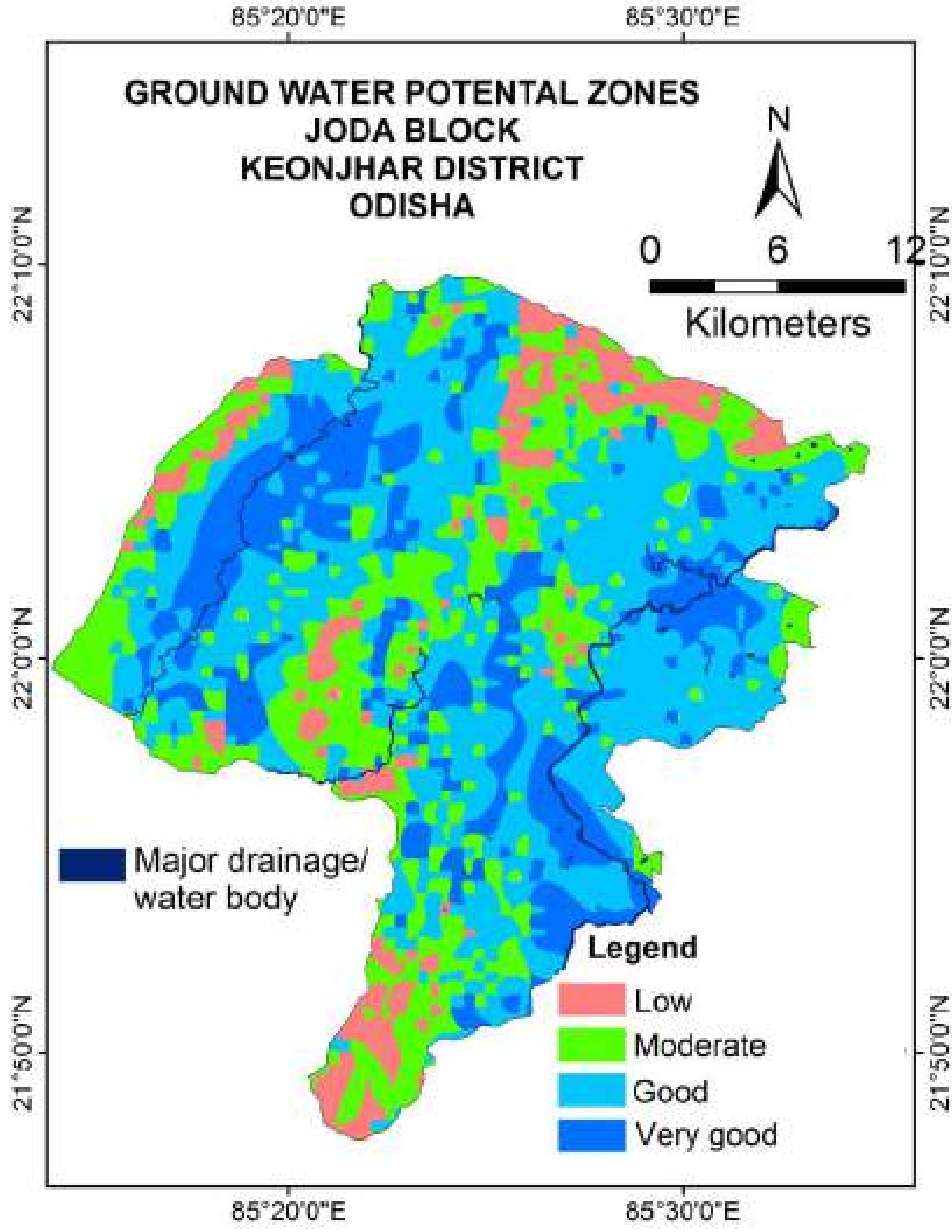
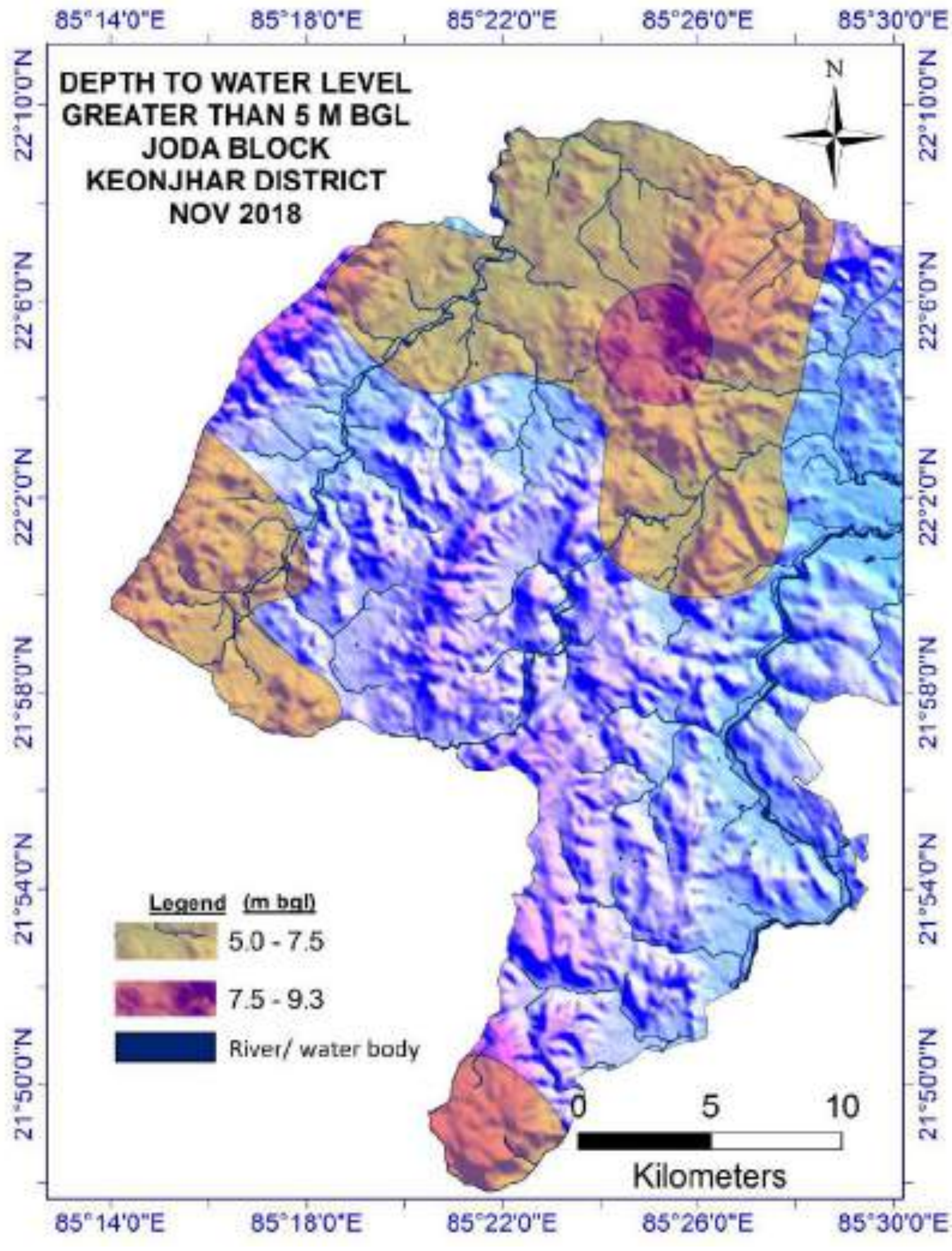

GROUND WATER POTENTAL ZONES
JODA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
85°20'0"E
85°30'0"E
22°10'0"N
22°0'0"N
21°50'0"N
Major drainage/
water body
Legend
Low
Moderate
Good
Very good

PLATE – 9.15


DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
JODA BLOCK
KEONJHAR DISTRICT
NOV 2018
N
85°14'0"E
85°18'0"E
85°22'0"E
85°26'0"E
85°30'0"E
22°10'0"N
22°6'0"N
22°2'0"N
21°58'0"N
21°54'0"N
21°50'0"N
Legend (m bgl)
5.0 - 7.5
7.5 - 9.3
River/ water body
0
5
10
Kilometers

PART II BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

6.0 KEONJHAR BLOCK

6.1 Salient information

Location, area and demography

Location (Plate 10.1)	85^0 28' - 85^0 51' E longitude 21^0 33' – 21^0 52'' N latitude
Area	697 sq. km
No. of Gram Panchayats	24
No. of villages	225
Population (Census 2011)	1,61,931
Literacy	58.7%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1711.4 mm
Monsoon normal rainfall	1304.1 mm (76% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	43331 Ha
Net sown area (2)	30474 Ha
Area sown more than once (1-2)	12857 Ha
Cropping intensity (%)	142.2 Ha
Area under forest	13069 Ha
Area under wasteland	487 Ha
Area under other uses	12043 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	16398 Ha *Kharif:* 10325 Ha *Rabi:* 6073 Ha

6.2 Drainage, geomorphology and soil types

The rivers such as the Ardei and Kanjhari, two of the major tributaries of Baitarani River, drain the block. The Ardei river basin along with its tributaries covers a major part of the block, where the river channels flow northerly/north-easterly and north-westerly. In contrast, in the Kanjhari river basin, the rivers flow easterly to north-easterly. The Kanjhari major irrigation project lies in this basin. The drainage pattern is dendritic to sub-trellis in nature. There are several small and large water bodies in the block (Plate 10.2), particularly in the Ardei river basin. The hydro-geomorphic units of pediments and buried pediments make up 84% of the block area. Structural hills comprising 8.5% of the block area is located in the western parts (Fig 10.1 and Plate 10.3). The pediments, buried pediments and valley fills (2.5% of block area) make important hydro-geomorphic units in the block. Among several linear dykes, the one in the western parts is most prominent, running in the NE-SW direction across the block and transverse to the local flow lines. Most of the block area (86%) possesses land surface slope of <5% (Fig 10.2), except the minor patches in the western hills and dykes (Plate 10.4). Red loamy (alfisol), red sandy (alfisol) and red and yellow (ultisol) types of soils predominate in the block.

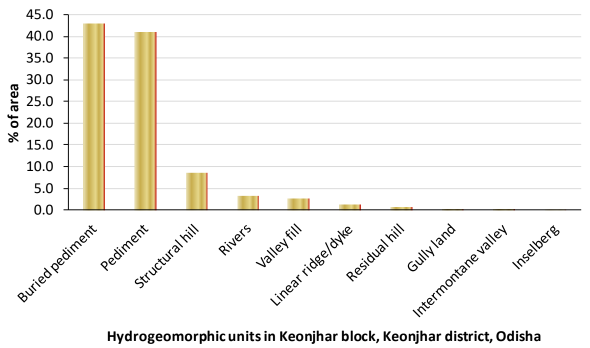


Figure 10.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Keonjhar block.

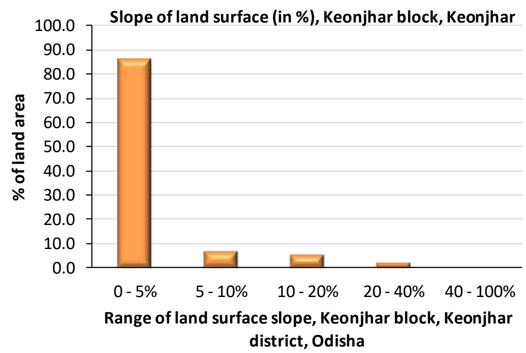


Figure 10.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Keonjhar block, Keonjhar district.

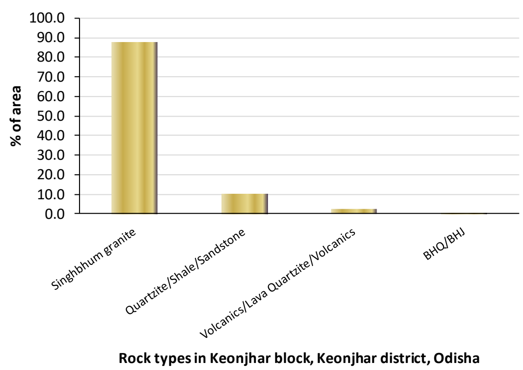


Figure 10.3: Percentage (%) of Keonjhar block area (Keonjhar dist.) covered by various rock types.

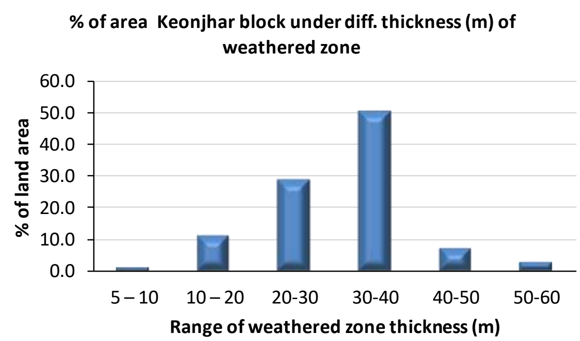


Figure 10.4: Bar diagram depicting the percentage (%) area of Keonjhar block, Keonjhar district falling under different weathered zone thickness (m) ranges.

6.3 Geology

Around 87% of the block area is occupied by Singhbhum Granites. The rest is covered by iron ore formations/metasediments and volcanics along the western and souther borders (Fig 10.3 and Plate 10.5).

6.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories in the hard rock areas of the block. The generalized hydrogeological map of the block is presented in Plate 10.7. The Singhbhum Granites posses low to moderate yield potential varying between 3-10 lps. The volcanics suite of rocks yield between 10-15 lps of water.

Except patches where 2.5-5.0 m bgl water levels were observed, the entire block registered water levels >5.0 m bgl (Plate 10.7). During the post-monsson period, however, except the patches in the Ardei river basin, the other areas registered water levels <5.0 m bgl, indicating good recharge from rainfall (Plate 10.8). The annual fluctuations in the water levels remained in between 2-6 m in the block (Plate 10.9).

6.5 Aquifer geometry and characters

The thickness of the weathered regolith overlying the fresh hard rock varies between 5– 60 m (Plate 10.10). About 29% and 50% of the block area possess weathered zone thickness in the ranges of 20-30 m and 30-40 m respectively (Fig 10.4). The thickness of the weathered residuum decreases towards east. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 10.5a-b.

In the block, 1-3 sets of fracture zones are encountered in bore wells within the depth of 100 m bgl (1st aquifer system). In major parts, 1-2 sets of fractures are found (Plate 10.11). Beyond this depth in the 2nd aquifer system, the fractures are depleted and in maximum cases, 0-1 sets of fracture zones are encountered during drilling (Plate 10.12). In major cases the bore wells yield in the range of 2.5-5.0 lps, though, in some wells 1.0-2.5 lps of water has been obtained (Plate 10.13).

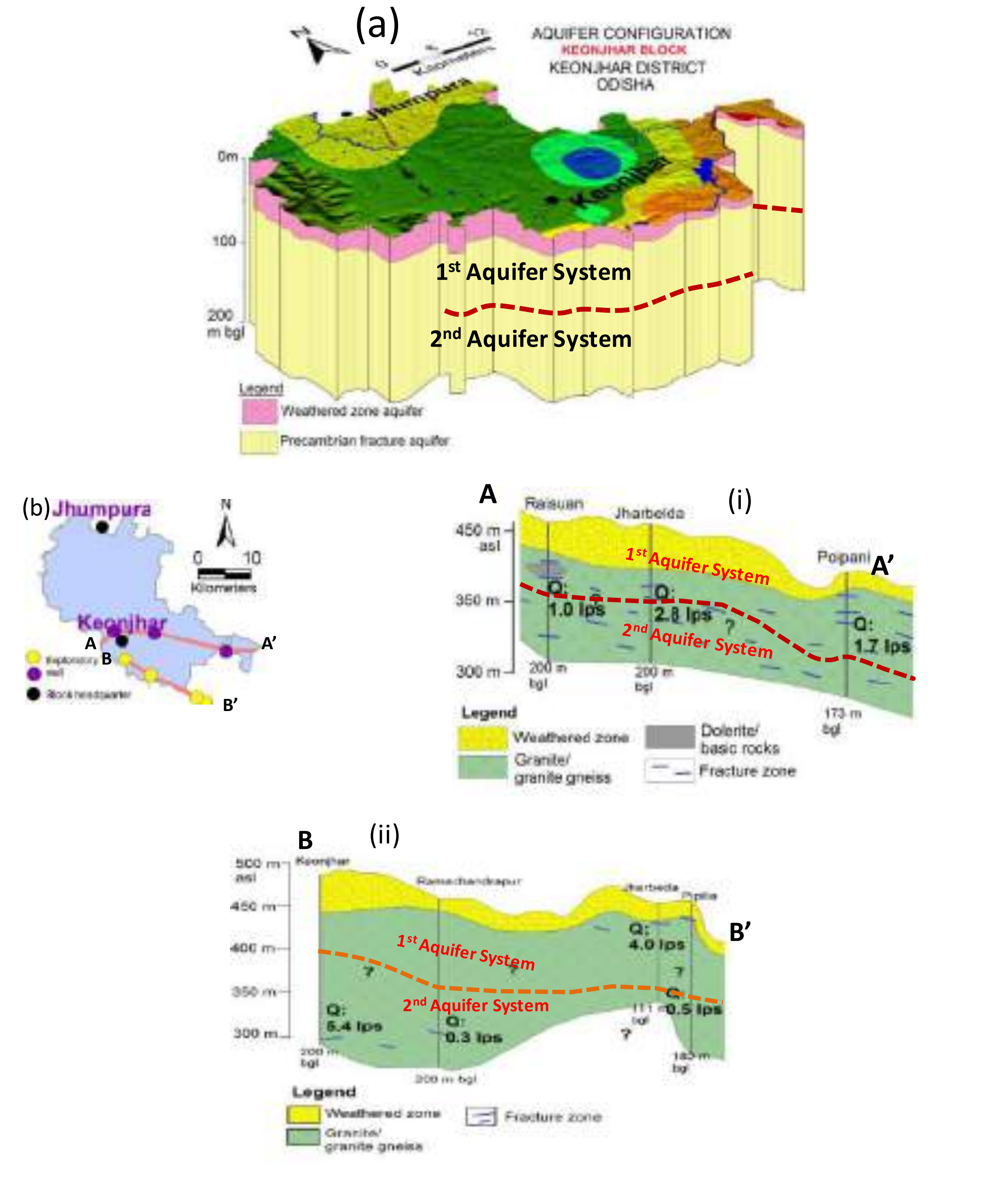


Figure 10.5: (a) 3D aquifer disposition in Keonjhar block, Keonjhar district. (b) (i) (ii) 2D hydrogeological transects (including their locations) A-A' and B-B' depicting the aquifer disposition in the block.

6.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 10.14). As per this analysis, the good to very good groundwater potential zones cover about 70% of the block area. The very good potential zones have been delineated in the south-central parts falling in the Ardei river basin (Fig 10.6).

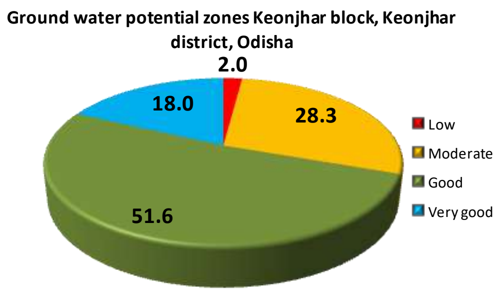


Figure 10.6: Pie diagram depicting the perentage (%) of Keonjhar block, Keonjhar district, Odisha, falling under different groundwater potential zones.

6.7 Ground water quality

Ground water in the block is alkaline in nature (Table 10.1) and pH range of 7.5-8.33. In major cases water is hard to very hard in nature. The mineralization is low to moderate with TDS in the range of 100-560 mg/L (ave.: 288.4 mg/L).

Table 10.1: Ground water quality at various locations in Keonjhar block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Potala	7.9	370	199	133	155	39	9	19.38	4.23	0	185	32	4.3	0.22
Chaka	8.05	480	242	189	144	37	23	18.88	5.45	0	157	58	22.52	0.16
Raikala	8	340	170	143	160	45	7	9.75	4.15	0	174	15	4.2	0.23
Shendcap	7.5	240	126	102	88	37	2	4.1	5.08	0	96	28	3.1	0.18
Sahadapur	8	370	217	102	134	27	9	20.75	26	0	146	30	32.37	0.22
Harshapur	8.2	840	459	245	247	86	7	60.78	33	0	270	131	9.333	0.19
Dhanurjayapur	7.9	590	269	255	273	39	38	16.87	3	0	298	23	2.8	0.51
Mahadeipur	8.1	190	100	82	72	31	1	4.5	1.1	0	79	23	1	0.28
Barigan	8.33	520	278	159	111	46	11	32	17.22	0	136	77	27	0.11
Gopalpur	7.89	350	204	145	127	48	6	14.3	8.31	0	155	34	16.1	0.42
Haridagot	7.79	360	183	90	54	26	6	26.51	9.25	0	66	60	22.5	0.16
Keonjhargarh	7.64	1070	555	350	176	72	41	75.15	13.6	0	215	191	54.9	0.22
Naranpur	7.96	1085	560	325	225	78	32	75.8	9.11	0	275	182	46	0.35
Padampur	8.07	555	271	230	127	72	12	12.82	0.66	0	155	81	14.8	0.23
Jharbeda	8.2	380	192	133	165	37	10	23.93	0.44	0	197	15	8.99	2.18
Saharposi 2	-	-	-	-	-	-	-	-	-	-	-	-	-	1.19
Tulasichoura 1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.05
Tulasichoura 2	-	-	-	-	-	-	-	-	-	-	-	-	-	1.28
Ghutkeswari 2	-	-	-	-	-	-	-	-	-	-	-	-	-	1.58
Ghutkeswari 3	-	-	-	-	-	-	-	-	-	-	-	-	-	1.01
Ghutkeswari 4	-	-	-	-	-	-	-	-	-	-	-	-	-	1.22
Min.:	**7.5**	**190**	**100**	**82**	**54**	**26**	**1**	**4.1**	**0.44**	**0**	**66**	**15**	**1**	**0.11**
Max.:	**8.33**	**1085**	**560**	**350**	**273**	**86**	**41**	**75.8**	**33**	**0**	**298**	**191**	**54.9**	**2.18**
Average	**8.0**	**516.0**	**268.4**	**178.9**	**150.5**	**48.0**	**14.3**	**27.7**	**9.4**	**0.0**	**173.6**	**65.3**	**18.0**	**0.62**

Ground water is fit for drinking and irrigation except certain pockets. In Naranpur Gram Panchayat, some source points of groundwater in a few villages (only fluoride levels given), the fluoride level exceeds the Bureau of Indian Standard (BIS 2012) desirable limit of 1.0 mg/L for drinking (Table 10.1). A few patients in the villages were also noticed with physical deformities, abnormal growth in mind and bending of spinal cord. The water types are predominantly Ca-HCO_3 types with Ca^{2+} and HCO_3^- as the principal ions contributing in the groundwater chemistry (Fig 10.7).

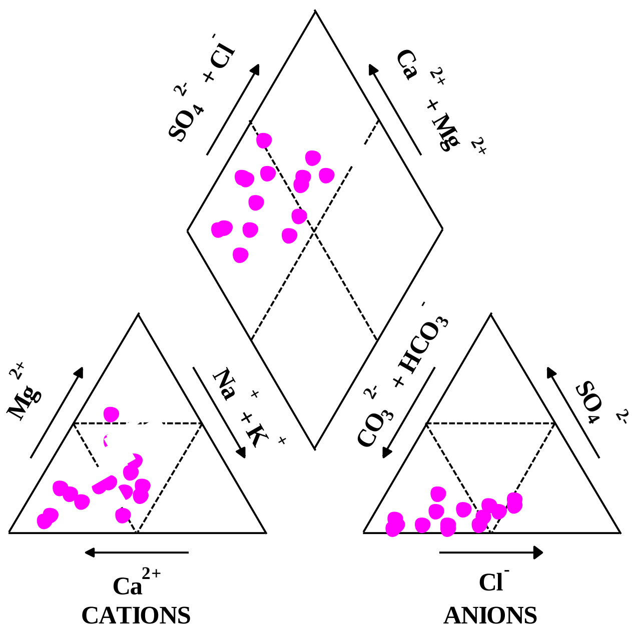


Figure 10.7: The Piper trilinear diagram depicting the groundwater quality in Keonjhar block, Keonjhar district.

6.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 10.2-10.4. The net dynamic groundwater available is 9317.8 Ham and the stage of groundwater development stands at 41.2%. Net resource available for future irrigation needs stands at 5368.3 Ham (Fig 10.8). The instorage/static groundwater resource component of 5051.2 Ham (Table 10.3) comes from the 1st aquifer system within 100 m bgl. The total groundwater available in the block stands at 14379.7 Ham.

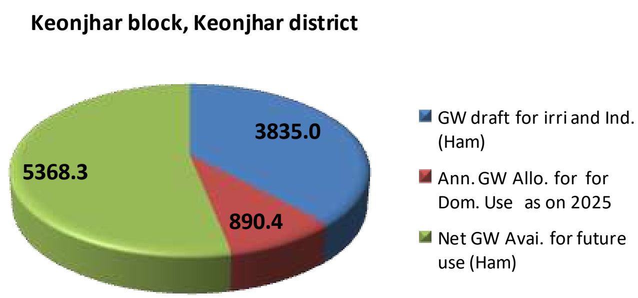


Figure 10.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Keonjhar block, Keonjhar district, Odisha.

Table 10.2: Salient information on annual dynamic groundwater resources, Keonjhar block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	9317.8
2. Irrigation draft (Ham)	3009.9
3. Industrial draft (Ham)	49.2
4. Domestic draft (Ham)	775.9
5. Total draft (Ham)	3835.0
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	890.4
7. Net groundwater available for future use (Ham)	5368.3
8. Stage of groundwater extraction (%)	41.2

Table 10.3: Total groundwater resoure available in the Keonjhar block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	9317.8
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	5051.2
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	10.8
	Block total	**14379.7**

6.9 Aquifer management plan

The existing stage of groundwater development of 41.2% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction structures as estimated in Table 10.4 (397 bore wells/dug-cum-bore wells and 3376 dug wells) are required to be constructed to develop the available additional resource of 5368.3 Ham. It can help in creating additional irrigation potential for 3072.5 Ha (Table 10.5). It can enhance the existing irrigation facility of 48% to 57%.

Only around 63.45 km^2 area in the block showed post-monsoon depth to water levels >5.0 m bgl (Plate 10.15; Table 10.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 6.66 MCM of water (Table 10.7) can be recharged by the help additional 13- percolations ponds, 7-subsurface dykes, 7-nala/contour bunds and 13-check dams (Table 10.8) with a total cost of 4.33 crores (Table 10.9).

Table 10.4: Number of additional feasible groundwater abstraction structures in Keonjhar block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	9317.8
2	Stage of GW deve. (%)	41.2
3	Present GW draft (Ham)	3835
4	Ground water draft at 60% stage of deve. (Ham)	5590.7
5	Addi. water to be deve. (Ham)	1755.7
6	Addi. No of BW/ STW feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	397
7	Addi. No. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	3376

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 10.5: Irrigation potential likely to be created in Keonjhar block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	41.2
2	Surplus GW avai. for 60% stage of deve. (Ham)	1755.7
3	Irri, Pot. likely to be created for Paddy (Ha)	877.8
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	877.8
5	Irri. Pot. likely to be created for veg. (Ha)	1316.8
6	Proj. area to be Irri. (ha)	3072.5

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 10.6: Areas in Keonjhar block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Keonjhar	58.76	4.69	63.45

Table 10.7: Estimation of volume of water required for artificial recharge to groundwater in Keonjhar block, Keonjhar district.

Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (mcm)	Total volume of water required to reharge (mcm)
Keonjhar	697.00	63.45	6.5	3.5	222.08	6.66

Table 10.8: Number of feasible structures in Keonjhar block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (mcm)	No of different freasible structures			
		Percolation tank (40%) @0.2 mcm	sub-surface dyke (15%) @0.15 mcm	Nala bund/contour bunding (15%) @0.15 mcm	Check dams & weirs (30%) @0.15 mcm
Keonjhar	6.66	13	7	7	13

Table 10.9: Estimation of cost of artificial recharge structures in Keonjhar block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Keonjhar	2.66	0.67	0.33	0.67	4.33

PLATE – 10.1

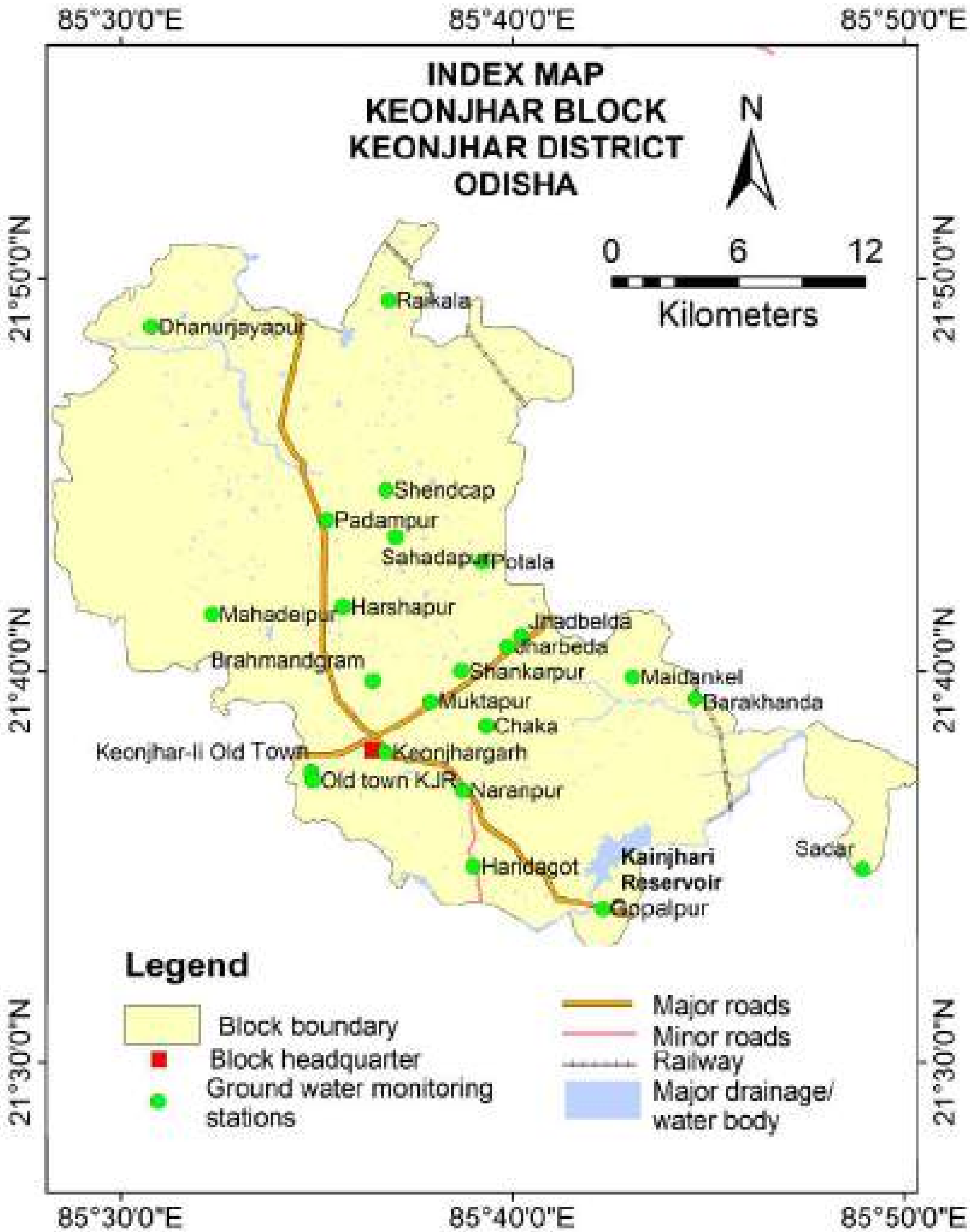

85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N
INDEX MAP
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
Raikala
Dhanurjayapur
Shendcap
Padampur
Sahadapur
Potala
Mahadeipur
Harshapur
Jhadbelda
Jharbeda
Brahmandgram
Shankarpur
Maidankel
Barakhanda
Muktapur
Chaka
Keonjhar-II Old Town
Keonjhargarh
Old town KJR
Naranpur
Haridagot
Kainjhari Reservoir
Gopalpur
Sadar
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body

PLATE – 10.2

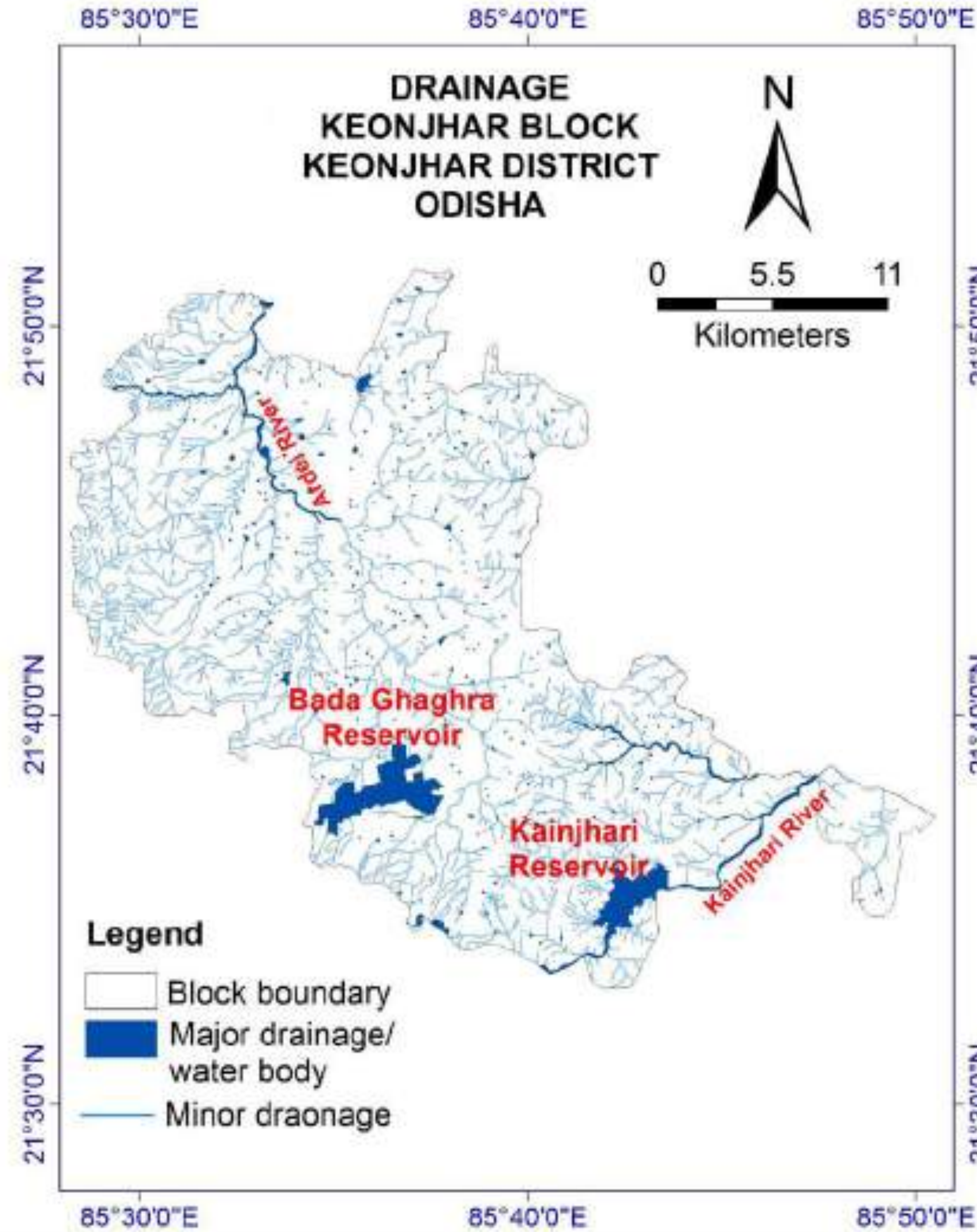

DRAINAGE
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5.5 11
Kilometers
85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Ardei River
Bada Ghaghra
Reservoir
Kainjhari
Reservoir
Kainjhari River
Legend
Block boundary
Major drainage/
water body
Minor draonage

