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Ministry of Jal Shakti,
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग,
Department of Water Resources,
River Development and
Ganga Rejuvenation

केंद्रीय भूमि जल बोर्ड
Central Ground Water Board

NAQUIM 2.0

जलभृत प्रबंधन योजना
Aquifer Management Plan
रायपुर शहर, रायपुर, छत्तीसगढ़
Raipur City, Raipur, Chhattisgarh

North Central Chhattisgarh Region (NCCR)
Raipur
2024

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Department of Water Resources
River Development and Ganga Rejuvenation
केंद्रीयभूमिजलबोर्ड
Central Ground Water Board

जलभृत प्रबंधन योजना
Aquifer Management Plan
रायपुर शहर, रायपुर, छत्तीसगढ़
Raipur City, Raipur, Chhattisgarh

प्राथमिकताप्रकार: शहरी इलाका
Priority Type: Urban Area

North Central Chhattisgarh Region (NCCR)
Raipur
2024

भारतसरकार

Government of India

जलशक्तिमंत्रालय

Ministry of Jal Shakti

जलसंसाधनविभाग, नदीविकासऔरगंगासंरक्षण

Department of Water Resources

River Development and Ganga Rejuvenation

केंद्रीयभूमिजलबोर्ड

Central Ground Water Board

जलभृत प्रबंधन योजना

Aquifer Management Plan

रायपुर शहर, रायपुर, छत्तीसगढ़

Raipur City, Raipur, Chhattisgarh

CONTRIBUTORS

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NORTH CENTRAL CHHATTISGARH REGION RAIPUR
2024

डॉ. सुनील कुमार अम्बष्ट
अध्यक्ष
Dr. Sunil Kumar Ambast
Chairman

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन,
नदी विकास और गंगा संरक्षण विभाग
केन्द्रीय भूमि जल बोर्ड
Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development & Ganga Rejuvention
Central Ground Water Board

Message

National Aquifer Mapping and Management Programme (NAQUIM) was initiated by Central Ground Water Board (CGWB) in 2012 with the goal of mapping and managing aquifers across India to promote sustainable groundwater use. So far the entire mappable area of 25 lakh km^2 has been covered under the NAQUIM programme. While these initial efforts have been highly impactful, they faced certain limitations especially in terms of spatial resolution.

Taking it forward, CGWB has now initiated **NAQUIM 2.0,** the next phase of aquifer mapping designed to provide a deeper, more detailed understanding of India's groundwater systems. During 2023-24, CGWB had completed NAQUIM 2.0 studies in 68 study areas. The study areas were selected in consultation with the State/UT government agencies.

I am confident that this report of NAQUIM 2.0 study will serve as a critical resource for government agencies, research institutions, NGOs, and the general public. By fostering a collaborative approach to groundwater management, this report will play a key role in safeguarding and sustaining India's precious ground water resources.

(Dr. Sunil Kumar Ambast)

Chairman, CGWB

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डॉ. ए. अशोकन, सदस्य

Dr. A. Asokan, Member

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नदी विकास और गंगा संरक्षण विभाग
केंद्रीय भूमि जल बोर्ड
Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development and Ganga Rejuvenation
Central Ground Water Board

Message

A realistic evaluation of the availability and utilization of a natural resource is imperative for formulating strategies to ensure its sustainable development and its management. This significance is heightened, especially in the context of groundwater in the Country, which faces escalating stress due to its extraction for diverse purposes. The consequence of this situation is a decline in groundwater levels, the desaturation of aquifers, and the deterioration of water quality, among other issues. Groundwater needs to be used and managed in a sustainable way to ensure its long-term sustainability.

The NAQUIM 2.0 study has involved meticulous fieldwork, advanced analysis, and detailed interpretation to ensure that our findings are both accurate and informative. The study covers various aspects, including availability, and potential for future development. The data and recommendations outlined after this study will be instrumental in guiding strategic decisions and supporting sustainable management of groundwater resources. The findings obtained after this study are of great importance not only to policymakers and stakeholders but also to the public. Understanding the status and potential of our groundwater resources is crucial for informed decision-making and fostering community engagement.

The report, titled "Report on Aquifer Management Plan of Raipur City, Raipur District, Chhattisgarh" serves as a comprehensive outcome of the exploration results. The report embodies water level behavior, ground water exploration, geophysical exploration, geochemical analysis, hydrometeorological aspects, statistical analysis, in Raipur City of Chhattisgarh state. This is the first attempt to synthesize the entire set of related data, analyze and interpret them and to present the findings on micro level in a format that appeal to the academicians, administrators and all the stakeholders in ground water.

The commendable endeavors undertaken by the Central Ground Water Board, North Central Chhattisgarh Region in the creation of the "Report on Aquifer Management Plan of Raipur City, Raipur District, Chhattisgarh" Report deserve praise. I have every confidence that this report will offer substantial benefits to a wide range of stakeholders, academicians, administrators and the public alike and will go a long way in the planning and management of the ground water resources for the state of Chhattisgarh

(Dr. A. Asokan)
Member (East)

डॉ. प्रबीर कु. नायक
शेत्रिया निर्देशक
Dr. Prabir K. Naik
Regional Director

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन,
नदी विकास और गंगा संरक्षण विभाग
केंद्रीय भूमि जल बोर्ड
Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development and Ganga Rejuvenation
Central Ground Water Board

Message

The development of groundwater resources has been undertaken over the years to meet domestic, irrigation, and industrial needs. However, the spatial distribution of groundwater availability is uneven, and its excessive exploitation by various users has been exerting continuous pressure on it. On the other hand, rapid urbanization, industrialization, and changes in land use have led to a decline in water levels in many parts of the country.

The Central Ground Water Board (CGWB) is actively engaged in the development and management of this resource through various scientific studies and techniques. Over the past four decades, CGWB's North Central Chhattisgarh Region (NCCR), Raipur, has collected an extensive dataset concerning the groundwater resources of Chhattisgarh. Based on this experience, with the data collected and available from the North Central Chhattisgarh Region, an aquifer mapping of the Raipur urban area was prepared.

This report encompasses all aspects related to groundwater in the study area, such as physics, meteorology, hydrology, drainage, geomorphology, geology, hydrogeology, groundwater resources, water chemistry, geophysics, groundwater problems, etc.

Titled "Report on Aquifer Management Plan of Raipur City, Raipur District, Chhattisgarh," this report was prepared by Scientist D, Mrs. Priyanka B. Sonbarse. I believe this report will prove extremely useful and beneficial for the water management plan of Raipur city and will serve as a valuable document for all stakeholders related to groundwater, such as academicians, administrators, and planners.

Although every effort has been made to minimize errors in the report, some inadvertent mistakes may remain. It is hoped that these errors will be viewed with an appropriate perspective.

डॉ. प्रबीर कुमार नायक
(क्षेत्रीय निदेशक)

Acknowledgement

I would like to express my gratitude to Dr. Sunil Kumar Ambasht, Chairman of the Central Ground Water Board, for providing the opportunity to prepare the Report on Aquifer Management Plan of Raipur City, Raipur District, Chhattisgarh.

I also extend my deep appreciation to Dr. A. Ashokan, former member of CGWB, for his encouragement and suggestions during the preparation of this report.

I am thankful to Dr. Prabir K. Naik, Regional Director of the Central Ground Water Board, North Central Chhattisgarh Region, Raipur, for his valuable guidance and continuous encouragement during the preparation of this report.

I am grateful to Mr. Ranjan Ray, Scientist (D), CHQ, Faridabad, for his guidance, and I also wish to thank Dr. Angrush Mukherjee, retired scientist of the Central Ground Water Board, for providing direction during the creation of this report. I thank Mr. B. Abhishek, Scientist (C), for his valuable guidance and suggestions during the preparation of the report.

I express my gratitude to Mr. Rajnikant Sharma, Scientist (C), and Mrs. Anita Bind, STA, for providing valuable input on chemical analysis and quality-related issues. I thank Mr. Ajay Kumar Sinha, Scientist (D), for sharing geophysical studies. I also thank Mr. Mukesh Anand, Scientist (C), and Ms. Sweta Mohanty, Assistant Hydrogeologist.

I am thankful to Mr. Sarboday Barik, Assistant Hydrogeologist, for data collection from the field. The author also expresses gratitude to state agencies for providing various necessary data. The author thanks the technical department, data center, chemical department, and library of the Central Ground Water Board, NCCR, Raipur, for providing various necessary data.

Priyanka B. Sonbarse
Scientist (D)

Executive Summary

During the Annual Action Plan: 2023-24 of Central Ground Water Board, North Central Chhattisgarh Region, Raipur, a study area of 504 km_2 study area was allocated under Phase-II of the National Project on Aquifer Mapping and Management (NAQUIM 2.0) in the Urban agglomeration of Raipur City Chhattisgarh State has been done.

This study of Raipur city was taken to get information in higher granularity with a focus on increasing the density of dynamic data like ground water level, ground water quality, etc. To provide issue - based scientific inputs for ground water management up to the zone level with involving state agencies in the studies for a sense of ownership.

Raipur City has faced overexploitation of Ground Water resources for over three decades due to Industrialization, Urbanization, Irrigation, Mining and change in land Use Land cover area resulting stress on water resource. The advent of new water well construction technologies has lessened reliance on traditional dug wells for these purposes.

According to the 2011 Census, the total population of Raipur city is 10,10,433. This includes male population of 518,611 and female population of 491,822.

Raipur city experiences a warm subtropical climate. The average annual rainfall in the area is approximately 1325.33 mm (average of last five years i.e. from 2018 to 2022).

Physiographically Raipur is situated in Mahanadi basin. The area displays a gently undulating topography with general slope towards north. The altitude ranges from 268 to 304 m amsl. The city area forms an elongated ridge like topography generating radial pattern of drainage (Fig.2). Kharun, a perennial tributary to River Seonath, is the main river draining the area with the help of Chhokra nallah and other small nallah system. The entire area is dotted with 49 number of tanks, and ponds.The main part of the city is covered with structural plains with elevation ranging from 0 to 306 m amsl. These plains lie on Proterozoic formations of the Chhattisgarh Supergroup.

Geologically, the area exhibits lithology of Precambrian age consisting of Chandi limestone, Charmuria Limestone and Gunderdehi Shales. The Charmuria Limestone and Gunderdehi Shale are not exposed in the area. subsurface geology as revealed by borehole data of the area shows that the contact of Chandi Formation and Gunderdehi Formation is sharp.

The pre-monsoon water level in Phreatic Aquifer ranged from 0.30 to 21.61 mbgl and post monsoon water level ranged from 0.37 to 15.24 mbgl whereas the seasonal fluctuation ranged from -7.10 t0 7.16 meters. The pre-monsoon water level in Fractured Aquifer ranged from 2 to 61 mbgl and post monsoon water level ranged from 1.6 to 28.1 mbgl whereas the seasonal fluctuation ranged from -6.11 t0 37.31 meters.

Basic hydro chemical analysis, heavy metal analysis, and iron analysis show that groundwater is suitable for drinking purposed.

Hard rock areas, potential aquifers were delineated in the city. Under the groundwater exploration program, 50 borewells which include EW, OW and Piezometers have been dug in the development block at a depth of 50 to 200 meters. They have given groundwater yield ranging from 0.2 to 13 LPS.

The groundwater resource calculation stage of groundwater development in the study area as of 2023 is 94.07% which was showing critical stage of ground water extraction. Therefore, it is extremely sensitive data and needs to be addressed to balance the groundwater draft and construct groundwater conservation structures in the study area as the stage is moving towards Over exploited classification.

The calculated current demand for irrigation in the area is 564.51 HAM while it is 4833.75 HAM for domestic use and 564.514 HAM for industrial area. A total of 5991.19 HAM of groundwater is available for future use to meet the future demand of groundwater and the stage of ground water extraction calculated under this study is 110.82 % which makes the Raipur City over exploited.

The major groundwater issues identified during the survey in the study area are as follows: Change in land use land cover area, increase in paved area Growing population and corresponding increase in groundwater draft. Urbanization and reducing recharge area. Depleting groundwater levels and quality and groundwater over exploitation. Drying of dug wells. Mining of limestone from quarries where continuous dewatering is done. Improper waste disposal pattern leading to groundwater quality issues. Improper Management of treated Kharun River water. Nitrate contamination due to improper sewerage system in city. in sufficient piped water supply networks, which is ultimately leading to stress on ground water resource. Irrigation practices in summer which requires a lot of ground water.

Supply-side management of aquifers includes water conservation and surface recharge through active and abandoned dug wells. The potential for conservation and augmentation of water resources through ponds, rooftop rainwater harvesting, and managed aquifer recharge through percolation tanks was assessed based on an integrated hydrogeological-geophysical study. Demand-side management of groundwater should focus on Recycle/ reuse to optimize the use, regulation, and management of the resources.

Making policy by the administration on groundwater recharge and utilization also helps in increasing groundwater. Proper sewerage networks, proper piped water supply connections and smart irrigation practices, judicious use of groundwater resources, artificial recharge techniques can help in sustainable management of water in the long run. Community-based approaches are an effective way to achieve water sustainability in areas at different levels of economic development.

कार्यकारी सारांश

केंद्रीय भूजल बोर्ड, उत्तर मध्य छत्तीसगढ़ क्षेत्र, रायपुर की वार्षिक कार्य योजना 2023-24 के दौरान, राष्ट्रीय जलभृत मानचित्रण और प्रबंधन परियोजना (NAQUIM 2.0) के चरण-II के तहत रायपुर शहर के शहरी समूह में 504 वर्ग किलोमीटर के अध्ययन क्षेत्र का आवंटन किया गया।

इस अध्ययन का उद्देश्य भूजल स्तर, भूजल गुणवत्ता आदि जैसे गतिशील डेटा की घनत्व बढ़ाकर उच्च-ग्रैन्युलैरिटी जानकारी प्राप्त करना था, ताकि राज्य एजेंसियों की भागीदारी के साथ क्षेत्र स्तर तक भूजल प्रबंधन के लिए मुद्दा-आधारित वैज्ञानिक इनपुट प्रदान किए जा सकें।

रायपुर शहर ने औद्योगिकीकरण, शहरीकरण, सिंचाई, खनन और भूमि उपयोग में परिवर्तन के कारण पिछले तीन दशकों से भूजल संसाधनों के अत्यधिक दोहन का सामना किया है, जिसके परिणामस्वरूप जल संसाधन पर दबाव बढ़ा है। नई जल कुओं की निर्माण तकनीकों के आगमन ने इन उद्देश्यों के लिए पारंपरिक खुदाई वाले कुओं पर निर्भरता को कम कर दिया है।

2011 की जनगणना के अनुसार, रायपुर शहर की कुल जनसंख्या 10,10,433 है, जिसमें 518,611 पुरुष और 491,822 महिलाएं शामिल हैं।

रायपुर शहर में गर्म उपोष्णकटिबंधीय जलवायु है। क्षेत्र में औसत वार्षिक वर्षा लगभग 1325.33 मिमी है (पिछले पांच वर्षों, यानी 2018 से 2022 तक का औसत)।

भौतिक रूप से, रायपुर महानदी बेसिन में स्थित है। क्षेत्र में धीरे-धीरे लहरदार स्थलाकृति है, जिसमें सामान्य ढलान उत्तर की ओर है। ऊंचाई 268 से 304 मीटर के बीच है। शहर का क्षेत्र एक लम्बी रिज जैसी स्थलाकृति बनाता है, जो रेडियल जल निकासी पैटर्न उत्पन्न करता है। खारुन, जो सियोनाथ नदी की एक बारहमासी सहायक नदी है, क्षेत्र की मुख्य नदी है, जो छोकड़ा नाला और अन्य छोटे नाला प्रणालियों की मदद से जल निकासी करती है। पूरे क्षेत्र में 49 टैंक और तालाब हैं। शहर का मुख्य भाग संरचनात्मक मैदानों से ढका हुआ है, जिसकी ऊंचाई 0 से 306 मीटर के बीच है। ये मैदान छत्तीसगढ़ सुपरग्रुप के प्रोटेरोज़ोइक संरचनाओं पर स्थित हैं।

भूवैज्ञानिक रूप से, क्षेत्र में प्रीकैम्ब्रियन युग की लिथोलॉजी है, जिसमें चांदी चूना पत्थर, चर्मुरिया चूना पत्थर और गुंडरदेही शेल शामिल हैं। चर्मुरिया चूना पत्थर और गुंडरदेही शेल क्षेत्र में उजागर नहीं होते हैं। क्षेत्र के बोरहोल डेटा से पता चलता है कि चांदी संरचना और गुंडरदेही संरचना का संपर्क तीव्र है। फ्रेटिक जलभृत में प्री-मानसून जल स्तर 0.30 से 21.61 मीटर बीजीएल तक और पोस्ट-मानसून जल स्तर 0.37 से 15.24 मीटर बीजीएल तक था, जबकि मौसमी उतार-चढ़ाव -7.10 से 7.16 मीटर तक था। फ्रैक्चर्ड जलभृत में प्री-मानसून जल स्तर 2 से 61 मीटर बीजीएल तक और पोस्ट-मानसून जल स्तर 1.6 से 28.1 मीटर बीजीएल तक था, जबकि मौसमी उतार-चढ़ाव -6.11 से 37.31 मीटर तक था।