PLATE – 10.3

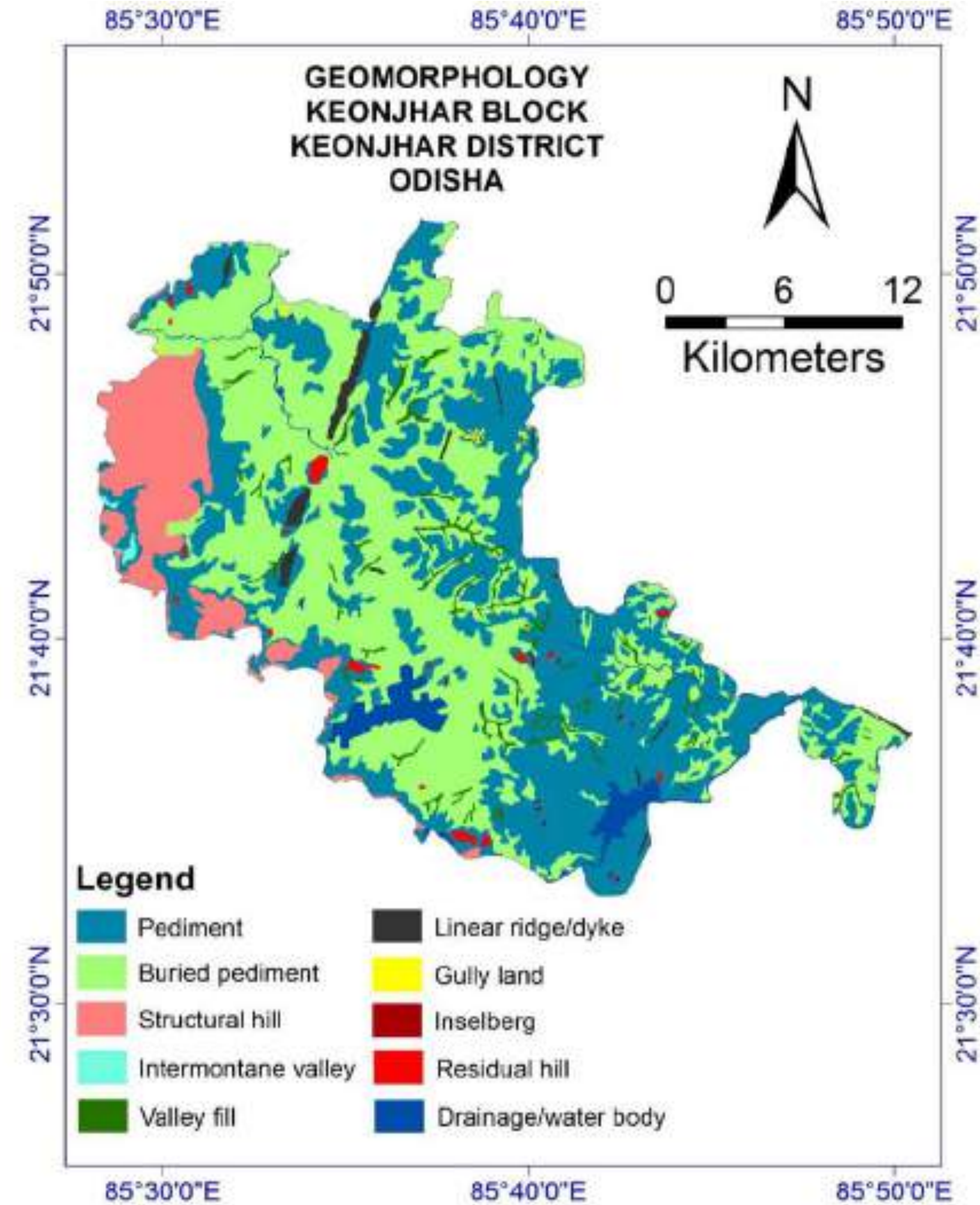
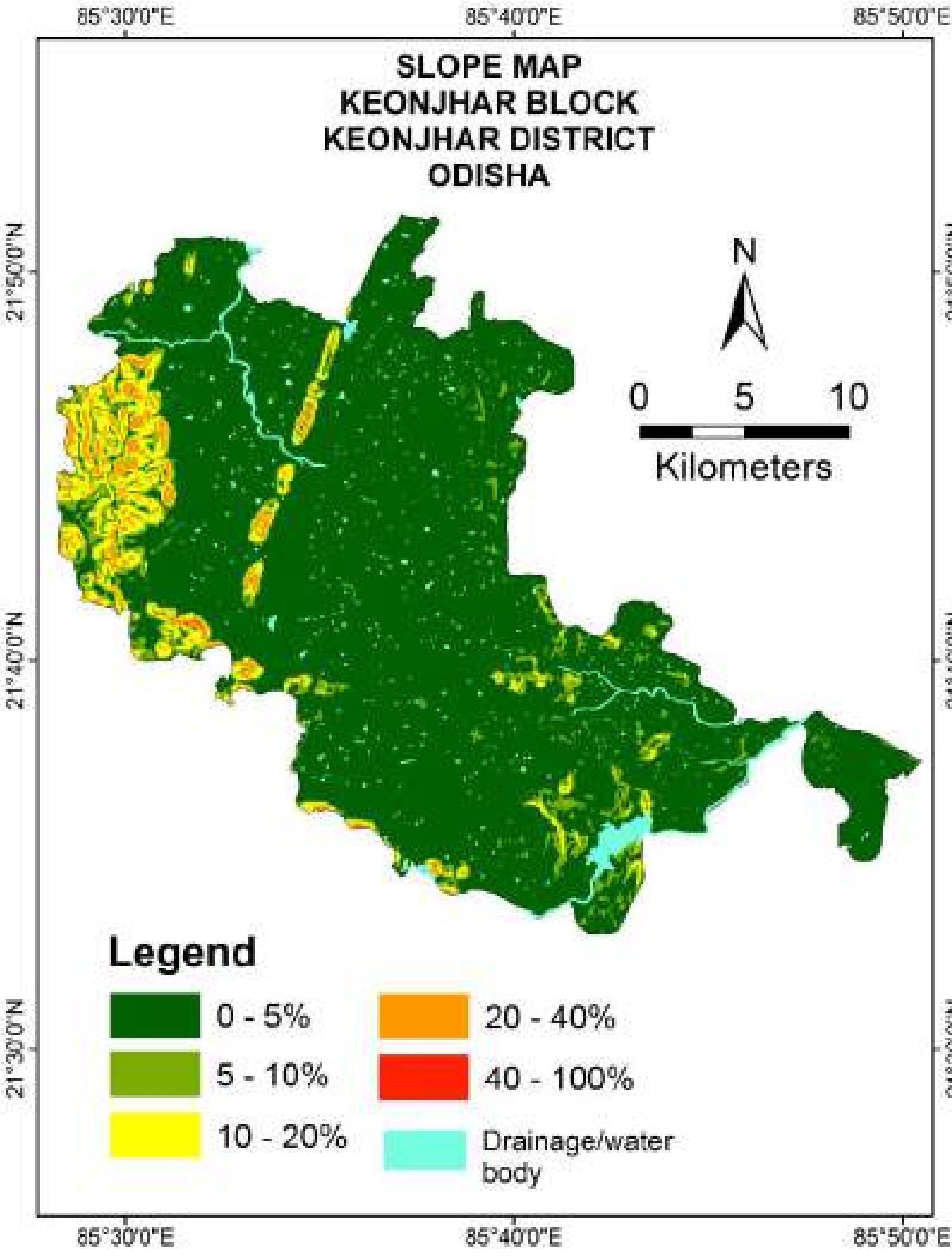

GEOMORPHOLOGY
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Legend
Pediment
Buried pediment
Structural hill
Intermontane valley
Valley fill
Linear ridge/dyke
Gully land
Inselberg
Residual hill
Drainage/water body

PLATE – 10.4



SLOPE MAP
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N
N
0
5
10
Kilometers
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 10.5

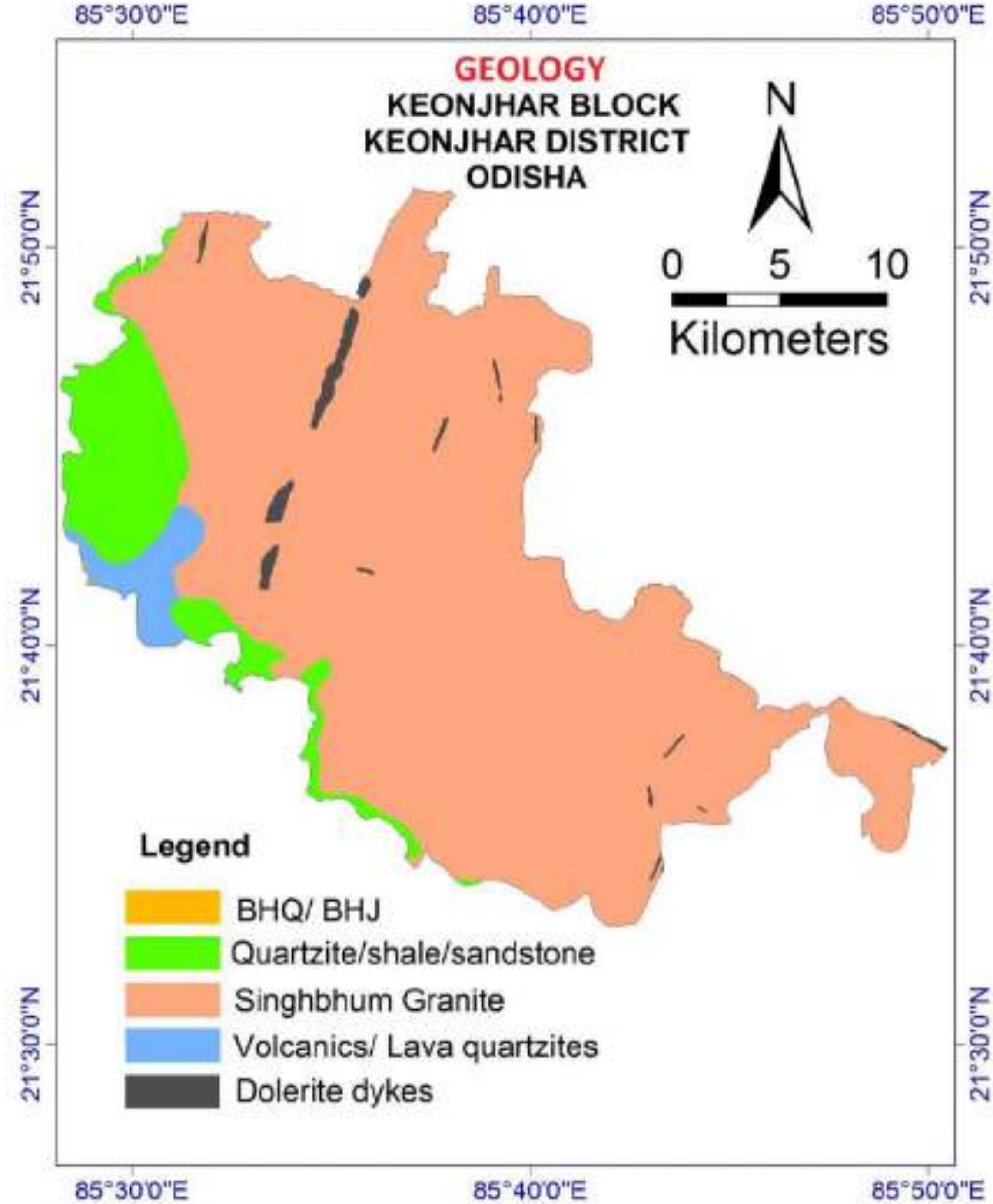
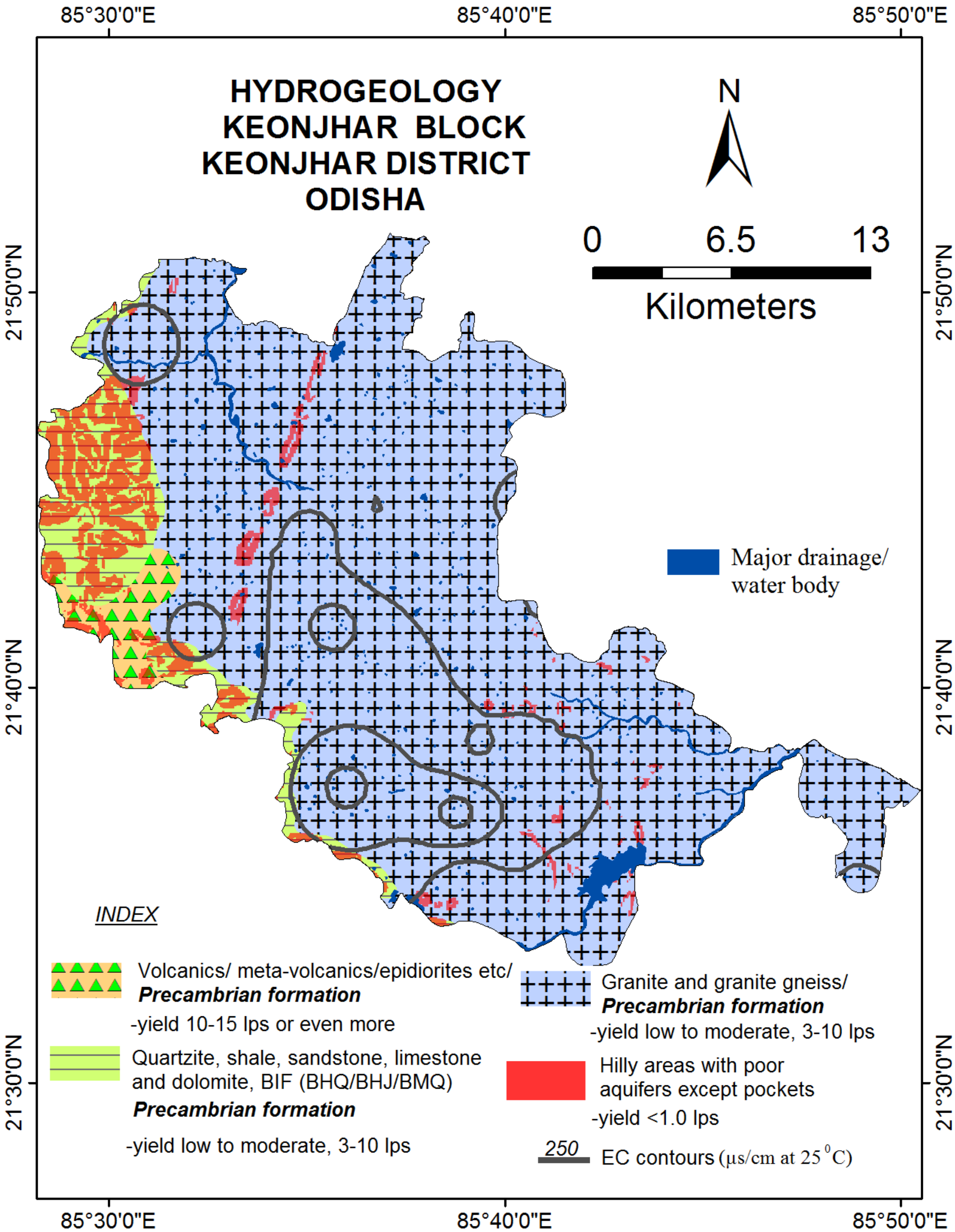

GEOLOGY
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Legend
BHQ/ BHJ
Quartzite/shale/sandstone
Singhbhum Granite
Volcanics/ Lava quartzites
Dolerite dykes

PLATE – 10.6



HYDROGEOLOGY
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6.5
13
Kilometers
85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Major drainage/ water body
INDEX
Volcanics/ meta-volcanics/epidiorites etc/
Precambrian formation
-yield 10-15 lps or even more
Quartzite, shale, sandstone, limestone and dolomite, BIF (BHQ/BHJ/BMQ)
Precambrian formation
-yield low to moderate, 3-10 lps
Granite and granite gneiss/
Precambrian formation
-yield low to moderate, 3-10 lps
Hilly areas with poor aquifers except pockets
-yield <1.0 lps
250
EC contours (µs/cm at 25 °C)

PLATE – 10.7

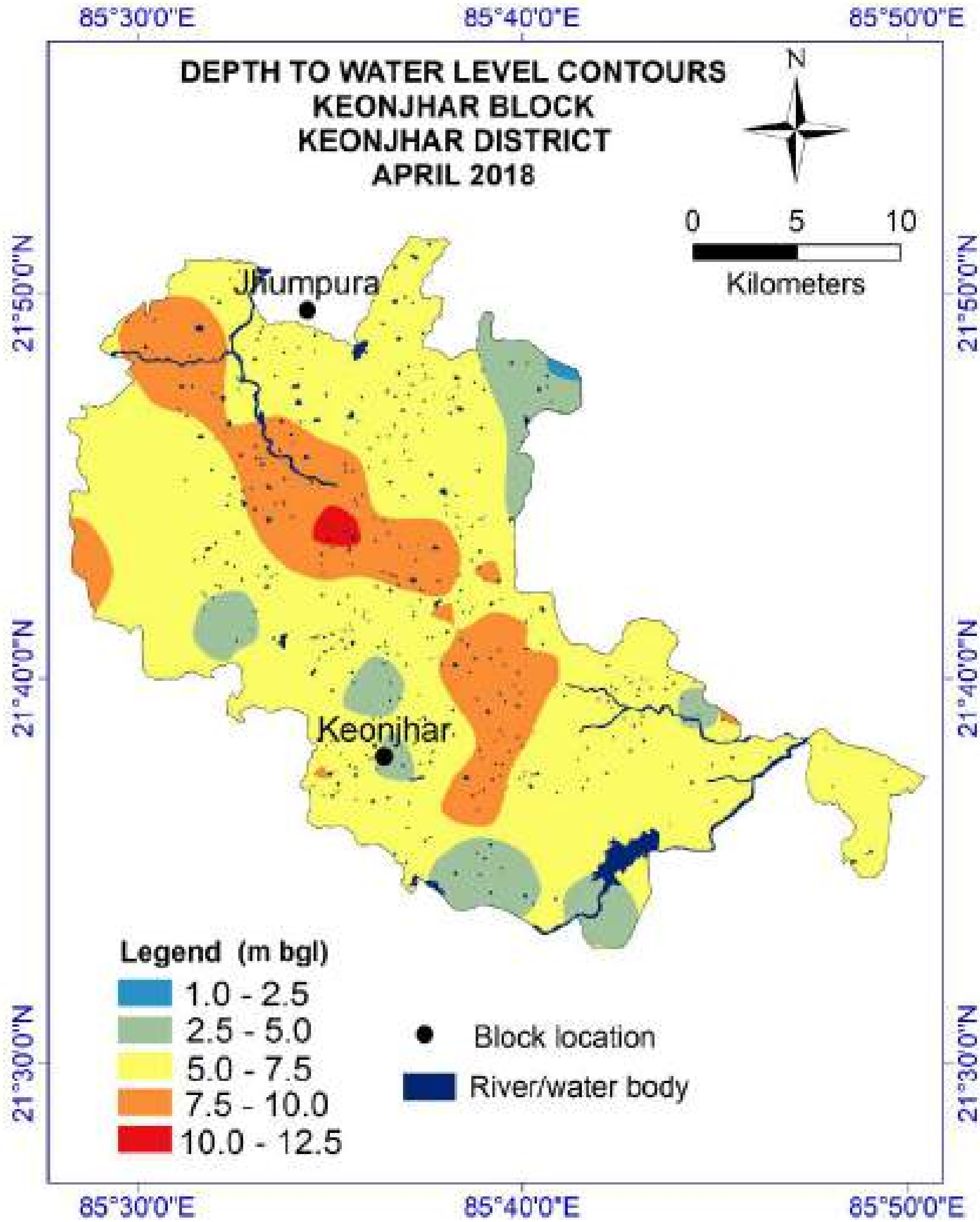
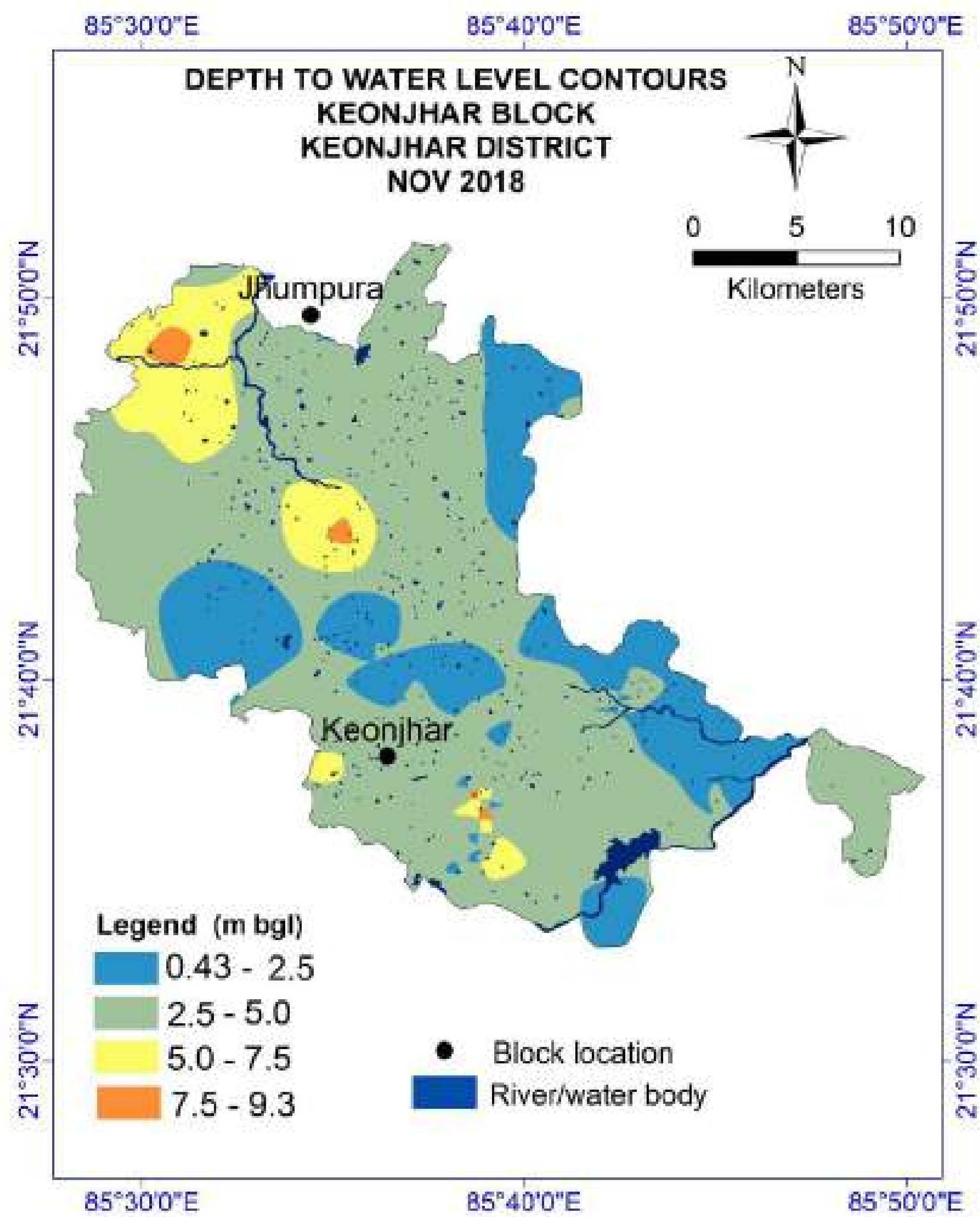

85°30'0"E
85°40'0"E
85°50'0"E
DEPTH TO WATER LEVEL CONTOURS
KEONJHAR BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0 5 10
Kilometers
21°50'0"N
21°40'0"N
21°30'0"N
Jhumpura
Keonjhar
Legend (m bgl)
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
Block location
River/water body

PLATE – 10.8



DEPTH TO WATER LEVEL CONTOURS
KEONJHAR BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 5 10
Kilometers
85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Jhumpura
Keonjhar
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
River/water body

PLATE – 10.9

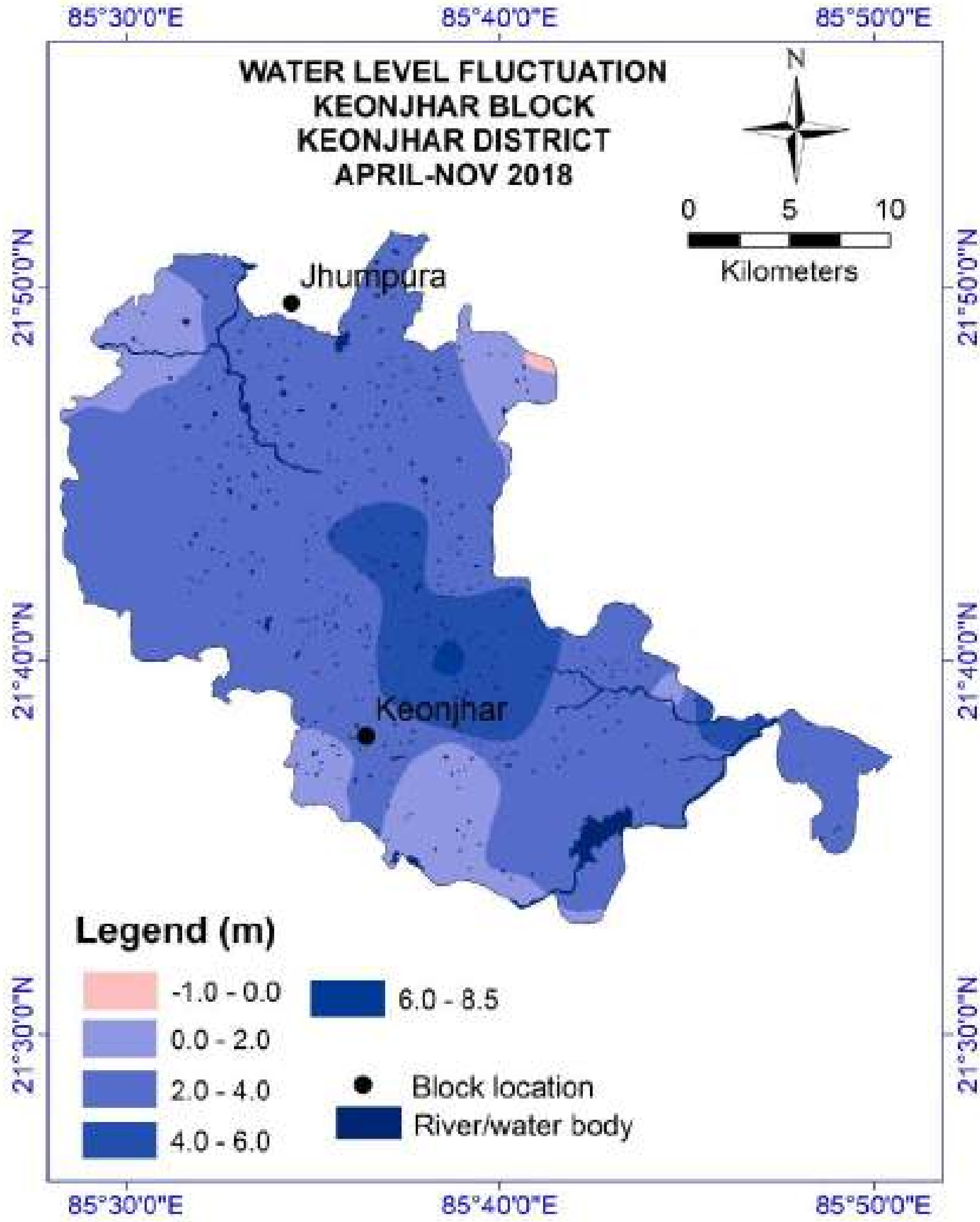

WATER LEVEL FLUCTUATION
KEONJHAR BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0 5 10
Kilometers
85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Jhumpura
Keonjhar
Legend (m)
-1.0 - 0.0
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
6.0 - 8.5
Block location
River/water body

PLATE – 10.10

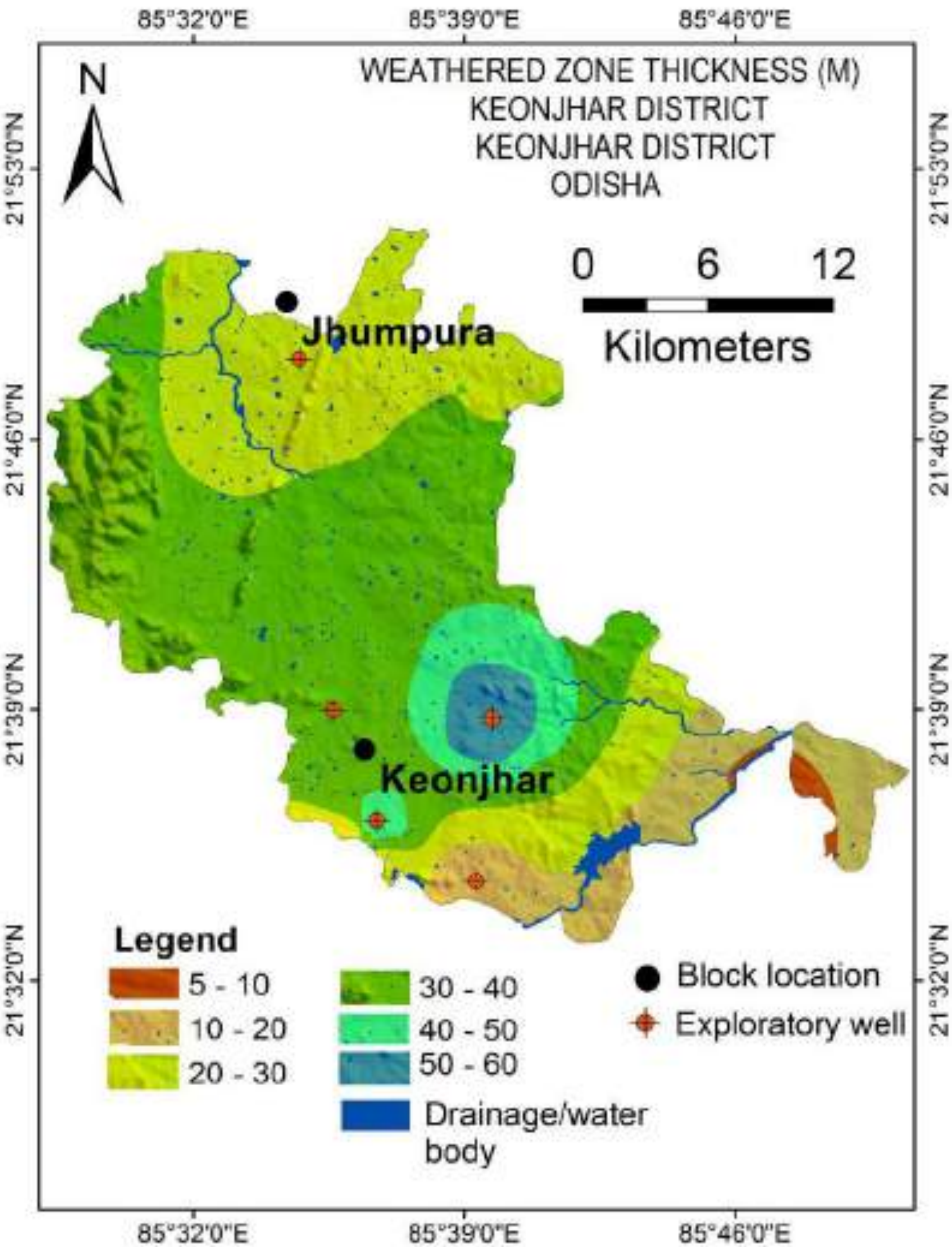

WEATHERED ZONE THICKNESS (M)
KEONJHAR DISTRICT
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
Jhumpura
Keonjhar
Legend
5 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
Drainage/water body
Block location
Exploratory well
85°32'0"E
85°39'0"E
85°46'0"E
21°53'0"N
21°46'0"N
21°39'0"N
21°32'0"N

PLATE – 10.11

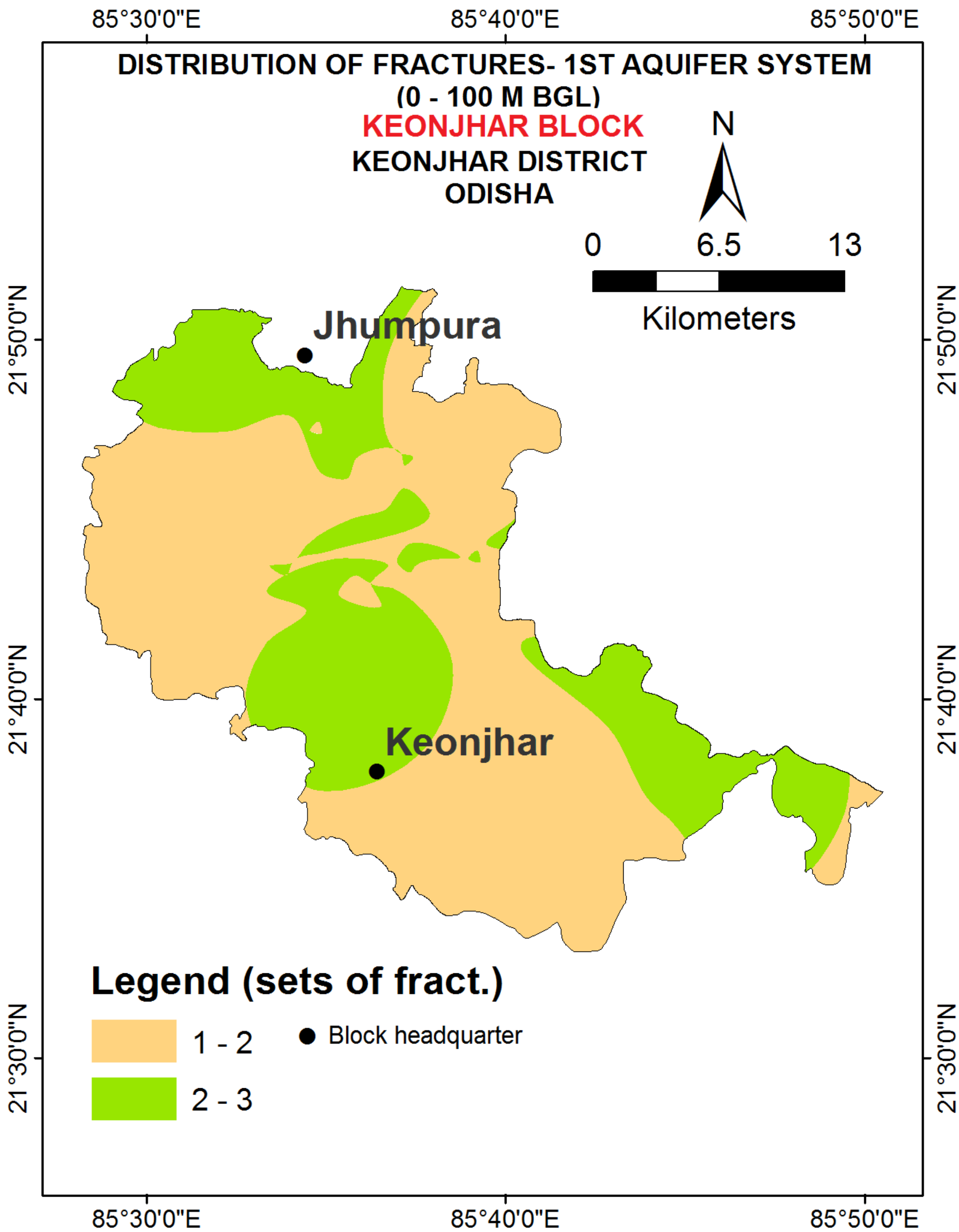
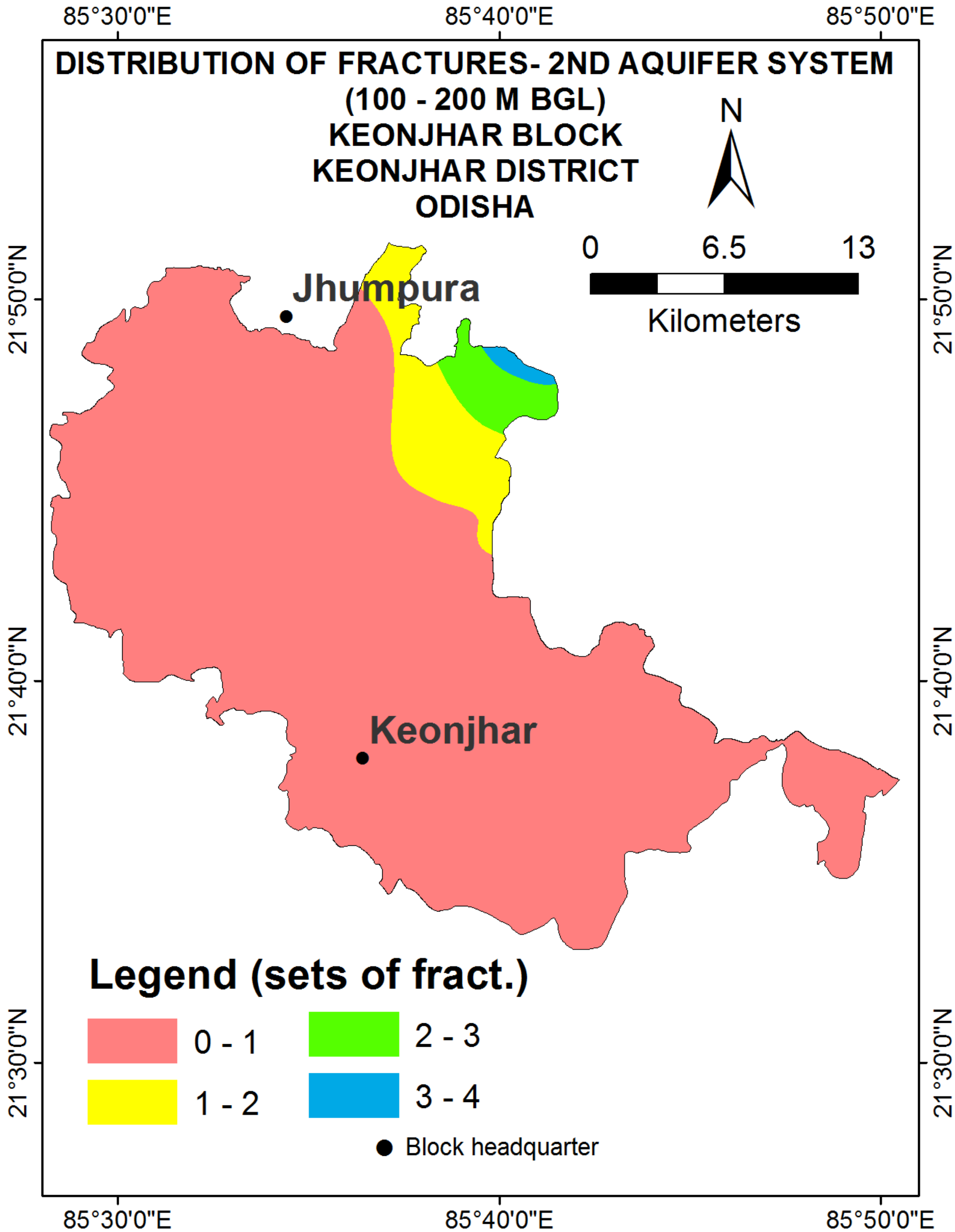

85°30'0"E
85°40'0"E
85°50'0"E
DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6.5
13
Kilometers
21°50'0"N
21°40'0"N
21°30'0"N
Jhumpura
Keonjhar
Legend (sets of fract.)
1 - 2
2 - 3
Block headquarter

PLATE – 10.12



DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6.5
13
Kilometers
Jhumpura
Keonjhar
Legend (sets of fract.)
0 - 1
1 - 2
2 - 3
3 - 4
Block headquarter
85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N