मूलभूत हाइड्रोकेमिकल विश्लेषण, भारी धातु विश्लेषण और लौह विश्लेषण से पता चलता है कि भूजल पीने के लिए उपयुक्त है।

कठोर चट्टान क्षेत्रों में, संभावित जलभृतों की पहचान की गई है। भूजल अन्वेषण कार्यक्रम के तहत, विकास खंड में 50 बोरवेल (जिसमें ईडब्ल्यू, ओडब्ल्यू और पiezोमीटर शामिल हैं) 50 से 200 मीटर की गहराई तक खोदे गए हैं। इनसे 0.2 से 13 एलपीएस तक का भूजल प्राप्त हुआ है।

अध्ययन क्षेत्र में 2023 तक भूजल विकास का चरण 94.07% है, जो भूजल निष्कर्षण के गंभीर चरण को दर्शाता है। अतः यह अत्यंत संवेदनशील डेटा है और इसे संतुलित करने के लिए अध्ययन क्षेत्र में भूजल संरक्षण संरचनाओं का निर्माण आवश्यक है, क्योंकि यह चरण अत्यधिक दोहन की श्रेणी की ओर बढ़ रहा है।

क्षेत्र में सिंचाई के लिए वर्तमान मांग 564.51 हेक्टेयर मीटर है, जबकि घरेलू उपयोग के लिए 4833.75 हेक्टेयर मीटर और औद्योगिक क्षेत्र के लिए 564.514 हेक्टेयर मीटर है। भविष्य में भूजल की मांग को पूरा करने के लिए कुल 5991.19 हेक्टेयर मीटर भूजल उपलब्ध है, और इस अध्ययन के तहत भूजल निष्कर्षण का चरण 110.82% है, जो रायपुर शहर को अत्यधिक दोहित बनाता है।

अध्ययन क्षेत्र में सर्वेक्षण के दौरान पहचानी गई प्रमुख भूजल समस्याएं निम्नलिखित हैं:

- भूमि उपयोग में परिवर्तन, पक्के क्षेत्रों में वृद्धि
- बढ़ती जनसंख्या और इसके साथ भूजल निष्कर्षण में वृद्धि
- शहरीकरण और पुनर्भरण क्षेत्रों में कमी
- भूजल स्तर और गुणवत्ता में गिरावट और भूजल का अत्यधिक दोहन
- खुदाई वाले कुओं का सूखना

Contents

List of Tables

List of Figures

List of Annexures

List of Photograph

CHAPTER-1

INTRODUCTION

1.1 NAQUIM

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic, hydrogeological and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers. In recent past, there has been a paradigm shift from “groundwater development” to “groundwater management”. As large parts of India particularly hard rocks have become water stressed due to rapid growth in demand for water due to population growth, irrigation, urbanization and changing lifestyle. Therefore, to have an accurate and comprehensive micro-level picture of groundwater in India, aquifer mapping in different hydrogeological settings at the appropriate scale is devised and implemented, to enable robust groundwater management plans. This will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural and many parts of urban India. To achieve this goal National Aquifer Mapping on a scale of 1:50000 was launched by CGWB in 2012 to delineate aquifers, characterize aquifers, and prepare aquifer management plans. This study was very much helpful in identifying suitable areas for,

i) Ground water-based supply schemes,
ii) Determining the sustainability of groundwater development,
iii) Prioritizing aquifers for managed aquifer recharge.
iv) Identifying aquifers for various purposes in regions where new urban centers or industrial hubs are likely to come up, plan integrated ground water recharge schemes.
v) Issuing advisories to state agencies on repercussions of continued development of groundwater in select areas, and recommendations to state agencies in respect of areas that have prospects for ground water development.

However, National Aquifer Mapping in the first phase was carried out on a large scale in which detailed observations of specific problems related to quantity and quality could not be addressed. Keeping the above limitations in mind and considering the future requirements, the broad objectives proposed for NAQUIM 2.0 studies were as follows;

i) Providing information in higher granularity with a focus on increasing the density of dynamic data like ground water level, groundwater quality, etc.

ii) Providing issue-specific scientific inputs for ground water management up to the Panchayat level.

iii) Providing printed maps to the users.

iv) Putting in place a strategy to ensure the implementation of the recommended strategies. Involving state agencies in the studies for a sense of ownership.

NAQUIM 2.0 is designed to provide detailed information to support groundwater management decisions at ground level. Since the issues are different in different areas, the studies under NAQUIM 2.0 are proposed as issue-specific and will be undertaken in prioritized focus areas.

Broadly 11 Priority areas are identified based on ground water related issues as given below. ***1: Water Stressed Areas; 2: Urban Agglomerate; 3: Coastal Areas; 4: Industrial Clusters and Mining Areas; 5: Areas with Springs as the principal source; 6: Areas with Deeper Aquifers; 7: Ground Water Contamination; 8: Auto flow zones; 9: Canal Command Areas, 10: Areas with poor ground water quality, 11: Other specific Issues*****.**

Keeping the above criteria *Raipur City of Raipur district was selected under Urban Agglomerate criteria for detailed studies under NAQUIM 2.0.*

A city is an outcome of physical growth process, reflects man's efforts and achievements in shaping his environment during the entire period of its development. The Raipur City has remained critical category from one decade due to rise in urbanization and industrialization in the state capital. With increasing population, industrialization and groundwater extraction, the delicate balance between demand and supply for both drinking and commercial purposes is dwindling.

With emerging new technologies of water well construction, the dependence on dug wells for drinking and irrigation purposes has been greatly reduced. This study enumerates the underlying conditions which lead to overexploitation of groundwater resources. The detailed aquifer scenario of Raipur city and aquifer-wise management strategies. The Administrative Map of Raipur Urban area is shown in Figure 1.

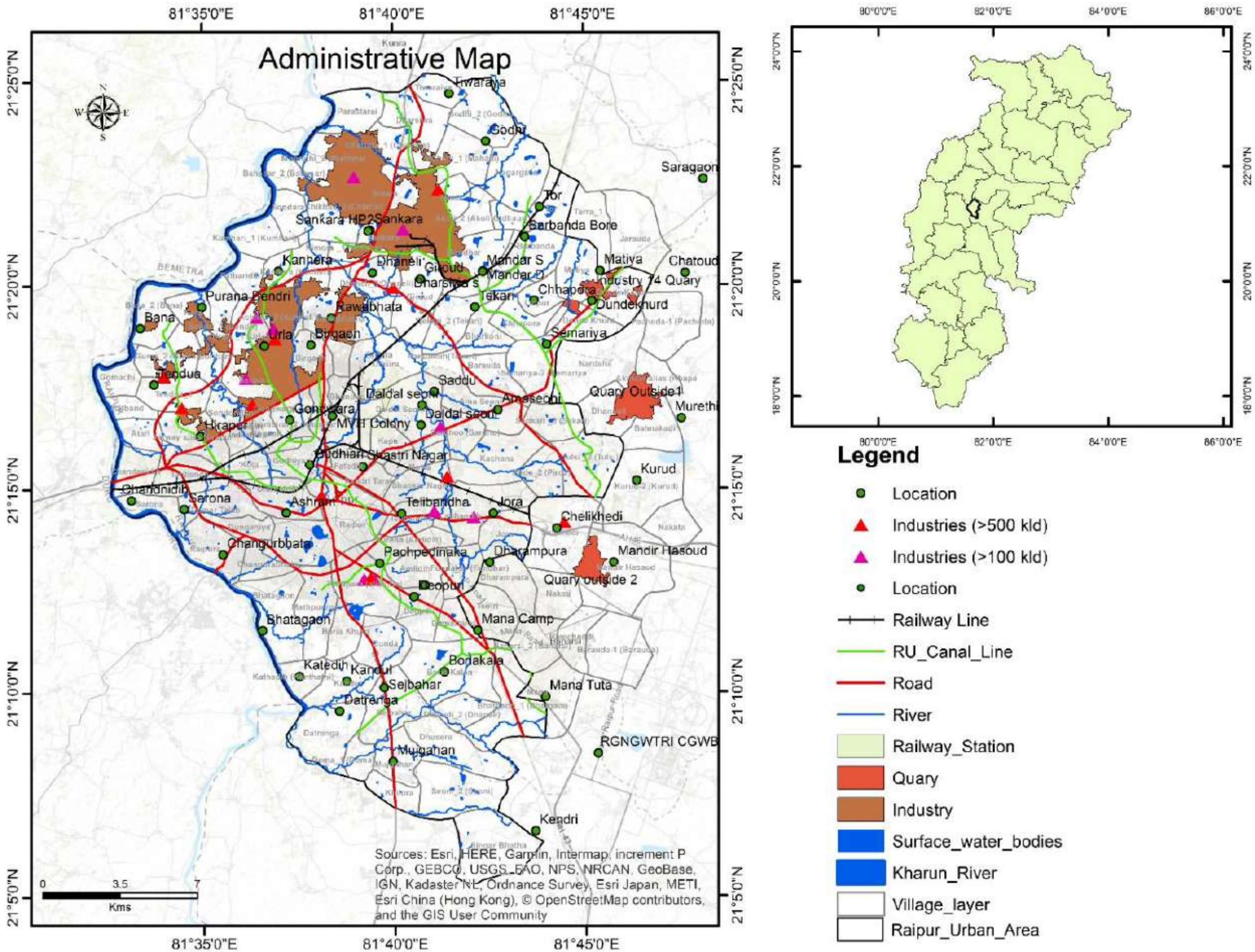


Figure 1 Administrative Map of Raipur Urban Area

1.2 ABOUT THE STUDY AREA

1.2.1 LOCATION, ADMINISTRATIVE SET UP & DEMOGRAPHY

Raipur city is the premier city and the capital city of the Chhattisgarh state, is an important administrative, commercial, industrial, and educational Centre. The established of Bhilai steel plant in proximity has given a great impetus to growth and its nodal location has contributed to its growing importance. Raipur city lies at the convergence of numerous roads, national highway no.6 Joining Kolkata and Mumbai runs through the city.

The city lies between 21° 10'and 21° 21' N latitudes and 81° 32' to 81° 44'E longitudes and falls under Survey of India toposheets no. 64G/11 & 64G/12. The town of Raipur has been in existence since the 9th century. As per one story, King Ramachandra's son Brahmdeo Rai had established Raipur and named it after himself at around 1402 A.D. He belonged to the Kalchuri dynasty of Tumman. Chhattisgarh was declared a separate commissionary in 1854 by the British Government with its headquarters at Raipur.

Raipur attained municipal status in early 1867 and was subsequently upgraded to Municipal Corporation in 1967. After independence Raipur district was included in the Central Provinces. Chhattisgarh was carved out of Madhya Pradesh and became a separate state in the year 2000. Raipur urban agglomerates cover an area of 504 sq. km. It is an important urban center of Raipur district and comes under Dharsiwa block in Raipur District. For administrative purpose, it is divided into 67 wards. The major drainage is Kharun river, Chhokra nala and tendua nala in the study area.

The city area forms an elongated ridge like topography generating radial pattern of drainage (Fig.2). Kharun, a perennial tributary to River Seonath, is the main river draining the area with the help of Chhokra nallah and other small nallah system. The entire area is dotted with more than 50 number of tanks, and ponds. The distributary No.8 of Mahanadi main canal with its minor's no.3 to 12 passes through the area. The length of the distributary is 17 km whereas minors account for about 29 km.