PLATE – 10.13

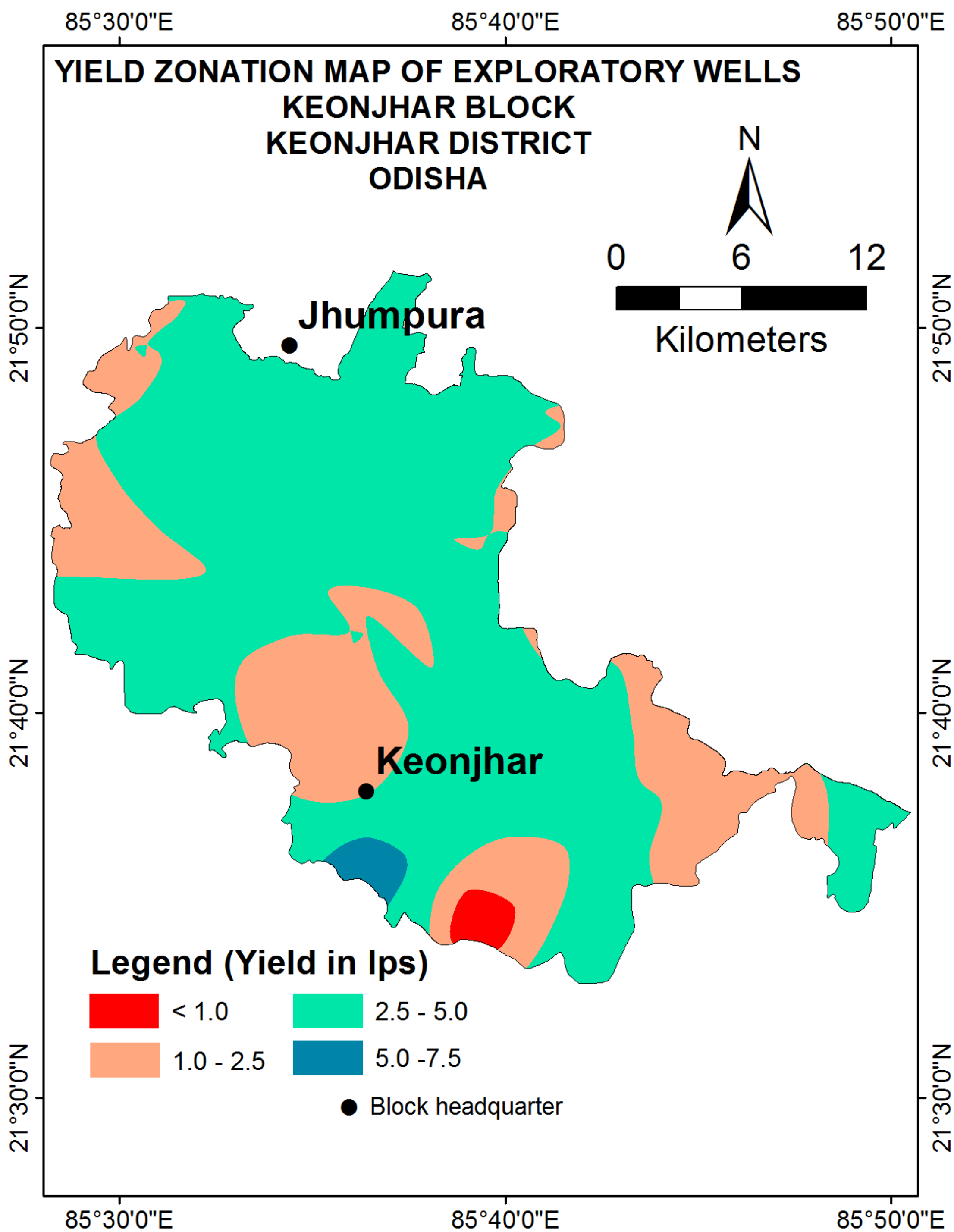

85°30'0"E
85°40'0"E
85°50'0"E
21°50'0"N
21°40'0"N
21°30'0"N
YIELD ZONATION MAP OF EXPLORATORY WELLS
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
Jhumpura
Keonjhar
Legend (Yield in lps)
< 1.0
2.5 - 5.0
1.0 - 2.5
5.0 -7.5
Block headquarter

PLATE – 10.14

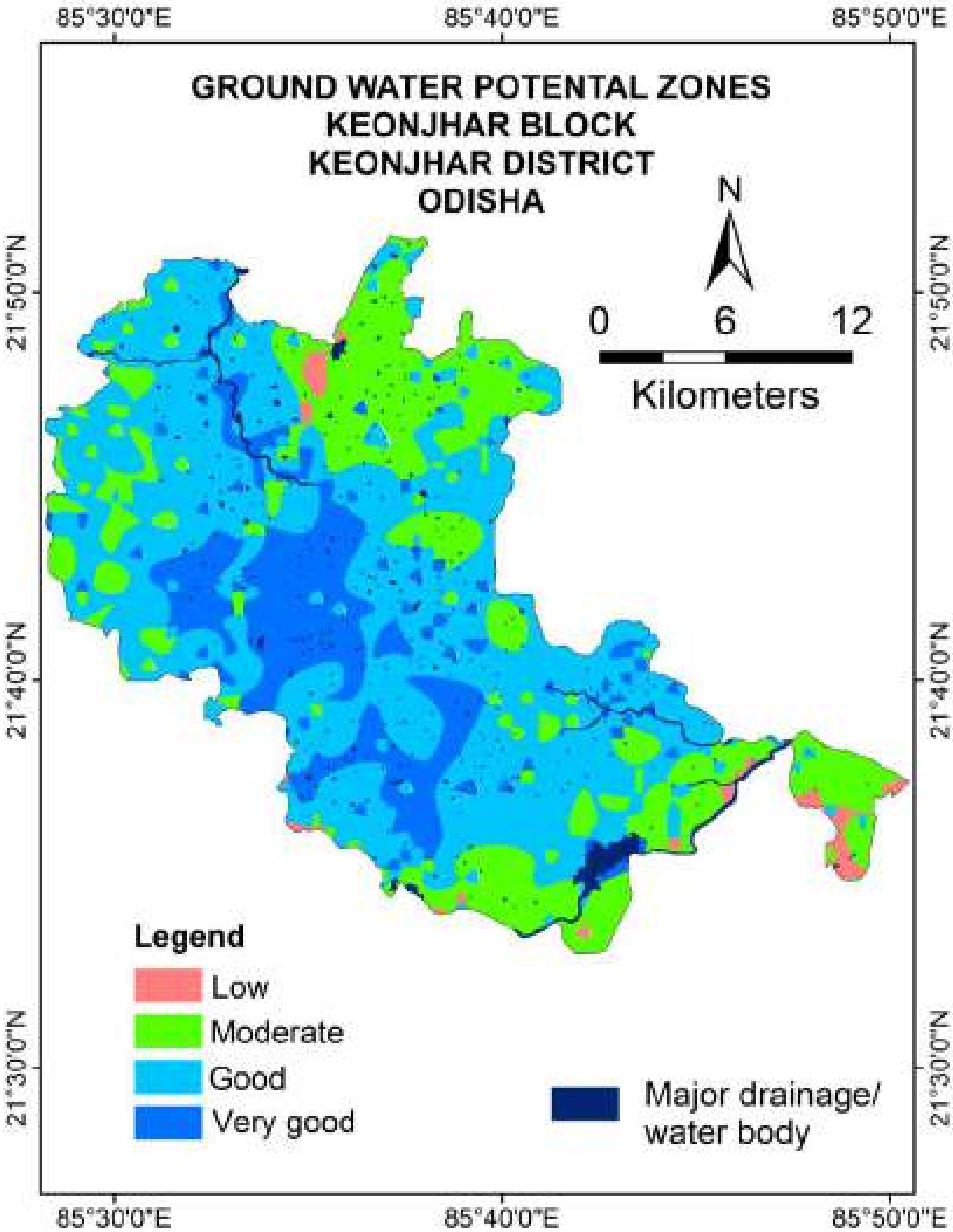
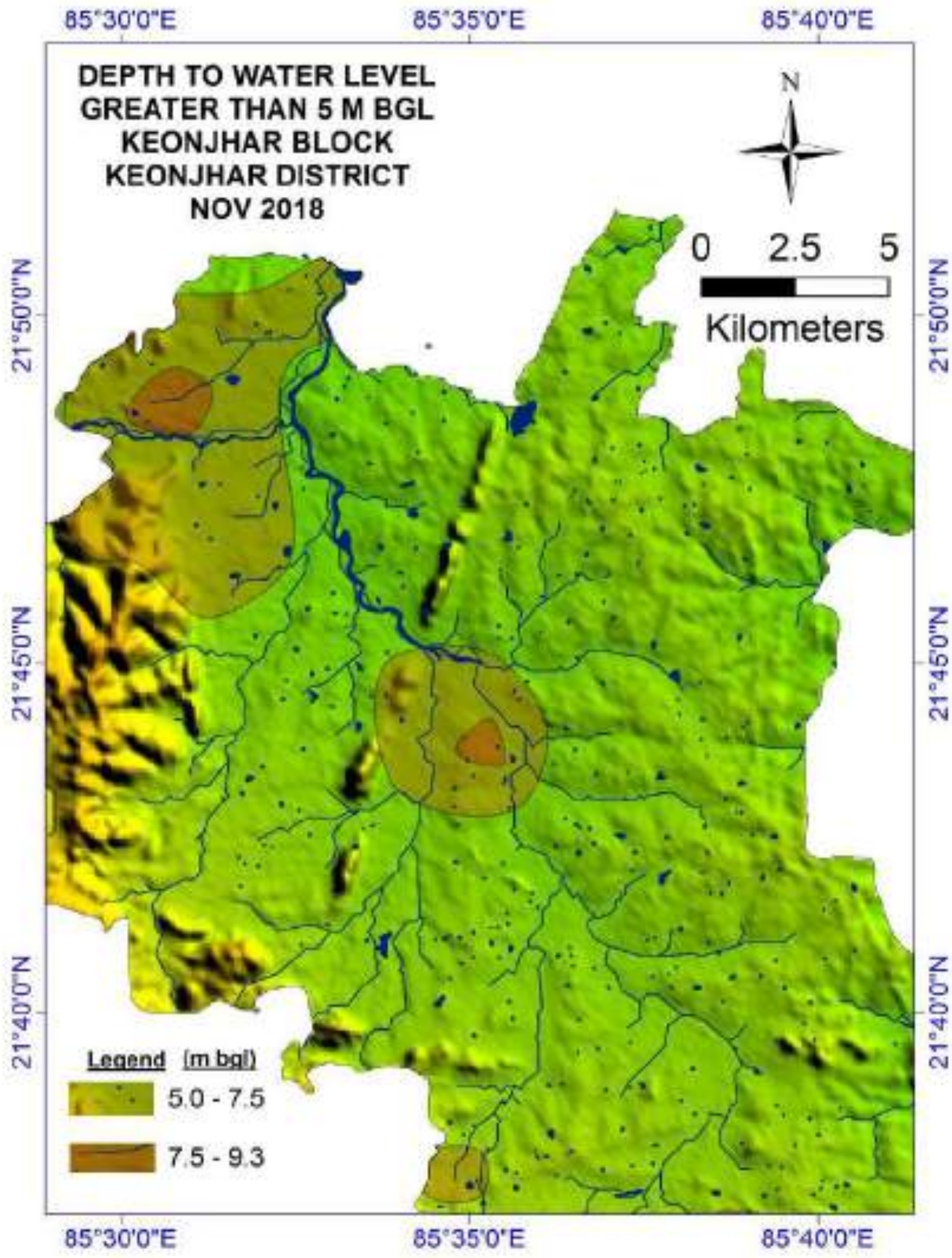

85°30'0"E
85°40'0"E
85°50'0"E
GROUND WATER POTENTAL ZONES
KEONJHAR BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
21°50'0"N
21°40'0"N
21°30'0"N
Legend
Low
Moderate
Good
Very good
Major drainage/
water body

PLATE – 10.15


DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
KEONJHAR BLOCK
KEONJHAR DISTRICT
NOV 2018
85°30'0"E
85°35'0"E
85°40'0"E
21°50'0"N
21°45'0"N
21°40'0"N
N
0 2.5 5
Kilometers
Legend (m bgl)
5.0 - 7.5
7.5 - 9.3

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

7.0 PATNA BLOCK

7.1 Salient information

Location, area and demography

Location (Plate 11.1)	85^0 40' - 86^0 05' E longitude 21^0 25' – 21^0 50'' N latitude
Area	423 sq. km
No. of Gram Panchayats	20
No. of villages	153
Population (Census 2011)	1,01,518
Literacy	58.63%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1155.3 mm
Monsoon normal rainfall	891.3 mm (77% of total)

Land use, agriculture and irrigation

Gross cropped area (1)	31270 Ha
Net sown area (2)	23799 Ha
Area sown more than once (1-2)	7471 Ha
Cropping intensity (%)	131.4 Ha
Area under forest	9721 Ha
Area under wasteland	1235 Ha
Area under other uses	11453 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	13429 Ha *Kharif:* 9785 Ha *Rabi:* 3644 Ha

7.2 Drainage, geomorphology and soil types

The Baitarani River, flowing along the eastern and southern border of the Patna block in south/south-east direction forms its principal drainage. The tributaries that join the river in the block include the Mermeda, Neorojol and Sita (Plate 11.2). The drainage pattern is dendritic to sub-trellis in nature. Several small water bodies are found in the northern half of the block (Plate 11.2).

The pediments, buried pediments and valley fills form the major hydro-geomorphic units in the block, combinedly covering 89% of the block area. These units are considered as potential from as far as groundwater occurrenec is concerned. The denudational hills occupy around 6% of the block area in the south-east corner. (Fig 11.1; Plate 11.3). There are several linear basic (dolerite) dykes in the block that run in NE-SW and NW-SE directions. A dyke in NW-SE direction runs about 40 km in the middle of the block (Plate 11.3). Except the hills in south-east corner (Plate 11.4), 90% of the block area depicts land surface slope of <5% (Fig 11.2). The soil types include the red loamy (alfisol) and red and yellow soils (ultisol).

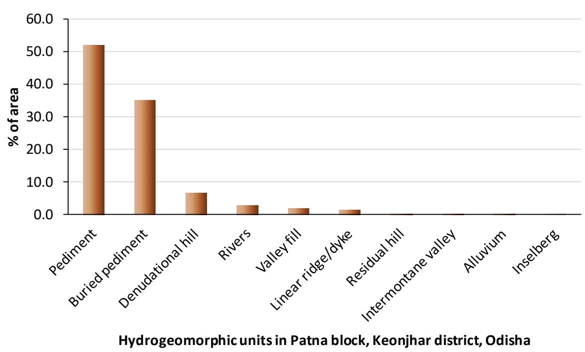


Figure 11.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Patna block.

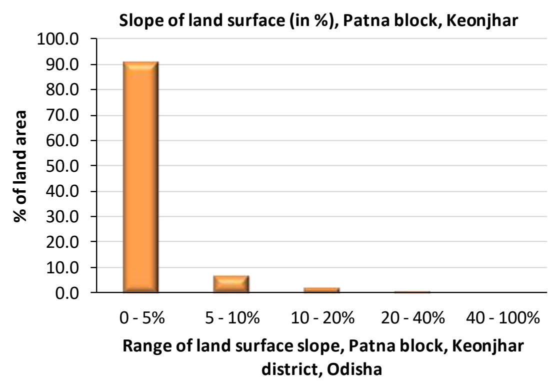


Figure 11.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Patna block, Keonjhar district.

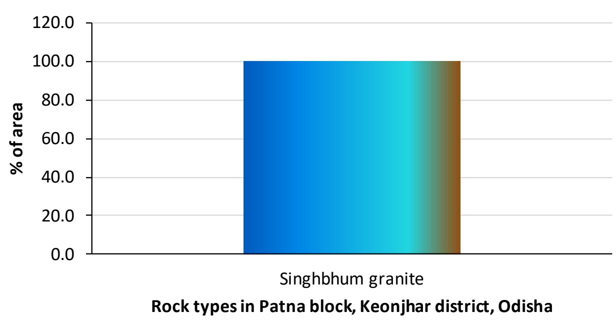


Figure 11.3: Percentage (%) of Patna block area (Keonjhar dist.) covered by various rock types.

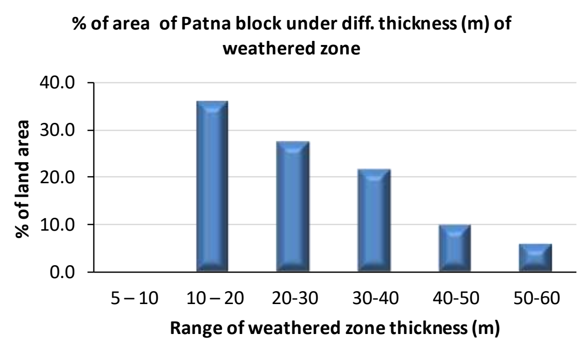


Figure 11.4: Bar diagram depicting the percentage (%) area of Patna block, Keonjhar district falling under different weathered zone thickness (m) ranges.

7.3 Geology

Entire block is occupied by the Singhbhum Granites. Only the basic dolerite dykes traverse the country rock at places (Fig 11.3 and Plate 11.5).

7.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories in the hard rock areas of the block. The generalized hydrogeological map of the block is presented in Plate 11.7. The Singhbhum Granites posses low to moderate yield potential varying between 3-10 lps.

Though, parts of the block in north in the along the Baitarani and in basins of Mermeda and Neorojol depicted water levels <5.0 m bgl, in major parts of the block those remained >5.0 m bgl (Plate 11.7). However, during the post-monsson period, the entire block registered water levels in the range of 0.43-5.0 m bgl, indicating good recharge from rainfall (Plate 11.8). The annual fluctuations in the water levels remained less than 2.0 m in parts along the Baitarani River and the Mermeda, Neorojol river basins (Plate 11.9). In other parts, it remained largely between 2-4 m.

7.5 Aquifer geometry and characters

The thickness of the weathered regolith overlying the fresh hard rock varies between 10–60 m (Plate 11.10). In the central and eastern parts it remains less than 20 m, whereas It increases up to 60 m in the western parts. The thickness in the range of 20-60 m covers 64% of the block area (Fig 11.4). The thick weathered zones form good prospect for groundwater to dug wells and shallow tube wells. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 11.5a-b.

In the block, maximum up to 4 sets of fracture zones are encountered in bore wells within the depth of 100 m bgl (1st aquifer system). The eastern parts are depleted in fractures in comparison to the western parts (Plate 11.11). In the 2nd aquifer system (100-200 m bgl), commonly 0-1 sets of fractures are found which increases up to 1-2 fractures in the western and south-central parts (Plate 11.12). Though, there are more fractures in the western parts, the yield in wells remained <2.5 lps in major cases. In the eastern parts, yield up to 10 lps has been observed (Plate 11.13).

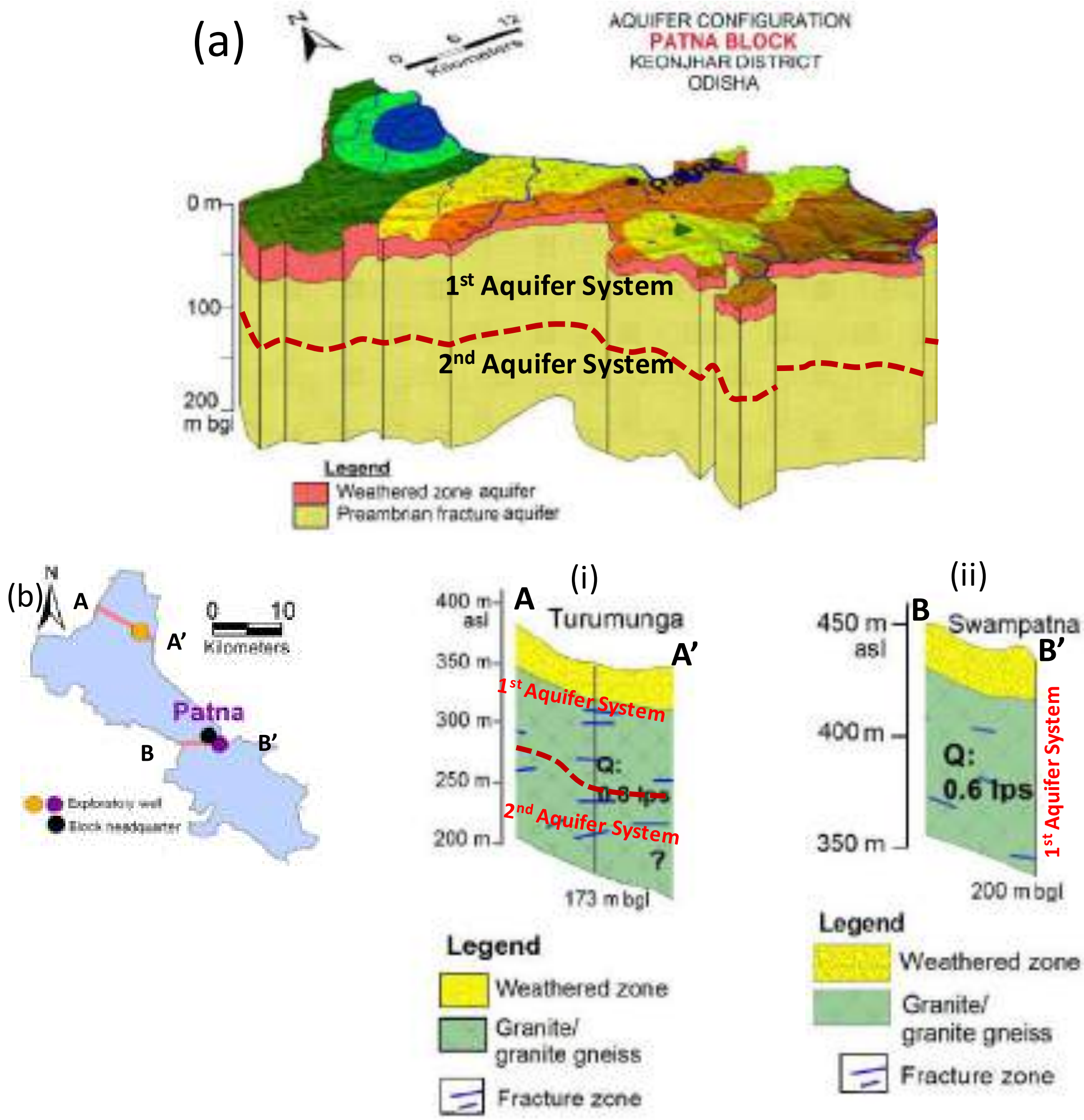


Figure 11.5: (a) 3D aquifer disposition in Patna block, Keonjhar district. (b) (i) (ii) 2D hydrogeological transects (including their locations) A-A' and B-B' depicting the aquifer disposition in the block.

7.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered

zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 11.14). The analysis indicated the good to very good groundwater potential zones largely falling in the in the western parts. 67% of the block area has been delineated to have godd to very good groundwater potential (Fig 11.6).

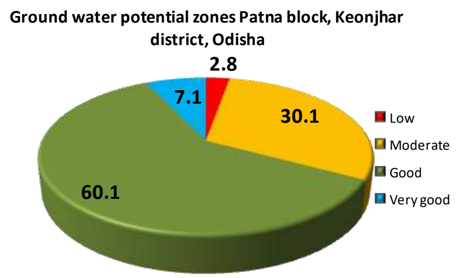


Figure 11.6: Pie diagram depicting the perentage (%) of Patna block, Keonjhar district, Odisha, falling under different groundwater potential zones.

7.7 Ground water quality

Ground water in the block is alkaline in nature (Table 11.1) and pH range of 7.11-8.37. The water is soft to hard in nature. The mineralization is low to moderate with TDS in the range of 52-442 mg/L (ave.: 181 mg/L). Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly Ca-HCO_3 types with Ca^{2+} and HCO_3^- as the principal contributing ions in the groundwater quality (Fig 11.7).

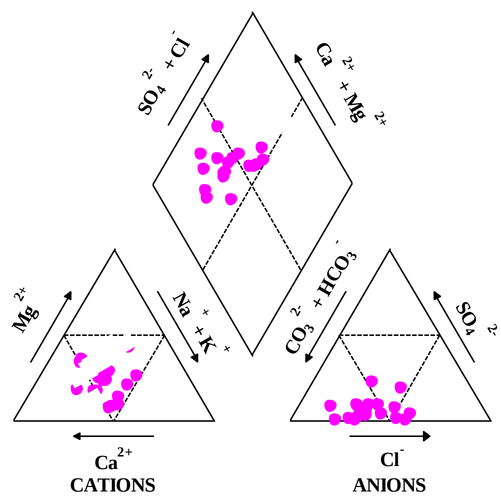


Figure 11.7: The Piper trilinear diagram depicting the groundwater quality in Patna block, Keonjhar district.

Table 11.1: Ground water quality at various locations in Patna block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Hirapasi	7.5	130	68	36	46	10	2	12.13	0.93	0	49	15	1	0.17
Childa	7.11	100	52	26	21	8	1	9.31	1.73	0	25	20	0	0.13
Kantiapada	8.3	410	203	143	165	37	12	27.51	0.4	0	180	23	14.5	0.83
Jodichatar	7.5	300	154	97	98	29	6	21.24	2.91	0	107	38	4.1	0.29
Kendeipasi	8.3	350	175	117	149	35	7	25.1	0.34	0	163	28	0	1.06
Baunsuli	8.15	230	117	87	88	27	5	9.79	3.67	0	96	23	1	0.17
Nuapada	8.37	650	340	209	167	47	22	37	21.91	15	173	100	10	0.23
Rudhiapada	8.09	230	121	68	71	18	6	11	10.42	0	86	23	10	0.13
Dianali	8.14	200	98	59	56	15	6	13	3.04	0	68	20	7	0.17
Patana	7.81	240	126	68	51	9	11	17	1.55	0	62	23	23	0.06
Saraskula	8.36	760	442	195	131	67	7	45	52.9	12	136	123	68	0.36
Burikhapuri	8.16	235	124	100	83	24	10	8.7	0.67	0	102	29	0.2	0.30
Kendeiposi	8.24	360	205	150	118	34	16	25	0.53	0	143	50	7.8	0.86
Khireitangri	7.97	785	410	330	196	76	34	22	15.33	0	239	110	32.7	0.55
Malliposi	7.61	225	136	65	54	16	6	21	8.99	0	66	43	8.4	0.12
Swampatna	7.66	445	250	155	123	40	13	17	31.3	0	149	55	19	0.14
Tangarpada	7.3	175	109	50	39	10	6	21.58	0.85	0	48	43	3.7	0.81
Turumunga	7.84	245	137	70	59	24	2	23.73	2.49	0	72	48	1.2	0.28
Min.:	**7.11**	**100**	**52**	**26**	**21**	**8**	**1**	**8.7**	**0.34**	**0**	**25**	**15**	**0**	**0.06**
Max.:	**8.37**	**785**	**442**	**330**	**196**	**76**	**34**	**45**	**52.9**	**15**	**239**	**123**	**68**	**1.06**
Average	**7.9**	**337.2**	**181**	**112.5**	**95.3**	**29.2**	**9.6**	**20.4**	**8.9**	**1.5**	**109.1**	**45.2**	**11.8**	**0.4**

7.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 11.2-11.4. The net dynamic groundwater available is 6252.2 Ham and the stage of groundwater development stands at 49.2%. Net resource available for future irrigation needs stands at 3151.0 Ham (Fig 11.8). The instorage/static groundwater resource component of 4511.9 Ham (Table 11.3) comes from the 1st aquifer system within 100 m bgl. The total groundwater available in the block stands at 10773.8 Ham.

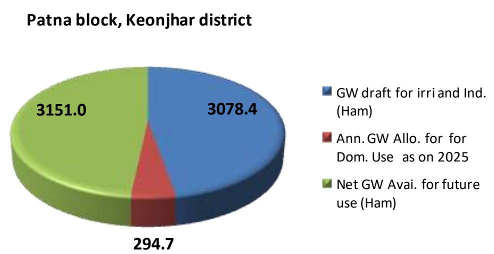


Figure 11.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Patna block, Keonjhar district, Odisha.

Table 11.2: Salient information on annual dynamic groundwater resources, Patna block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	6252.2
2. Irrigation draft (Ham)	2796.5
3. Industrial draft (Ham)	10.0
4. Domestic draft (Ham)	272.0
5. Total draft (Ham)	3078.4
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	294.7
7. Net groundwater available for future use (Ham)	3151.0
8. Stage of groundwater extraction (%)	49.2

Table 11.3: Total groundwater resoure available in the Patna block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	6252.2
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	4511.9
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	9.6
	Block total	**10773.8**

7.9 Aquifer management plan

The existing stage of groundwater development of 49.2% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction

structures as estimated in Table 11.4 (152 bore wells/dug-cum-bore wells and 1294 dug wells) are required to be constructed to develop the available additional resource of 3151.0 Ham. It can help in creating additional irrigation potential for 1076.6 Ha (Table 11.5).

A very negligible area of only 1.10 km^2 in the block showed post-monsoon depth to water levels >5.0 m bgl (Plate 11.15; Table 11.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. Volume of water required for recharge is only 0.1 MCM (Table 11.7), which can be attained by constructing either a percolation tank or a check dam (Table 11.8). The total cost may vary between 15-20 lakh (Table 11.9).

Table 11.4: Number of additional feasible groundwater abstraction structures in Patna block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	6252.2
2	Stage of GW deve. (%)	49.2
3	Present GW draft (Ham)	3078.4
4	Ground water draft at 60% stage of deve. (Ham)	3751.3
5	Addi. water to be deve. (Ham)	672.9
6	Addi. No of BW/ STW feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	152
7	Addi. No. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	1294

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 11.5: Irrigation potential likely to be created in Patna block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	49.2
2	Surplus GW avai. for 60% stage of deve. (Ham)	672.9
3	Irri, Pot. likely to be created for Paddy (Ha)	403.7
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	336.4
5	Irri. Pot. likely to be created for veg. (Ha)	336.4
6	Proj. area to be Irri. (ha)	1076.6

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 11.6: Areas in Patna block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Patna	1.10	0.00	1.10

Table 11.7: Estimation of volume of water required for artificial recharge to groundwater in Patna block, Keonjhar district.

Name of block	Total area of the block (km^2)	Area identified for artificial recharge (km^2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to reharge (MCM)
Patna	423.00	1.10	6	3	3.30	0.10

Table 11.8: Number of feasible structures in Patna block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (MCM)	No of different freasible structures			
		Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
Patna	0.10	1	0	0	1

Table 11.9: Estimation of cost of artificial recharge structures in Patna block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Patna	0.2	0.00	0.00	0.15	0.15-0.20

PLATE – 11.1

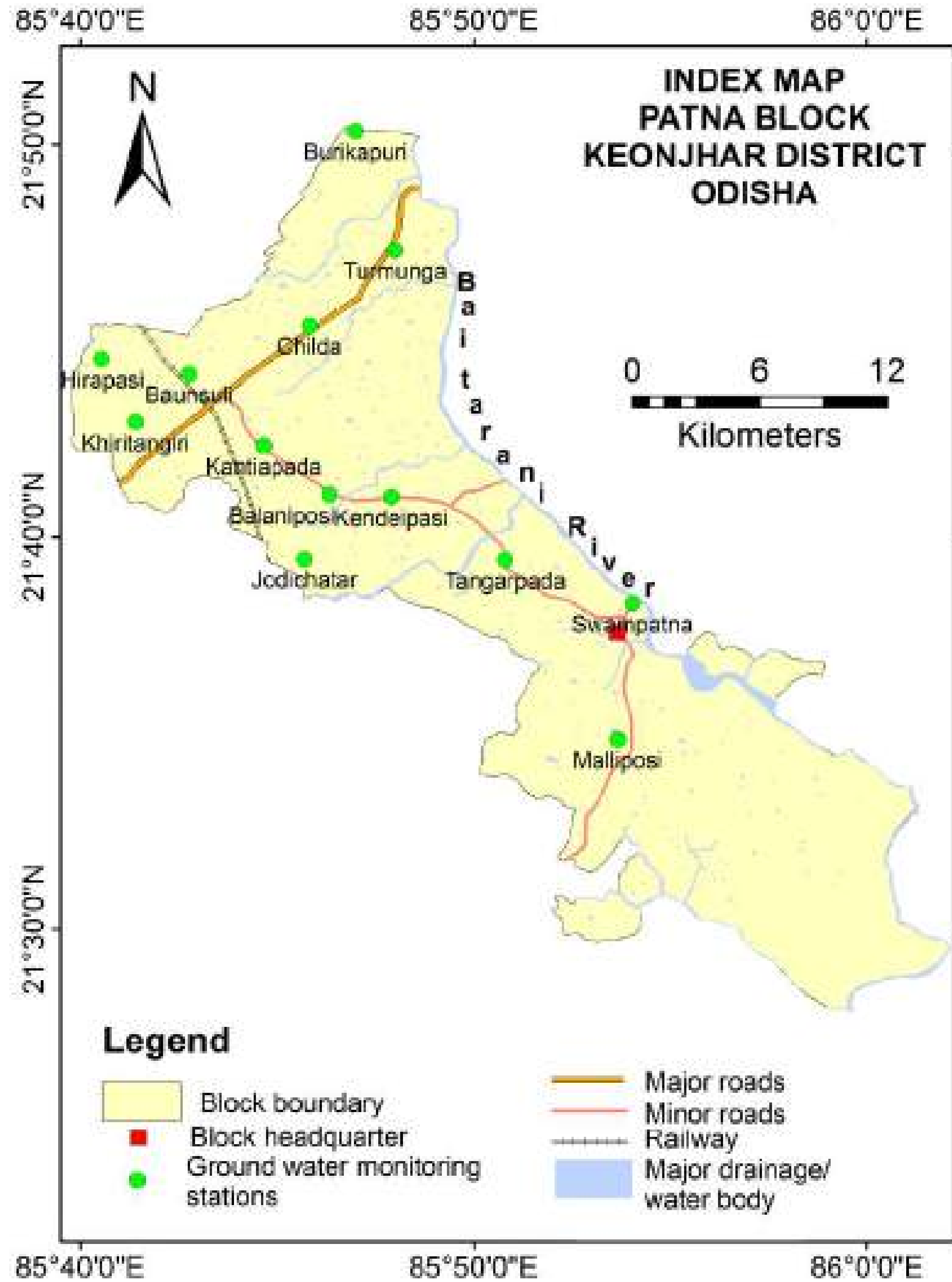

85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
N
INDEX MAP
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
0 6 12
Kilometers
Burikapuri
Turmunga
Childa
Hirapasi
Baunsuli
Khiritangiri
Kantiapada
Balanipos
Kendeipasi
Jodichatar
Tangarpada
Swampatna
Mallipos
Baitarani River
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body

PLATE – 11.2

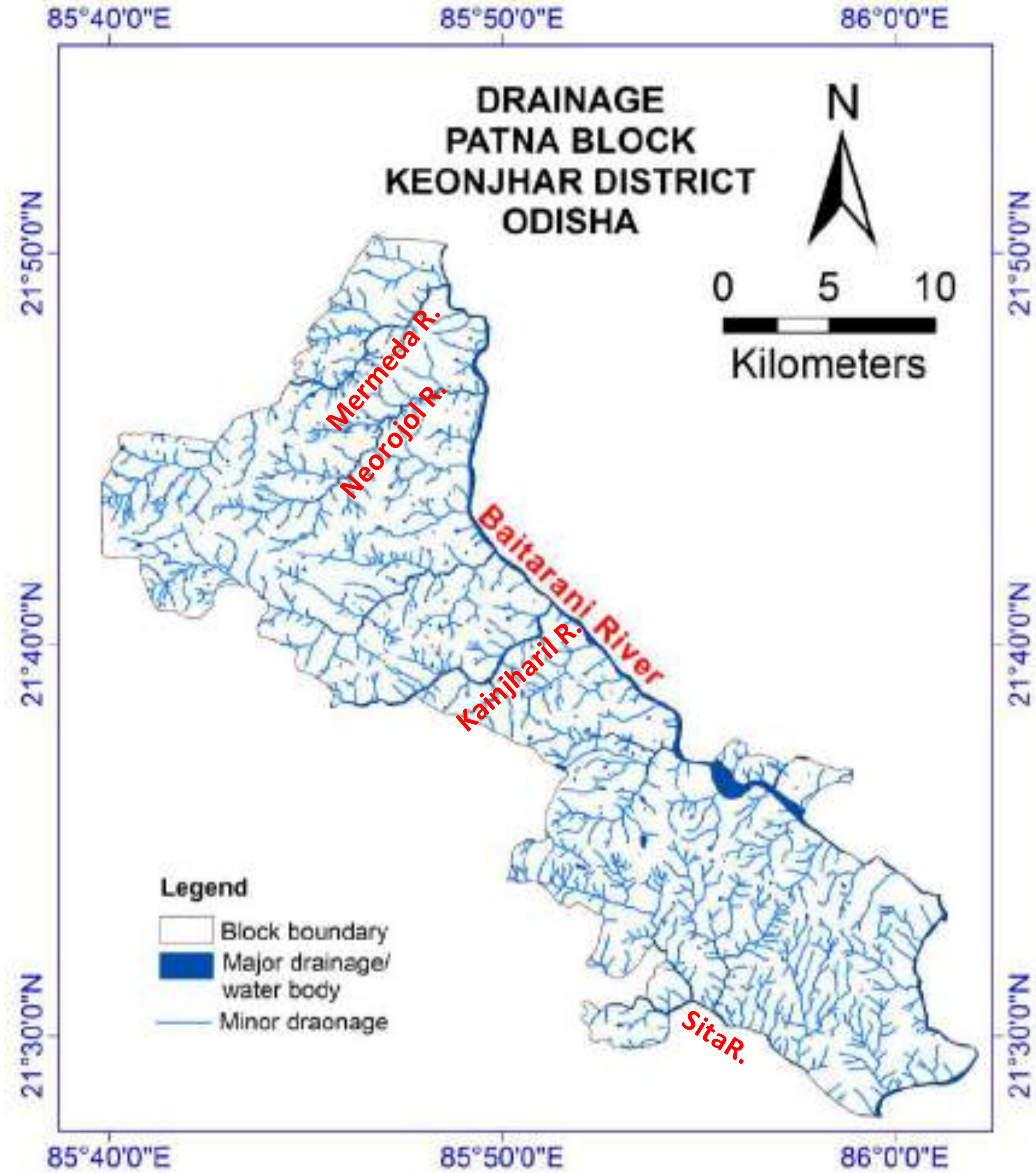

DRAINAGE
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Mermeda R.
Neorojol R.
Baitarani River
Kainjharil R.
SitaR.
Legend
Block boundary
Major drainage/ water body
Minor draonage