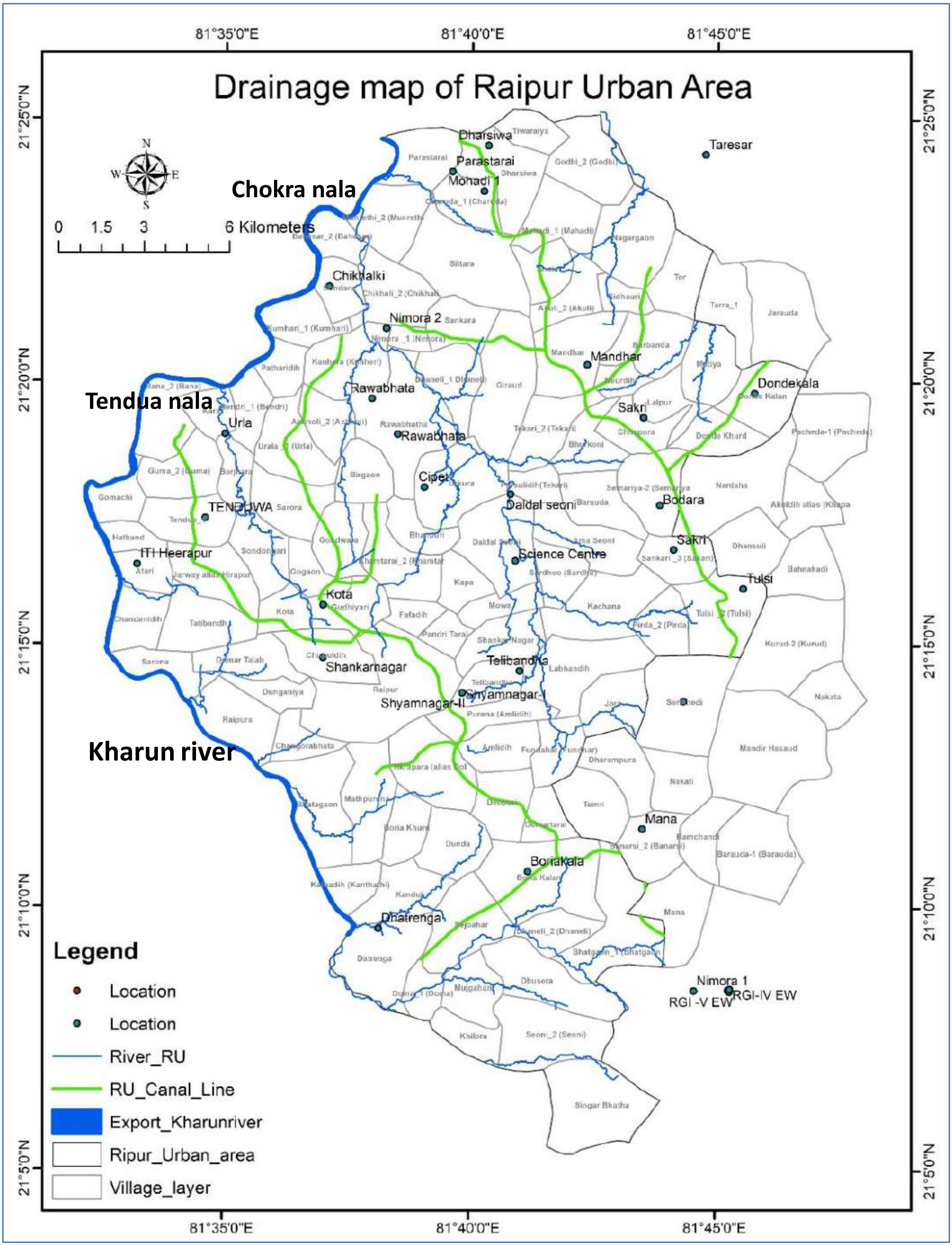


Figure 2: Drainage Map of the Study Area

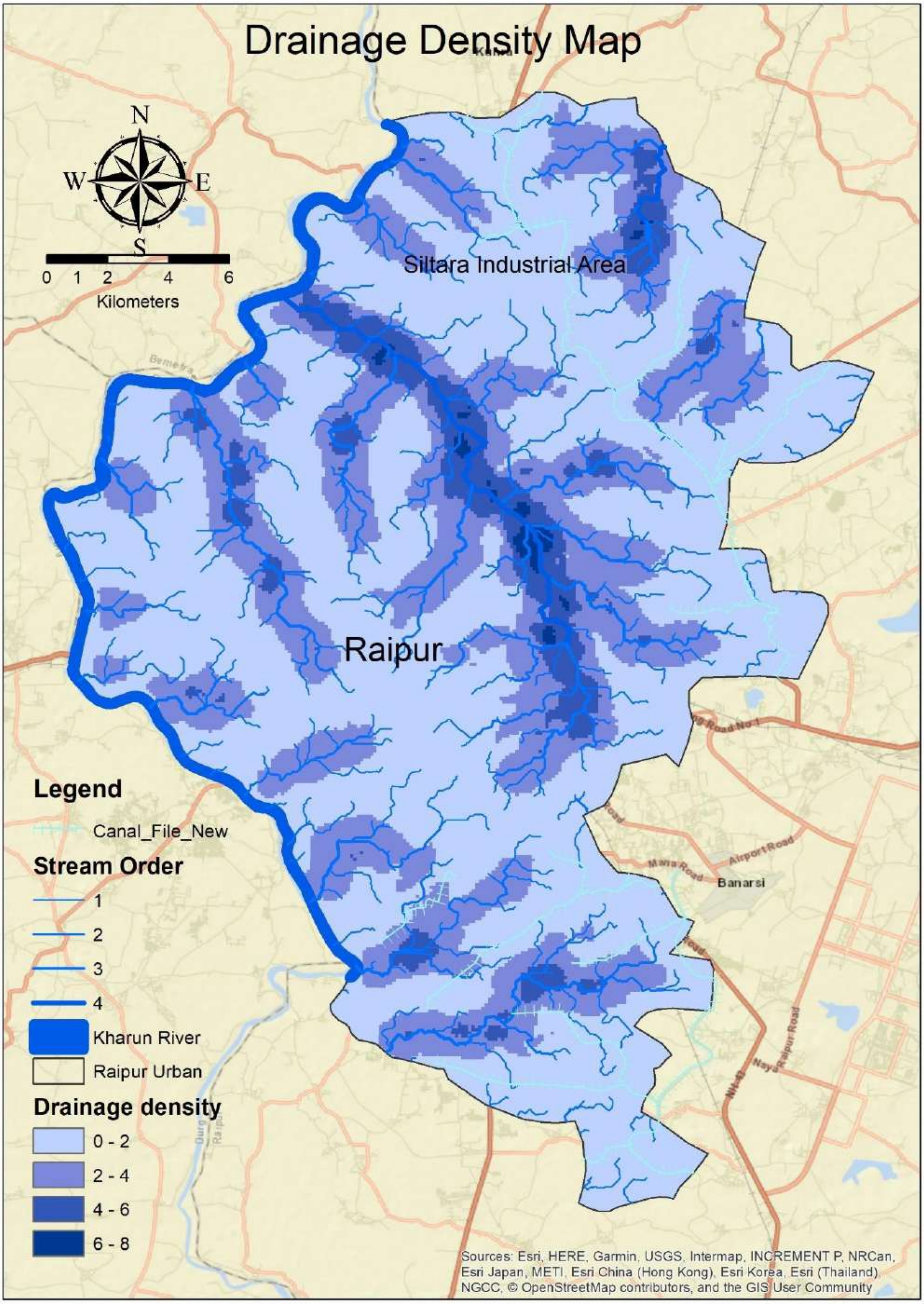


Figure 3: Drainage Density Map of Study Area

1.2.2 DEMOGRAPHY

The total population of Raipur city as per the Raipur Nagar Nigam data is 1,010,433 as per the CG Census 2011, but the population as per Raipur Municipal Corporation is 14,33,000 as per year 2024. The population break up i.e. male-female in urban is given below -

Table 1 Population Break-Up

Block	Total population	Male	Female
RAIPUR	1,010,433	518,611	491,822

Source: CG Census, 2011

1.2.3 GEOMORPHOLOGY:

Geomorphologically the study area displays: 1. Structural plain on Proterozoic rock, 2. Flood Plain.

Geomorphologically the area exhibits a structural plain. All these Geomorphologic structures come under the physiographic unit which belongs to Chhattisgarh basin area. The Central Chhattisgarh Plain is represented by Structural Plain on Proterozoic rocks which cover major area in the eastern & central part of the district. This unit is developed over rocks of Purana sedimentary basin of Chhattisgarh. This unit has extensive cris-crossed fractures and joints. They are having gently sloping erosional surfaces and thin to moderate cover of soil. Figure 4 shows the Geomorphology in the study area.

The study area is topographically flat and elevation varies from 225 to 325 m asl (Fig. 1). Raipur City is located at a higher elevation. The slope is gentle, with an average slope towards the north. Drainage is dendritic and governed by fractures. The Chokra Nalla flows northward and joins the Kharun River, a tributary of the Mahanadi River. Fractures identified in the field and those delineated from DEM, orient in three directions.

It was observed that water infiltrates through these fractures which have been widened by solution activity. The Chokra Nala watershed spreads over 80 km^2 and generates more than 600 mm (48 MCM) of runoff from annual rainfall of 1258 mm. This ephemeral runoff is stored in surface ponds/talabs.

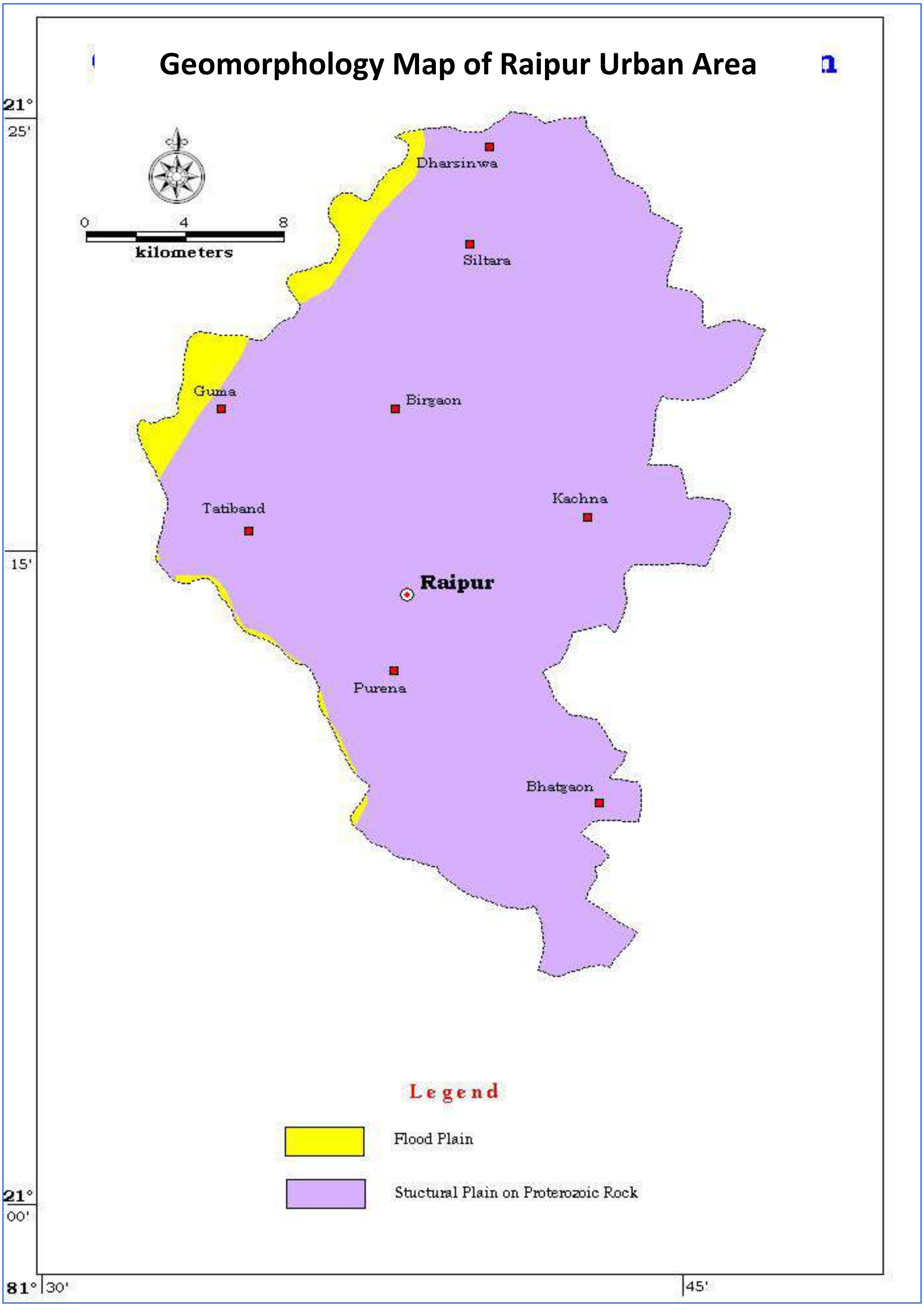


Figure 4 Geomorphology Map of the Study Area

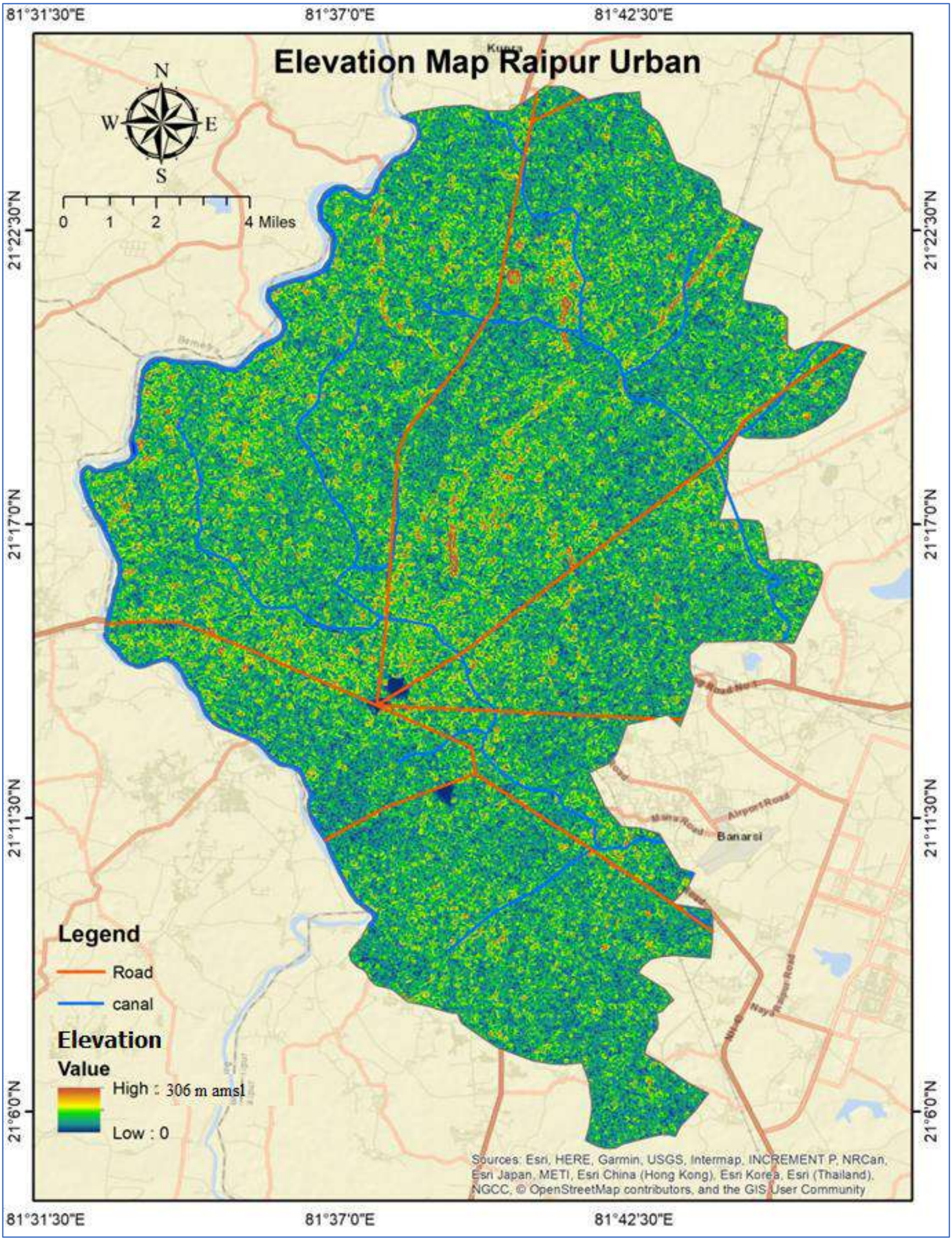


Figure 5 Elevation Map of the Study area

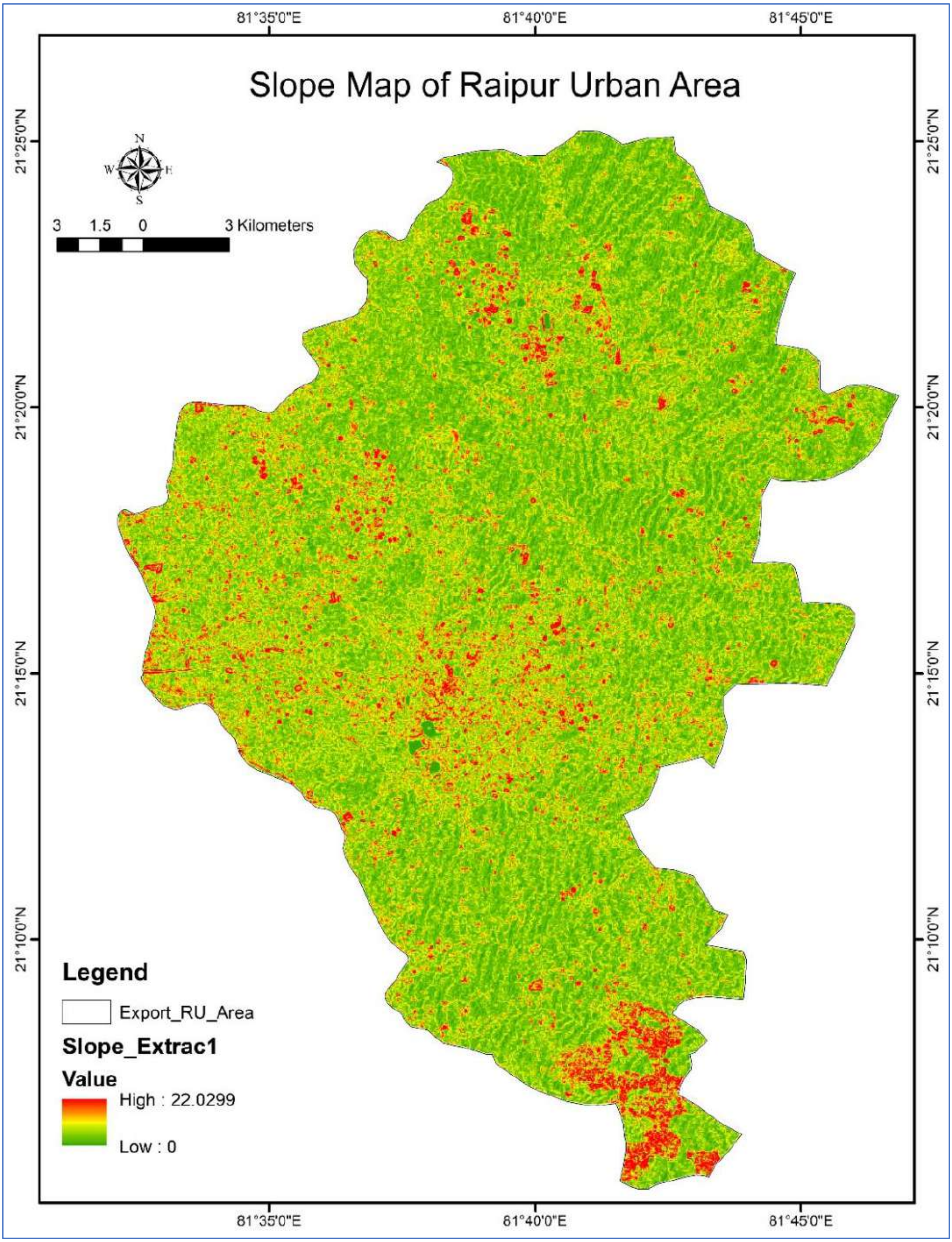


Figure 6 Slope Map of the Study area

1.2.4 SOIL

The soils in the district are having variations. Mainly two types of soils are abundant in the study area and are mostly insitu in nature. The soils in and around Raipur are primarily alluvial, deposited by rivers. These soils are fertile.

Vertisol: The Vertisol are mostly found northern & central and are almost impermeable when saturated. They are sticky in wet season and are very hard in dry season.

Ultisol: The ultisol types of soil are found in eastern parts of the district and are red to yellow in colour. This colour is attained mainly due to the accumulation of iron oxide, which is highly insoluble in water.

In general, it can be said that the area is covered by red sandy soils, red loamy soils, medium black soils, deep black soils, lateritic soils. Figure 8 represents the different kind of soil that present in the study area.

Table 2 Details of different kind of soil

Sl No	US Soil taxonomy	Indian equivalent
1	Vertisol	Deep black soil
		Medium black soil
2	Ultisol	Lateritic soil
		Red and yellow soil

Soil thickness varies from place to place and average thickness is approximately 10 m (Bodhankar and Chatterjee 1994). Red and black soils are the two main types. Most part of the watershed is covered by fertile deep black soils (Rendzina) with small patches of lateritic red soils (Terra Rossa). Black soil originates from limestone weathering and concretionary red soil from incongruent weathering of silicate rocks (Raymahashay 2005).