PLATE – 11.3

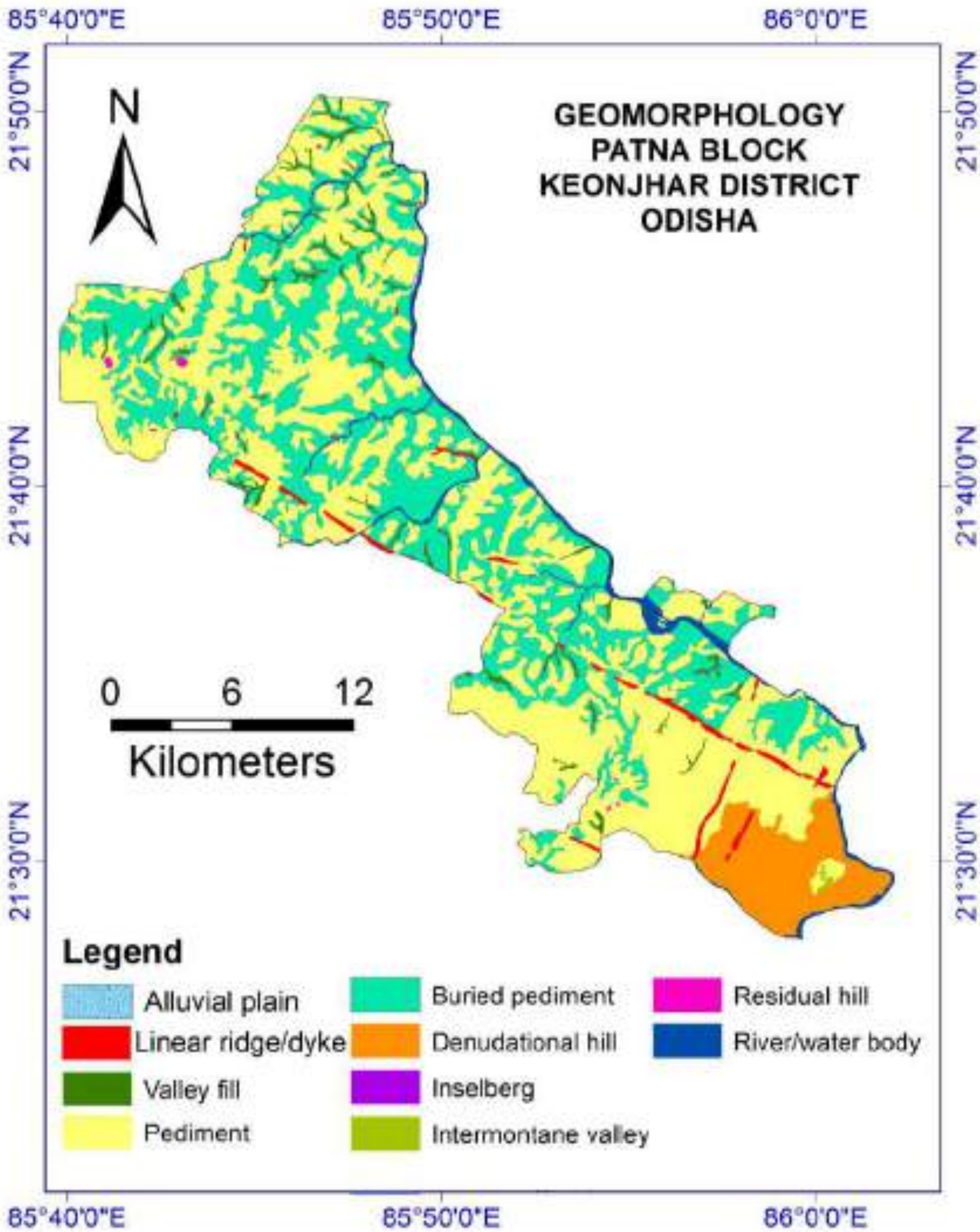

85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
N
GEOMORPHOLOGY
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
0 6 12
Kilometers
Legend
Alluvial plain
Linear ridge/dyke
Valley fill
Pediment
Buried pediment
Denudational hill
Inselberg
Intermontane valley
Residual hill
River/water body

PLATE – 11.4

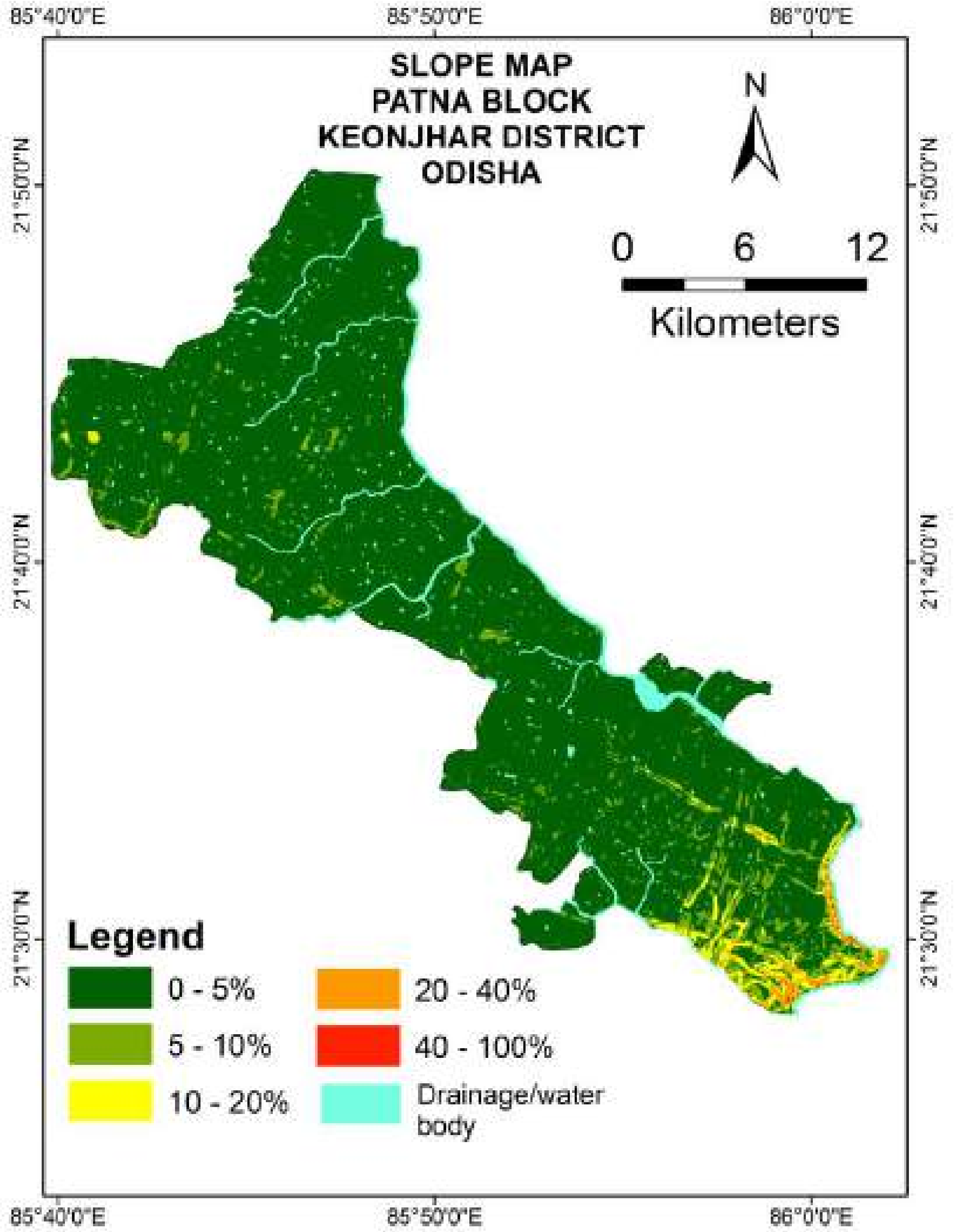
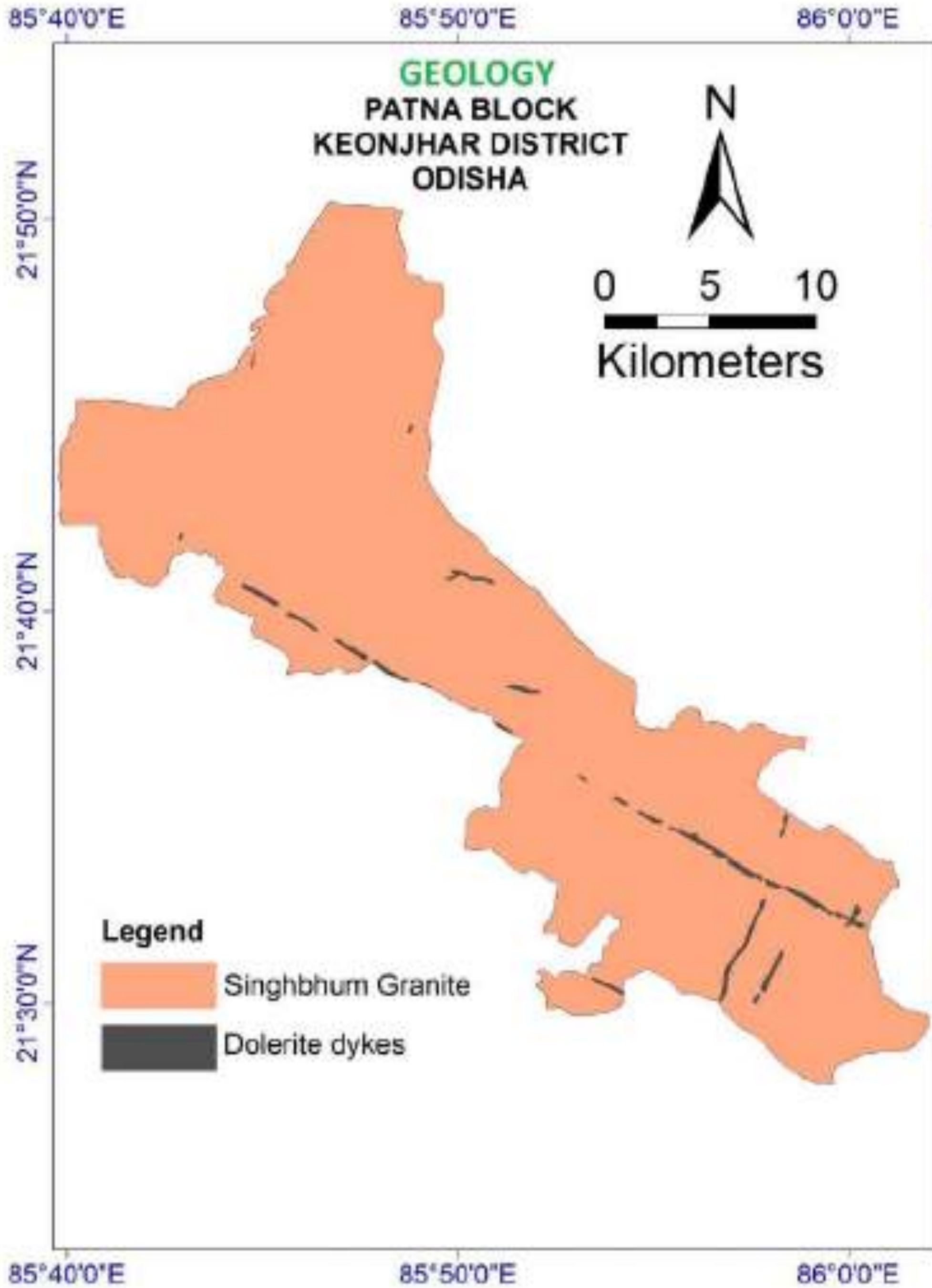
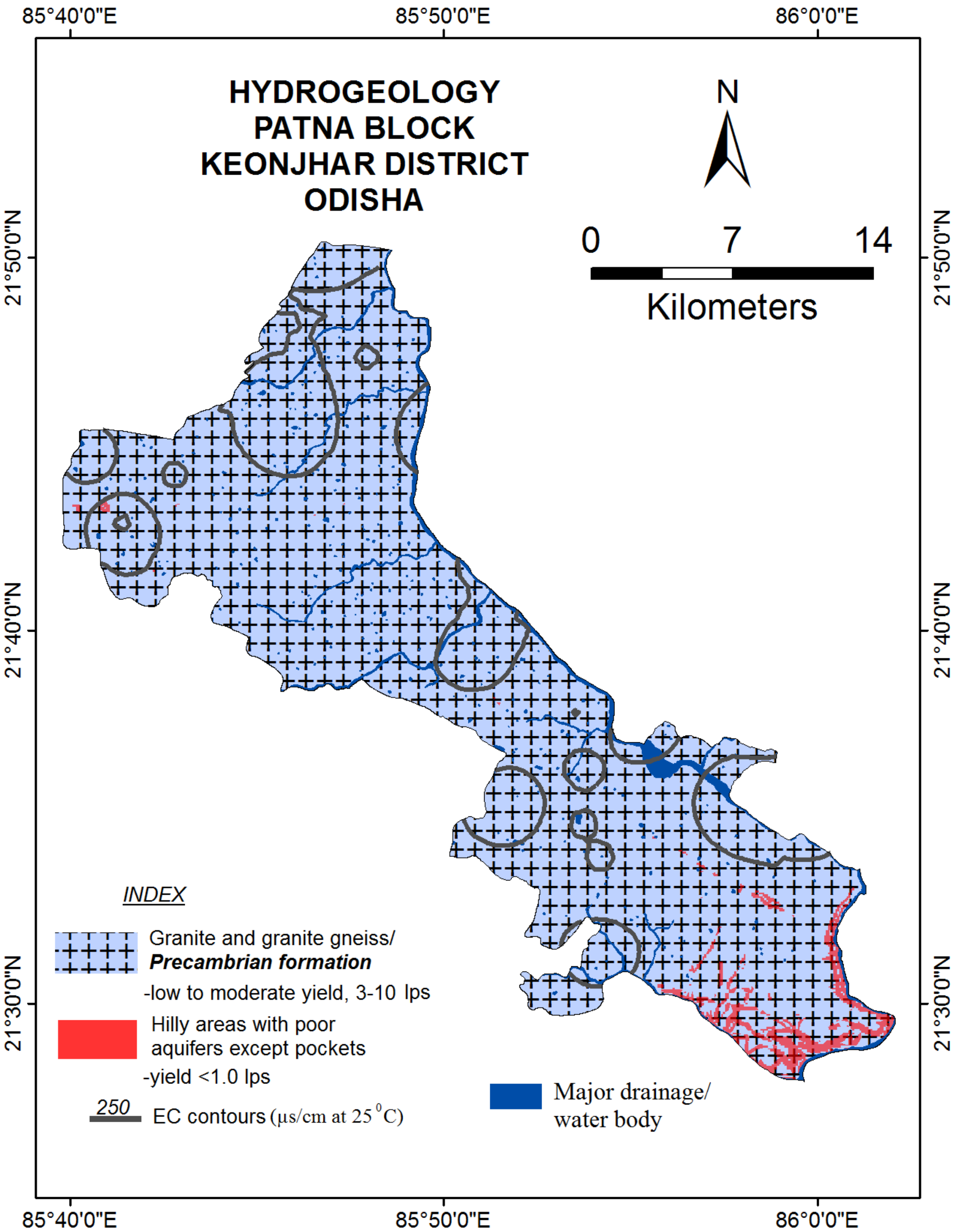

85°40'0"E
85°50'0"E
86°0'0"E
SLOPE MAP
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
21°50'0"N
21°40'0"N
21°30'0"N
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 11.5



GEOLOGY
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Legend
Singhbhum Granite
Dolerite dykes

PLATE – 11.6



85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
HYDROGEOLOGY
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 7 14
Kilometers
INDEX
Granite and granite gneiss/
Precambrian formation
-low to moderate yield, 3-10 lps
Hilly areas with poor
aquifers except pockets
-yield <1.0 lps
250
EC contours (μs/cm at 25 °C)
Major drainage/
water body

PLATE – 11.7

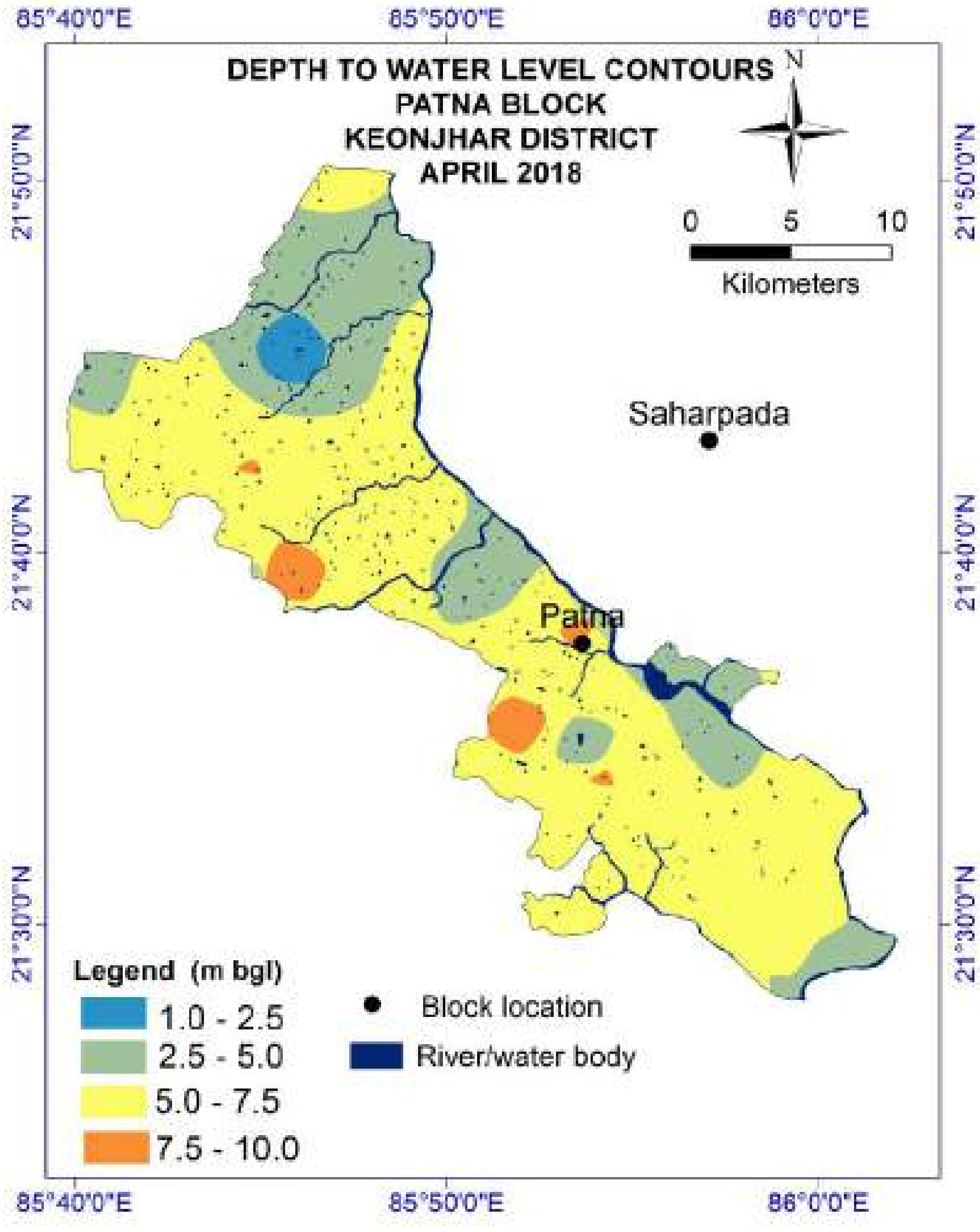

DEPTH TO WATER LEVEL CONTOURS
PATNA BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0 5 10
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Saharpada
Patna
Legend (m bgl)
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
Block location
River/water body

PLATE – 11.8

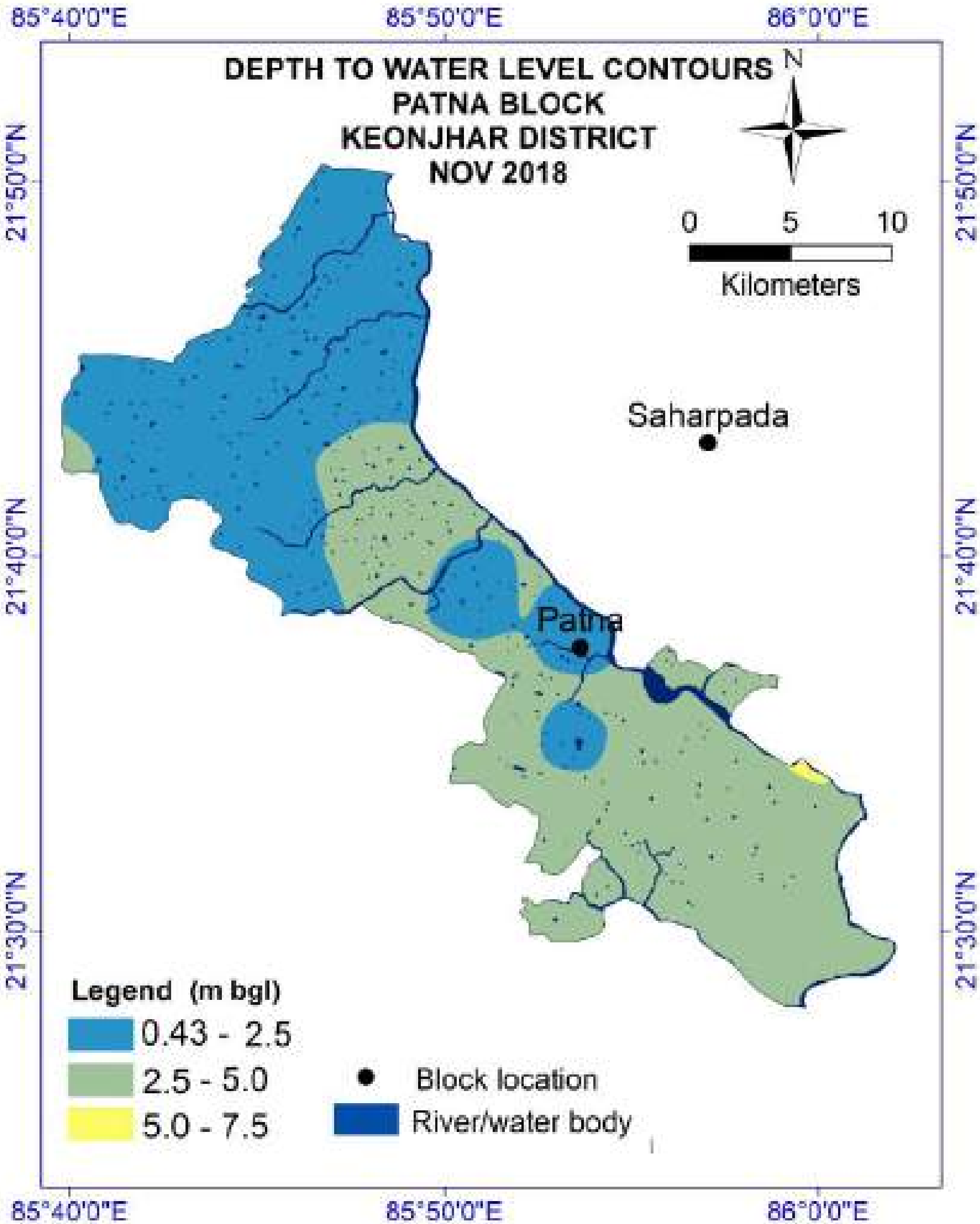

DEPTH TO WATER LEVEL CONTOURS
PATNA BLOCK
KEONJHAR DISTRICT
NOV 2018
85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
N
0 5 10
Kilometers
Saharpada
Patna
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
Block location
River/water body

PLATE – 11.9

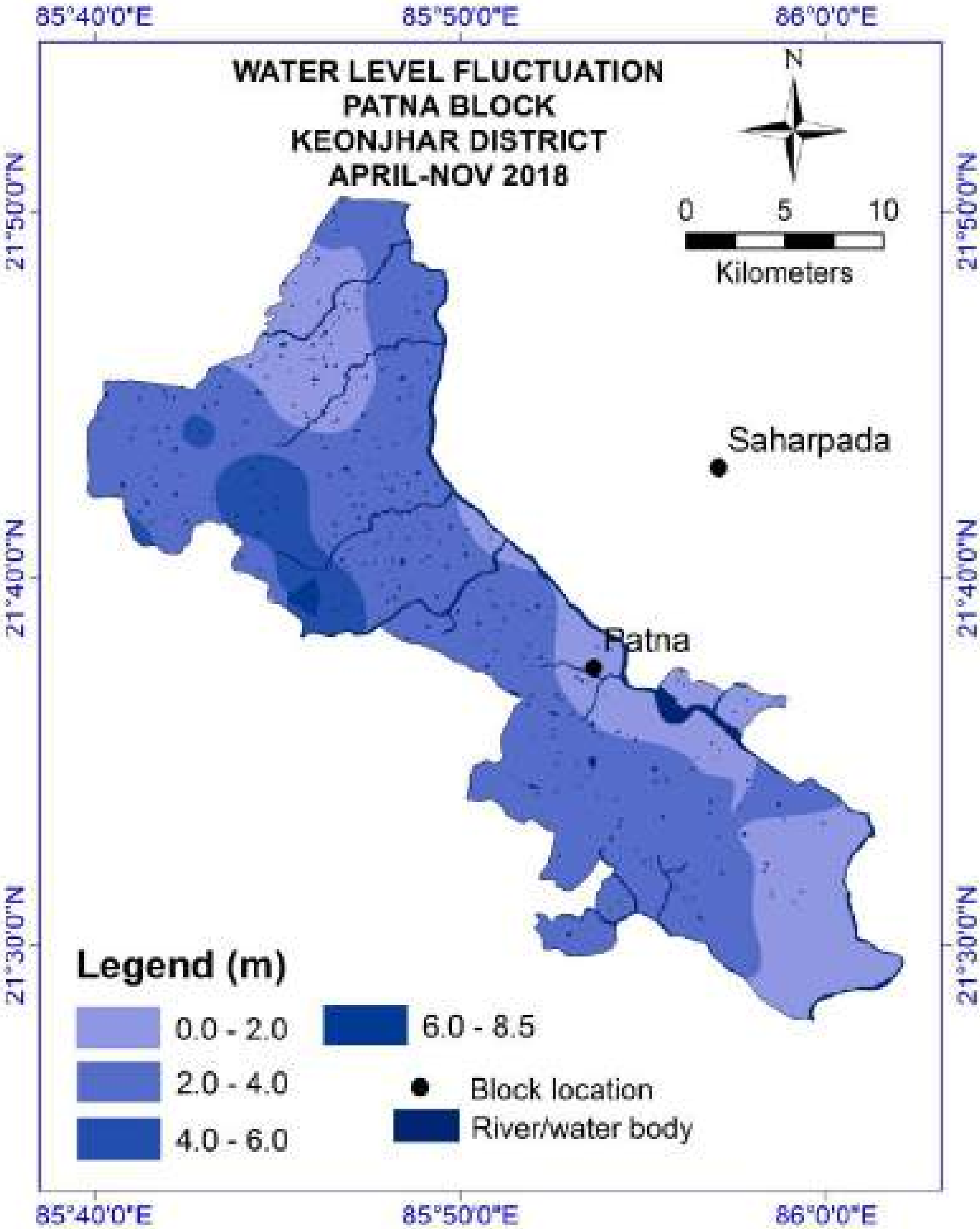

85°40'0"E
85°50'0"E
86°0'0"E
WATER LEVEL FLUCTUATION
PATNA BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0 5 10
Kilometers
21°50'0"N
21°40'0"N
21°30'0"N
Saharpada
Patna
Legend (m)
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
6.0 - 8.5
Block location
River/water body

PLATE – 11.10

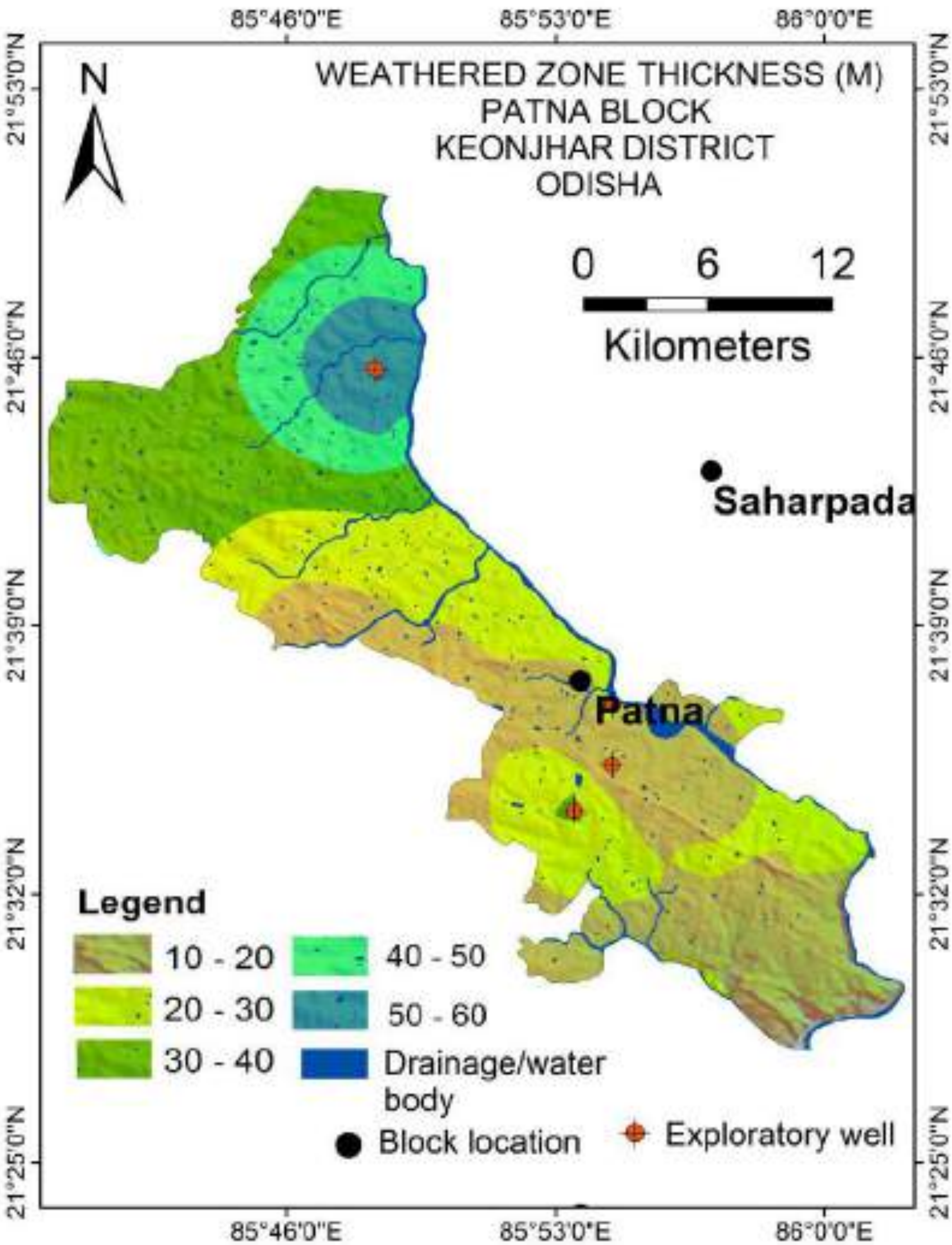

WEATHERED ZONE THICKNESS (M)
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
85°46'0"E
85°53'0"E
86°0'0"E
21°53'0"N
21°46'0"N
21°39'0"N
21°32'0"N
21°25'0"N
Saharpada
Patna
Legend
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
Drainage/water body
Block location
Exploratory well

PLATE – 11.11

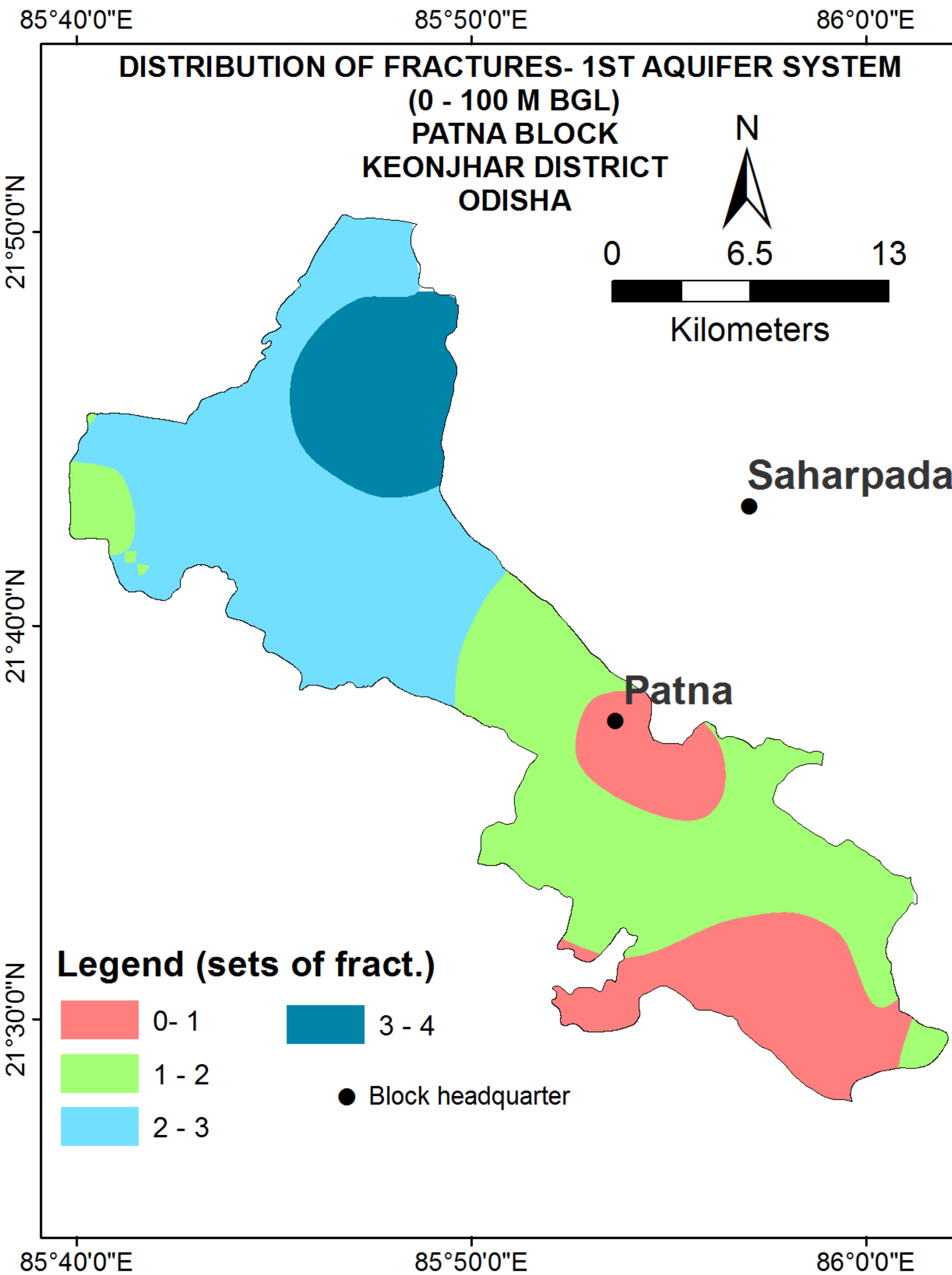

DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6.5
13
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Saharpada
Patna
Legend (sets of fract.)
0- 1
1 - 2
2 - 3
3 - 4
Block headquarter