Soil infiltration rates were measured to know the water flux and its control on groundwater recharge. High infiltration in dry soils favors recharge initially. Infiltration rate decreases sharply up to 80 mm/h within 10–15 min when the soils reach saturation, and this amount is the basic infiltration rate (Fig. 7). Field saturated hydraulic conductivity (Kfs) estimated from infiltration data varies from 54 in black soils to 56 mm/h in other type. This information ascertains the effect of soil properties on natural and artificial recharge (Reed 1990; Lin 2010). The soils are mainly free draining, but high clay content decreases the recharge. Initial high infiltration rates favour recharge, but also lead to clogging of pore spaces by muddy water.

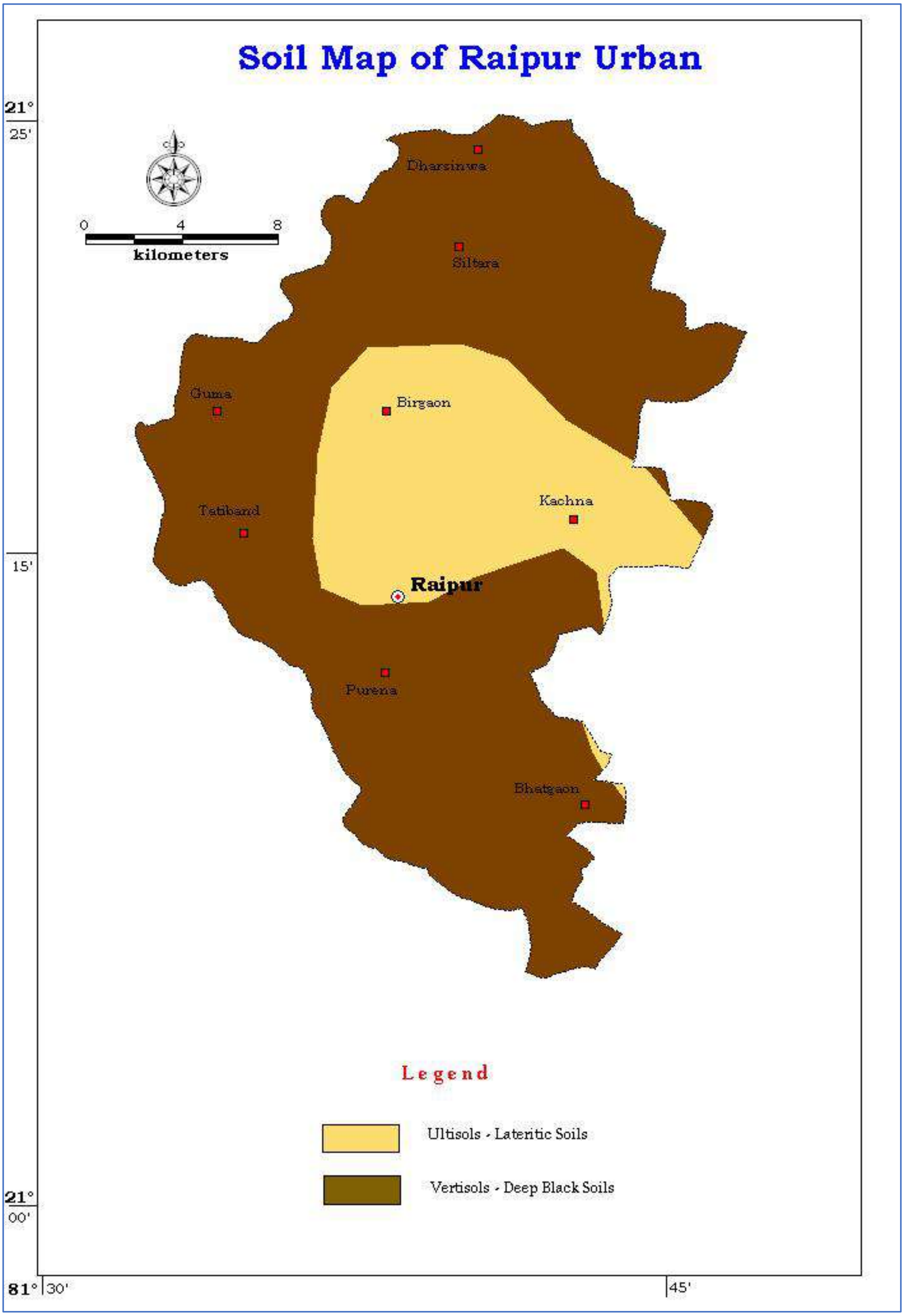


Figure 7 Soil map of the study area

1.2.5 GEOLOGY

Raipur is mainly underlain by hard rock which belongs to Precambrian age, partly by these alluvium and laterite of Quaternary age occur in very isolated pocket with and limited extension. Hard rock mainly sandstone, shale, limestone / dolomite sequence belong to Proterozoic Purana rocks of Chhattisgarh Super Group.

The laterite occurs as capping over the country rock in pockets particularly in elevated area in limited thickness. The recent alluvium with limited thickness and extension occurs along the major river and stream channels (Figure 7).

Chandi Formation: Chandi formation comprises a thick sequence of Stromatolitic limestone, dolomite & shale has a gradational contact with the underlying Gunderdehi shale. The limestone is pink to light grey in color. fine grained with extensive development of stromotalitic structure and is thickly bedded. Minor shale partings are present. Stromalities are grey to brown in colour with intercolumnar space filled with argillaceous carbonate material. In middle horizon of this formation, stromatilitic limestone and flaggy limestone are associated with green calcareous shale. The green shale is friable and splintery, calcareous and at places itself contains columnar stromatalitic structure inclined to bedding plane. Upper horizon is predominantly pink to purple, medium to coarse grained dolomitic limestone with characteristic development of stromatalities. The rock has a mottled appearance due to dolomite crystals. It is generally massive in look and is associated with purple to grey shale intercalations. Towards upper part, the rock gradually changes and devoid of stromatalitic structure. The rock is also gypsiferous containing gypsum in cavities.

Gunderdehi formation: Gunderdehi Formation, which occupies the central and southern part of the Raipur and, some part of Dongargarh block acts as an aquiclude. Only weathered mantle to a depth of 30m is Productive for water.

Charmuria formation: In Raipur district the Ranidhar Member comprising of cherty limestone and dolomite is mainly calcareous in nature and is deposited above sandstone of Chandrapur Formation. It is the most prolific aquifer. Due to heterogeneity of the contact and cherty limestone, the development of solution cavities along the bedding plane is very common and these cavernous zones are filled with clay material and intraformational conglomerate.

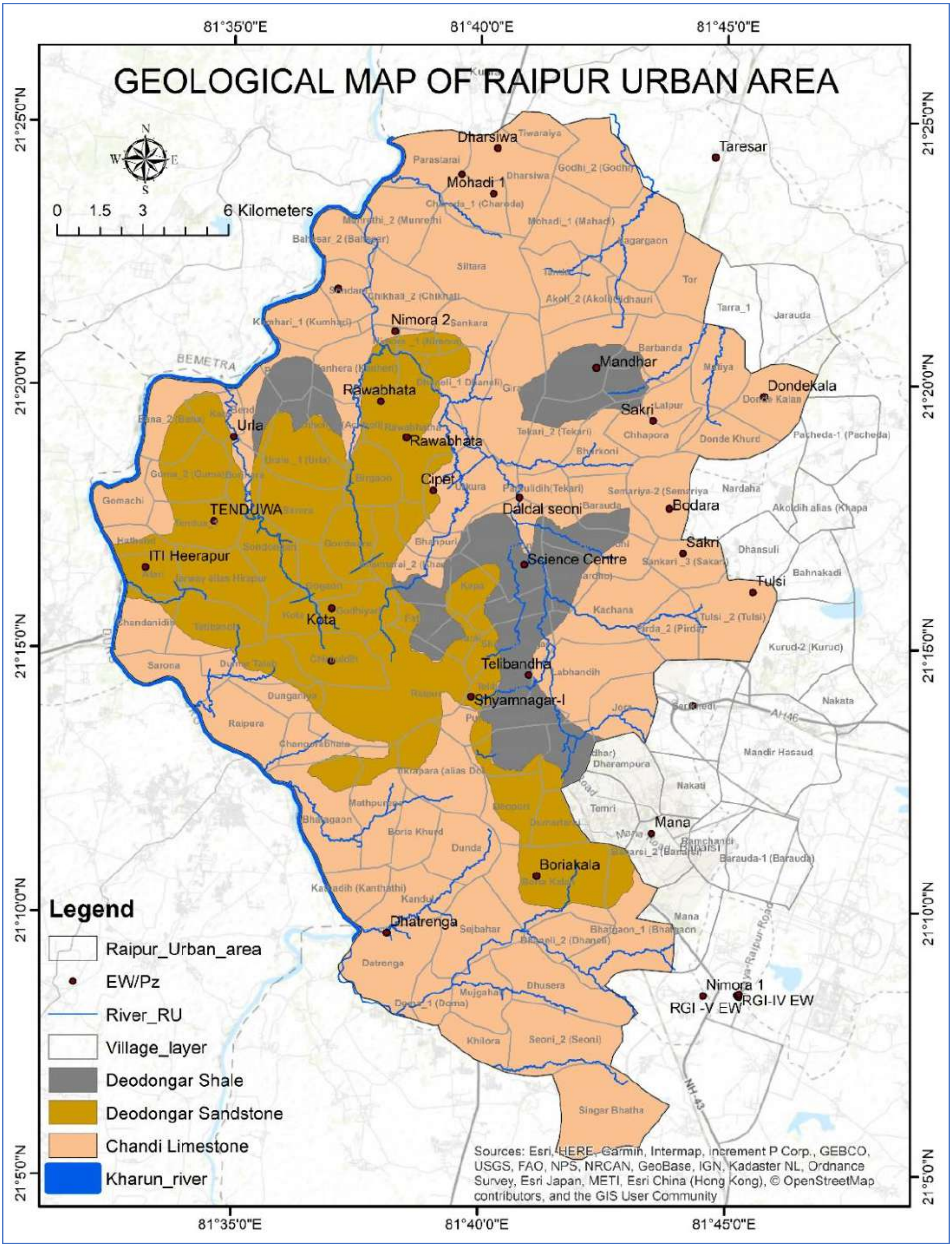


Figure 8 Geological map of the study area

Table 3 Geology of Raipur

	Formation	Intrusives		Dolerite dykes
CHHATTISGARH SUPERGROUP	RAIPUR GROUP	Manairi Formation (70m)		Purple shale with dolomite, dolomitic limestone, and gypsum
		Hirri Formation (70m+)		Grey dolomite, argillaceous dolomite
		Tarenga Formation(180m)	Bilha Member	Purple dolomitic argillite
			Dagauri Member	Green clay, chet and shale intercalation (tuffaceous?)
			Kusmi Member	Purple and bedded limestone Purple argillaceous stromatolitic dolomite
		Chandi Formation (67m)	Nipania Member	Purple and grey stromatolitic limestone and dolomite with flaggy limestone – shale intercalation/ferruginous glauconitic arenite and shale
		Gunderdehi Formation	Pendri/Deodonger Member	Purple and grey stromatolitic limestone and dolomite with flaggy limestone-shale intercalation/ferruginous glauconitic arenite and shale
			Newari Member	Pink and buff stromatolitic limestone and dolomite
			Andha/Dotopar Member	Predominantly pink, purple and grey shale with limestone intercalations/ arenite/ buff to green shale member in the middle
		Charmuria Formation (490m)	Bagbura Member	Purple limestone (phosphatic)
			Kasdol Member	Dark grey bedded limestone/argillaceous limestone with minor shale intercalations
			Ranidhar Member	Cherty limestone and dolomite (phosphatic at places)
			Sirpur Member	Chert and clay intercalatin

Table 4 Local Geology of Raipur Urban area

Formation	GEOLOGY	Lithology	Area (in Sq km)	Age
RAIPUR GROUP Chandi Formation	Deodongar member	Sandstone	128.73 (25.5%)	Paleo to Meso Proterozoic
		Shale	50 (10 %)	
	Pendri member	Limestone (Karstic & Dolomitic nature)	325 (64.48%)	
	Total area		504 (100 %)	

The rocks of Chandi formation are exposed in Raipur Urban area. They are, in general horizontally bedded to gently dipping, structurally non-deformed rocks. However local warping due to competent in competent layering of sandstone/ Shale can be seen in vertical sections of Mahadevghat, Chokra Nala crossing at Bilaspur Road, around Budha Talab area and other places. The limestone is thickly bedded to massive in nature, showing two sets of prominent nearly vertical Joints along NE-SW and E-W direction. Highly irregular development of Karst is evident in the area. The karst features generally observed in the area are sinkholes and dolines, micro karren and karren and solution channel or cavities. The stromatolitic bioharms seem to be controlling the development of karstic feature at surface along with the joint and bedding pattern.

The shales are thinly laminated to bedded having irregular thickness due to uneven depositional basin floor. The shales are non-calcareous, impervious and yellow to pale in colour. The sandstone are highly brittle, silicified, ferruginous, glauconitic, ortho-quartzitic in nature and are thinly bedded to laminated occupying generally the elevated parts in the area.

Subsurface geology observed during the course of ground water exploration in the area shows that Chandi limestone are intercalated with purple to gray calcareous shale at places. The thickness varies from 56-136 m in the area. Chandi limestone are followed by Gunderdehi shale and Charmuria limestone. The Gunderdehi shales are purple in colour, calcareous with fractured zones in upper part. The minimum thickness observed in the area is 227m. The Charmuria limestone are gray, flaggy, thinly laminated and non-stromatolitic. Subsurface dolerite intrusive is running roughly E-W to NE-SW direction in Kota- Samta colony area.

1.2.6 HYDROMETEOROLOGY

The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August and nearly 95% of the annual rainfall is received during this period. The rainfall of the study area for 42 years was analyzed. The data was obtained from the (CHIRPS) climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. As per the data analysis of 42 years, It can be noticed that in last 42 years the maximum average annual rainfall is noticed in year 1994 which shows 1866.23 mm whereas the minimum is observed is 967.37 in year 2000.

The average annual rainfall for the study area is around 1,325.53 which is presented below in Figure 5.

Figure 9 Rainfall Hydrograph of Raipur Urban from year 1981 to 2022

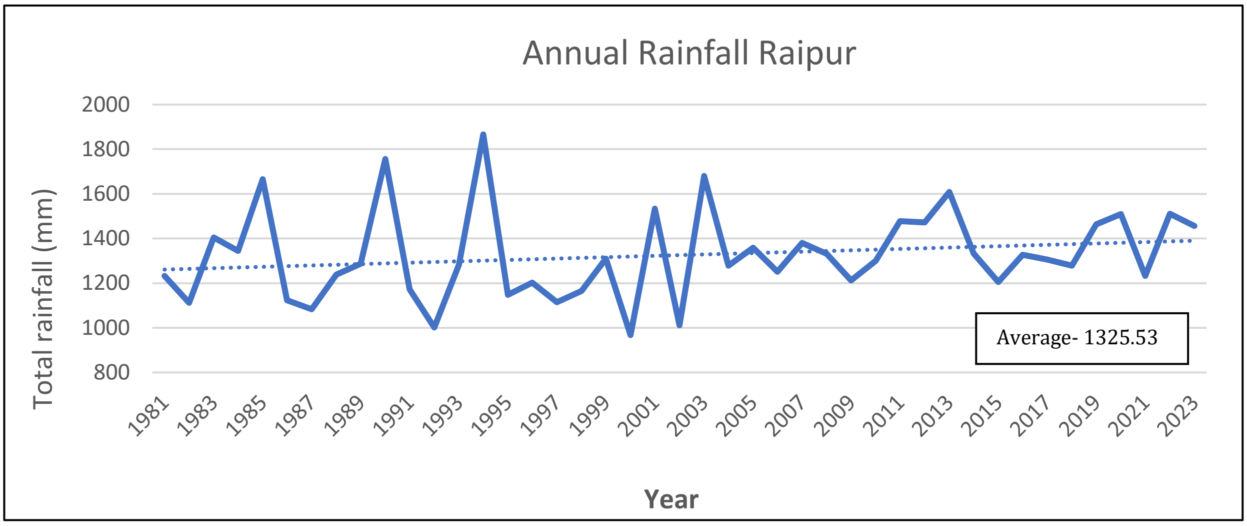
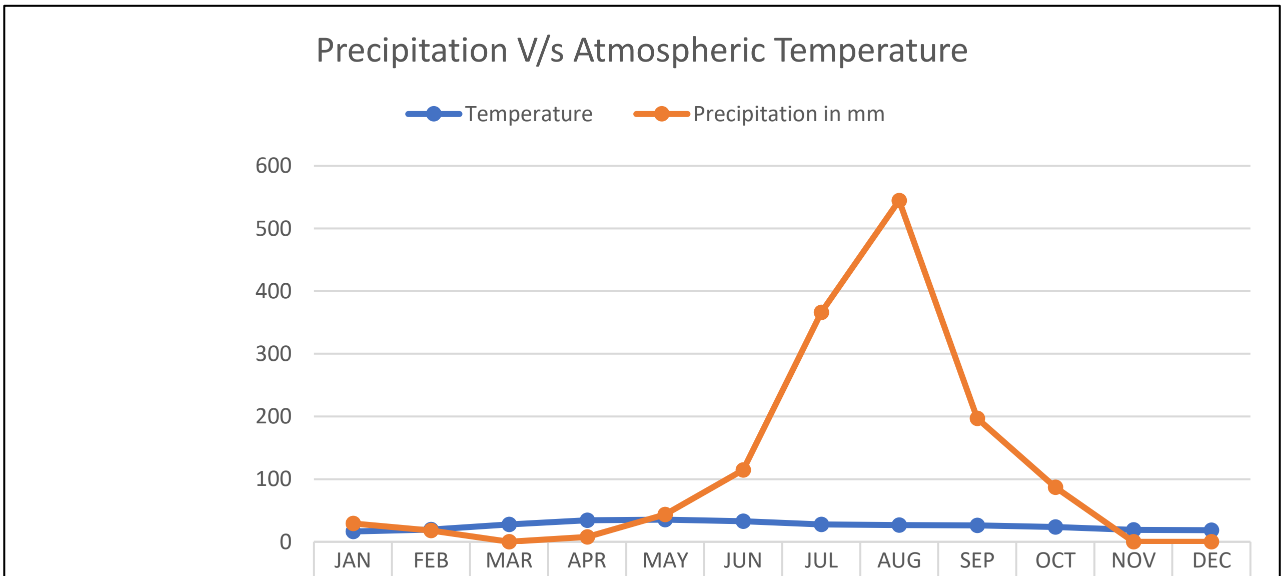