PLATE – 11.12

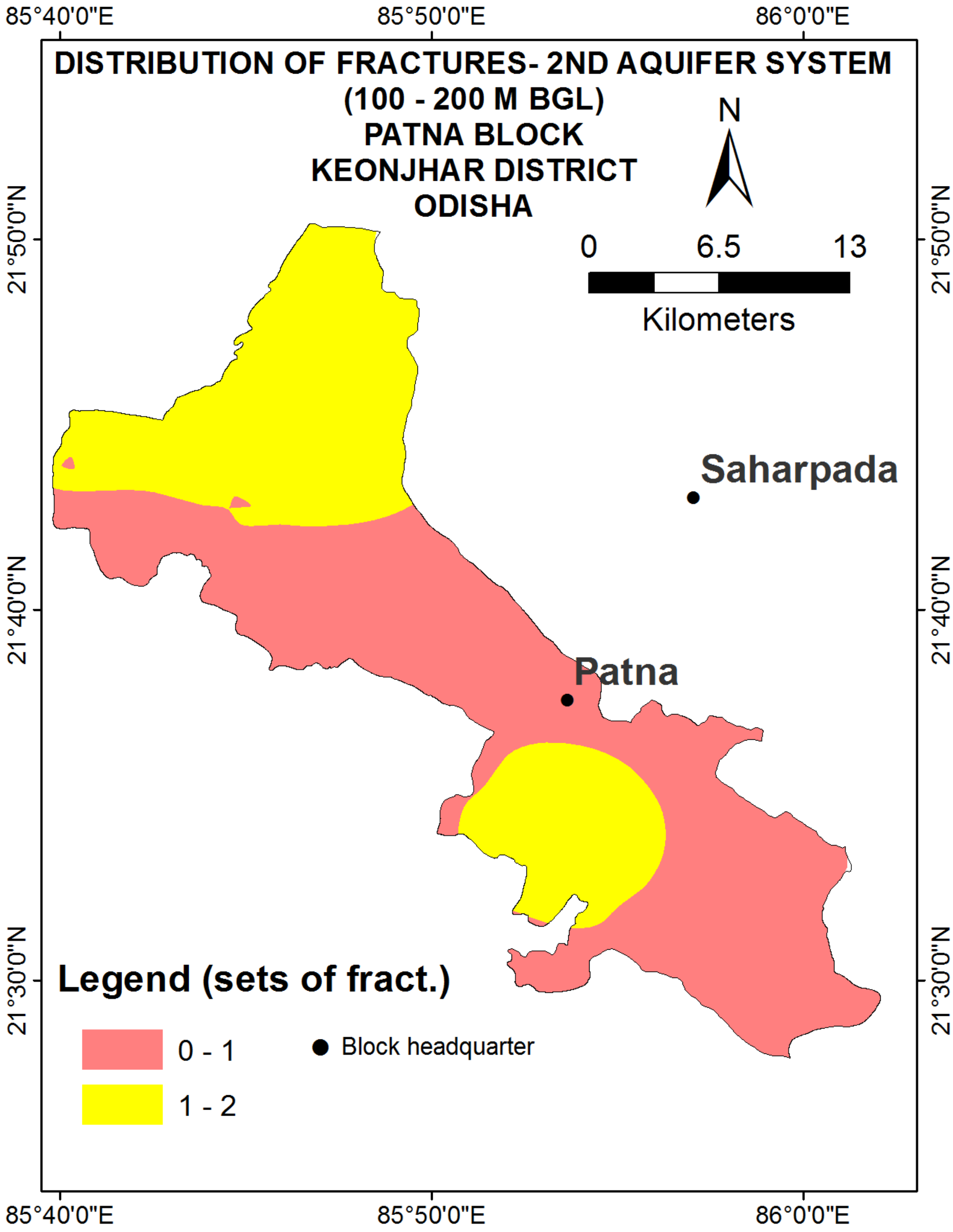
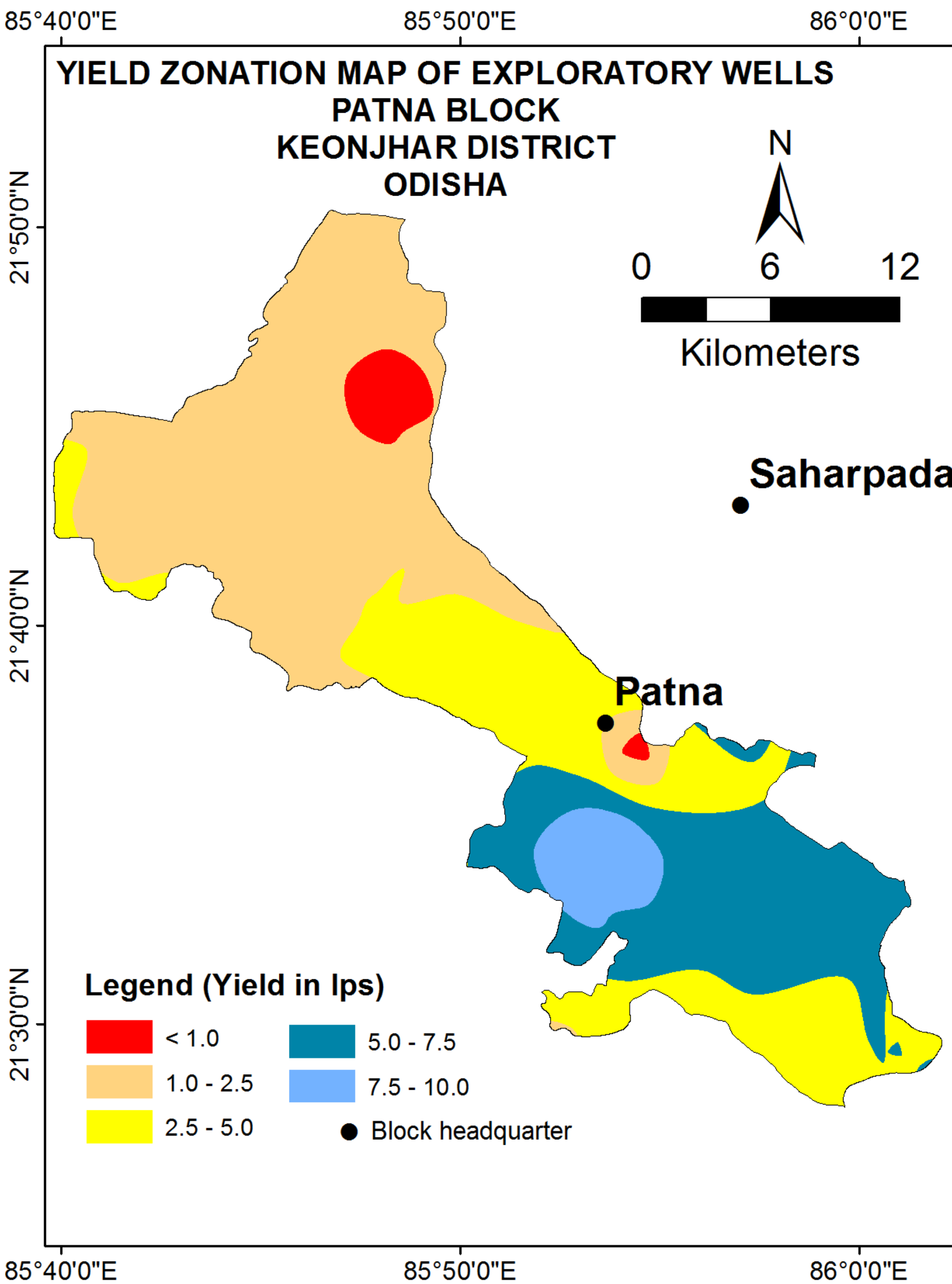
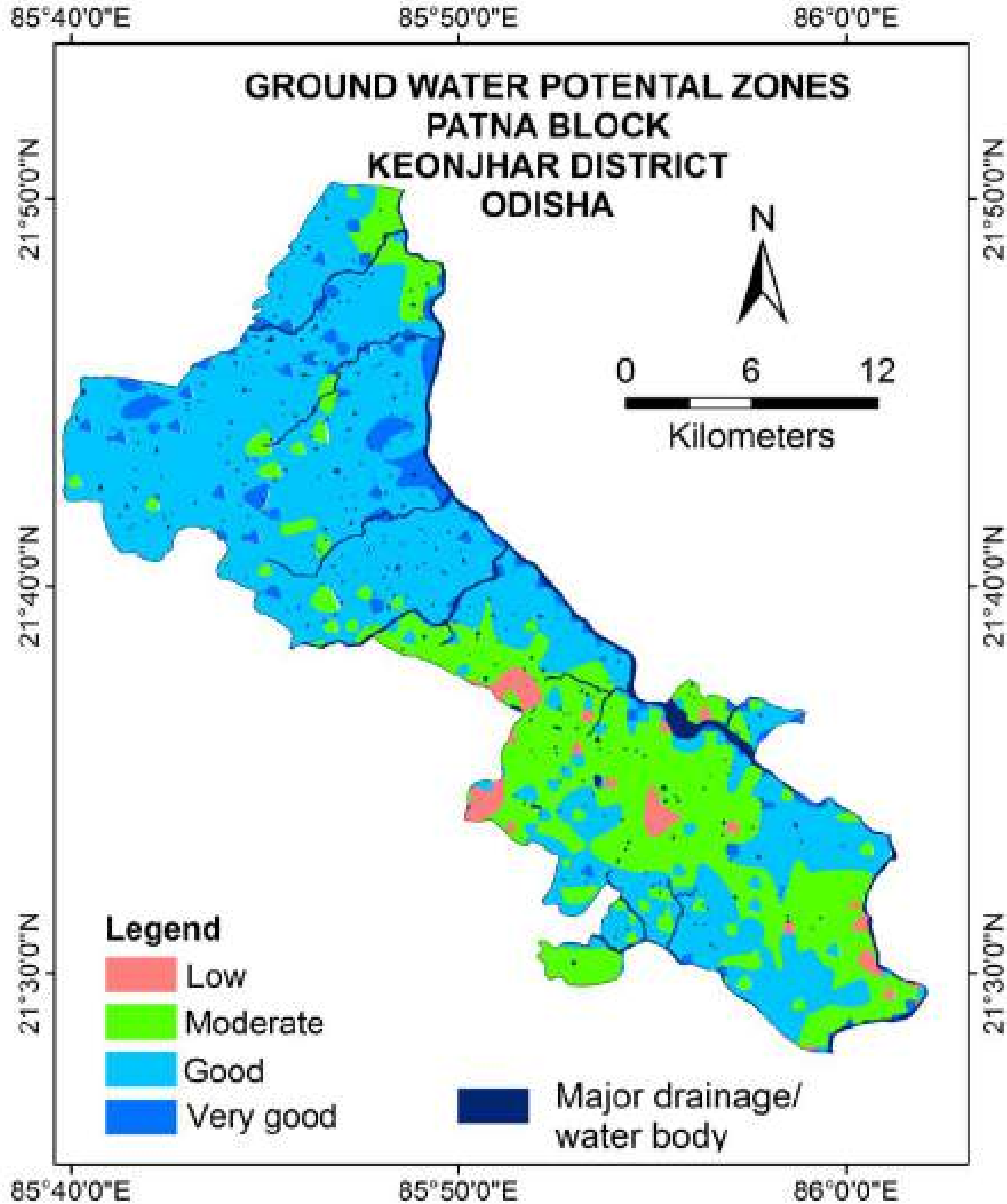

85°40'0"E
85°50'0"E
86°0'0"E
DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6.5
13
Kilometers
21°50'0"N
21°40'0"N
21°30'0"N
Saharpada
Patna
Legend (sets of fract.)
0 - 1
1 - 2
Block headquarter

PLATE – 11.13



YIELD ZONATION MAP OF EXPLORATORY WELLS
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
N
0
6
12
Kilometers
Saharpada
Patna
Legend (Yield in lps)
< 1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
Block headquarter

PLATE – 11.14


GROUND WATER POTENTAL ZONES
PATNA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
85°40'0"E
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Legend
Low
Moderate
Good
Very good
Major drainage/
water body

PART II BLOCK-WISE AQUIFER MAPPING AND MANAGEMENT PLAN, KEONJHAR DISTRICT, ODISHA

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

8.0 SAHARPADA BLOCK

8.1 Salient information

Location, area and demography

Location (Plate 12.1)	85^0 49' - 86^0 10' E longitude 21^0 38' – 21^0 49'' N latitude
Area	402 sq. km
No. of Gram Panchayats	20
No. of villages	139
Population (Census 2011)	88,314
Literacy	56.54%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1050.5 mm
Monsoon normal rainfall	823.6 mm (78.4 of total)

Land use, agriculture and irrigation

Gross cropped area (1)	28649 Ha
Net sown area (2)	23365 Ha
Area sown more than once (1-2)	5284 Ha
Cropping intensity (%)	122.6 Ha
Area under forest	6098 Ha
Area under wasteland	857 Ha
Area under other uses	11051 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	4289 Ha *Kharif:* 2460 Ha *Rabi:* 1829 Ha

8.2 Drainage, geomorphology and soil types

The river Baitarani is master drainage in the block flowing along its western border in south-east direction. The tributaries flowing westerly/south-westerly/southerly and north-westerly join the Baitarani on its left bank. The drainage pattern is dendritic in nature. There are several small bodies found dispersed in the block (Plate 12.2).

The pediments, buried pediments and valley fills form the major hydro-geomorphic units in the block, together covering 95% of the block area. These units are considered as potential from as far as groundwater occurrenec is concerned (Fig 12.1 and Plate 12.3). These units are considered as potential from as far as groundwater occurrenec is concerned. There are several linear basic (dolerite) dykes that run in NE-SW and NW-SE directions. Around 97% of the block area depict land surface slope of <5% (Fig 12.2) which is suitable for groundwater recharge (Plate 12.4). The soil types include the red loamy (alfisol) and red and yellow soils (ultisol).

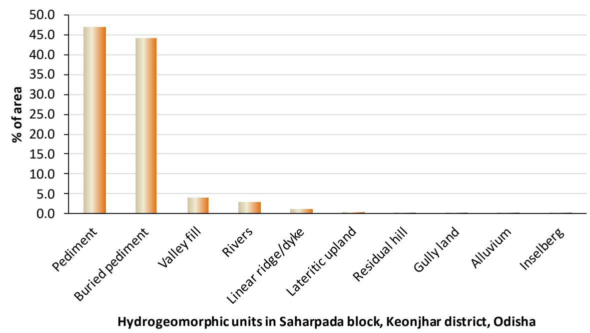


Figure 12.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Saharpada block.

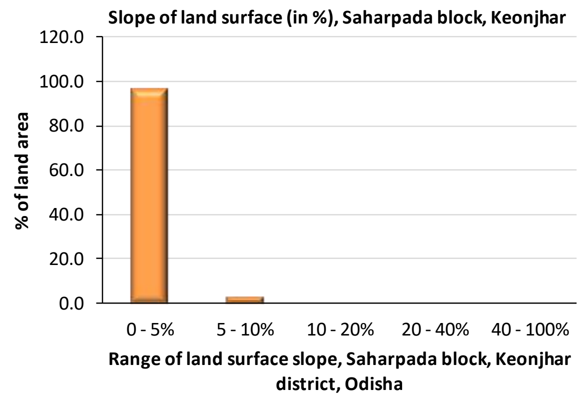


Figure 12.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Saharpada block, Keonjhar district.

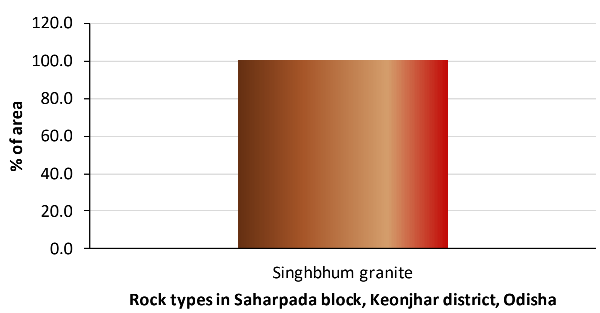


Figure 12.3: Percentage (%) of Saharpada block area (Keonjhar dist.) covered by various rock types.

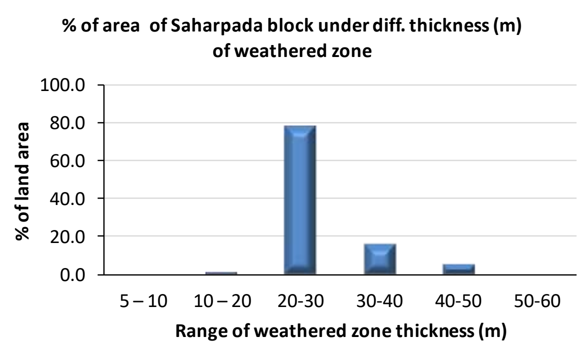


Figure 12.4: Bar diagram depicting the percentage (%) area of Saharpada block, Keonjhar district falling under different weathered zone thickness (m) ranges.

8.3 Geology

Entire block is occupied by the Singhbhum Granites. Only the basic dolerite dykes traverse the country rock at places (Fig 12.3 and Plate 12.5).

8.4 Hydrogeology

The weathered residumm at shallow depth and the fractures zones in the hard rock at deeper depths form the groundwater repositories in the block. The generalized hydrogeological map of the block is presented in Plate 12.7. The Singhbhum Granites posses low to moderate yield potential varying between 3-10 lps.

During the pre-monsoon (year 2018) measurement, around 70% area of the block depicted water levels >5.0 m bgl (Plate 12.7). In rest of the area, those were in the range of 2.5-5.0 m bgl. During the post-monsson period, except the patch around Saharpada town and another in the south-east corner of the block, rest area of 84% showed water levels <5.0 m bgl, indicating good recharge from rainfall (Plate 12.8). The annual fluctuations in the water levels remained less than 2.0 to 4 m (Plate 12.9).

8.5 Aquifer geometry and characters

In major parts of the block (78% of area), the thickness of weathered regolith overlying the fresh hard rock varies between 20-30 m (Plate 12.10; Fig 12.4). The thickness increases up to 60 m in the western parts of the block. The thick weathered zones form good prospect for groundwater to dug wells and shallow tube wells. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 12.5a-b.

In the block, more commonly 1-2 sets of fracture zones are encountered in bore wells within the depth of 100 m bgl (1st aquifer system). It seems the number of fractures increase towards west (Plate 12.11). Beyond this depth in the 2nd aquifer system, the fractures are depleted and commonly 0-1 sets of fracture zones are encountered during drilling (Plate 12.12). Several bore wells in the block have been drilled which give yield in the range of 2-8 lps. In major cases, the bore wells yield between 2.5-5.0 lps (Plate 12.13), though in some cases the yield up to 10 lps has been noticed. The yield in wells decrease towards west in the block.

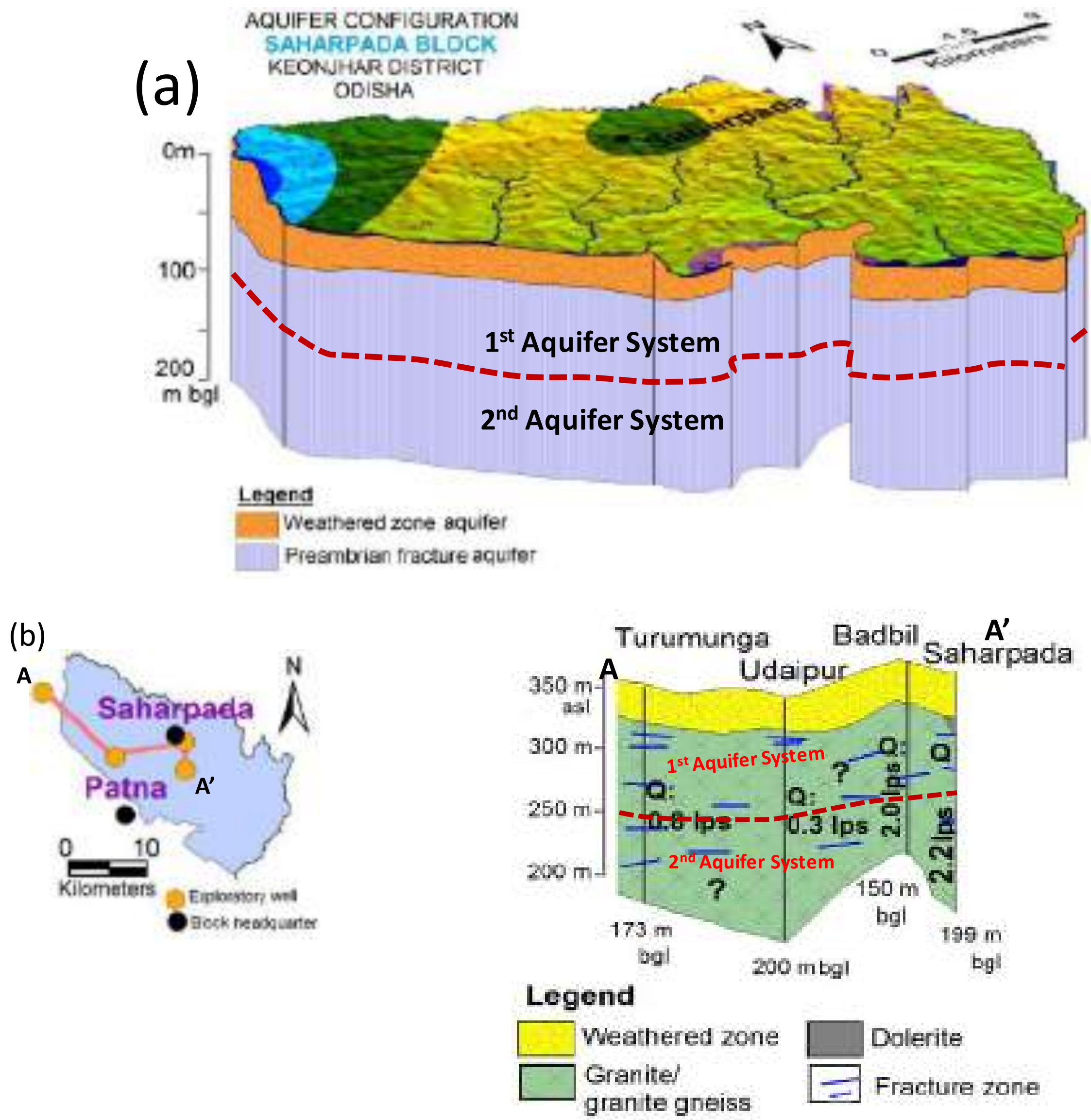


Figure 12.5: (a) 3D aquifer disposition in Saharpada block, Keonjhar district. (b) 2D hydrogeological transect (including its location) A-A' depicting the aquifer disposition in the block.

8.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 12.14). As per this analysis major parts (67.5% area) of the block come under low to moderate groundwater potential zones (Fig 12.6). The good to very good potential zones have been delineated in a ~5 km wide tract along the left bank of the Baitarani River (Plate 12.14).

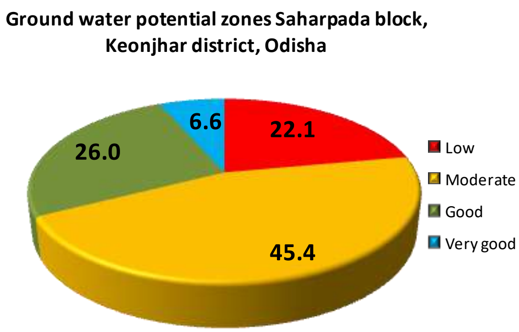


Figure 12.6: Pie diagram depicting the perentage (%) of Saharpada block, Keonjhar district, Odisha, falling under different groundwater potential zones.

8.7 Ground water quality

Ground water in the block is alkaline in nature (Table 12.1) and pH range of 6.9-8.24. The water is moderately hard to very hard. The mineralization is low to moderate with TDS varying between 38-429 mg/L (ave.: 175 mg/L).

Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly Ca-HCO_3 types with Ca^{2+} and HCO_3^- as the principal ions contributing in the groundwater chemistry (Fig 12.7).

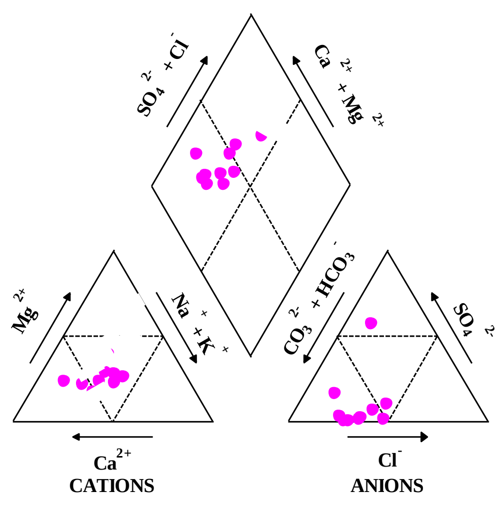


Figure 12.7: The Piper trilinear diagram depicting the groundwater quality in Saharpada block, Keonjhar district.

Table 12.1: Ground water quality at various locations in Saharpada block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Balabhadrapur	7.9	270	139	102	108	29	7	10.01	8.67	0	118	23	3.8	0.13
Digapasi	7.65	250	1202	92	93	20	10	11.68	4.05	0	101	25	0	0.09
Machhagarh	8.15	100	53	36	36	10	2	6.82	0.88	0	39	13	1	0.08
Belasarei	7.8	250	128	107	93	31	7	6.97	1.85	0	101	13	18.95	0.20
Kendujoda	8.24	640	306	230	242	41	30	36.96	8.13	0	264	60	1	0.18
Kapundi	6.9	70	38	20	10	4	2	5.73	0.78	0	11	3	16.8	0.09
Rajnagar	8.15	820	429	255	294	57	27	54.44	25.85	0	320	105	3.1	0.26
Gajitangri	7.31	200	93	60	44	16	5	9.5	5.41	0	54	29	0.6	0.19
Kothagarh	8.07	655	310	215	142	50	22	21.91	41.2	0	173	98	30.1	0.15
Udaipur	7.72	155	97	55	49	14	5	16.2	0.7	0	60	26	5.2	0.12
Min.:	**6.9**	**70**	**38**	**20**	**10**	**4**	**2**	**5.73**	**0.7**	**0**	**11**	**3**	**0**	**0.08**
Max.:	**8.24**	**820**	**429**	**255**	**294**	**57**	**30**	**54.44**	**41.2**	**0**	**320**	**105**	**30.1**	**0.26**
Average	**7.79**	**341**	**175**	**117**	**111.1**	**27.2**	**11.7**	**18.022**	**9.752**	**0**	**124.1**	**39.5**	**8.055**	**0.15**

8.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 12.2-12.4. The net dynamic groundwater available is 4010.9 Ham and the stage of groundwater development stands at 56.8%. Net resource available for future irrigation needs stands at 1707.2 Ham (Fig 12.8). The instorage/static groundwater resource component of 5490.9 Ham (Table 12.3) comes from the 1st aquifer system within 100 m bgl. The total groundwater available in the block stands at 9509.6 Ham.

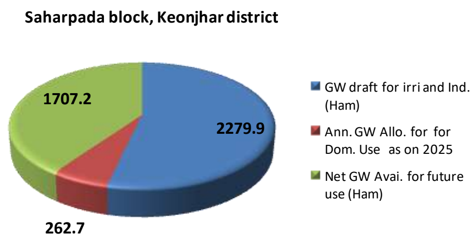


Figure 12.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Saharpada block, Keonjhar district, Odisha.

Table 12.2: Salient information on annual dynamic groundwater resources, Saharpada block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	4010.9
2. Irrigation draft (Ham)	2018.6
3. Industrial draft (Ham)	22.4
4. Domestic draft (Ham)	238.9
5. Total draft (Ham)	2279.9
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	262.7
7. Net groundwater available for future use (Ham)	1707.2
8. Stage of groundwater extraction (%)	56.8

Table 12.3: Total groundwater resoure available in the Saharpada block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	4010.9
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	5490.9
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	7.8
	Block total	**9509.6**

8.9 Aquifer management plan

The existing stage of groundwater development of 56.8% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction

structures as estimated in Table 12.4 (29 bore wells/dug-cum-bore wells and 244 dug wells) are required to be constructed to develop the available additional resource of 126.6 Ham. It can help in creating additional irrigation potential for 202.6 Ha (Table 12.5).

Only around 65.62 km^2 area in the block showed post-monsoon depth to water levels >5.0 m bgl (Plate 12.15; Table 12.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 5.91 MCM of water (Table 12.7) can be recharged by the help additional 12- percolations ponds, 6-subsurface dykes, 6-nala/contour bunds and 12-check dams (Table 12.8) with a total cost of 3.84 crores (Table 12.9).

Table 12.4: Number of additional feasible groundwater abstraction structures in Saharpada block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	4010.9
2	Stage of GW deve. (%)	56.8
3	Present GW draft (Ham)	2279.9
4	Ground water draft at 60% stage of deve. (Ham)	2406.5
5	Addi. water to be deve. (Ham)	126.6
6	Addi. No of BW/ STW feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	29
7	Addi. No. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	244

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 12.5: Irrigation potential likely to be created in Saharpada block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	56.8
2	Surplus GW avai. for 60% stage of deve. (Ham)	126.6
3	Irri, Pot. likely to be created for Paddy (Ha)	76
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	63.3
5	Irri. Pot. likely to be created for veg. (Ha)	63.3
6	Proj. area to be Irri. (ha)	202.6

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 12.6: Areas in Saharpada block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Saharpada	65.62	0.00	65.62

Table 12.7: Estimation of volume of water required for artificial recharge to groundwater in Saharpada block, Keonjhar district.

Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to reharge (MCM)
Saharpada	402.00	65.62	6	3	196.87	5.91

Table 12.8: Number of feasible structures in Saharpada block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (MCM)	No of different freasible structures			
		Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
Saharpada	5.91	12	6	6	12

Table 12.9: Estimation of cost of artificial recharge structures in Saharpada block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Saharpada	2.36	0.59	0.30	0.59	3.84

PLATE – 12.1

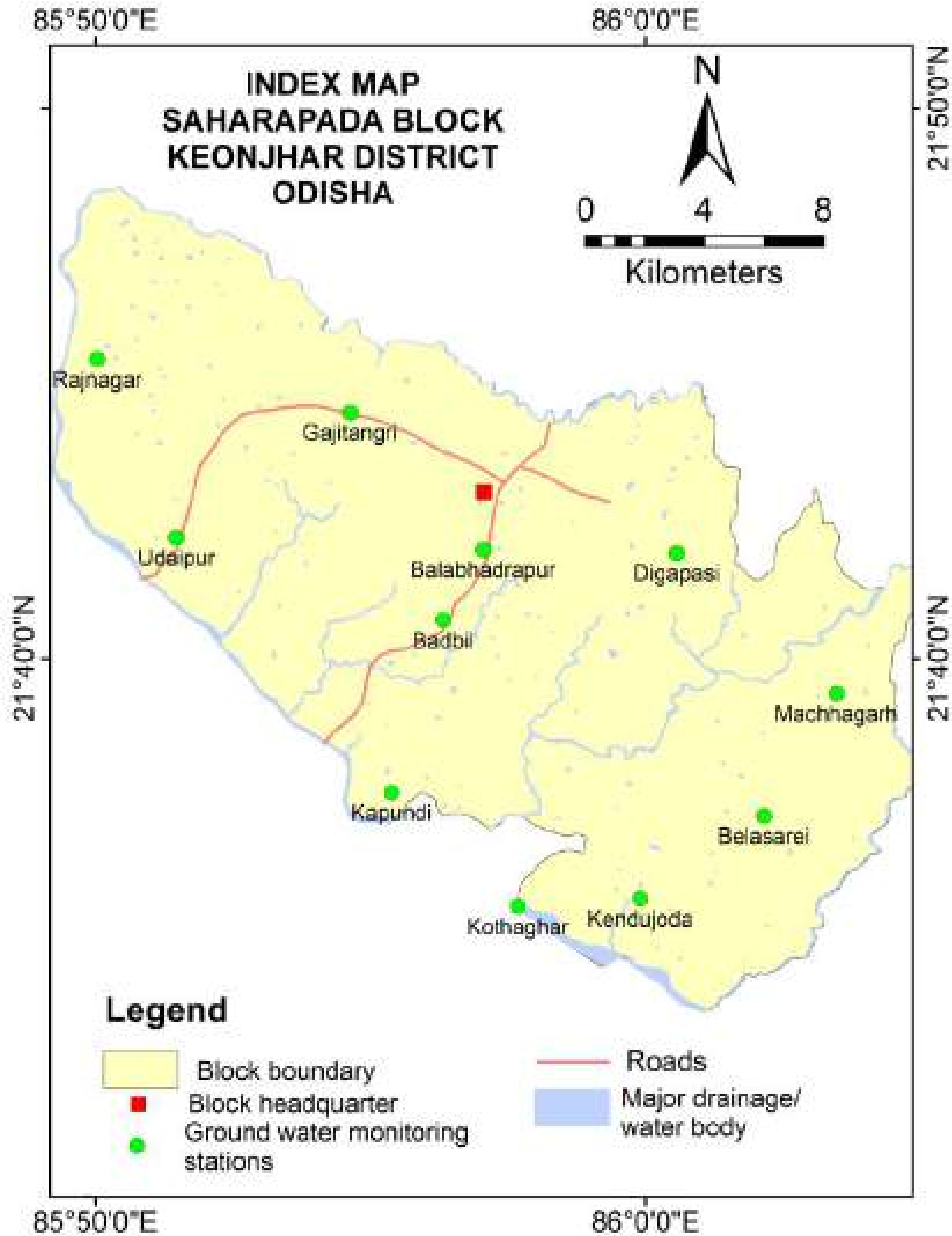

85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
INDEX MAP
SAHARAPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
4
8
Kilometers
Rajnagar
Gajitangri
Udaipur
Balabhadrapur
Digapasi
Badbil
Machhagarh
Kapundi
Belasarei
Kothaghar
Kendujoda
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Roads
Major drainage/ water body

PLATE – 12.2

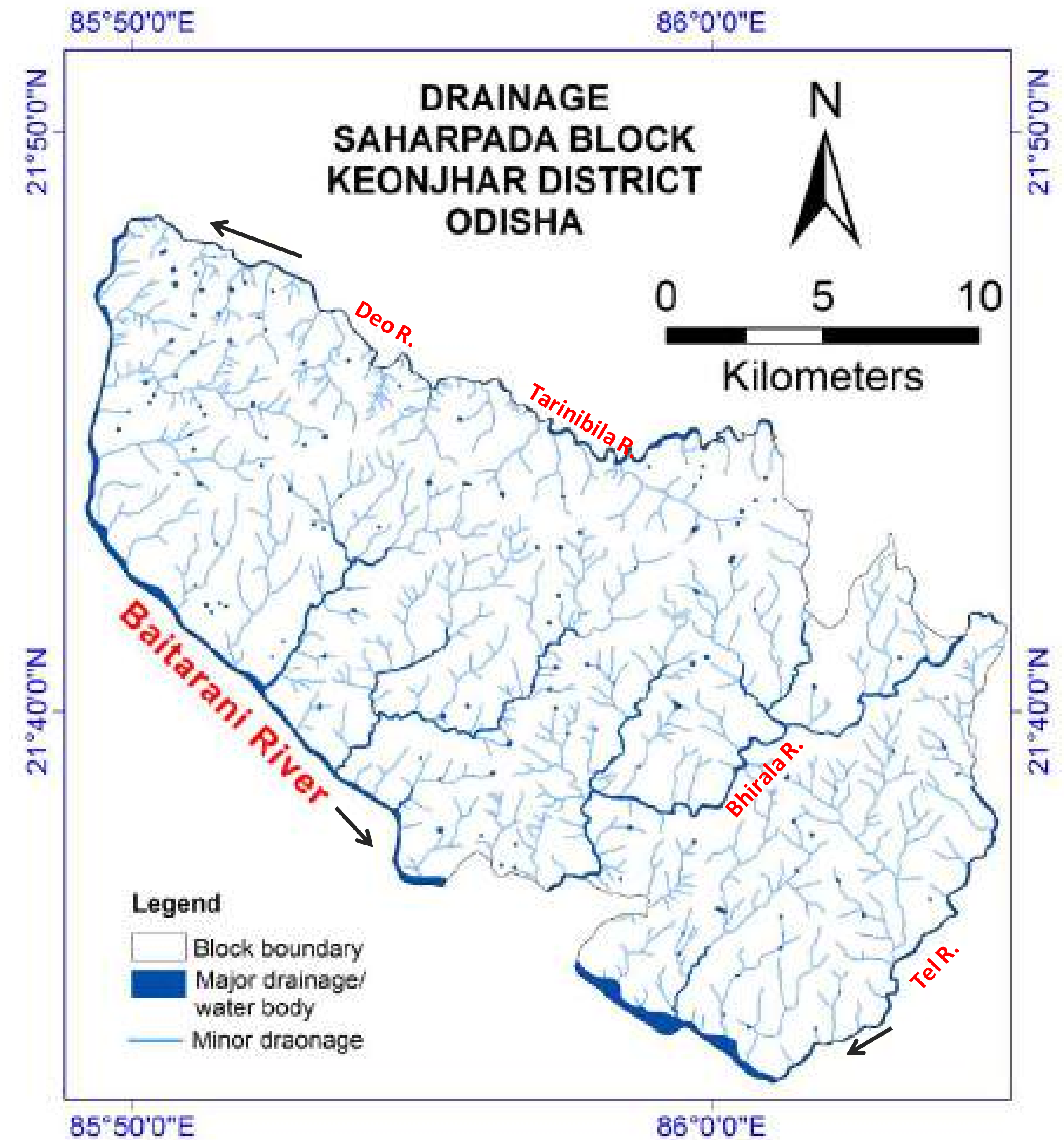

85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
DRAINAGE
SAHARPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
5
10
Kilometers
Deo R.
Tarinibila R.
Baitarani River
Bhirala R.
Tel R.
Legend
Block boundary
Major drainage/
water body
Minor draonage

PLATE – 12.3

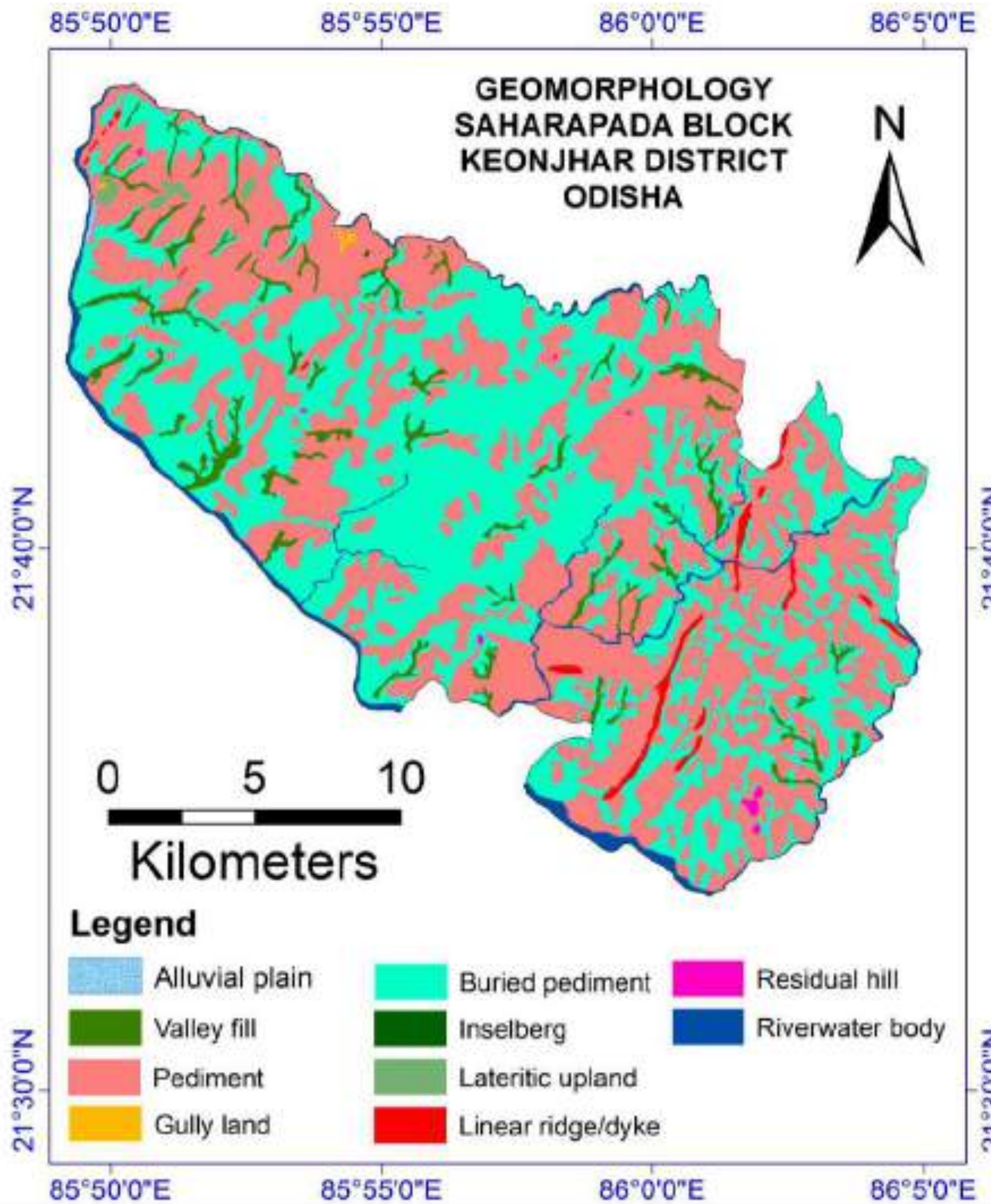

GEOMORPHOLOGY
SAHARAPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
85°50'0"E
85°55'0"E
86°0'0"E
86°5'0"E
21°40'0"N
21°30'0"N
0
5
10
Kilometers
Legend
Alluvial plain
Valley fill
Pediment
Gully land
Buried pediment
Inselberg
Lateritic upland
Linear ridge/dyke
Residual hill
Riverwater body