Table 5 Rainfall data of the Raipur City from year 1981 to 2020 (Source: CHIRPS)

Year	Rainfall	Percent change
1981-1990	1324.803	-
1991-2000	1223.2	-7.67
2001-2010	1333.73	9.04
2011-2020	1398.2	4.83

Figure 10 Precipitation Vs Atmospheric Temperature variation



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temperature	16.47	19.73	27.85	34.54	35.35	32.81	27.8	26.58	26.36	23.76	19.23	18.33
Precipitation in mm	29.38	17.91	0.16	7.86	43.4	114.4	366	544.75	197.1	87.04	0	0

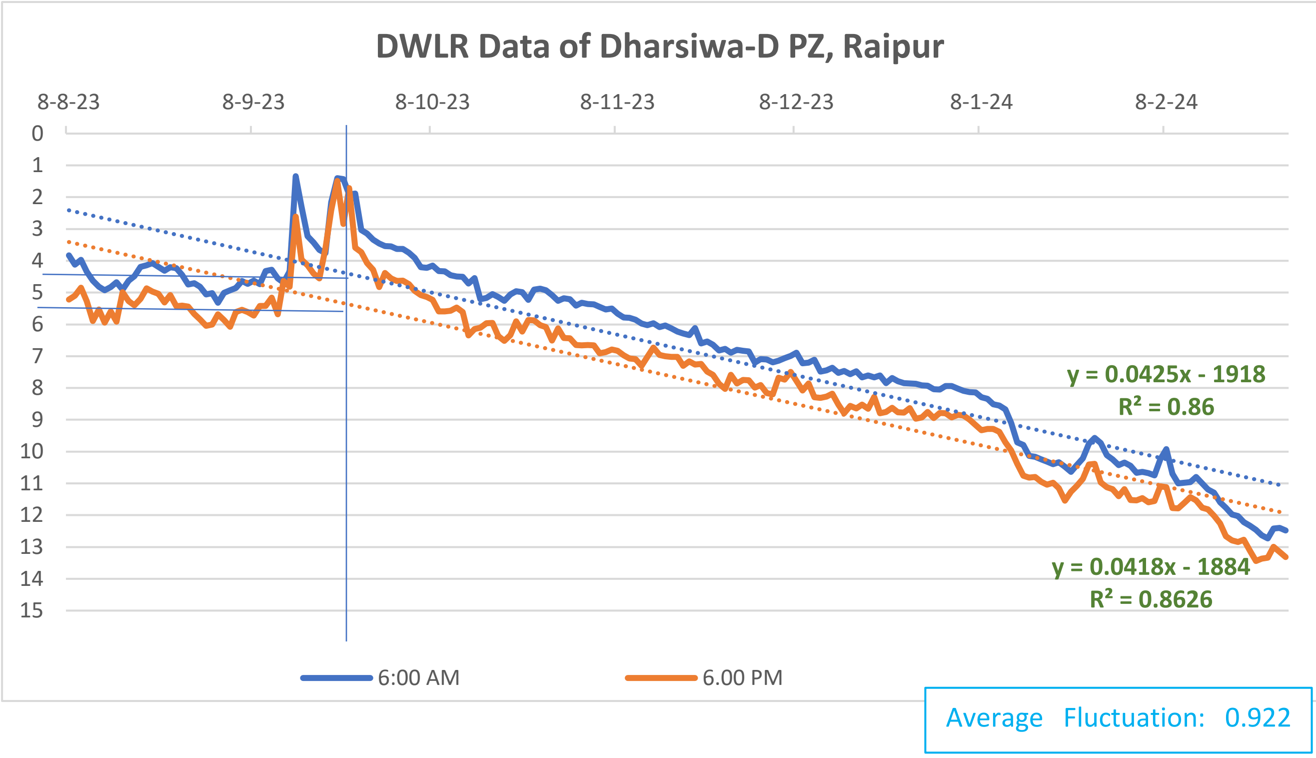


Figure 11 Graph showing variation in water-level with time in Dharsiwa D Peizometer

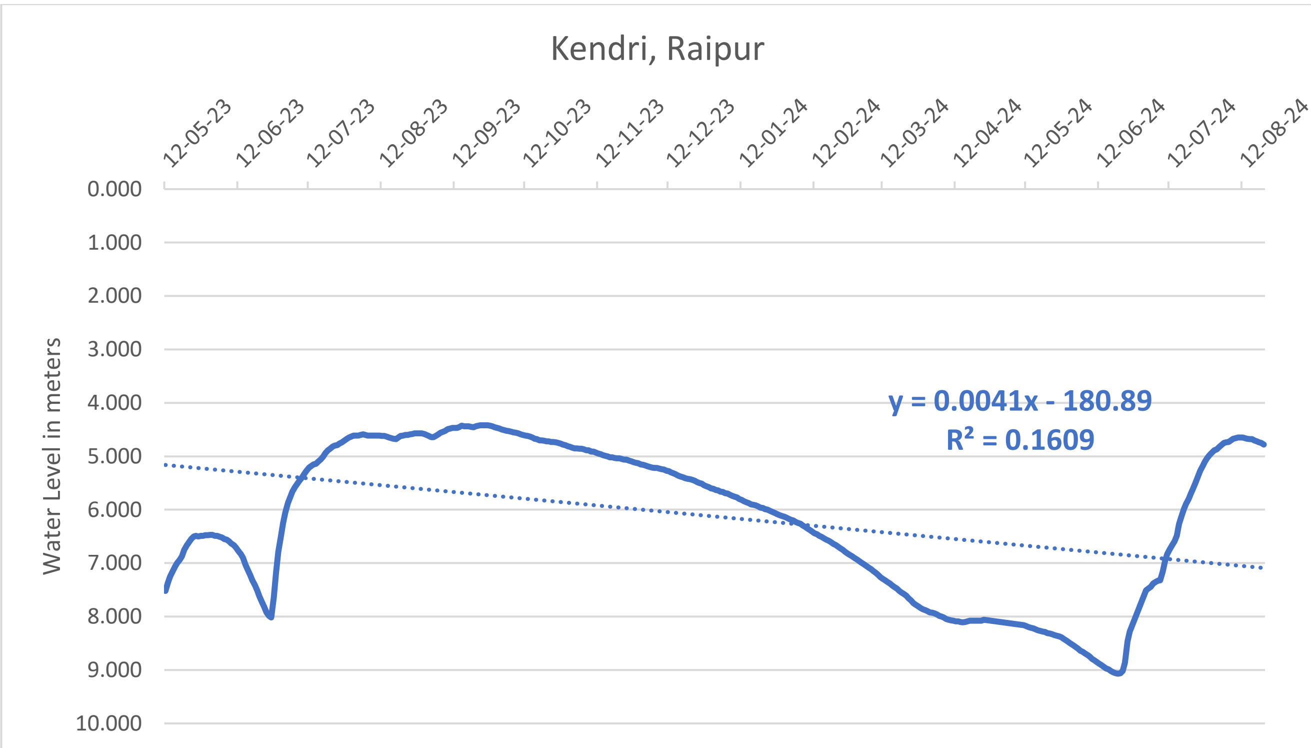


Figure 12 Graph showing variation in water-level and Temperature with time in Kendri, Raipur Peizometer

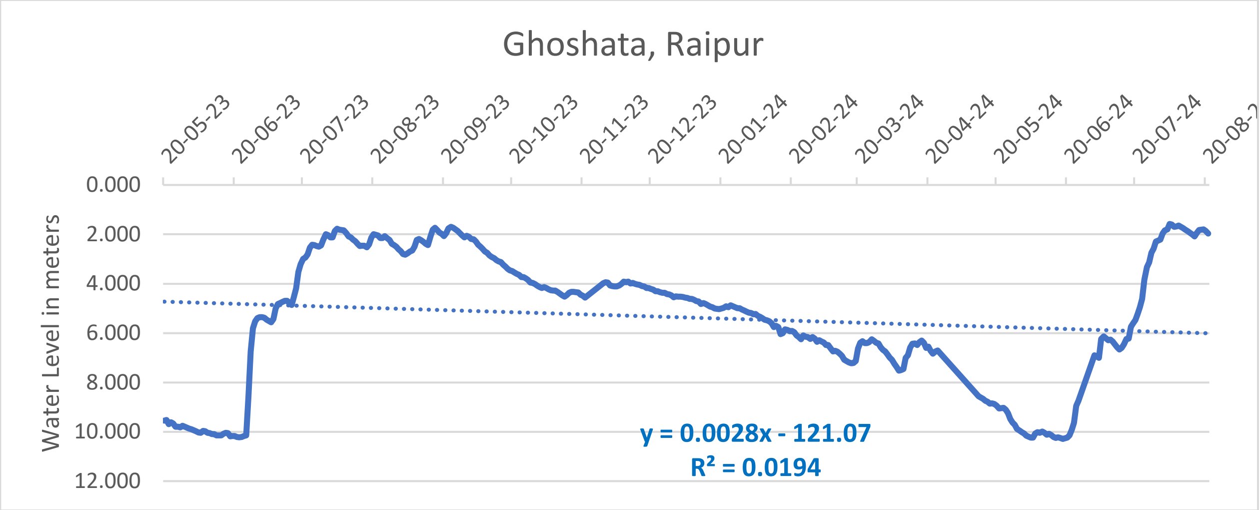


Figure 13 Graph showing variation in water-level and Temperature with time in Ghoshata Peizometer

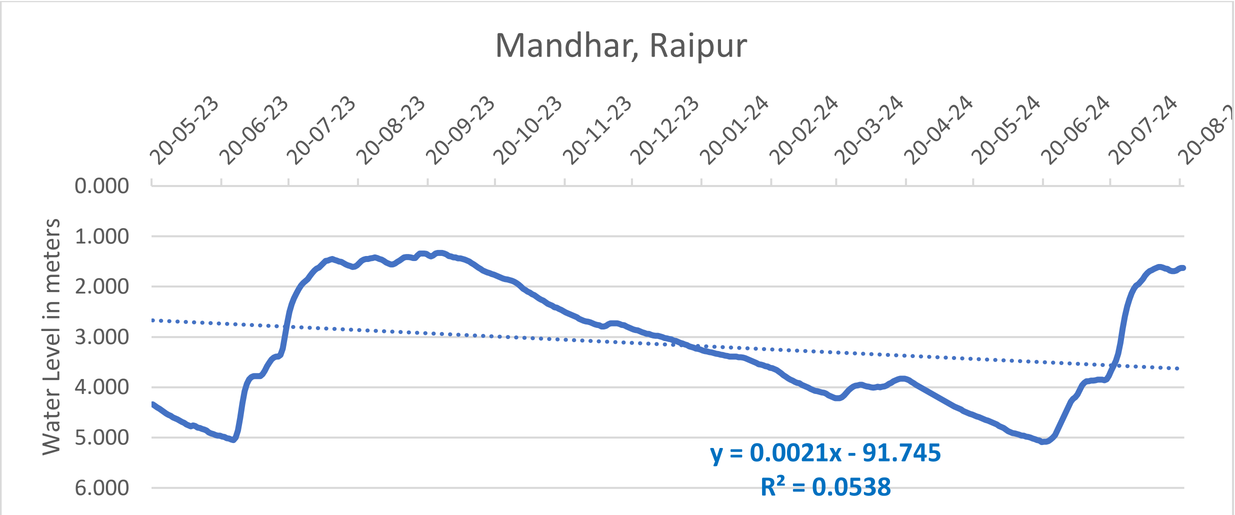


Figure 14 Graph showing variation in water-level and Temperature with time in Mandhar Peizometer

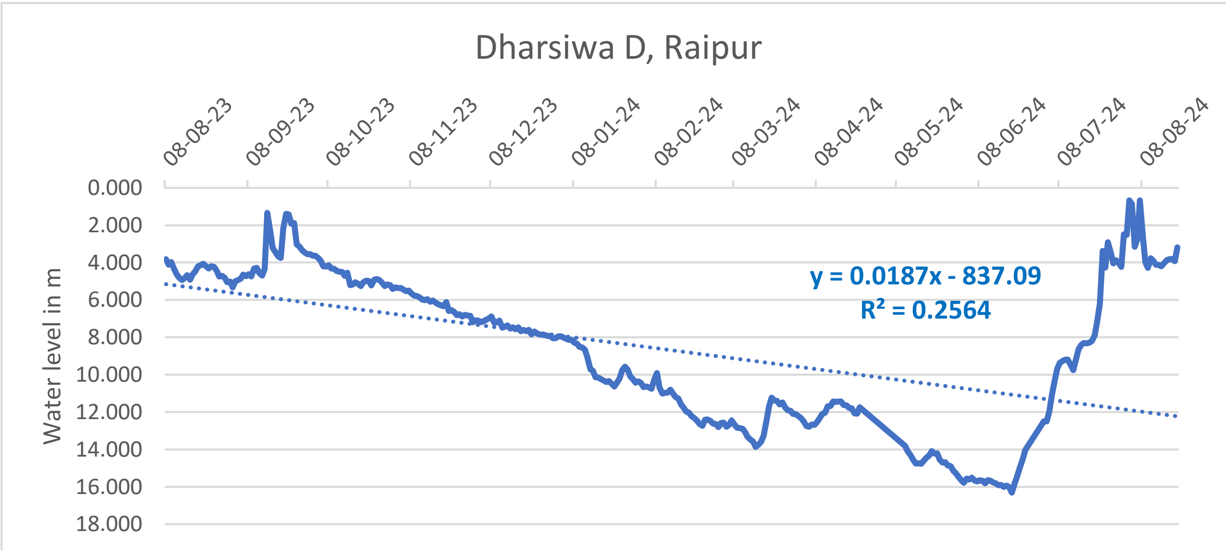


Figure 15 Graph showing variation in water-level and Temperature with time in Dharsiwa D Peizometer

1.2.7 LAND USE/LAND COVER

The Raipur urban area at present is 504 sq km. The land use pattern in the past was entirely different as compared to the present time. Most of the area was occupied either by agricultural land or water bodies in the form of tanks and ponds. The city municipal limit in 1962 was restricted to only 20.44 sq km, now which is 504 sq km. The city limit is the most densely populated area. Maximum area is allotted to residential use. The total residence area in 1962 was only 4.19, in 2005 it was 38 sq km and now it is 189.14 Sq km. In this process the agricultural land has been rapidly converted into industrial and residential categories and water bodies have been reduced substantially. In present context the proliferation in building activities and construction of metaled road has rendered substantial part of land totally impermeable which is now effecting/ retarding the direct percolation of rainwater. The resultant run off goes away directly to river Kharun from where the precious source is drained away.

The land-use and land-cover (LULC) data for the Raipur Urban area is presented in the table, outlining the distribution of various classes across the region. Water bodies occupy a minimal percentage, accounting for 2% of the area. Trees and vegetation cover the area about 2 % of the total land area. Agricultural land area comprises of 43 % of the region. The habitation which includes urban area, Industries, infrastructure occupies 39 % of the area. Grass land, comprising 12.6 % of the landscape. This diverse distribution of land-use and land-cover classes reflects the varied and dynamic nature of the Raipur City, encompassing a blend of agricultural area and habitation clustered in State capital.

The major land use in Raipur district includes pastures, built-up and cultivable land (Fig. 3). About 42 % of the area around Raipur city is cultivated mainly for rain-fed crops. Main crops include wheat, pulses, soybean, groundnut, and paddy.

Raipur has many natural talabs/ponds of total 123 nos. that have historically stored rainwater for utilization, but the number has been reduced to 42. Around the city, the talabs cover an area of about 3 km^2. Telibandha Lake (Fig. 1) covers an area of 0.12 km^2 in extension and receives runoff from a drainage area of 1.14 km^2. The average depth of the lake is about 2.9 m (Bornemann and Groschke 2012) and can accommodate a maximum water of 17,108 m^3 to a water depth of 1.4 m. Other talabs include Raja talab (0.05 km^2), Bada Khamardih talab (0.03 km^2) and Pandri talab (0.014 km^2).

These ponds have lot of importance in groundwater management in the area which needs to be evaluated particularly for Managed Aquifer Recharge program. The change in Land Use land cover from Year 2017 to 2021 is show in in figure 14 & 15 and the percentage change is shown in table below.

Table 6 Change in Land use land cover area from 2017 to 2021

Sr. no	**LULC Classification**	Area in 2017 (in Sq. km)	Area in 2017 (%)	Area in 2021 (in Sq. km)	Area in 2021 (%)	Area (in Sq km 2022)	Area in 2022 (%)
1	Water bodies	8.77	1.77	9.81	1.98	9.85	2 %
2	Trees	9	1.82	9.39	1.90	9.41	1.86 %
4	Flooded Vegetation	12.77	2.58	3.01	0.61	3.01	0.6 %
5	Agricultural Land	209.73	42.31	221.06	44.61	221.02	43 %
6	Habitation	155.85	31.44	188.76	38.09	189.14	39%
7	Barren land	0.24	0.05	0.24	0.05	0.24	0.04 %
8	Grass land	99.34	20.04	63.24	12.76	63.45	12.6 %
	Total	**495.7**	**100 %**	**495.51**	**100 %**	**504**	**100 %**

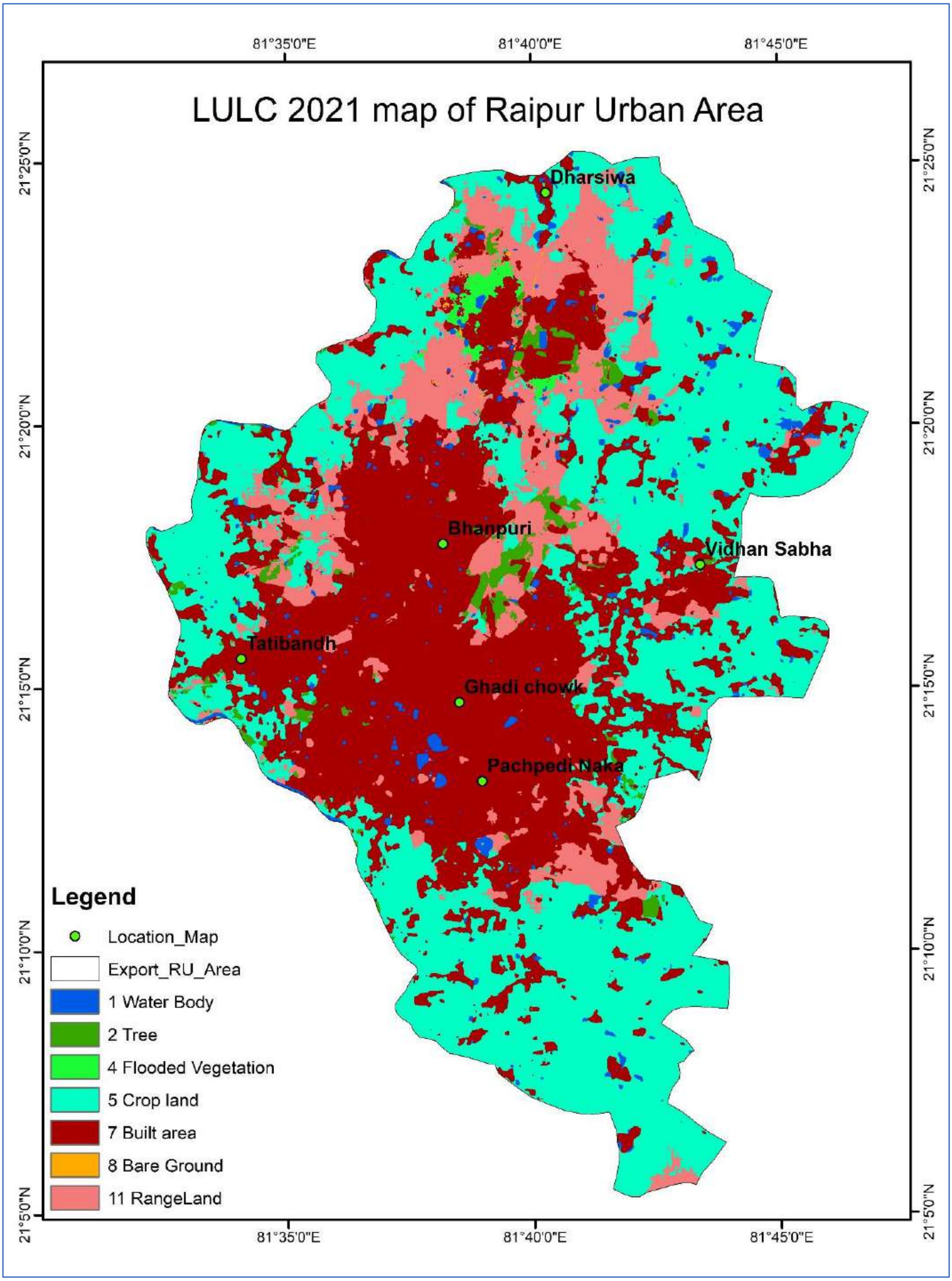


Figure 16 Land use land cover map of the study area

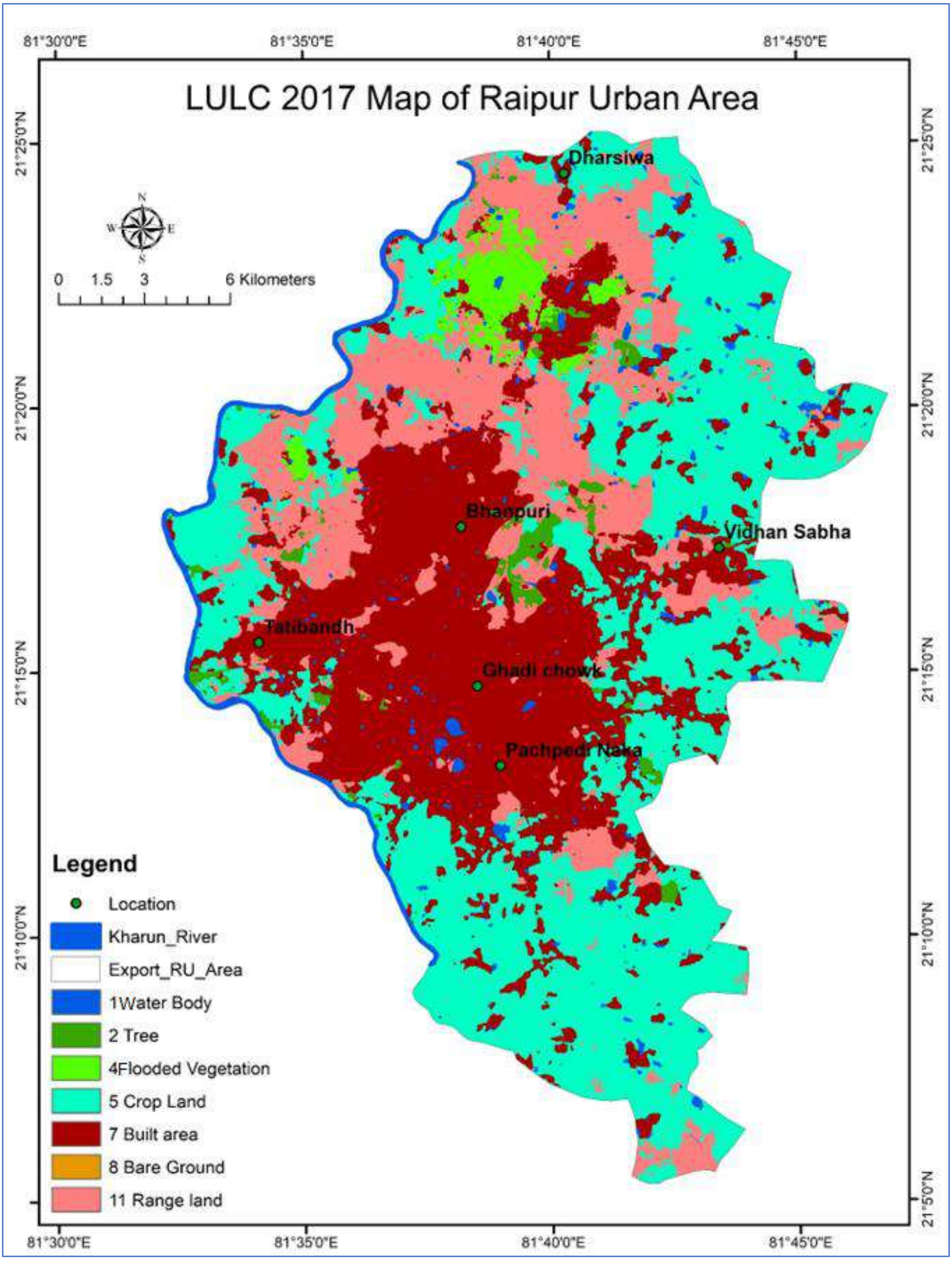
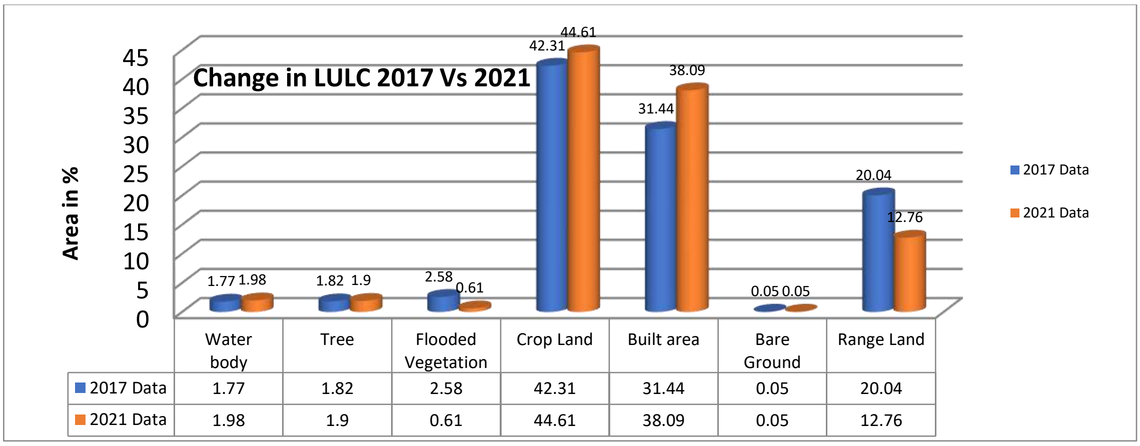


Figure 17 Land use land cover map of the study area



	Water body	Tree	Flooded Vegetation	Crop Land	Built area	Bare Ground	Range Land
2017 Data	1.77	1.82	2.58	42.31	31.44	0.05	20.04
2021 Data	1.98	1.9	0.61	44.61	38.09	0.05	12.76

Figure 18 Land Use Land Cover 2017 Vs 2021

1.2.8 AGRICULTURE, IRRIGATION, CROPPING PATTERN

Agriculture is practiced in the area during Kharif and Rabi season every year. During the Kharif, cultivation is done through rainfall while during the Rabi season, it is done through ground water as well as partly through surface water like canals and other sources. The groundwater abstraction structures are generally Dugwells, Borewells /tubewells. The principal crops are paddy, wheat, vegetables and pulses. The agricultural pattern, cropping pattern and area irrigated data of Raipur city is given in Table No. 4, 5, 6.

Table 7 Cropping pattern (in ha)

Kharif	Rabi	Cereal				Pulses	Tilhan	Mirch Masala	Sugarcane
		Paddy	Wheat	Jowar & Maize	Others				
24142	6560	69111.47	1706	154.9		7906	969	123	125
Source: Statistical Handbook									

Table 8 Area irrigated by various sources (in ha)

No. of canal s (private and Govt.)	Irrigated area	No.of bore wells/ Tube wells	Irrigated area	No. Of dug wells	Irrigated area	No. of Ponds	Irrigated area	Irrigated area by other sources	Net Irrigated area	% of irrigated area wrt. Net sown area
2	12998	3152	8581	60	77	69	500	1522	23678	77.12
Source: Statistical Handbook										

Table 9 Contribution of Groundwater in Irrigation Pattern (in ha)

Area Irrigated through Borewells/Tube wells	Area Irrigated through Dug wells	Area Irrigated through Groundwater	Net Area Irrigated through all sources	% Groundwater contribution in Irrigation w.r.t Net Irrigated Area
3152	77	5927.5	9577.20	55.67

1.2.9. WASTE GENERATION

Karstic limestone terrain is highly sensitive to groundwater pollution due to it conduit nature. Along with the increasing population and industrialization in Raipur Urban, the problem of disposal of solid and liquid waste is emerging in a big way. The present population of RUA is nearly 14.33 lakhs and generates 533.61 tons of solid waste per day from 3,46,128 nos of House. Voluminous quantity from this waste is collected by municipality and is used to fill up the low-lying areas in outskirts of Raipur City. Through, the solution cavities of limestone the leachates percolate down to ground water system. Though in central part of the city, the karstic limestone is covered with impermeable shales, limestone is exposed in the periphery. With the radial growth of the town ship the low-lying limestone areas are used as the sites of waste disposal at present.

The most hazardous sites, which are presently used for solid waste disposal, are along the ring road No. 1 in Rajender Nagar, Changorabhata and Dangania. According to WHO, 80% of the diseases in the world population are due to consumption of polluted water and Raipur is no exception. It has been reported and observed every year in the groundwater dependent area that just after the first few showers in June, the complaints of various diseases suddenly increase. This may be because leachates percolate down through the karst conduit and contaminate the aquifer. However, subsequent rain dilutes the concentration and makes the system almost normal.

The present practice of disposal of solid waste in limestone terrain ie in Sarona area in city as well as in Sakti Village must be stopped immediately. It is universally accepted that ground water system is polluted slowly but once polluted its revival is almost impossible. The dumping zones should be shifted to more impermeable layers/ parts of the sity or outside, where contamination is less specifically in Shale areas. Proper legislative action in this regard is required to be initiated.

The present population of RUA is 14,33,000 and generates 525700 tons of solid waste per day which means the per capita solid waste generation is 2.72 per day in RUA. The total voluminous quantity which is not parted is collected by municipality and dumped in in Sakri Village dumping ground. Laying sewers under slums should be a top priority, and efforts should be made to connect the slums situated along the sewer belt to the rehabilitated sewer network. One more STP should be built near Chingri nalla.

Table 10 Population and Waste generated

Sr. no	Type	
1	Population (RUA)	14,33,000 persons
2	Solid Waste Generated	525700 tons
3	Per Capita waste generated	2.72 per day

The Geology of Sankri is Limestone and through, the solution cavities of limestone the leachates percolate down to ground water system. Though in central part of the City the karstic limestone is covered with impermeable shales, limestone is exposed in the periphery. With the radial growth of the town ship the low-lying limestone areas are used as the sites of waste disposal at present which shows high nitrate contents in nearby villages.

The most hazardous sites, which are used for solid waste disposal, are along the ring road No. 1 in Rajender Nagar, Changorabhata and Dangania. According to WHO, 80% of the diseases in the world population are due to consumption of polluted water. It has been reported and observed every year in the groundwater dependent area that just after the first few showers in June, the complaints of various diseases suddenly increased. This may be due to the fact that leachates percolate down through the karst conduit and contaminate the aquifer. However, subsequent rain dilutes the concentration and makes the system almost normal.

The present practice of disposal of solid waste in limestone terrain must be stopped immediately and shifted to non-permeable location after proper hydrogeological investigation.

1.2.10. SEWERAGE GENERATION

Sewerage management is very critical in the city specially in slums. The majority of wastewater disposal happens through a network of surface drainage/ nalas, nearby open space or water body. About 80 per cent of the water that reaches households leaves as waste. Their greywater is drained in the nalas of the city and then collected in 6 nos of weir and transported to existing 3 nos of STP. The total sewerage length in Raipur city is only 55.97 Km while the length of roads in the city are 980.2 km.