PLATE – 12.4

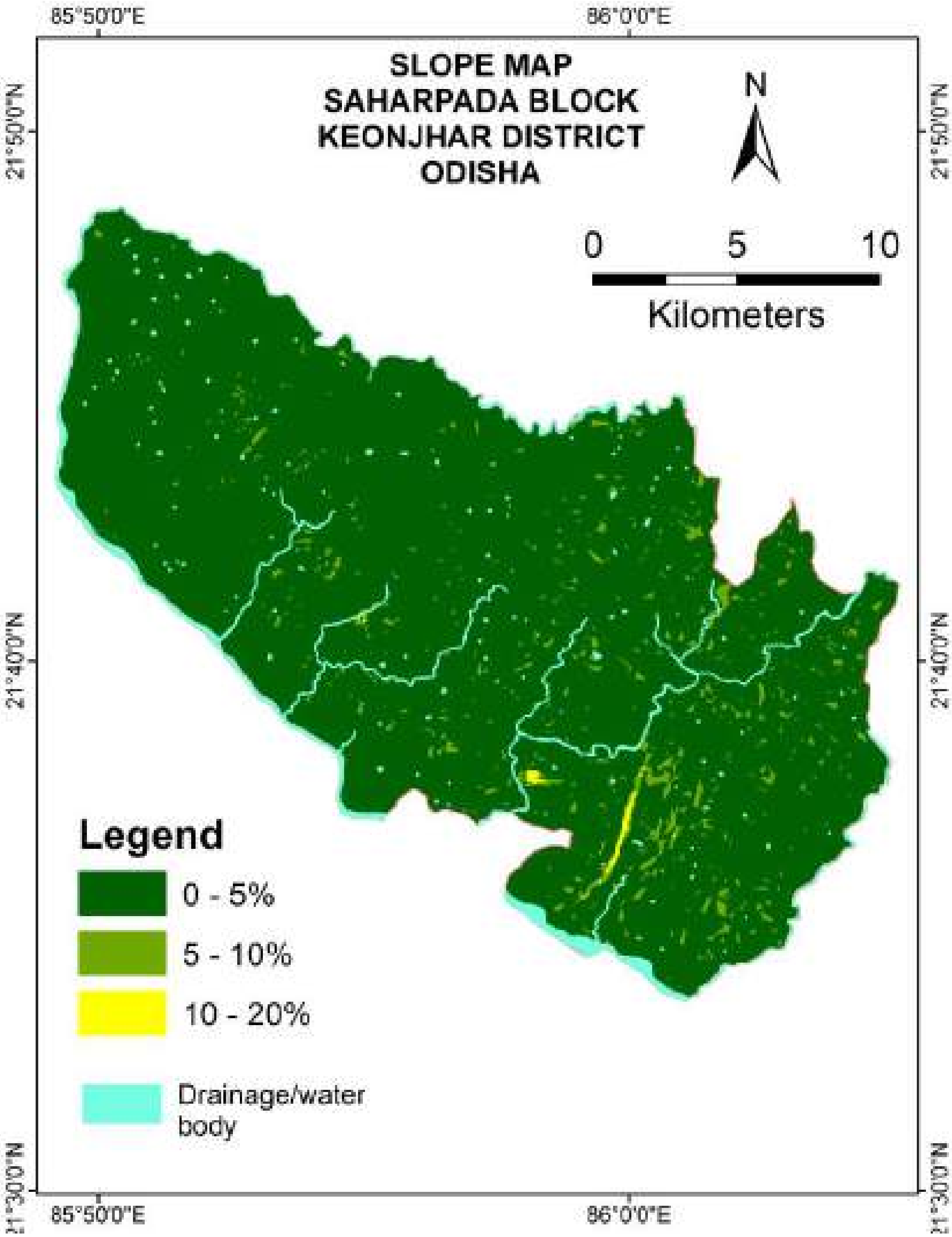

SLOPE MAP
SAHARPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
Legend
0 - 5%
5 - 10%
10 - 20%
Drainage/water body
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N

PLATE – 12.5

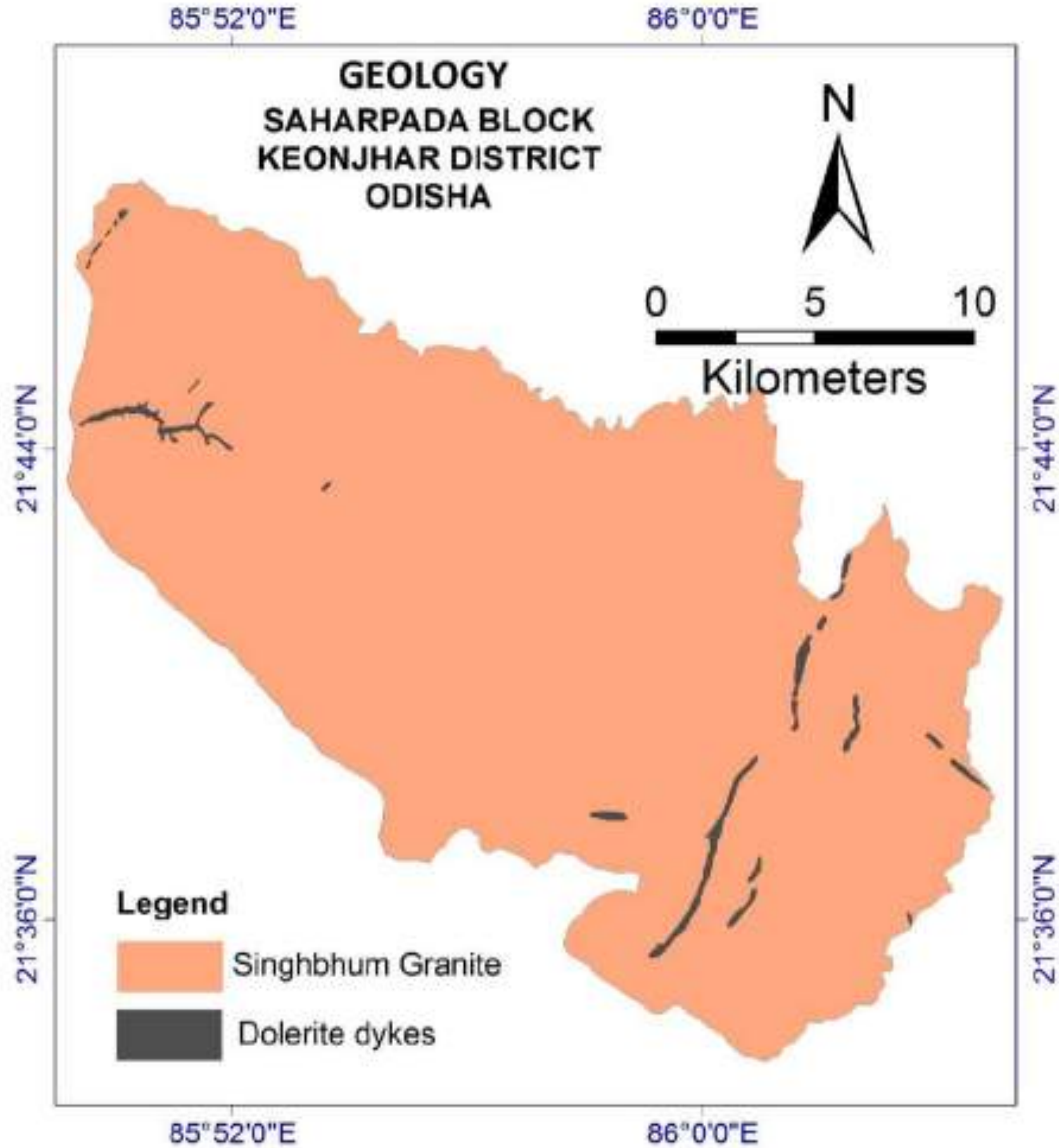

GEOLOGY
SAHARPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°52'0"E
86°0'0"E
21°44'0"N
21°36'0"N
Legend
Singhbhum Granite
Dolerite dykes

PLATE – 12.6

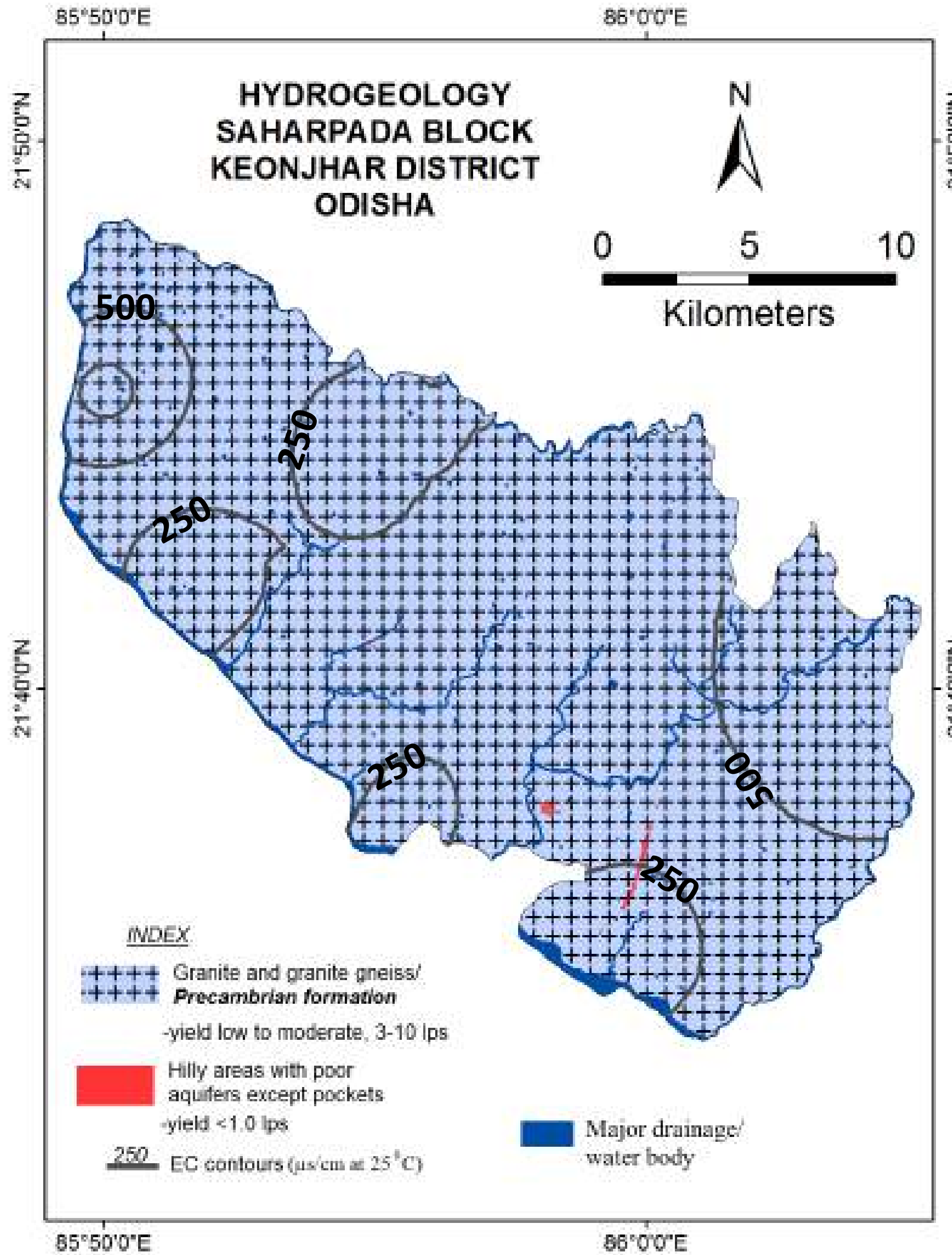

85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
HYDROGEOLOGY
SAHARPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
500
250
250
250
500
250
INDEX
Granite and granite gneiss/
Precambrian formation
-yield low to moderate, 3-10 lps
Hilly areas with poor
aquifers except pockets
-yield <1.0 lps
250 EC contours (µs/cm at 25°C)
Major drainage/
water body

PLATE – 12.7

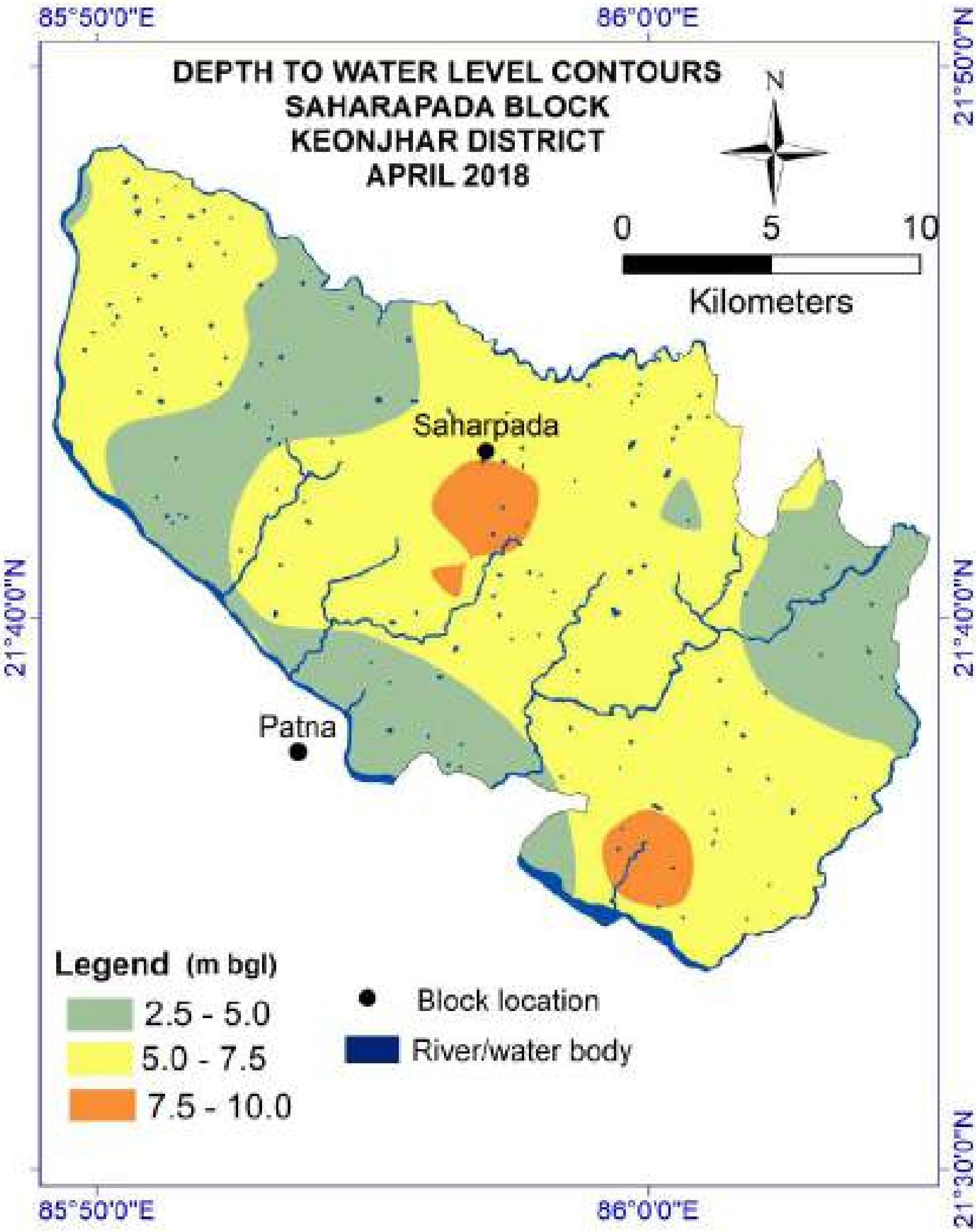

DEPTH TO WATER LEVEL CONTOURS
SAHARAPADA BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0
5
10
Kilometers
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
Saharpada
Patna
Legend (m bgl)
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
Block location
River/water body

PLATE – 12.8

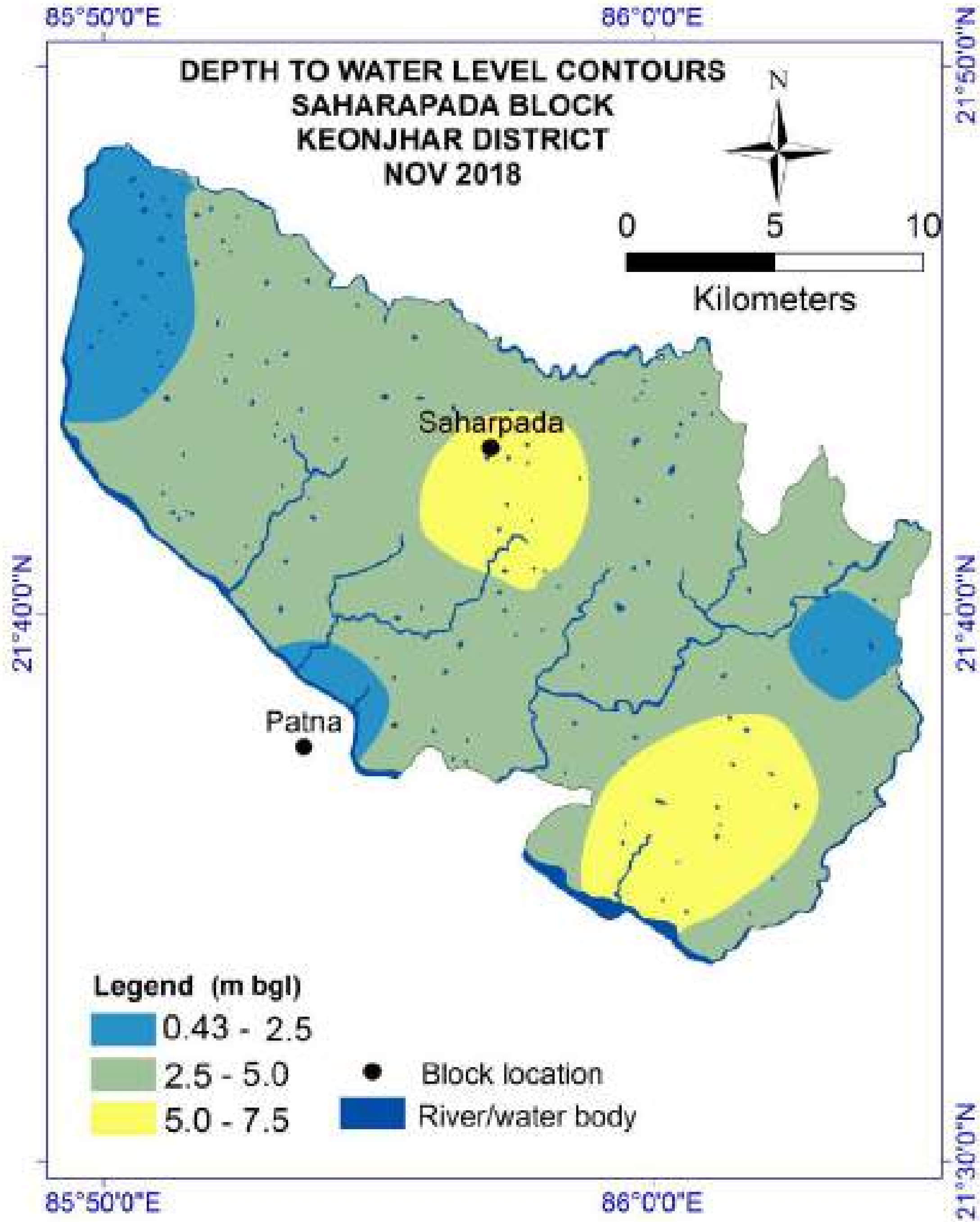

85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
DEPTH TO WATER LEVEL CONTOURS
SAHARAPADA BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0 5 10
Kilometers
Saharpada
Patna
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
Block location
River/water body

PLATE – 12.9

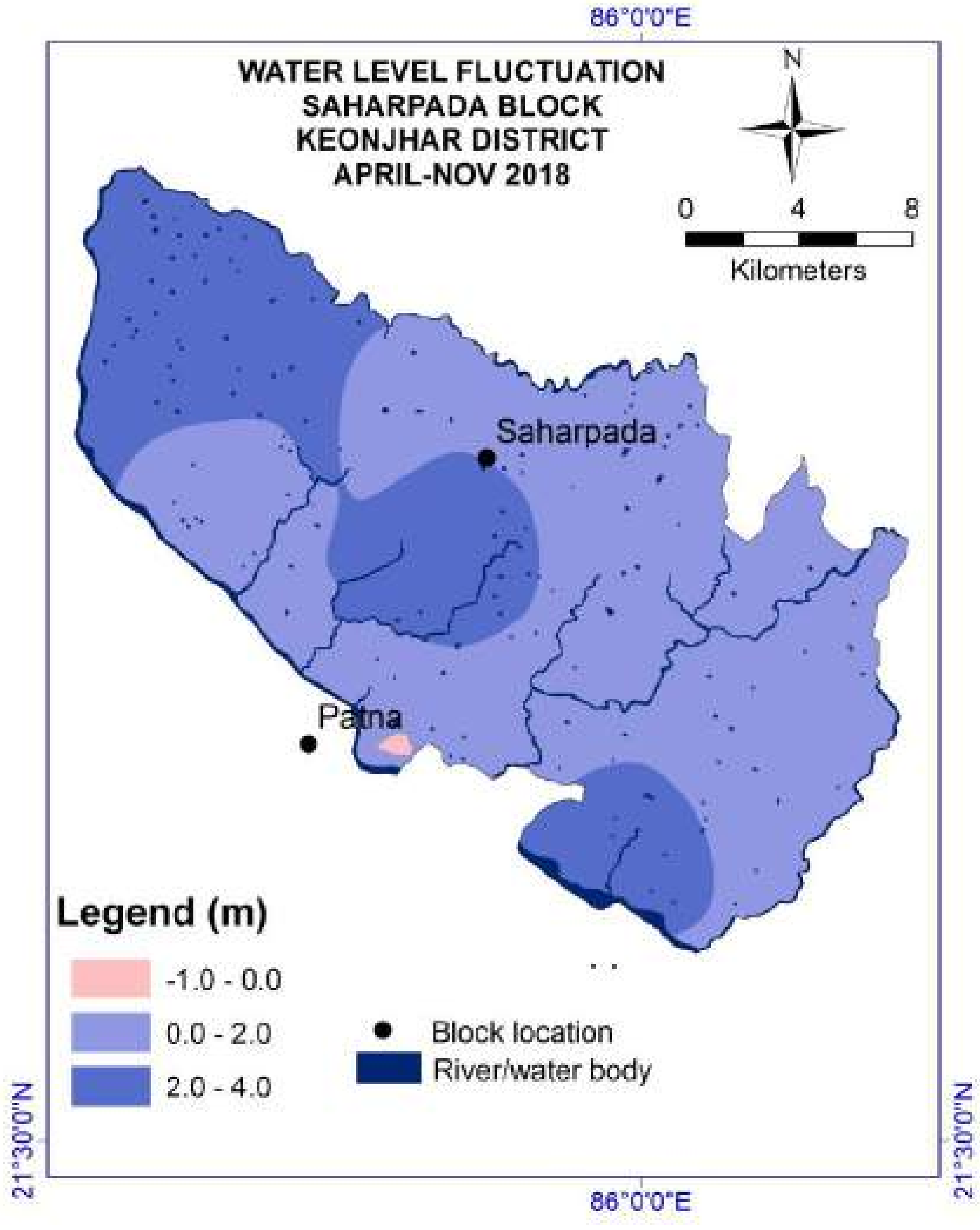
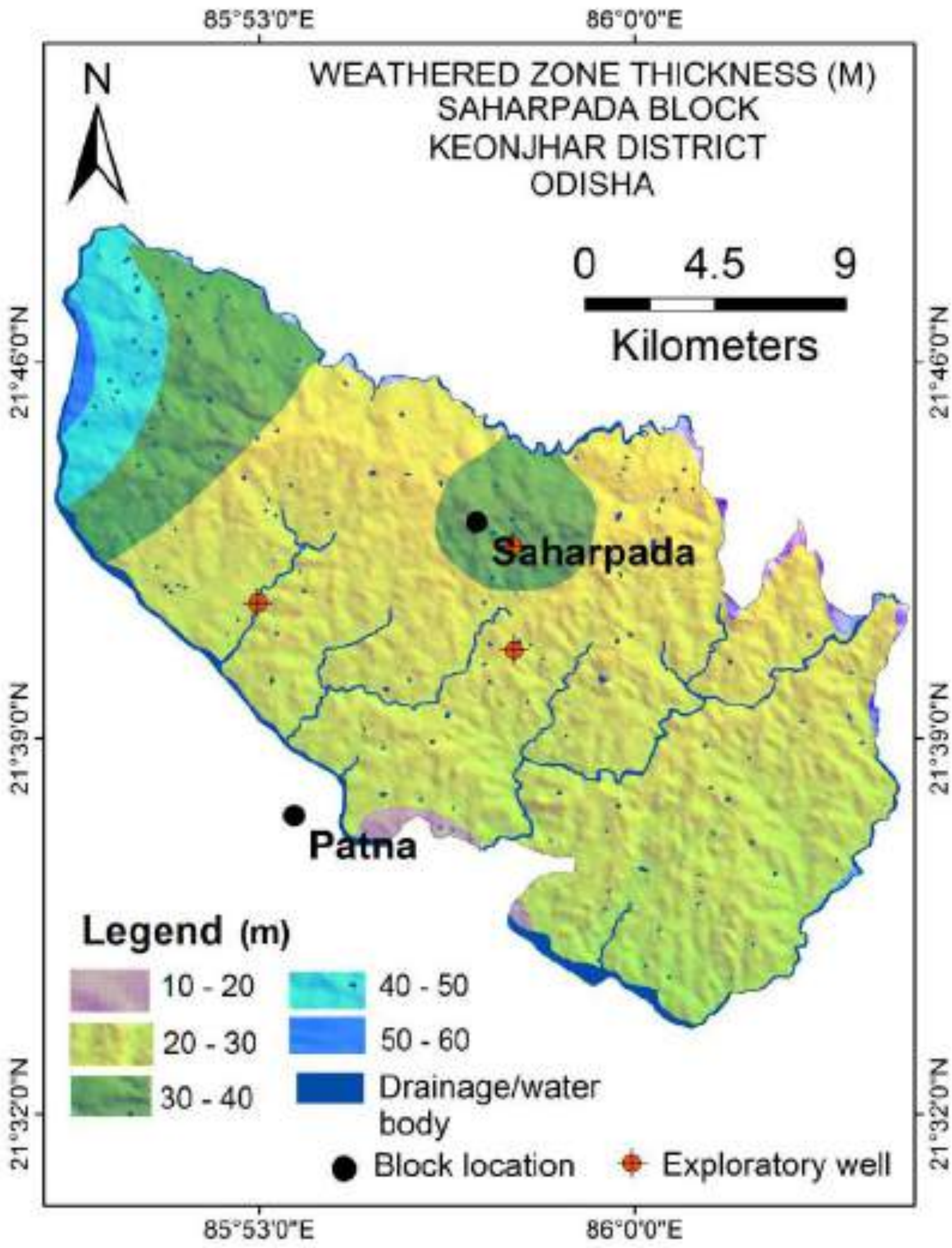

WATER LEVEL FLUCTUATION
SAHARPADA BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0
4
8
Kilometers
86°0'0"E
21°30'0"N
Saharpada
Patna
Legend (m)
-1.0 - 0.0
0.0 - 2.0
2.0 - 4.0
Block location
River/water body

PLATE – 12.10



WEATHERED ZONE THICKNESS (M)
SAHARPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
4.5
9
Kilometers
85°53'0"E
86°0'0"E
21°46'0"N
21°39'0"N
21°32'0"N
Saharpada
Patna
Legend (m)
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
Drainage/water body
Block location
Exploratory well

PLATE – 12.11

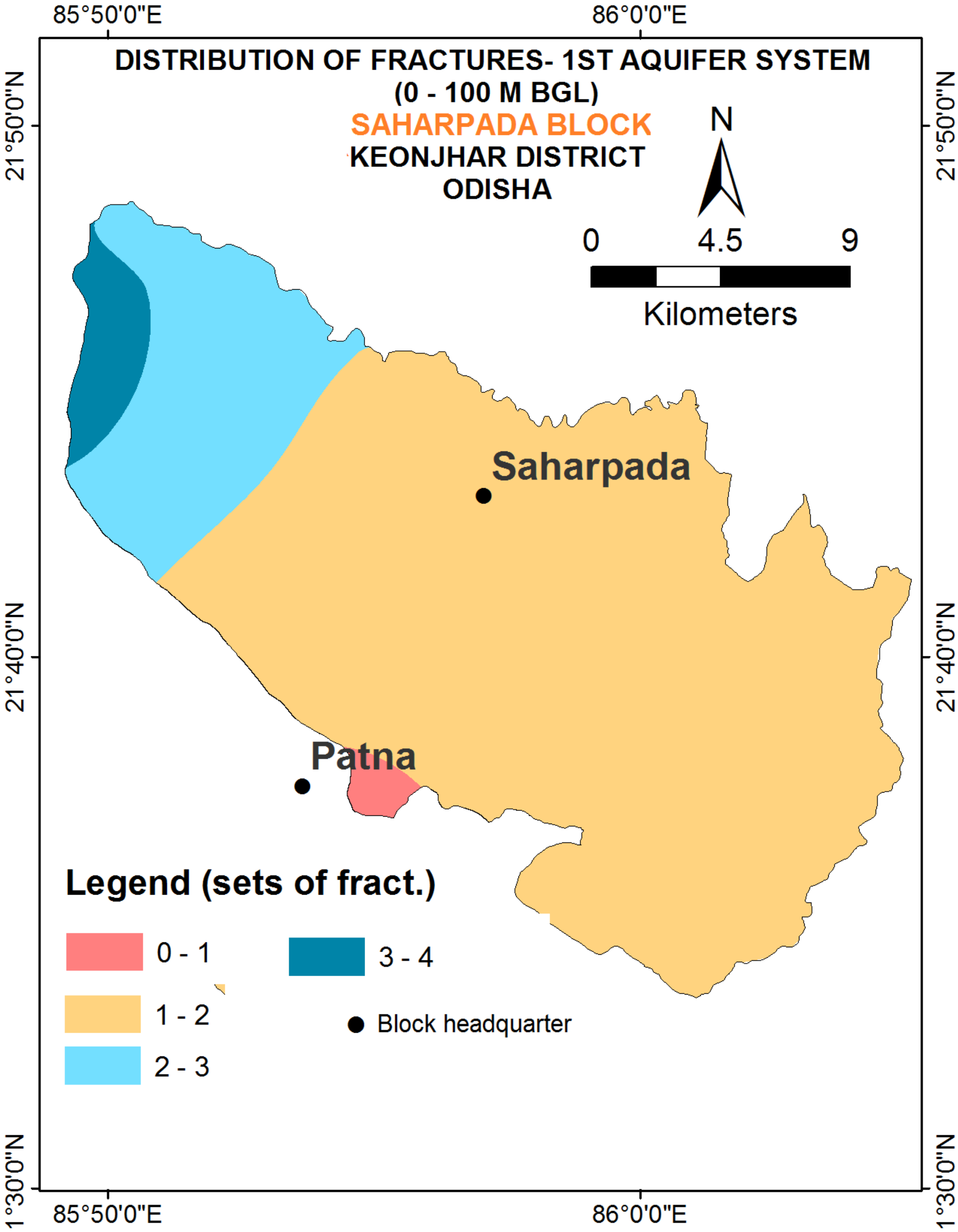

85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
1°30'0"N
DISTRIBUTION OF FRACTURES- 1ST AQUIFER SYSTEM
(0 - 100 M BGL)
SAHARPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
4.5
9
Kilometers
Saharpada
Patna
Legend (sets of fract.)
0 - 1
3 - 4
1 - 2
2 - 3
Block headquarter

PLATE – 12.12

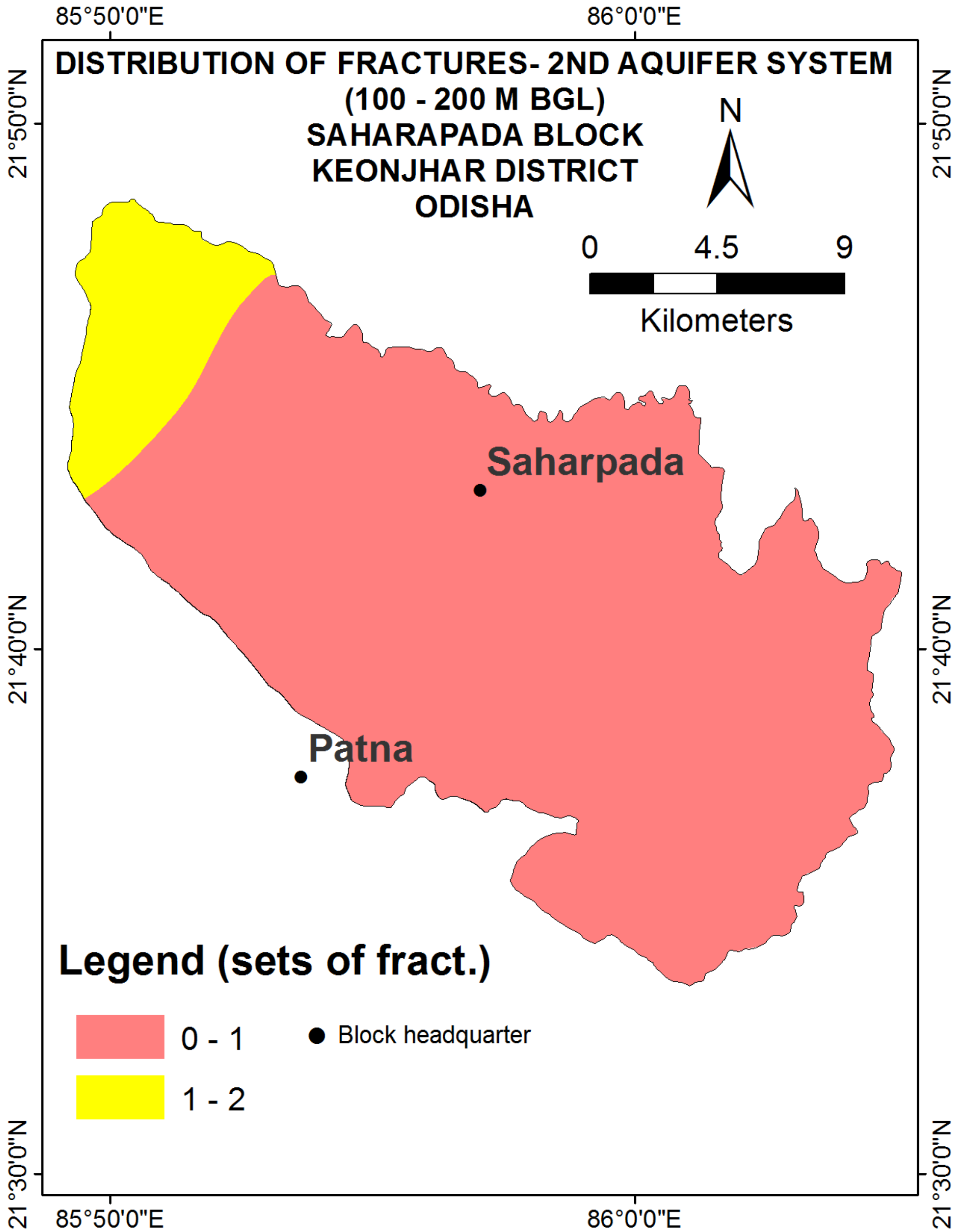

DISTRIBUTION OF FRACTURES- 2ND AQUIFER SYSTEM
(100 - 200 M BGL)
SAHARAPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
4.5
9
Kilometers
Saharpada
Patna
Legend (sets of fract.)
0 - 1
1 - 2
Block headquarter
85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N

PLATE – 12.13

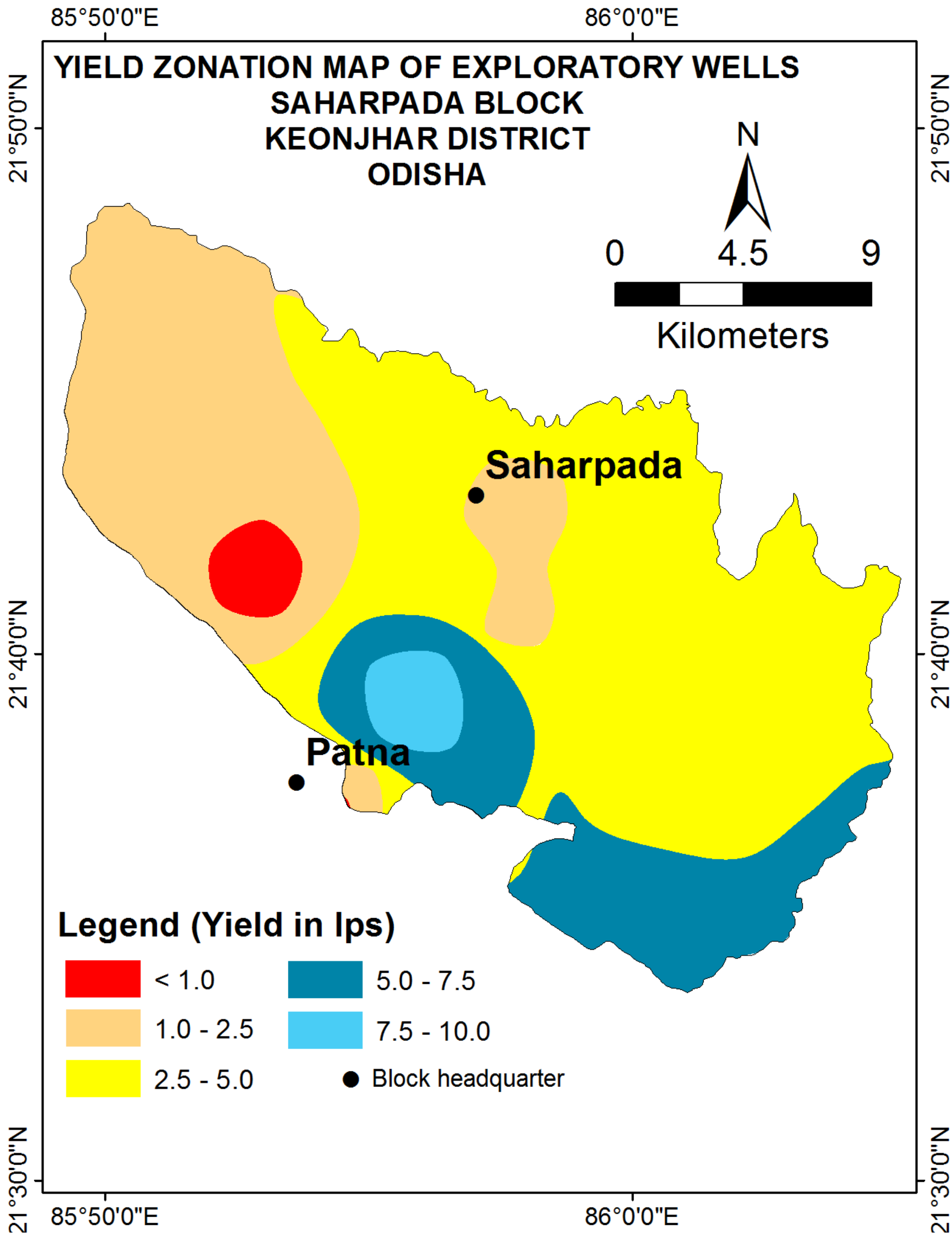

85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
YIELD ZONATION MAP OF EXPLORATORY WELLS
SAHARPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
4.5
9
Kilometers
Saharpada
Patna
Legend (Yield in lps)
< 1.0
1.0 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
Block headquarter