It is observed that due to inappropriate and insufficient sewerage connections the surface water bodies like Chokra nala is contaminating, because only 57% sewerage is connected to these networks remaining near about 43 % population lacks any system or disposal of sewerage generated is flown on open drainage channels ultimately draining into natural water bodies and polluting the ground water.

Table 11 Population and STP data

Sr. no	Type	
1	Population (RUA)	14,33,000 persons
2	Treated water available	310 MLD
3	Sewerage generated (80% of water supply)	191 MLD
4	Sewerage Treatment facility Available	206 MLD

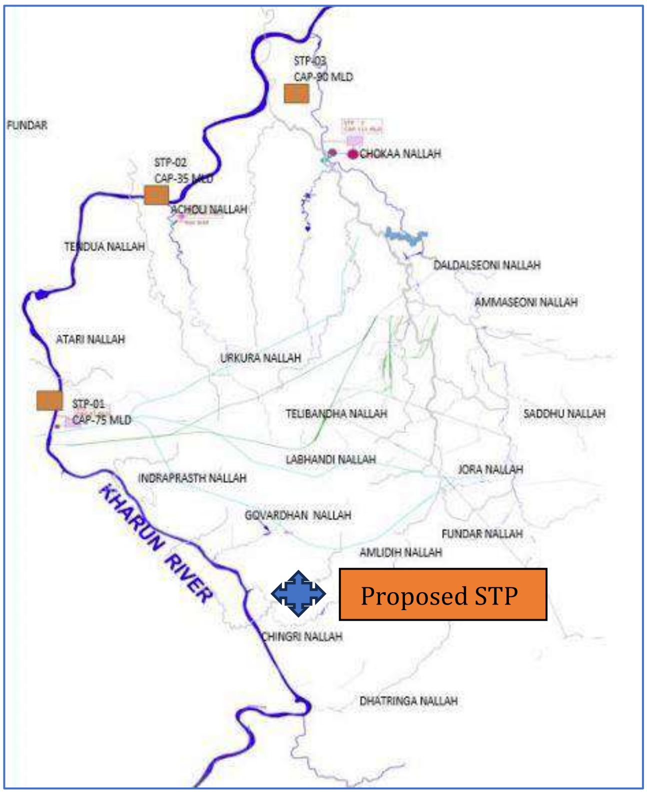


Figure 19 Map showing STP locations

1.2.11 INDUSTRIAL AREA

As a result of overall development, Raipur has emerged as an important, commercial cum industrial center of Chhattisgarh. The Raipur city have Total 1630 nos of industries, 330 nos of Infrastructures and 25 nos of Mining in the boundary.

As per the information from CGWA NOCAP 1799 nos of Industries/ Mining/ Infrastructure which falls under small industries need water 10 KLD, 168 nos of Industries/ Mining/ Infrastructure fall under medium category and 13 nos. Industries/ Mining/ Infrastructure falls under large scale with prominent players such as Monnet Ispat, Jindal etc. The per capita water requirement for commerce and industry has been worked out as 135 liter per day by department of town and country planning.

Though, the major industries of the area are using surface water, but many industries are having their own ground water abstraction which has increased the consumption of groundwater. EC value as high as 3600 s\cm has been observed in industrial estate around Bhanpuri. However, the impact of industrialization on groundwater quality has to be ascertained in detail.

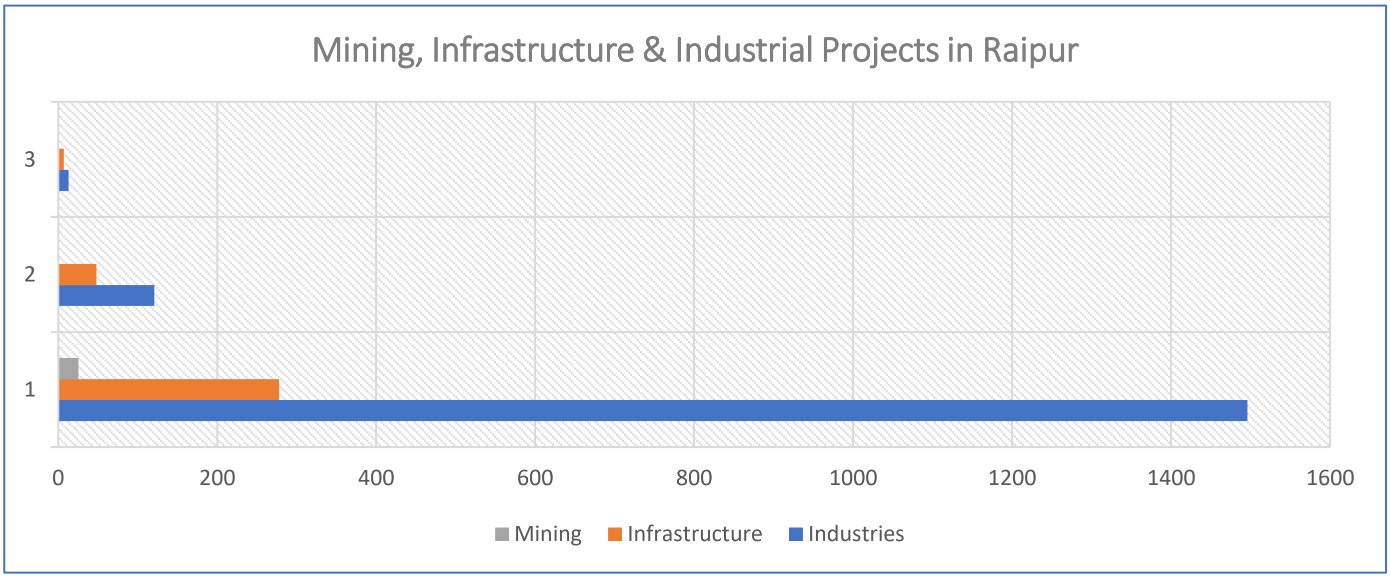


Figure 20 Mining, Infrastructure & Industrial Projects in Raipur

1.2.12 MINING OF LIMESTONE AROUND RAIPUR

Limestone is being excavated in more than 30 limestone quarries located in and around RUA (i.e. Mathpurena, Temri and Pirda). At these sites, the quarries are 17 to 20 m. deep, cutting the phreatic water table. To continue with mining activity, dewatering, particularly in post monsoon period (September to January), is necessary.

In the Mathpurena quarry dewatering of large amount of ground water has been observed causing substantial loss of precious ground water. The ground water contour map of Raipur reflects that the quarry area is situated on the steeply gradational limbs of ground water contour cutting the flow lines. The mining of ground water at this point is causing lowering of the water table in the higher altitudes. Therefore, through mining activities a substantial quantity of groundwater is being thrown out in post monsoon period.

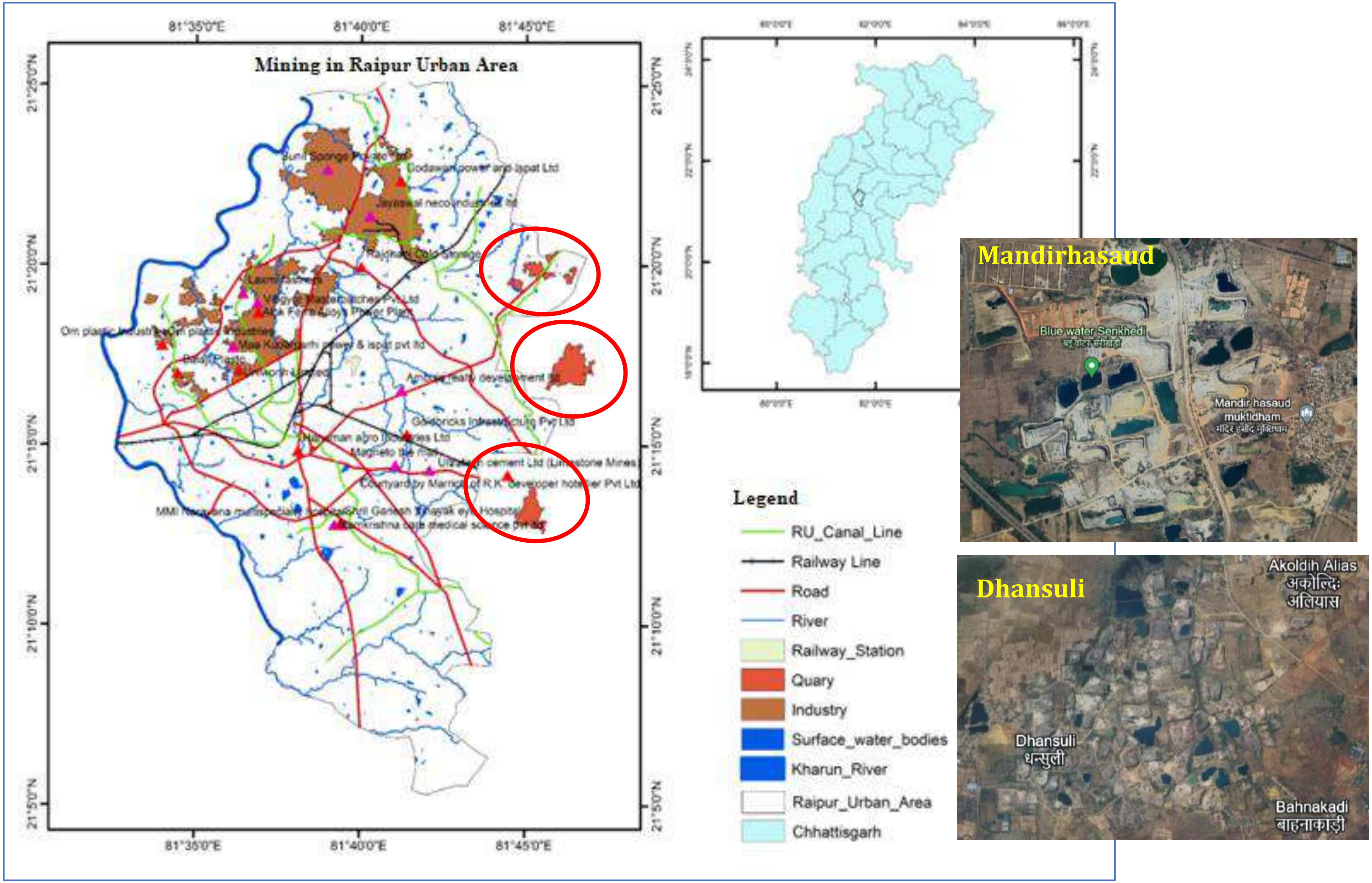


Figure 21 Mining Area around Raipur

CHAPTER 2

PRIORITY TYPES

Rapid urbanization and unprecedented increasing pressure of multiplying anthropogenic activities are the main issues to water resources management in urban centers. The growing water pressure caused by the disproportionate increase in population and urbanization in large cities has triggered several adverse effects on groundwater resources. A common effect is the reduction of the natural recharge (produced by rainfall) of the underlying aquifer due to changes in land use/cover, overexploitation, and changes in the precipitation regime. The overall sustainable growth in last three decade made India one of the few rapidly growing nations in the world. The urban centers became the hotspot for the growth. In India over 372 town and cites (Class -I) having more than 1 lakh population in 2023. India is second largest in world in urban system where 285 million people are presently living in urban areas.

As a state capital rapid urbanization has affected the overall ground water regime of Raipur Urban Agglomerate. Almost entire Peninsular India is occupied by hard rock and is dominated by crystalline with patches of karstic carbonates. Being a karstic terrain, the area is highly sensitive to various anthropogenic activities. With the present draft to recharge ratio, the sustainability of abstraction structures is severely threatened. The hard rock areas and its cities face acute scarcity of water during prolong summer apart from sporadic quality problems. Raipur, the capital city of Chhattisgarh State is no exception than the general trend in hard rock of India. Figure 17 shows the change in built up areas in city and figure 18 shows the change in Ground water extraction.

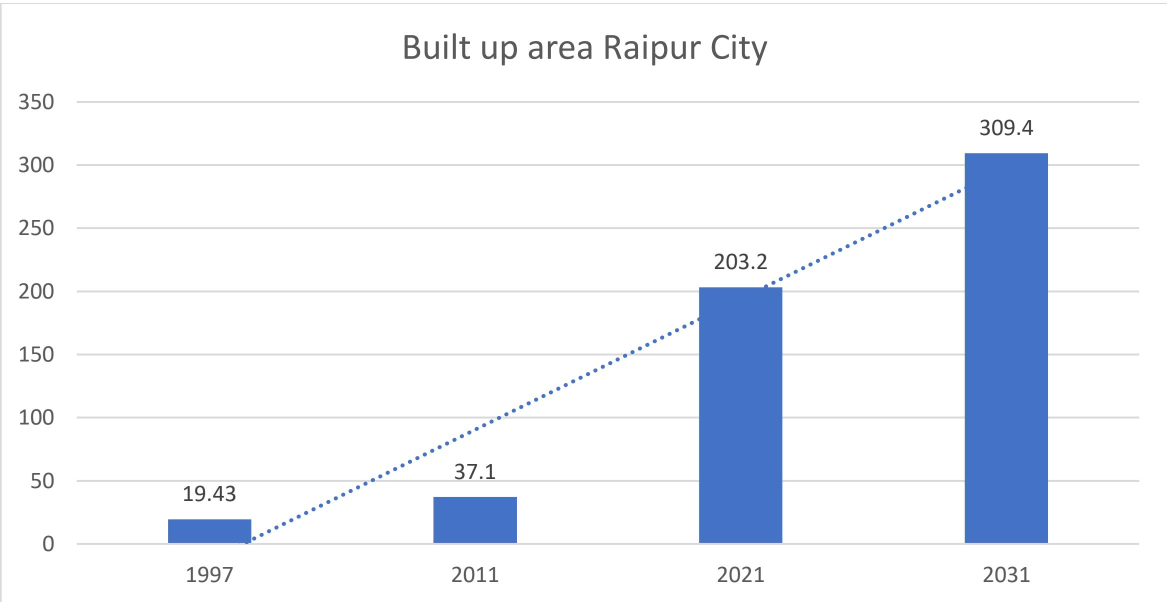


Figure 22 Built up area Raipur City

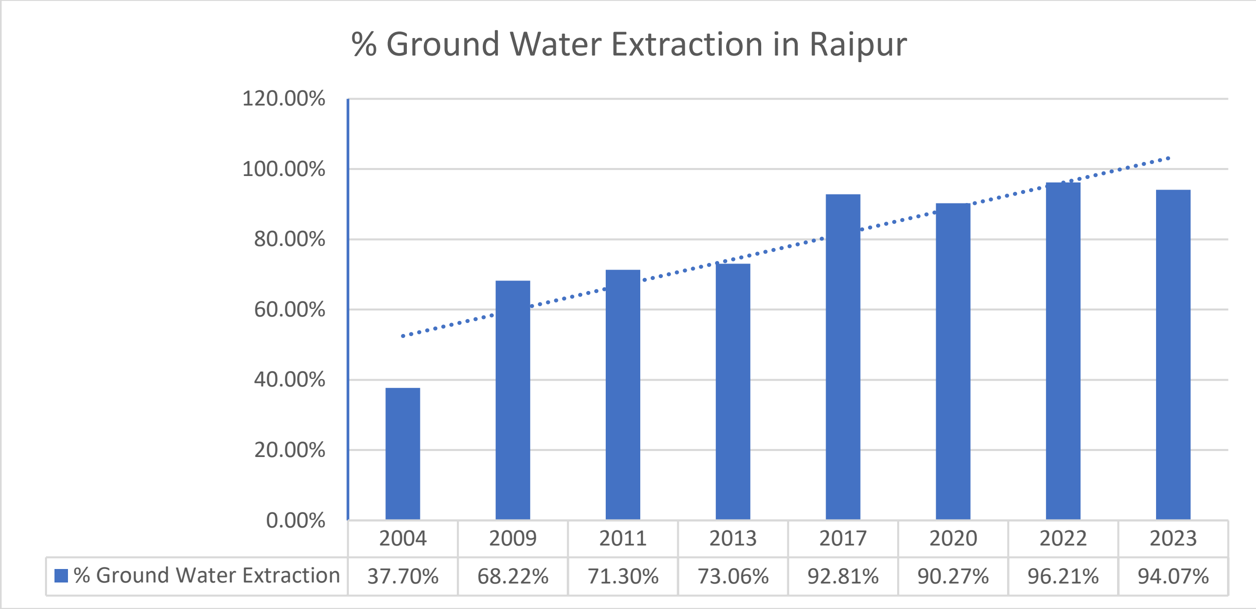


Figure 23 Groundwater Extraction in Raipur

1. Change In Lifestyle Related and Ground Water Depletion

Over the years particularly due to rapid urbanization the change in the life style related to water use has increased the per capita consumption of water tremendously. The modem lifestyle with running tap water, WC flush, use of washing machine has increased the per capita water requirement substantially particularly in last 3 decades.