PLATE – 12.14

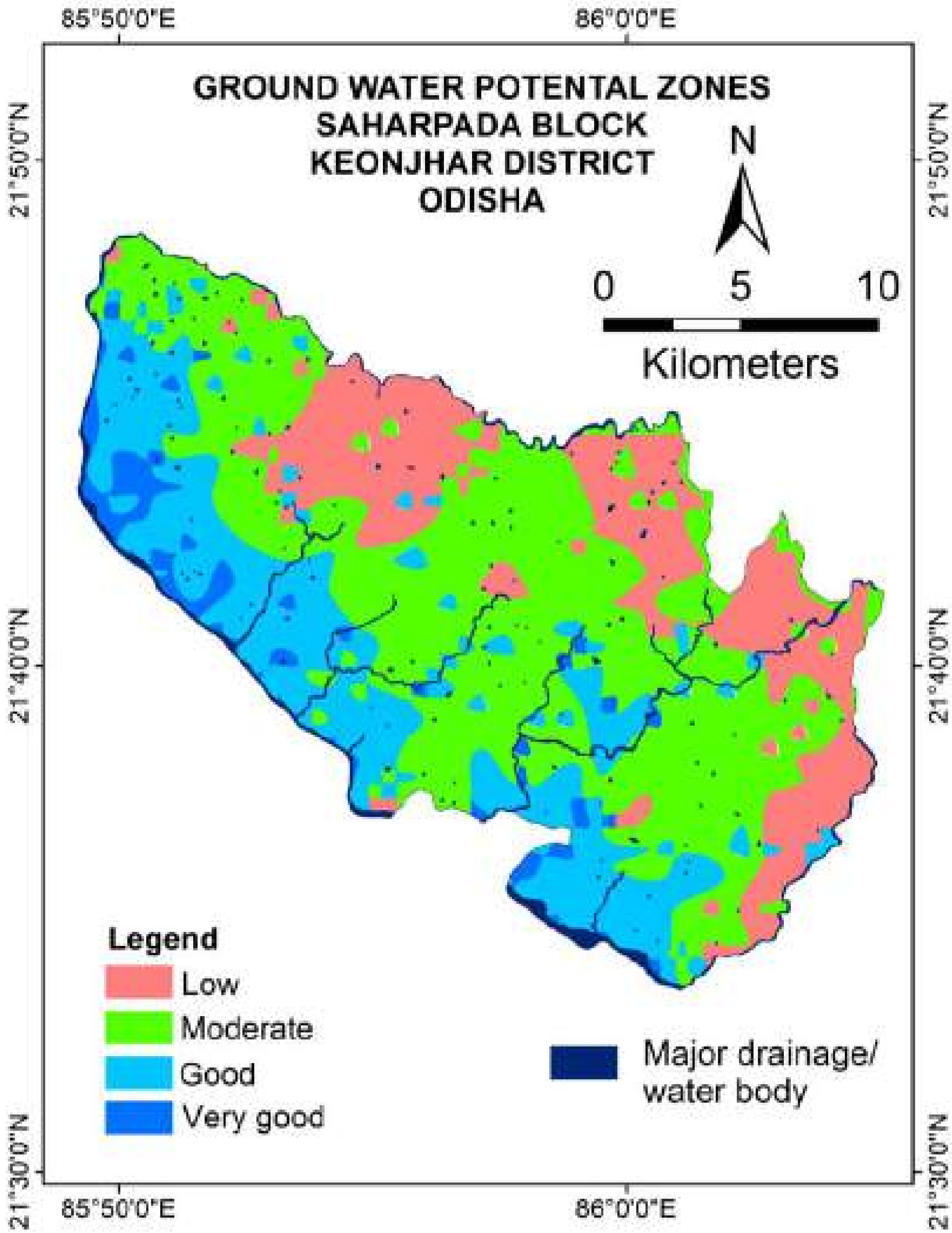
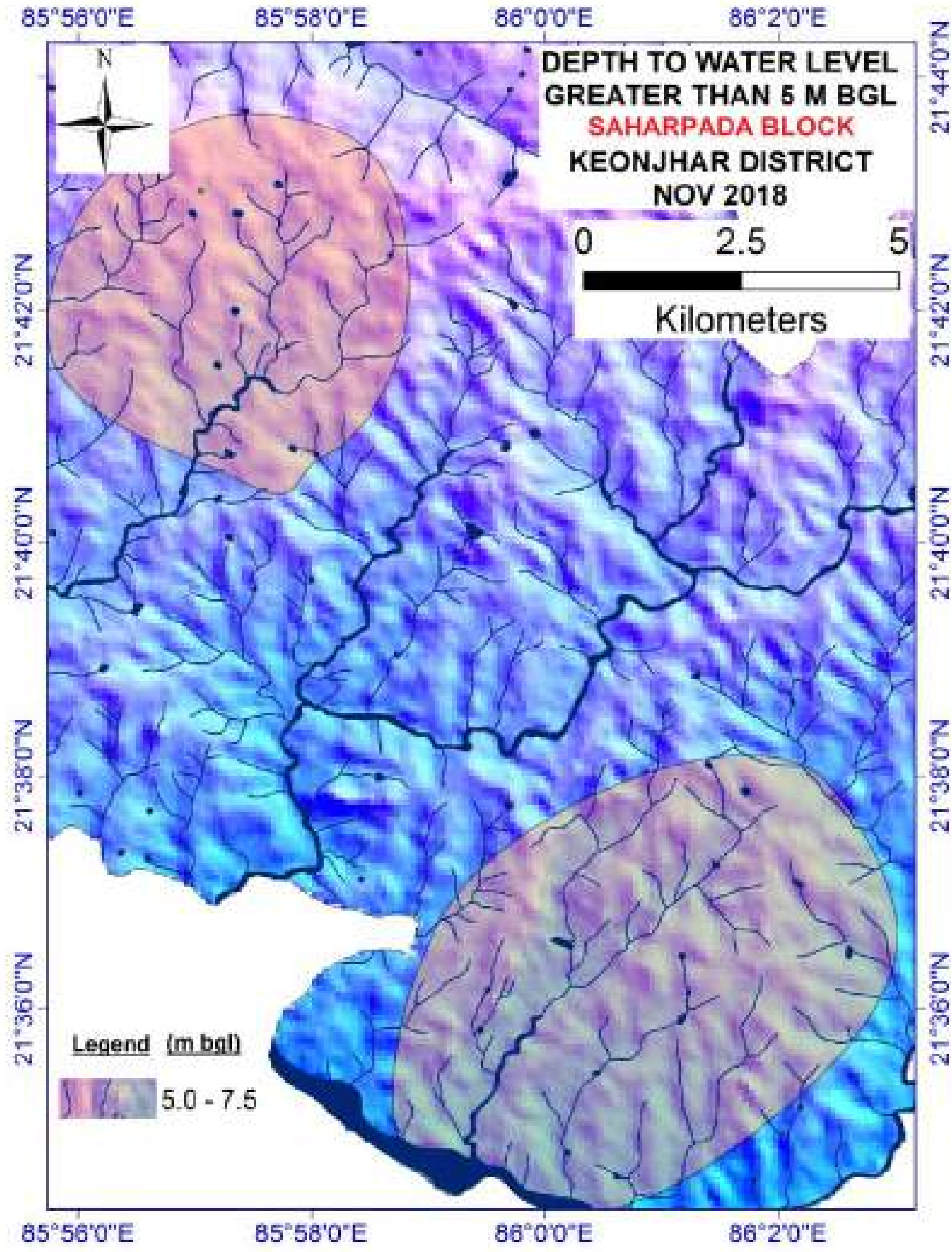

85°50'0"E
86°0'0"E
21°50'0"N
21°40'0"N
21°30'0"N
GROUND WATER POTENTAL ZONES
SAHARPADA BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
Legend
Low
Moderate
Good
Very good
Major drainage/
water body

PLATE – 12.15


85°56'0"E
85°58'0"E
86°0'0"E
86°2'0"E
21°44'0"N
21°42'0"N
21°40'0"N
21°38'0"N
21°36'0"N
N
DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
SAHARPADA BLOCK
KEONJHAR DISTRICT
NOV 2018
0 2.5 5
Kilometers
Legend (m bgl)
5.0 - 7.5

HYDROGEOLOGICAL FRAMEWORK AND GROUND WATER DEVELOPMENT PROSPECTS & AQUIFER MANAGEMENT PLAN

9.0 TELKOI BLOCK

9.1 Salient information

Location, area and demography

Location (Plate 13.1)	85^0 15' - 85^0 42' E longitude 21^0 06' – 21^0 30'' N latitude
Area	961 sq. km
No. of Gram Panchayats	22
No. of villages	149
Population (Census 2011)	96,590
Literacy	55.86%

Climate and rainfall

Climate	Hot and humid
Normal annual rainfall	1560.5 mm
Monsoon normal rainfall	1292.2 mm (83 of total)

Land use, agriculture and irrigation

Gross cropped area (1)	21407 Ha
Net sown area (2)	15310 Ha
Area sown more than once (1-2)	6097 Ha
Cropping intensity (%)	139.8 Ha
Area under forest	59118 Ha
Area under wasteland	2142 Ha
Area under other uses	14936 Ha
Important cropping seasons	Kharif and rabi
Total irrigated area (as on 2015-16)	7035 Ha *Kharif:* 4987 Ha *Rabi:* 2048 Ha

9.2 Drainage, geomorphology and soil types

The rivers such as Samakoi, Hanumattia and Remala are the major ones that drain the block. In the northern half of the block, the rivers flow southerly, northerly to westerly and belong to the Brahmani River Basin in the west of the Keonjhar district. The southern half of the block, the rivers flow southerly to south-easterly (Plate 13.2) and drain into the Baitarani River.

The drainage pattern is dendritic to sub-parallel in nature. There are a few medium to large reservoirs in the block (Plate 13.2).

The structural hills cover a significant portion (~35% of total geographic area) of the block in the eastern and western parts (Plate 13.3). However, the groundwater promising hydro-geomorphic units like pediments, buried pediments and intermonatne valley cover around 60% of the block area (Fig 13.1 and Plate 13.3). Except the hills in the eastern half and the western border, around 57% of the block area depict land surface slope of <5% (Plate 13.4; Fig 13.2). Another 13% area show surface relief of <10%, which is also suitable for infiltration and recharge of groundwater. The soil types include the red gravel (ultisol) and red sandy soil (alfisol).

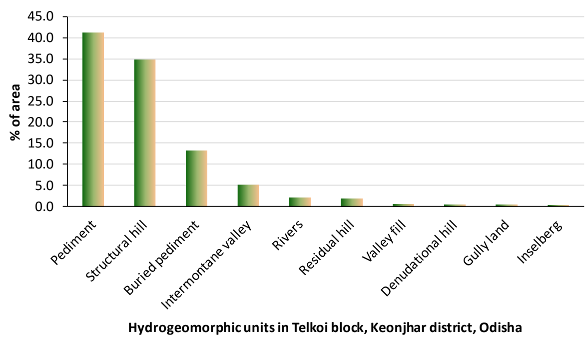


Figure 13.1: Bar diagram depicting the area percent (%) distribution of different hydro-geomorphic units in Telkoi block.

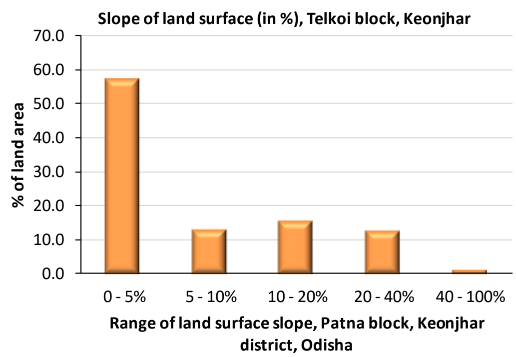


Figure 13.2: Bar diagram depicting the area percent (%) distribution of ground surface slope in Telkoi block, Keonjhar district.

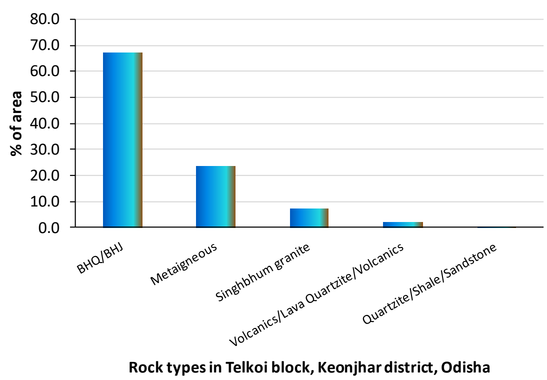


Figure 13.3: Percentage (%) of Telkoi block area (Keonjhar dist.) covered by various rock types.

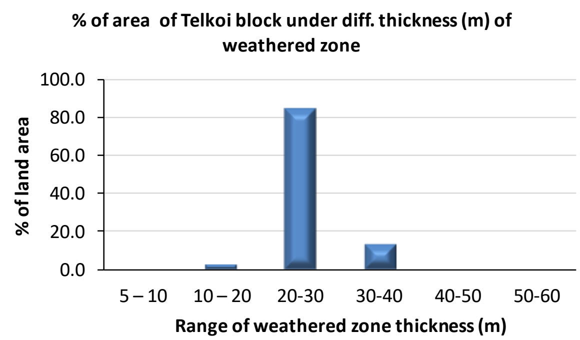


Figure 13.4: Bar diagram depicting the percentage (%) area of Telkoi block, Keonjhar district falling under different weathered zone thickness (m) ranges.

9.3 Geology

The block is predominantly occupied by metasediments and Banded Iron Formations (BHQ/BHJ/BMQ). The lithologies cover 67% of the block area. Other rock types include the Singhbhum Granite, granite gneisses and volcanics suite of rocks (Fig 13.3 and Plate 13.5).

9.4 Hydrogeology

The weathered residumm in the Precambrian rocks at shallow depth and the fracture zones at deeper depths form groundwater repositories in the hard rock areas of the block. The generalized hydrogeological map of the block is presented in Plate 13.7. The Singhbhum Granites, granite gneisses and BIF bear low to moderate yield potential varying between 3-10 lps, whereas the yield in the volcanics remains quite satisfactory in the range of 10-40 lps.

The pre-monsoon (year 2018) water levels in the block were deeper in the range of 5.0-12.5 m bgl except a few patches in the eastern side (Plate 13.7). The deepest water levels occurred in the northern half close to the Samakoi River. However, during the post-monsoon measurements, most of the areas showed rise in water levels up to <5.0 m bgl, except the patches close to the river as cited above (Plate 13.8). This indicated good recharge from rainfall. The annual fluctuations in the water levels remained largely between <2.0 to 4.0 m (Plate 13.9).

9.5 Aquifer geometry and characters

In a larger part of the block (84% of area) the thickness of the weathered zone remained in the range of 20-30 m. Another 13% of the area showed the thickness range of 30-40 m (Plate 13.10; Fig 13.4). The thick weathered zones form good prospect for groundwater to dug wells and shallow tube wells. The general 3D and 2D disposition of the aquifers in the block has been produced in Fig 13.5a-b. With the present set of data and unavailability of bore well data, it is difficult to opine about the fracture zones in the block. However, such geological formations as found in the block generally possess 2-3 sets of fractures within 100 m depth (1st aquifer system) in other blocks of the district. In the 2nd aquifer system (100-200 m bgl), 0-1 sets of fractures are encountered during drilling.

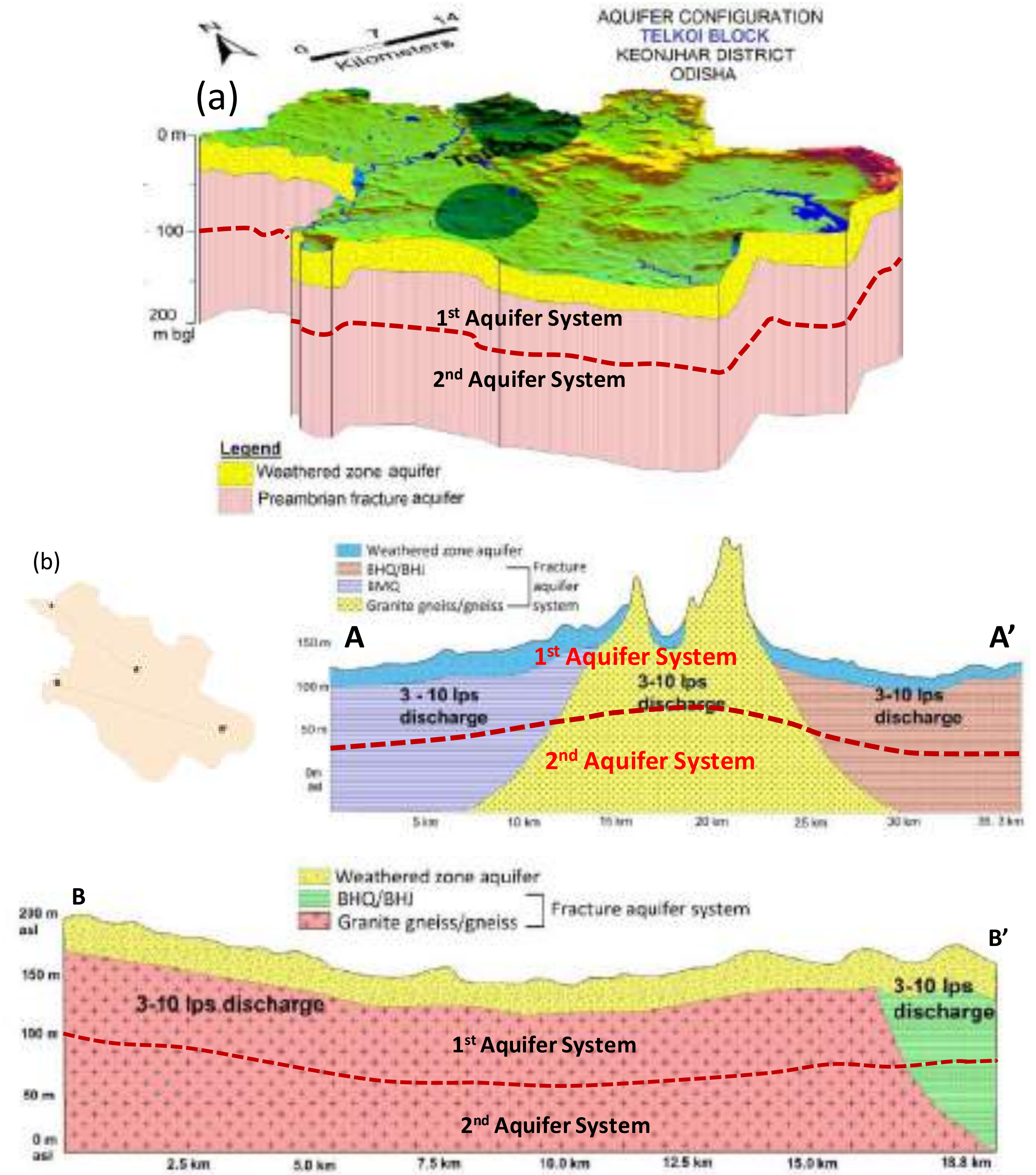


Figure 13.5: (a) 3D aquifer disposition in Telkoi block, Keonjhar district. (b) 2D hydrogeological transects (including their locations) A-A' and B-B' depicting the aquifer disposition in the block.

9.6 Ground water potential zones

Based on the overlay analysis (in GIS platform) of 9 input parameters (Geomorphology, Geology, land slope, land use/land cover, drainage density, lineament density, soil, weathered

zone thickness and rainfall) which control the occurrence and movement of groundwater, the probable groundwater potential zones in the block have been delineated (Plate 13.14). As per this analysis, the good to very potential zones of groundwater lie in the northern half in the Samakoi River basin and close to the Remala reservoir (Plate 13.14). Around 40% of the geographical area of the block has been delineated as forming good to very groundwater potential zones (Fig 13.6).

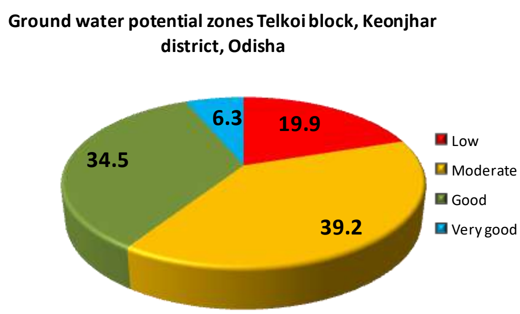


Figure 13.6: Pie diagram depicting the perentage (%) of Telkoi block, Keonjhar district, Odisha, falling under different groundwater potential zones.

9.7 Ground water quality

Ground water in the block is alkaline in nature (Table 13.1) and pH range of 7.51-8.21. The water is moderately hard to very hard in nature. The mineralization is low to moderate with TDS in the range of 55-502 mg/L (ave.: 203 mg/L). Ground water is fit for drinking and irrigation except certain pockets. The water types are predominantly Ca-HCO_3 followed by Ca-HCO_3–Cl types (Fig 13.7).

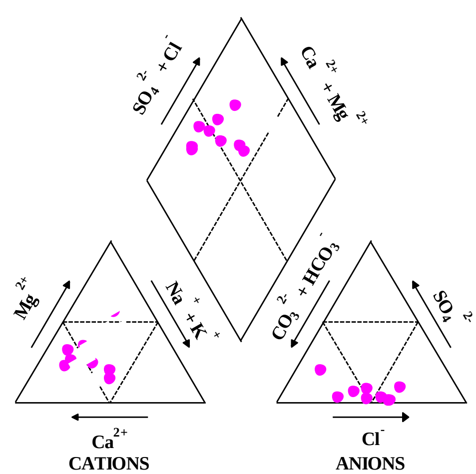


Figure 13.7: The Piper trilinear diagram depicting the groundwater quality in Telkoi block, Keonjhar district.

Table 13.1: Ground water quality at various locations in Telkoi block, Keonjhar district.

LOCATIONS	pH	EC (µS/cm)	Ground water quality parameters in mg/L											
			TDS	TH	Alkalinity	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	F
Binjhabahal	8.21	980	502	350	146	36	63	50	5.66	0	179	214	40	0.16
Kantalei	7.95	120	55	41	35	11	3	2	2.59	0	43	5	10	0.18
Akul	7.72	195	117	85	59	20	9	7.5	3.99	0	72	38	2.2	0.209
Bimala	7.97	410	209	170	113	44	15	5.4	10.05	0	137	55	11.3	0.23
Jagmohanpur	7.94	650	329	260	132	62	26	31.71	1.45	0	161	120	6.9	0.337
Kaliahata	7.51	100	67	35	25	10	2	9.3	3.94	0	30	26	0.7	0.148
Katalaposi	7.96	305	176	140	113	42	9	9.8	3.6	0	137	38	4.6	0.292
Padang	7.6	155	93	50	34	14	4	13.9	3.68	0	42	36	0.6	0.153
Telkoi	8.16	565	282	195	127	52	16	35.5	1.16	0	155	81	19.3	0.232
Min.:	**7.51**	**100**	**55**	**35**	**25**	**10**	**2**	**2**	**1.16**	**0**	**30**	**5**	**0.6**	**0.148**
Max.:	**8.21**	**980**	**502**	**350**	**146**	**62**	**63**	**50**	**10.05**	**0**	**179**	**214**	**40**	**0.337**
Average	**7.89**	**386.67**	**203**	**147**	**87.11**	**32.33**	**16.33**	**18.35**	**4.01**	**0.00**	**106.22**	**68.11**	**10.62**	**0.22**

9.8 Ground water resources

The salient information on the annual dynamic groundwater resources are produced in Table 13.2-13.4. The net dynamic groundwater available is 6885.7.6 Ham and the stage of groundwater development stands at 31.6%. Net resource available for future irrigation needs stands at 4682.7 Ham (Fig 13.8). The instorage/static groundwater resource component of 5865.9 Ham (Table 13.3) comes from the 1st aquifer system within 100 m bgl. The total groundwater available in the block stands at 12764.1 Ham.

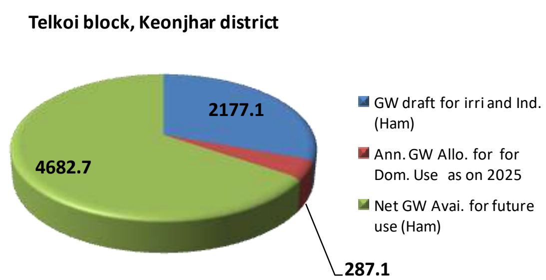


Figure 13.8: Bar diagram depicting the net dynamic groundwater resource (in Ham) available for future use, Telkoi block, Keonjhar district, Odisha.

Table 13.2: Salient information on annual dynamic groundwater resources, Telkoi block, Keonjhar district, Odisha (Phreatic/unonfined/1st Aquifer).

1. Net dynamic groundwater resources available (Ham)	6885.7
2. Irrigation draft (Ham)	1898.0
3. Industrial draft (Ham)	17.9
4. Domestic draft (Ham)	261.2
5. Total draft (Ham)	2177.1
6. Annual groundwater resource (Ham) allocation for for domestic use up to 2025	287.1
7. Net groundwater available for future use (Ham)	4682.7
8. Stage of groundwater extraction (%)	31.6

Table 13.3: Total groundwater resoure available in the Telkoi block, Keonjhar district, Odisha.

Sl No.	Category of groundwater resource	Resource (Ham)
1	Annual dynamic groundwater resources (Ham) of 1st Aquifer System	6885.7
2	Static/ In-storage groundwater resource (Ham) of 1st Aquifer System	5865.9
3	Static/ In-storage groundwater resource (Ham) of 2nd Aquifer System	12.6
	Block total	**12764.1**

9.9 Aquifer management plan

The existing stage of groundwater development of 31.6% can safely be increased up to 60% without much negative effect on the water level. Additional groundwater abstraction

structures as estimated in Table 13.4 (442 bore wells/dug-cum-bore wells and 3758 dug wells) are required to be constructed to develop the available additional resource of 1954.3 Ham. It can help in creating additional irrigation potential for 3713.2 Ha (Table 13.5). It can help in enhancing the existing irrigation facility of 33% to 50%.

Only around 105.65 km^2 area in the block showed post-monsoon depth to water levels >5.0 m bgl (Plate 13.15; Table 13.6). The area can be utilized for groundwater recharge through artificial means, by constructing percolation ponds, sub-surface dykes, nala/contour bunds and check dams. A total of 11.09 MCM of water (Table 13.7) can be recharged by the help additional 22- percolations ponds, 11-subsurface dykes, 11-nala/contour bunds and 22-check dams (Table 13.8) with a total cost of 7.21 crores (Table 13.9).

Table 13.4: Number of additional feasible groundwater abstraction structures in Telkoi block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Net dynamic GW avail. (Ham)	6885.7
2	Stage of GW deve. (%)	31.6
3	Present GW draft (Ham)	2177.1
4	Ground water draft at 60% stage of deve. (Ham)	4131.4
5	Addi. water to be deve. (Ham)	1954.3
6	Addi. No of BW/ STW feasible in Each block (assuming unit draft as 2.21/ ham/struct./ yr) using 50% of surplus	442
7	Addi. No. of DW feasible (assuming unit draft as 0.26/ ham/struct./ yr) using 50% of surplus	3758

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Addi.- additional; struct.- structure; yr.- year; avail.- availability

Table 13.5: Irrigation potential likely to be created in Telkoi block, Keonjhar district, Odisha (as on 31st Mar 2017) by enhancing the stage of groundwater development up to 60%.

Sl No.	Salient feature	
1	Present stage of GW development (%)	31.6
2	Surplus GW avai. for 60% stage of deve. (Ham)	1954.3
3	Irri, Pot. likely to be created for Paddy (Ha)	781.7
4	Irri. Pot. likely to be created for ground nut, oil seed (Ha)	977.2
5	Irri. Pot. likely to be created for veg. (Ha)	1954.3
6	Proj. area to be Irri. (ha)	3713.2

Abbreviations: GW- groundwater; deve.- development; Ham- hectare meter; Irri.- irrigation; yr.- year; avail.- availability; proj- projected

Table 13.6: Areas in Telkoi block with depth to water level (DTW) >5.0 m bgl

Name of block	Total area in diff. DTW ranges (Km2)		Total area with DTW >5.0 m bgl (Km2)
	DTW 5.0 - 7.5 m bgl	DTW 7.5 - 9.3 m bgl	
Telkoi	104.07	1.58	105.65

Table 13.7: Estimation of volume of water required for artificial recharge to groundwater in Telkoi block, Keonjhar district.

Name of block	Total area of the block (km2)	Area identified for artificial recharge (km2)	Average DTW (m bgl)	Total thickness of aquifer to be saturated (m)	Aquifer volume to raise water level to 3 m bgl (MCM)	Total volume of water required to reharge (MCM)
Telkoi	961.00	105.65	6.5	3.5	369.76	11.09

Table 13.8: Number of feasible structures in Telkoi block, Keonjhar district for artificial recharge to groundwater

Name of block	Total reharge volume required (MCM)	No of different freasible structures			
		Percolation tank (40%) @0.2 MCM	sub-surface dyke (15%) @0.15 MCM	Nala bund/contour bunding (15%) @0.15 MCM	Check dams & weirs (30%) @0.15 MCM
Telkoi	11.09	22	11	11	22

Table 13.9: Estimation of cost of artificial recharge structures in Telkoi block, Keonjhar district.

Name of block	Cost of artificial recharge structures				Total cost in each block (rupees in crores)
	Percolation tank (40%) @20 lakhs	sub-surface dyke (15%) @10 lakhs	Nala bund/contour bunding (15%) @5 lakhs	Check dams & weirs (30%) @5 lakhs	
Telkoi	4.44	1.11	0.55	1.11	7.21

PLATE – 13.1

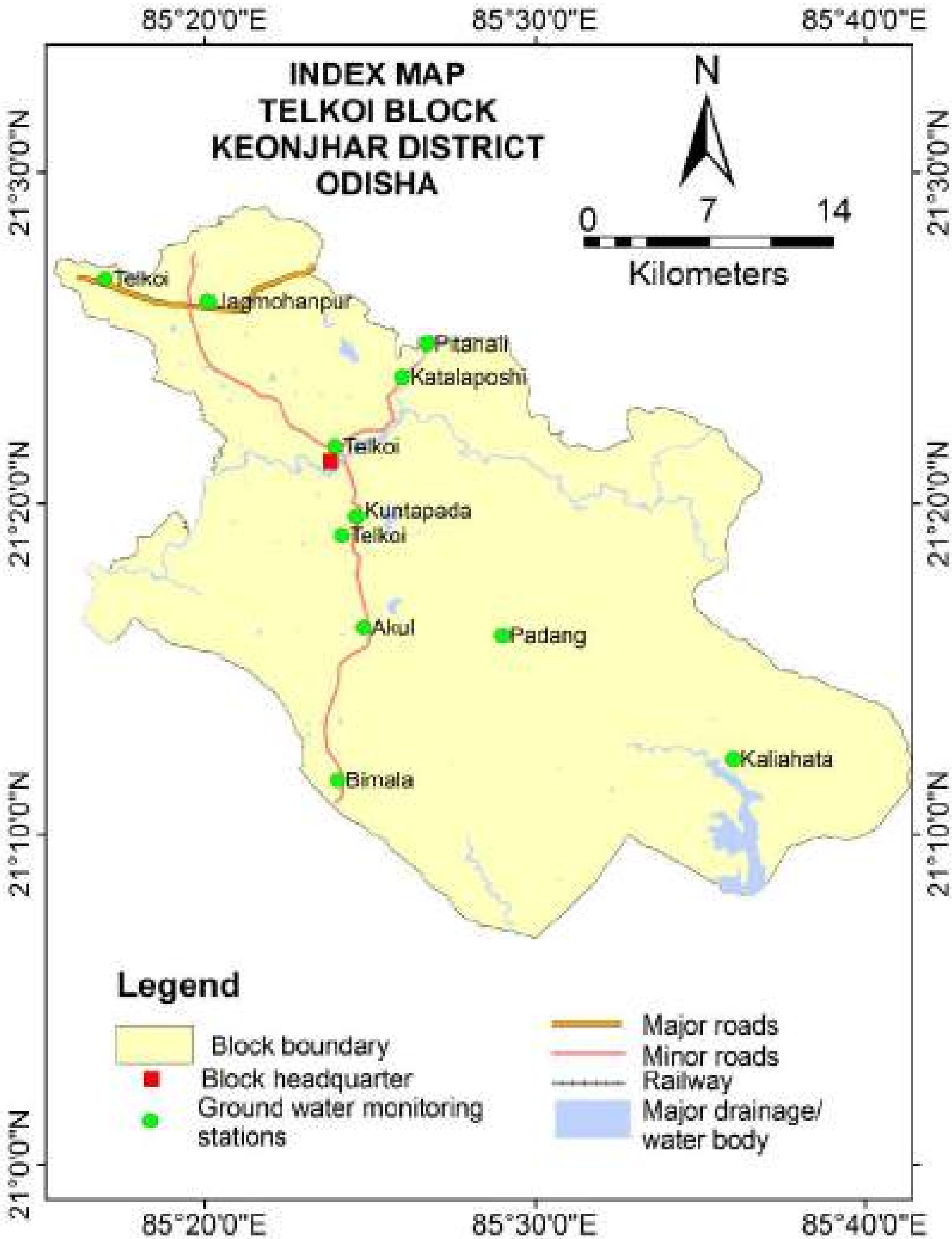

85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
INDEX MAP
TELKOI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
7
14
Kilometers
Telkoi
Jagmohanpur
Pitanali
Katalaposhi
Telkoi
Kuntapada
Telkoi
Akul
Padang
Kaliahata
Bimala
Legend
Block boundary
Block headquarter
Ground water monitoring stations
Major roads
Minor roads
Railway
Major drainage/ water body

PLATE – 13.2

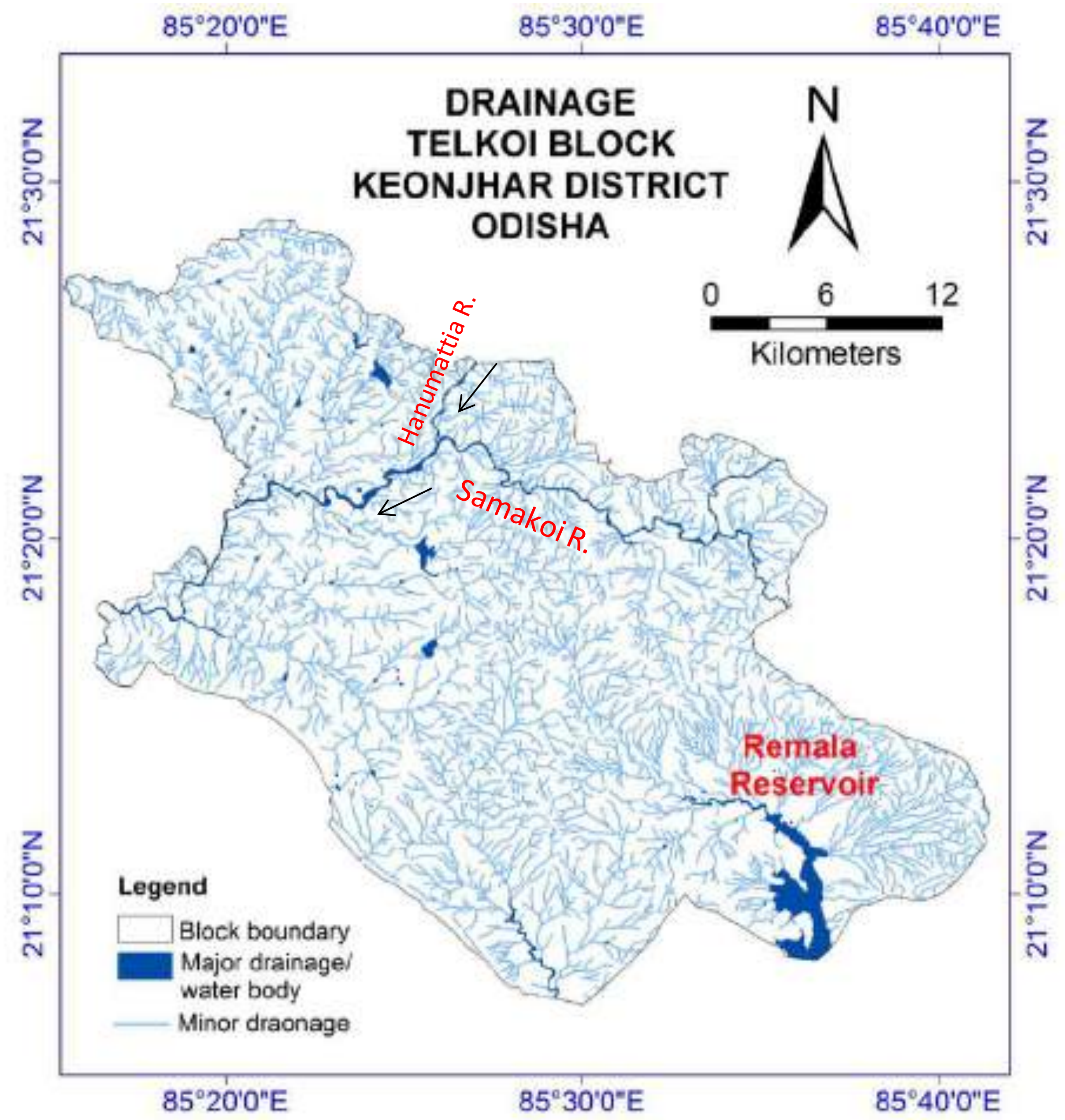

85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
DRAINAGE
TELKOI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
Hanumattia R.
Samakoi R.
Remala Reservoir
Legend
Block boundary
Major drainage/ water body
Minor draonage

PLATE – 13.3

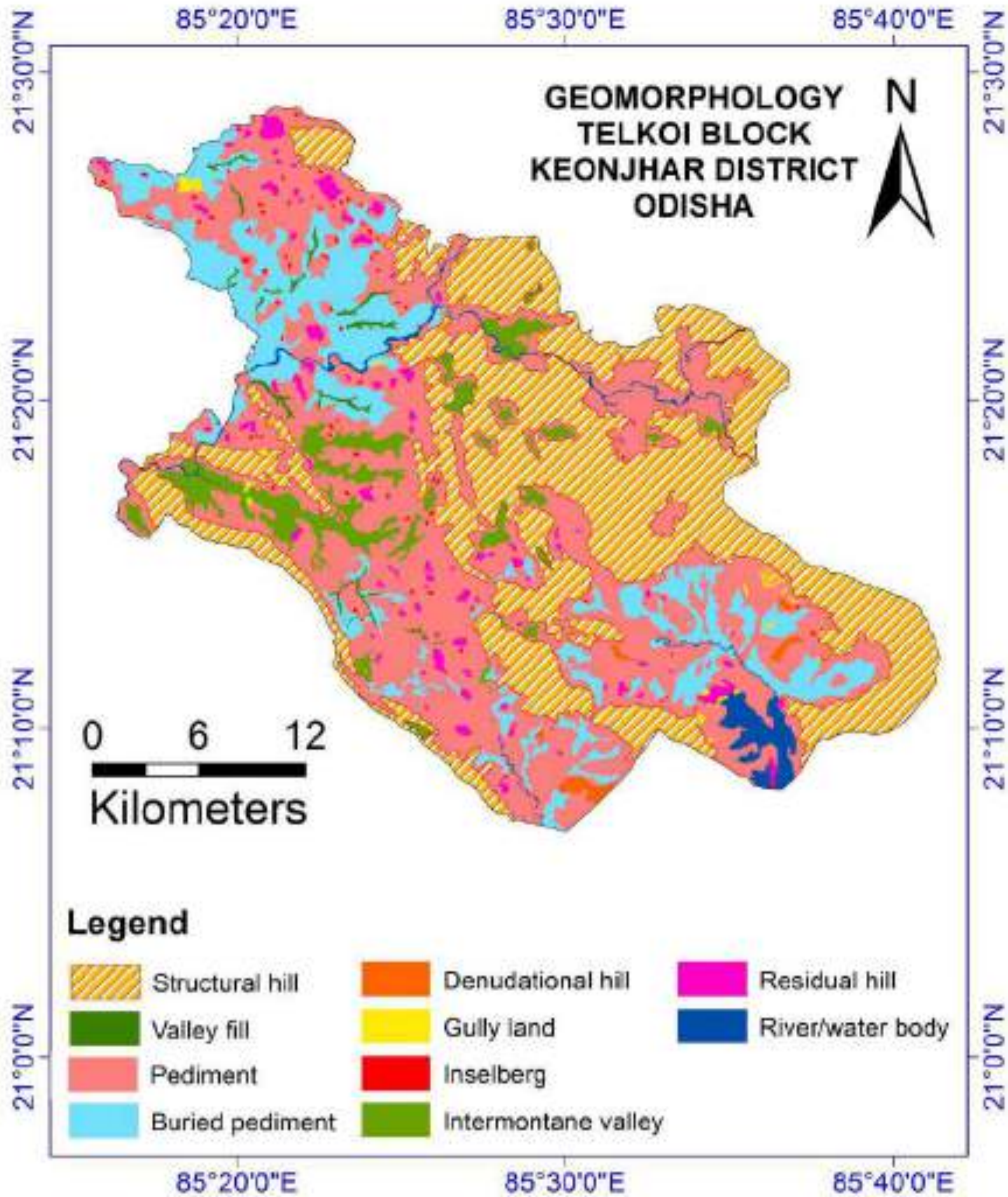

85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
GEOMORPHOLOGY
TELKOI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0
6
12
Kilometers
Legend
Structural hill
Valley fill
Pediment
Buried pediment
Denudational hill
Gully land
Inselberg
Intermontane valley
Residual hill
River/water body

PLATE – 13.4

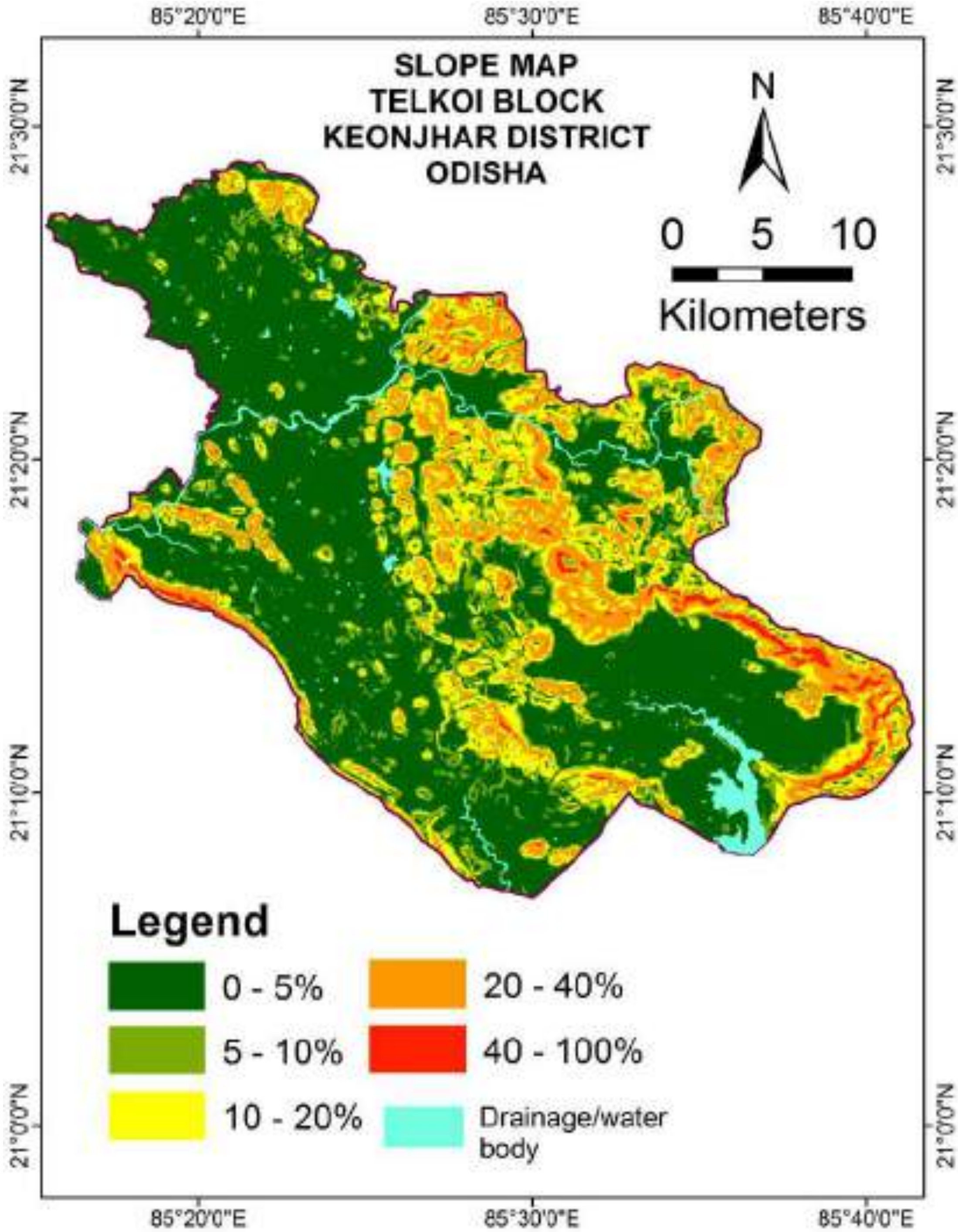
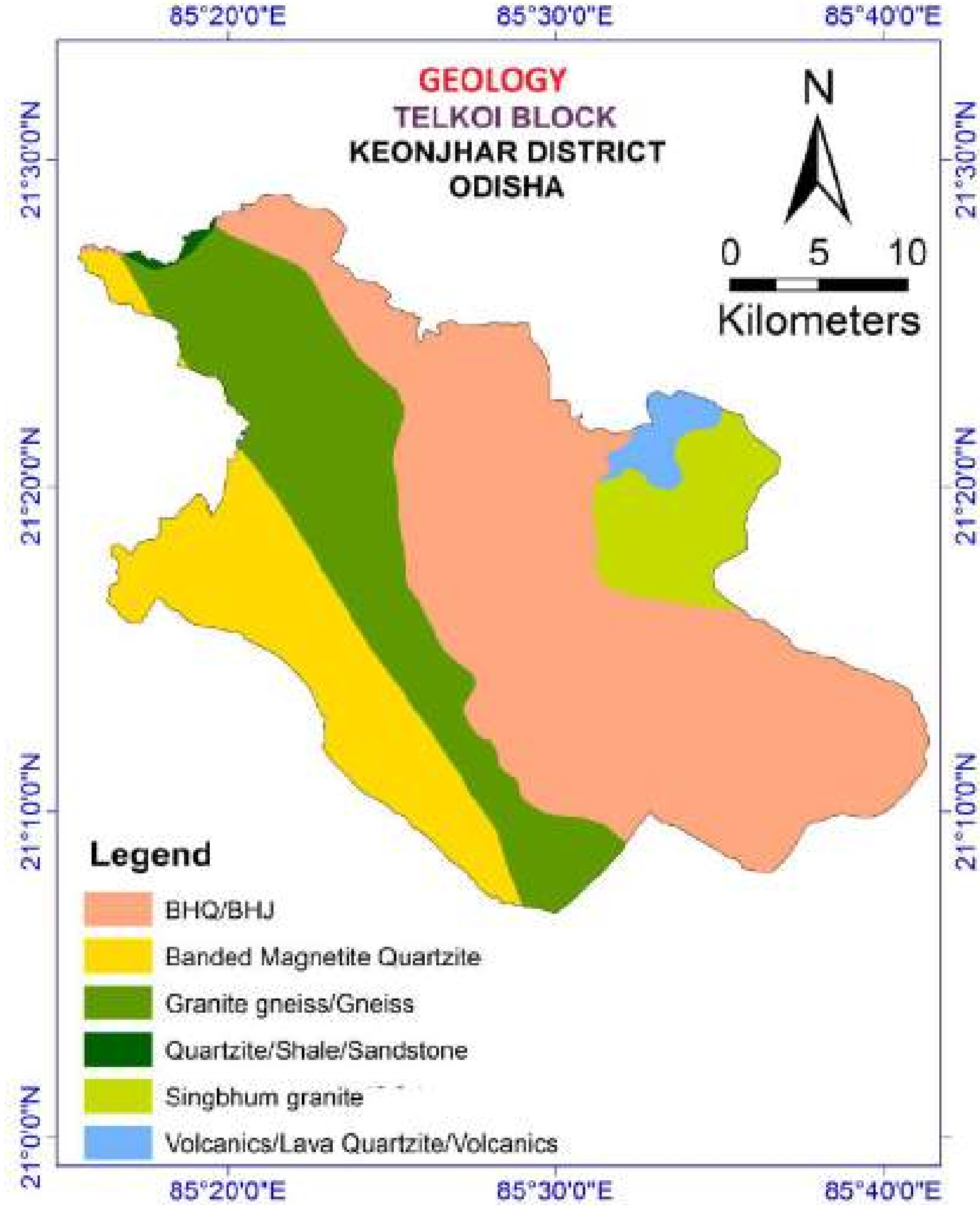

SLOPE MAP
TELKOI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend
0 - 5%
5 - 10%
10 - 20%
20 - 40%
40 - 100%
Drainage/water body

PLATE – 13.5



GEOLOGY
TELKOI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 5 10
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend
BHQ/BHJ
Banded Magnetite Quartzite
Granite gneiss/Gneiss
Quartzite/Shale/Sandstone
Singbhum granite
Volcanics/Lava Quartzite/Volcanics

PLATE – 13.6

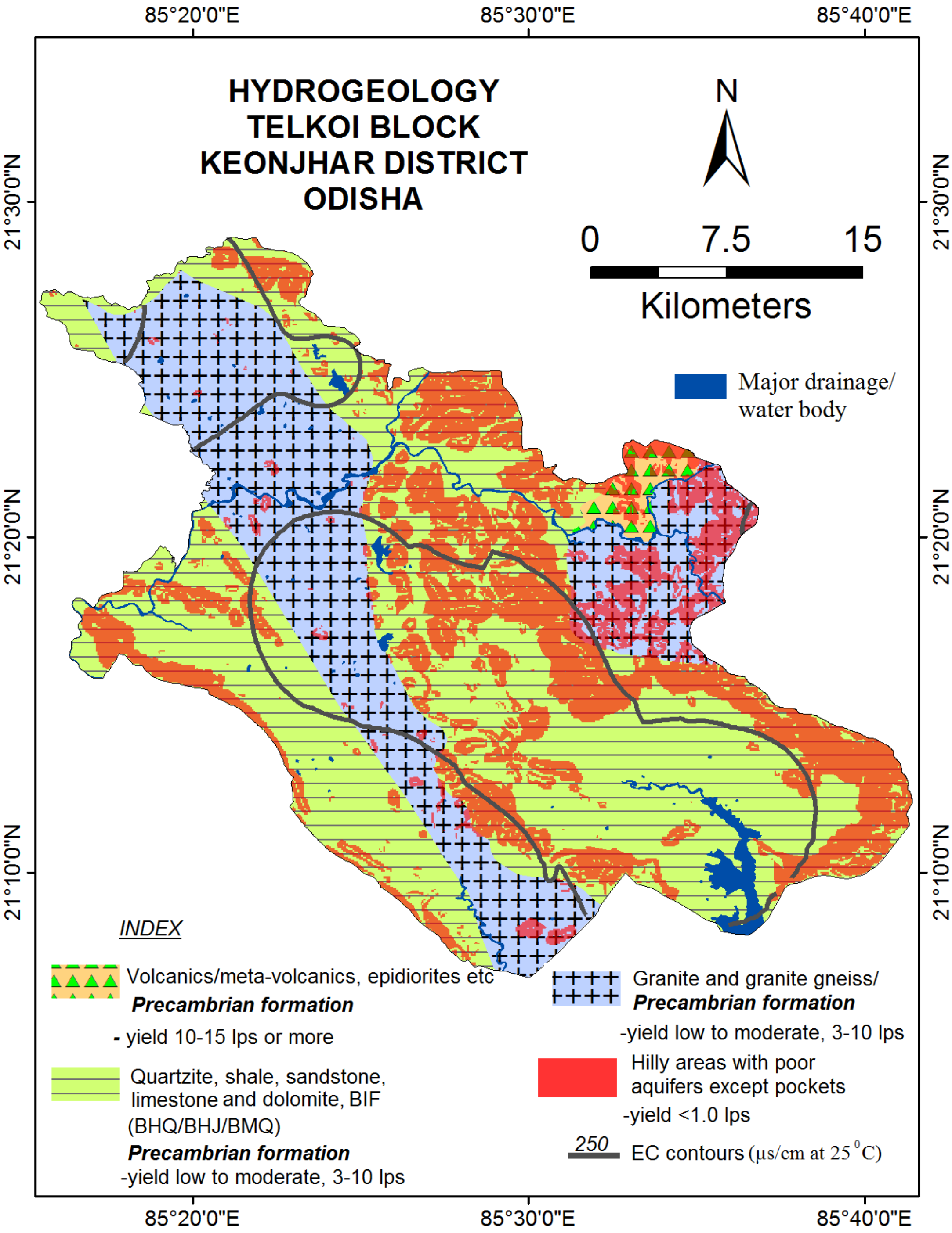
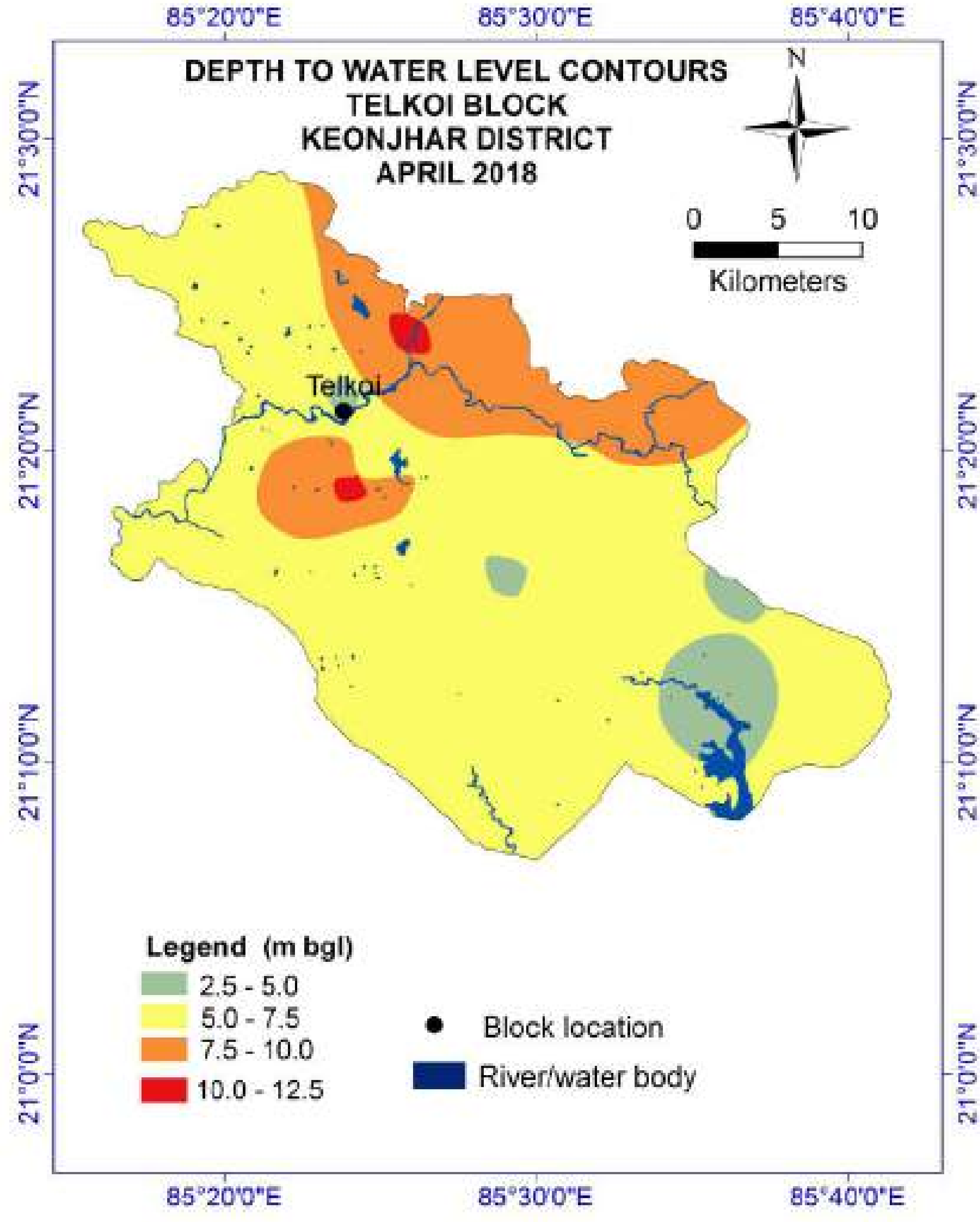

85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
HYDROGEOLOGY
TELKOI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 7.5 15
Kilometers
Major drainage/ water body
INDEX
Volcanics/meta-volcanics, epidiorites etc
Precambrian formation
- yield 10-15 lps or more
Quartzite, shale, sandstone, limestone and dolomite, BIF (BHQ/BHJ/BMQ)
Precambrian formation
-yield low to moderate, 3-10 lps
Granite and granite gneiss/
Precambrian formation
-yield low to moderate, 3-10 lps
Hilly areas with poor aquifers except pockets
-yield <1.0 lps
250 EC contours (μs/cm at 25 °C)

PLATE – 13.7



DEPTH TO WATER LEVEL CONTOURS
TELKOI BLOCK
KEONJHAR DISTRICT
APRIL 2018
N
0 5 10
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Telkoi
Legend (m bgl)
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
10.0 - 12.5
Block location
River/water body

PLATE – 13.8

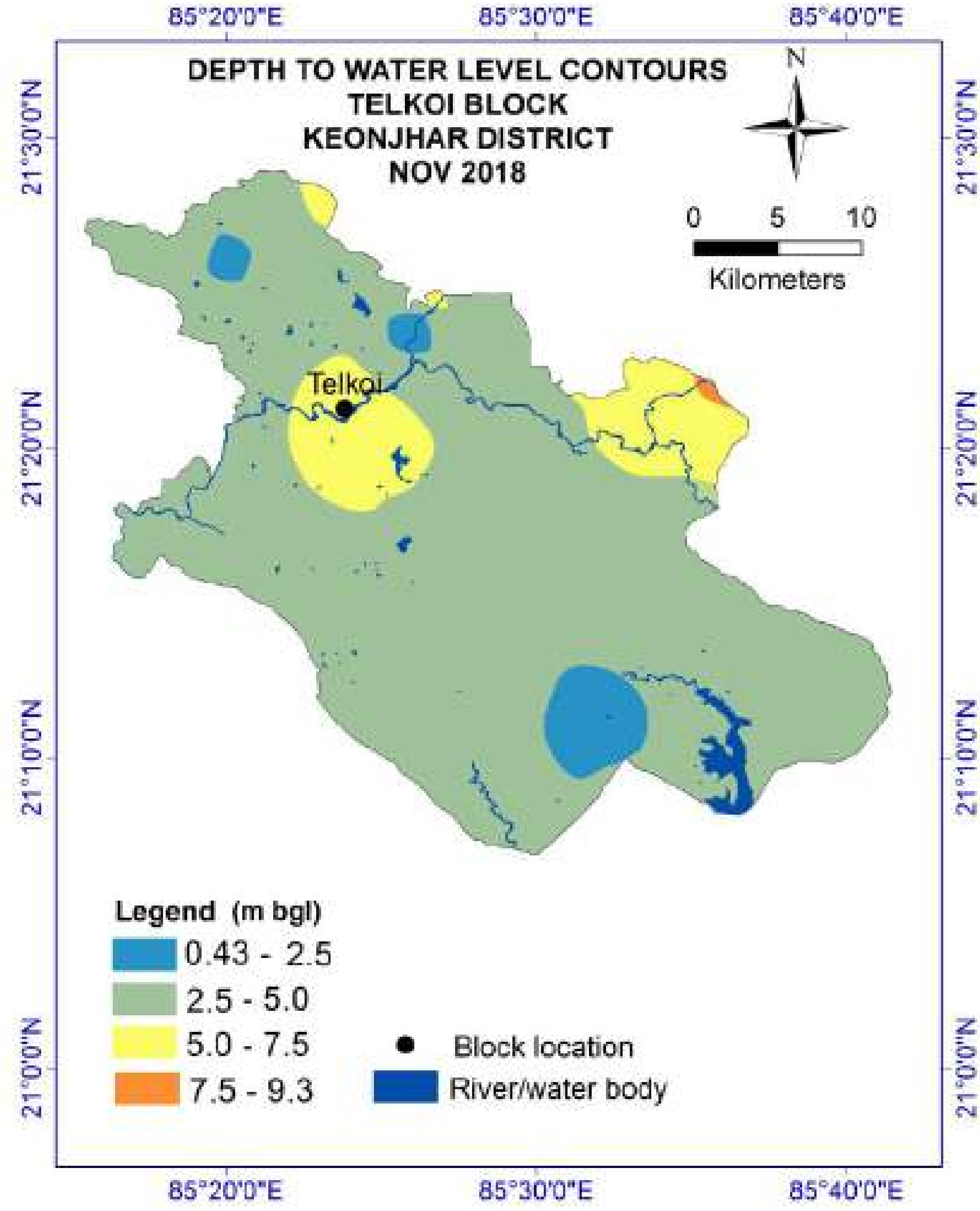

DEPTH TO WATER LEVEL CONTOURS
TELKOI BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0
5
10
Kilometers
Telkoi
85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
21°0'0"N
Legend (m bgl)
0.43 - 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 9.3
Block location
River/water body

PLATE – 13.9

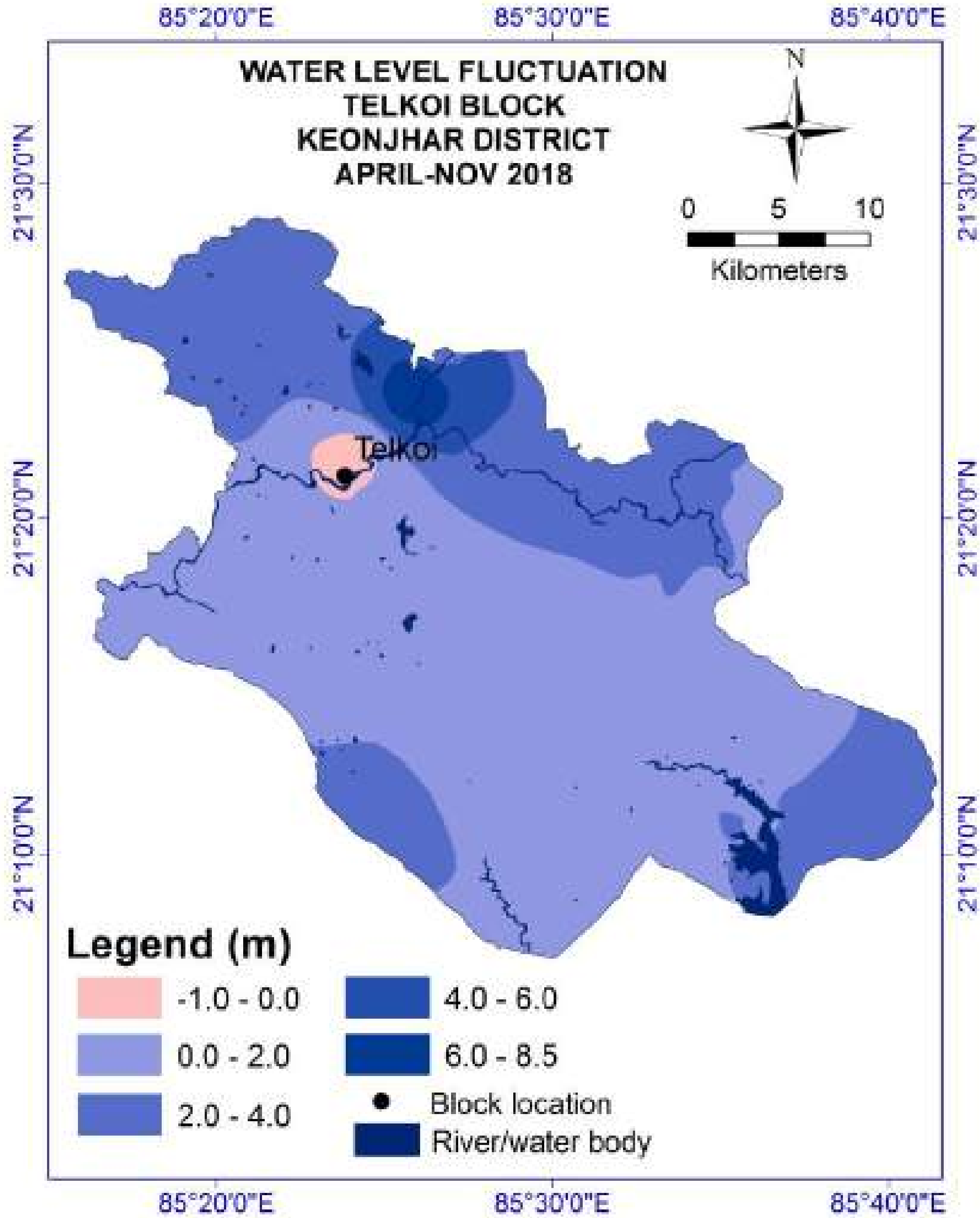

WATER LEVEL FLUCTUATION
TELKOI BLOCK
KEONJHAR DISTRICT
APRIL-NOV 2018
N
0 5 10
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
Telkoi
Legend (m)
-1.0 - 0.0
0.0 - 2.0
2.0 - 4.0
4.0 - 6.0
6.0 - 8.5
Block location
River/water body

PLATE – 13.10

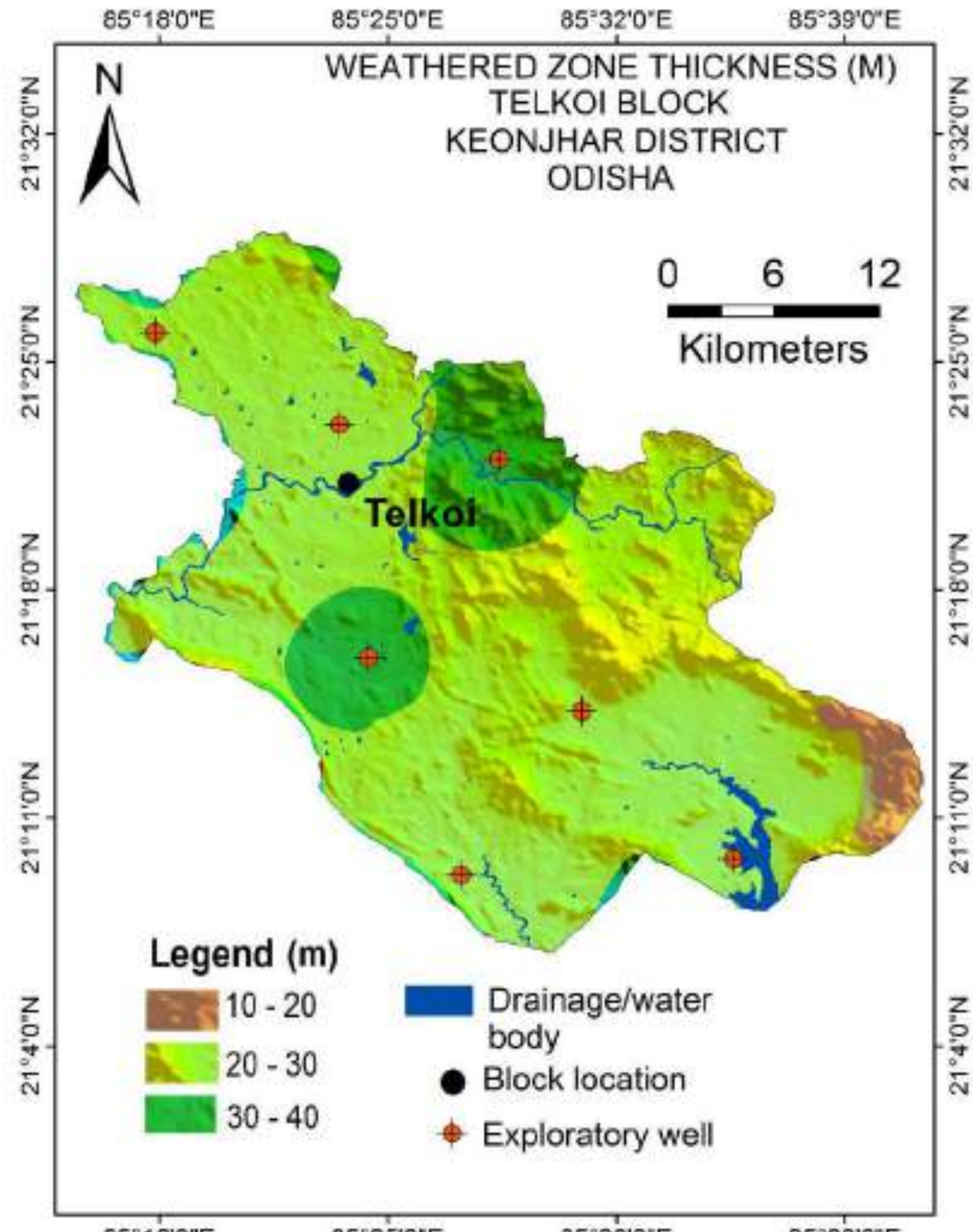

WEATHERED ZONE THICKNESS (M)
TELKOI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
Telkoi
Legend (m)
10 - 20
20 - 30
30 - 40
Drainage/water body
Block location
Exploratory well
85°18'0"E
85°25'0"E
85°32'0"E
85°39'0"E
21°32'0"N
21°25'0"N
21°18'0"N
21°11'0"N
21°4'0"N

PLATE – 13.14

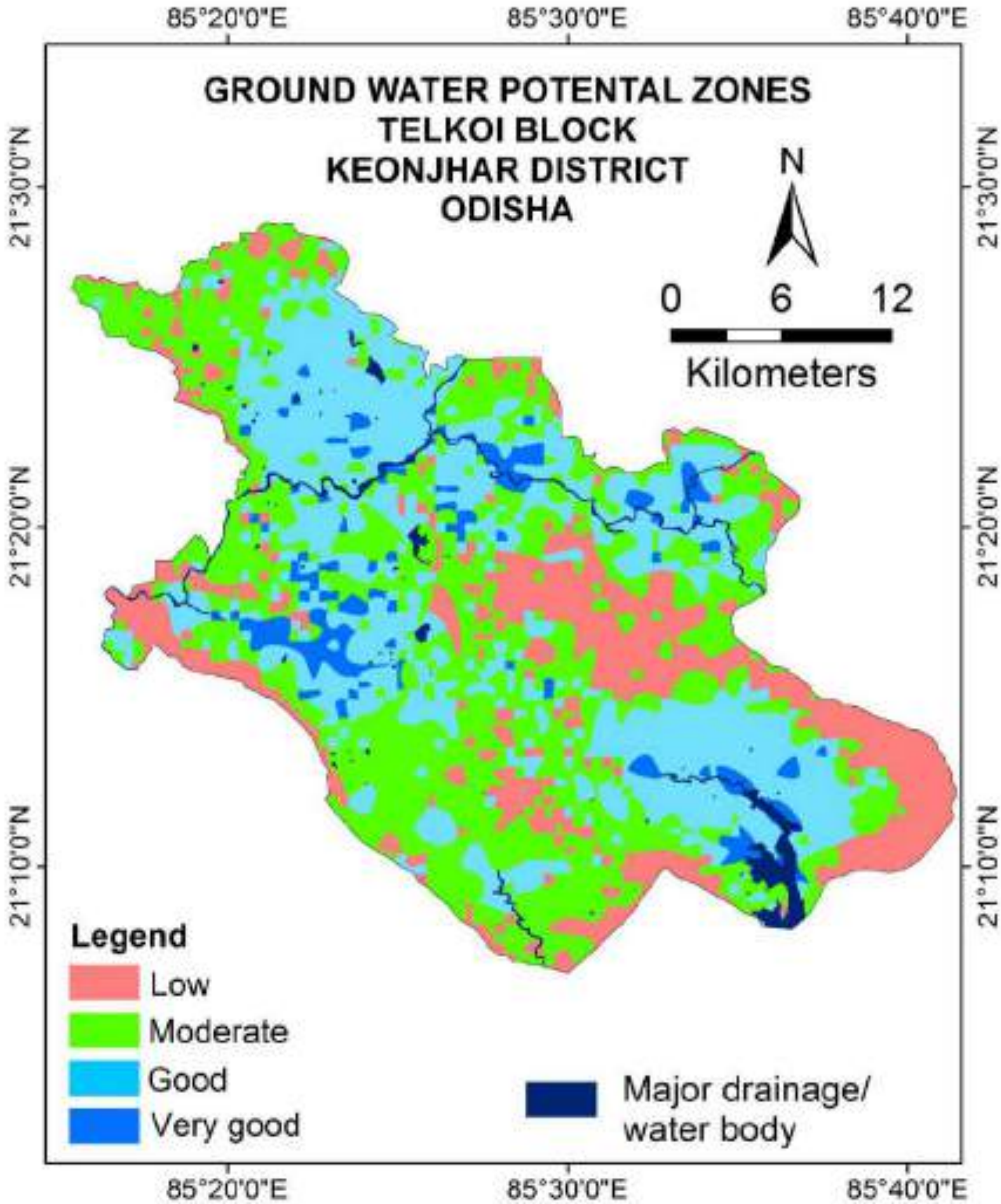
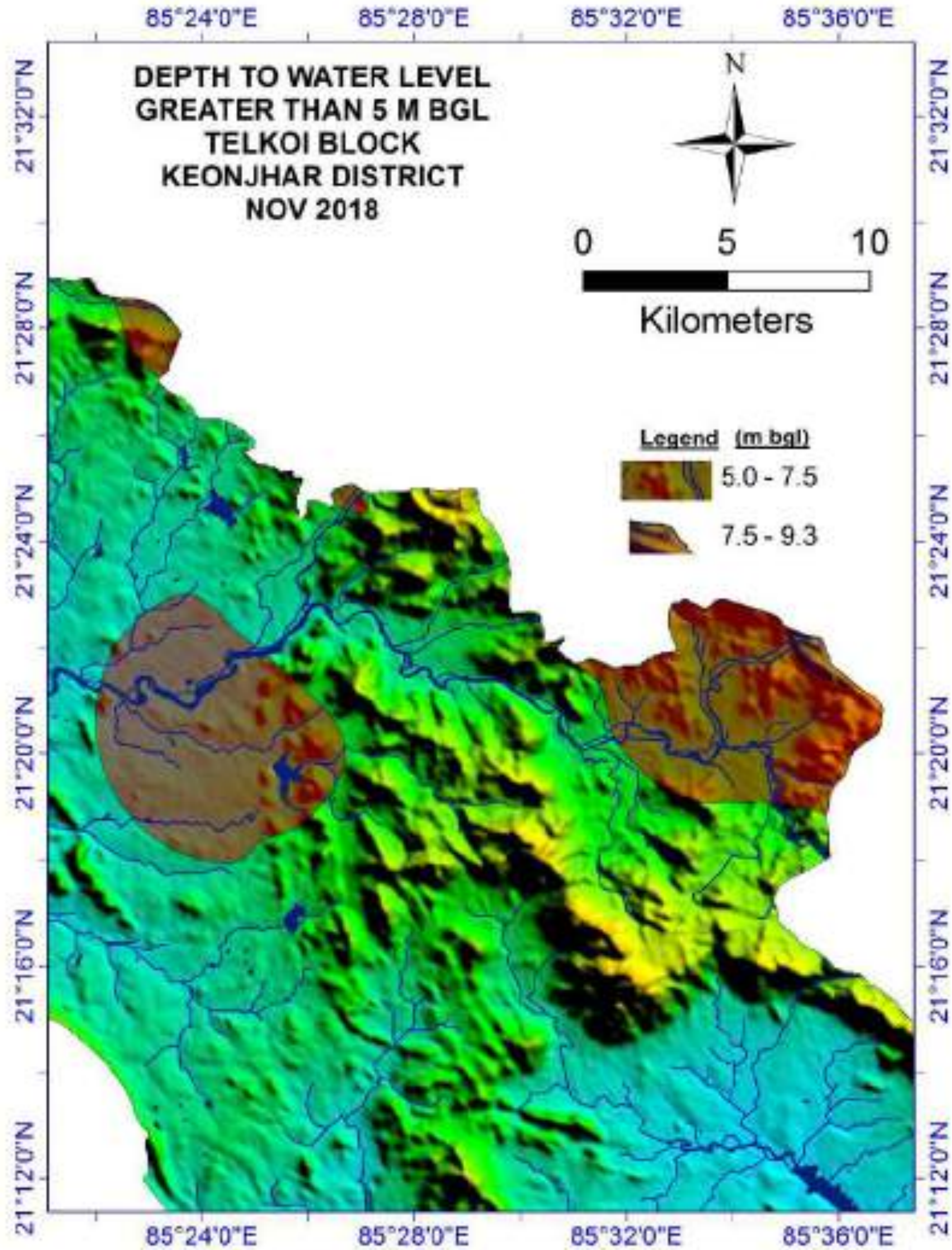

GROUND WATER POTENTAL ZONES
TELKOI BLOCK
KEONJHAR DISTRICT
ODISHA
N
0 6 12
Kilometers
85°20'0"E
85°30'0"E
85°40'0"E
21°30'0"N
21°20'0"N
21°10'0"N
Legend
Low
Moderate
Good
Very good
Major drainage/
water body

PLATE – 13.15


DEPTH TO WATER LEVEL
GREATER THAN 5 M BGL
TELKOI BLOCK
KEONJHAR DISTRICT
NOV 2018
N
0
5
10
Kilometers
Legend (m bgl)
5.0 - 7.5
7.5 - 9.3
85°24'0"E
85°28'0"E
85°32'0"E
85°36'0"E
21°32'0"N
21°28'0"N
21°24'0"N
21°20'0"N
21°16'0"N
21°12'0"N

स्वच्छ भारत
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