The conventional dug wells were replaced first by borewells with hand pumps and subsequently by power pumps, bringing easy availability of water resulting in more casual approach towards use of precious ground water. single cropped agriculture land of RUA has been partially converted into double-cropped area due to awareness. However the overall area of agriculture land has reduced substantially in RUA. This change of lifestyle has brought a definite impact on water resources in general and ground water in particular.

2. Growth In Population & Water Supply

The water requirement is based on the population and industrialization of an area. The Water requirement of Raipur is worked out @ 135 lit/Capita/day (Ipcd) from the RUA population of 14,33,000 (As per Raipur population Census 2024). Based on these estimates the total domestic water requirement of RUA is worked out is 0.1935 MCM per day from 4 nos of intake wells which further supply to total 4 nos of water Treatment plants with capacity 357.5 MLD (i.e 47 MLD, 80 MLD, 80 MLD and 150 MLD). The river Kharun is the principal source of water supply. The total water supply piped connections in RUA given by municipal corporation is 2,27,110 nos.

Table 12 Intake well capacity and Total Availability

Sr. no	Type	Capacity and Name	Total Availability
1	Intake well	NEER-11.30 MLD, KHEER-22.70 MLD, SAGAR-230 MLD, SARITA-80 MLD, Kharun-13.50 MLD	357.5 MLD
2	Water treatment plant	Old-47.5 MLD, 150 MLD & 80 mLD New 80 MLD	357.5 MLD
3	Population	14,33,000 persons	
4	Water demand	0.1935 MCM	0.1935 MCM

The current water supply is sufficient to meet the total demand. However, due to improper utilization and management of available water resources, treated water is being discharged back into the Kharun River.

3. High Water Demand in Commercial sector: Raipur Urban typically have a higher population density, leading to increased demand for water resources for domestic, industrial, and commercial uses. Raipur city is a hub for industries in Siltara and Urla areas, businesses, and services, all of which require large amounts of water for various processes. City Major infrastructures like hospitals, schools, and recreational facilities require consistent water supplies, further increasing demand of ground water.

4. Groundwater Depletion due to private drilling: There are many countless privately drilled Bore wells, used for extracting groundwater, are not included in official counts, leading to challenges in accurately assessing total groundwater usage in Raipur Urban. The overall requirement is basically met through surface and ground water resources. Over-extraction of groundwater in cities lead to a significant drop in the water table, making groundwater studies crucial for sustainable management.

5. Pollution Risk: Urbanization is leading to the risk of groundwater contamination from industrial discharges, sewage leaks, and other pollutants, necessitating regular monitoring. Aging or poorly maintained sewage systems can leak, allowing untreated wastewater to infiltrate the ground and contaminate groundwater with pathogens, nutrients, and organic pollutants. Nitrate problem are encountered in city.

6. Infrastructure Development: The development changes in land use, which can affect groundwater recharge and quality. The paved areas increases which leads to runoff of water. Understanding these impacts is essential for planning and management. Excavation, drilling, and other construction activities can disrupt natural groundwater flow and affect the quality and quantity of available groundwater.

7. Water Security: Ensuring a reliable and sustainable water supply in urban areas is critical, making groundwater studies essential for long-term planning and water security. Understanding groundwater dynamics helps mitigate risks such as land subsidence, water shortages, and pollution, contributing to the overall resilience of urban water systems.

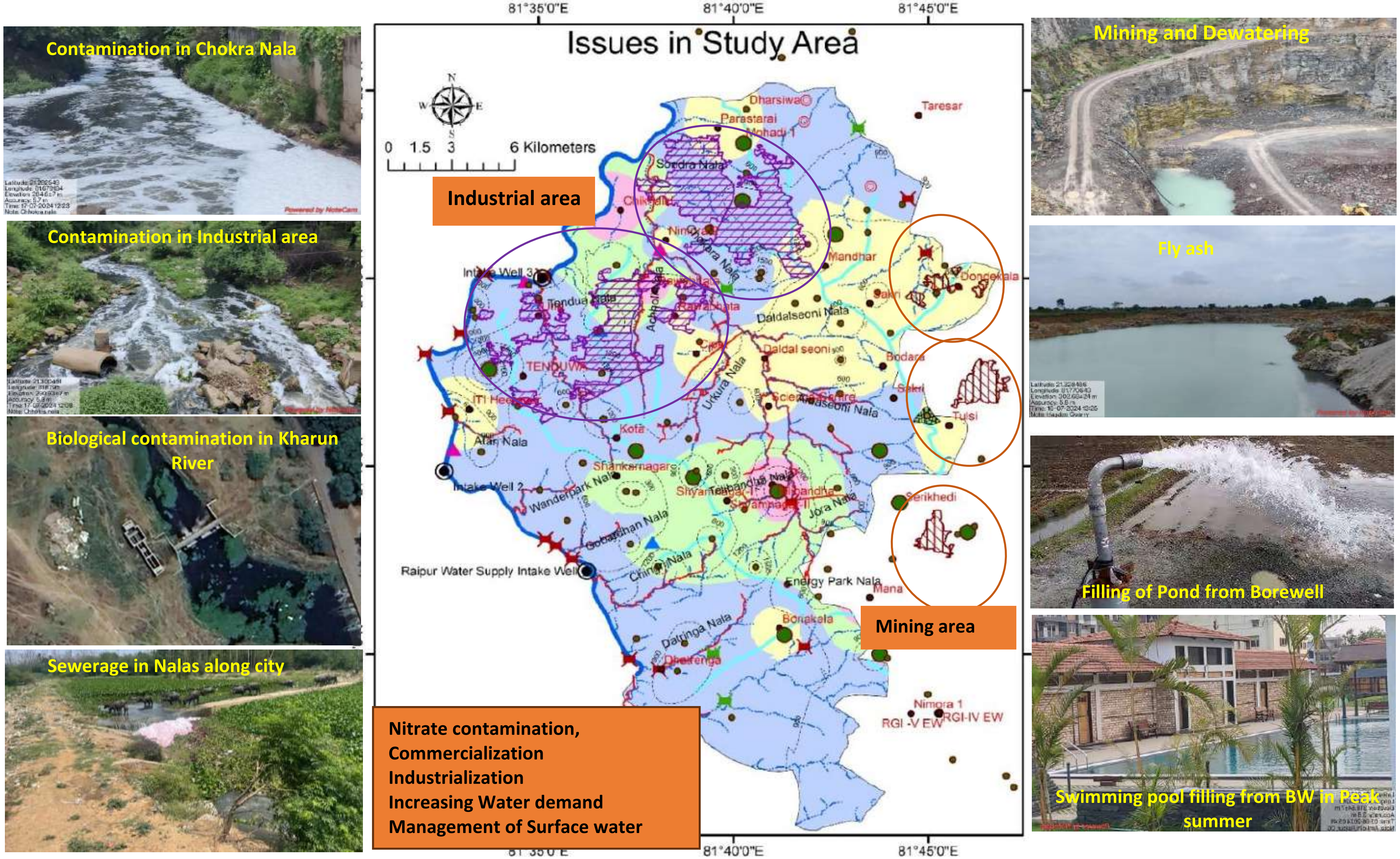


Figure 24 Issues in Raipur Urban area

CHAPTER 3

PREVIOUS STUDY

Previous study includes National Aquifer Mapping study taken in Year 2020-21 by CGWB stressed on following points;

1. Conjunctive use of water resources and creation of more ponds may be given importance.
2. Due to large scale pumping from Chandi Formation for irrigation, the water level in this formation goes deep in summer and the sustainability of shallow hand pumps are threatened. If the water of irrigation tanks or check dam in deeper water level area can be used effectively for artificial recharge through gravity head recharge well, it can enhance the sustainability of hand pumps (the lifeline for rural drinking water) in the area. These tanks can provide additional water for delayed recharge to aquifer after monsoon.
3. All the unused dug wells may be converted to recharge structures by filling suitable filter material (Layers of equal thicknesses of Sand at the bottom followed by Gravels and then by Pebbles). Presently these dug wells are acting as a source of pollution to ground water due to dumping of domestic waste.
4. The source of nitrate in ground water is mostly anthropogenic. Hence, dug wells in the affected areas are to be substituted by borewells or tubewells to avoid the phreatic aquifer.
5. Creation of Sewage Treatment Plant (STP) in urban area and construction of soak pit in rural areas should be given due importance to prevent ground water contamination.
6. Reuse of GW in urban area may be encouraged in urban areas particularly in Raipur town.
7. The exploration by Central Ground Water Board has indicated the presence of potential fractured zones down to 130 mbgl. The optimum desirable depth of bore wells in the district is between 50 and 90mbgl. The yield of bore wells tapping the deeper aquifer of the area goes up to 13lps. The exploration data indicates that Chandi limestone formations is the most potential in the area.
8. The chemical quality of the ground water of shallow as well as deeper aquifers is good and is suitable for drinking, irrigation and industrial purposes.
9. As per the GWRA 2023 the Annual Extractable Ground Water Recharge (Ham) is 9577.20 ham. The Net Ground Water Availability for future use is 152.99 ham. Current Annual Ground Water Extraction for all purposes is 8108.58 ham out of which 3896.74 ham is for irrigation. The overall Stage of Ground Water Extraction in the district is 94.07 %. The Dharsiwa blocks falls in critical category.
10. About 60% of the urban drinking water supply schemes in the district depends on ground water.

CHAPTER 4

OBJECTIVE OF PRESENT STUDY

The objectives of the present study are to delineate:

1. Aquifer Dispositions: The primary goal is to obtain a comprehensive understanding of the aquifer layouts within the study area. This involves detailed geological and geophysical surveys to map out the aquifer characteristics such as their size, shape, depth, and the extent of the weathered zones. Weathering refers to the breakdown of rocks into smaller particles, and its thickness can greatly influence the storage and movement of groundwater. By mapping this weathered thickness, the study aims to identify the most efficient zones for groundwater extraction and recharge.

2. Aquifer-wise Groundwater Levels: This objective focuses on monitoring and recording the water levels in different aquifers over time to determine their fluctuations and long-term trends. Understanding the seasonal and annual changes in groundwater levels is crucial for assessing the aquifer's health, recharge rates, and sustainability. It also helps in developing models to predict future changes in water availability and to plan accordingly for water resource management.

3. Delineation of Recharge Areas: Identifying areas where groundwater recharge is naturally occurring, as well as those that could benefit from artificial recharge, is essential. This involves examining soil types, topography, and existing water flow patterns. Following the delineation, the study will propose a detailed artificial recharge plan, which may include structures like percolation tanks, recharge wells, and check dams designed to enhance the natural replenishment of aquifers.

4. Estimation/Refinement of Parameters: Accurate estimation of parameters such as canal seepage factors and seepage from ponds is crucial for assessing the overall groundwater resources. This aspect of the study will refine these parameters using both field measurements and modeling techniques, thereby improving the reliability of the water resource assessment. It aims to provide a better quantification of the available groundwater and the contribution of various sources to aquifer recharge.

5. Assessment of Groundwater Resources (Refinement of Parameters): Expanding on the prior objective, this task entails conducting a thorough evaluation of groundwater resources within the study region. Through the enhancement of assessment parameters and methodologies, we aim to furnish more precise and dependable information crucial for implementing sustainable groundwater management practices. This comprehensive 48 assessment facilitates informed decision-making regarding the utilization and conservation of groundwater resources.

5. Ground Water Quality: Assessing the quality of groundwater is vital for ensuring its safety for consumption and other uses. This part of the study involves the collection and analysis of water samples from different aquifers to measure parameters such as pH, salinity, hardness, and the presence of contaminants. The data gathered will guide the management practices to address any quality issues and to maintain the standards required for drinking water.

8. Artificial Recharge Plan: Creating an artificial recharge strategy is vital for restoring depleted aquifers and sustaining groundwater levels. This goal emphasizes identifying appropriate locations and employing methods like rainwater harvesting and managed aquifer recharge to boost groundwater recharge rates, ensuring long-term groundwater sustainability

6. Identification of Potential Aquifers for Drinking Water Supply: Not all aquifers are equally suitable for providing drinking water due to differences in water quality and yield. This objective entails identifying which aquifers have the potential to serve as reliable and safe sources of drinking water. It involves both quantity and quality assessments and taking into account the sustainability of extracting water from these aquifers.

7. A Plan for Drinking Water Source Sustainability: The final goal is to ensure the long-term sustainability of drinking water sources. This requires a strategic plan that includes both the protection and sensible use of groundwater. It will focus on demand-side management, which looks at water use efficiency, conservation practices, and altering consumption patterns to reduce the strain on water resources. The plan will also include public education campaigns, policy recommendations, and the integration of water saving technology.

CHAPTER 5

AQUIFER CHARACTERISTICS

5.1 DATA GAP AND DATA GENERATED

The NAQUIM (National Aquifer Mapping and Management) initiative has been crucial for understanding groundwater resources. Under NAQUIM-1, carried out in Raipur during 2019-20, a dataset focusing on exploration geophysical and water-level datasets of the phreatic aquifer at a 1:50,000 scale was generated. This helped in tentatively identify the hydrological setup of the area.

Building on this foundation, NAQUIM-2.0 conducted detailed mapping at a finer scale of 1:10,000 and generated additional datasets beyond the exploration, geochemical, and geophysical datasets:

1. Accurate delineation of all waterbodies in the Urban area.
2. Accurate spatial distribution of check-dams, Intake wells, WTP, STP identified through imagery analysis in Google Earth.
3. Delineation of canal and canal command areas.
4. Calculation of rainfall from 1981 to 2022 over the entire block using Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS).
5. Exact land use land cover area identified through GIS-based studies and field verification.
6. Area -wise well discharge, casing depth, and exact depth of fracture occurrence.
7. Soil infiltration studies to determine the spatial distribution of recharge rates.

These enhanced datasets from NAQUIM-2.0 aim to provide a more detailed and accurate understanding of the groundwater resources and hydrological characteristics of the region, aiding in better management and sustainable utilization of these resources. The data are shown in table no 13 & 14 as given below

Table 13 Data Required

S. No.	Items	Data Requirement	Data Availability	Data Gap
1.	Rainfall Data	Meteorological Stations spread over the project area	NASA	No Data Gap
2.	Soil	Soil map and Soil Infiltration Rate	1:200000	Soil Infiltration Rate across the study area
3.	Land use	Latest Land Use pattern	Land use data of 2023	No Data Gap
4.	Geomorphology	Digitized Geomorphological	Downloaded from	No Data Gap

		map	NRSC, ISRO, Hydrabad.	
5.	Geophysics	Geophysical data in each Quadrant	38 VES	66 VES
6.	Exploration Data	EW in each Quadrant with Aquifer Parameters	12 EW's	09 PZ
7.	Aquifer Parameters	Aquifer parameters for all the quadrants	07 Pump test	05 PYT and 04 Slug Test
8.	Recharge Parameters	Recharge parameters for different soil and aquifer types based on field studies	Recharge parameters given in Resources Estimation	100 % data gap in the spatial distribution of extraction wells and calculation of unit draft according to cropping pattern
9.	Discharge Parameters / Draft Data	Discharge parameters for different GW abstraction structures	Discharge parameters given of existing wells in 1:50,000 Scale	Village-level discharge data required
10.	Geology	All the maps on 1:50,000 Scale. Hard and digitized copies.	Hard copies of only a few geological maps from GSI	Soft copies of the entire study area

Table 14 Data Generated

S. No.	Items	Data Generated	Data Collected
1	Rainfall Data		1981 to 2022 data collected from NASA
2	Geophysical data	Carried out 20 VES at 11 sites	Geophysical data is not available with any other department in the State.
3	GW Exploration	Construction of 9 PZ. Carried out Aquifer test for the determination of Aquifer parameters	Tubewell details of about 20 wells collected from State Government Departments (PHE)
4	GW Regime Monitoring	Established 111 key stations for analyzing water-level behavior in the aquifer.	Water level data sets have been collected for both pre-monsoon and post-monsoon periods, covering 111 dug wells, 21 bore wells, and 68 hand pumps. (Source JJM)
5.	GW Resource Refinement		Village-wise accurate number of irrigation wells and water supply wells collected from Janpad panchayat.
5	GW Quality Monitoring	Water samples were collected from 15 dug wells, 67 tubewells, and handpumps both in pre and post.	
6	Surface water Quality Monitoring		
7	Nagar Nigam Data		The City Development Plans have been collected for Raipur Nagar Nigam, (Source Nagar Nigam)

5.2 AQUIFER DISPOSITION

5.2.1 OBJECTIVE

The primary objective is to characterize the spatial distribution and properties of aquifers within geological formations. This includes defining lithological boundaries, mapping stratigraphic layers, and determining the geometry of aquifer units. Rock Works allows for the integration of diverse data types, such as bore hole logs, geophysical surveys, and hydrogeological measurements, to facilitate a holistic understanding of the aquifer disposition. Rock Works offers tools for interpolating and modeling the separate meters in three-dimensional space, aiding in the creation of accurate hydrogeological models.

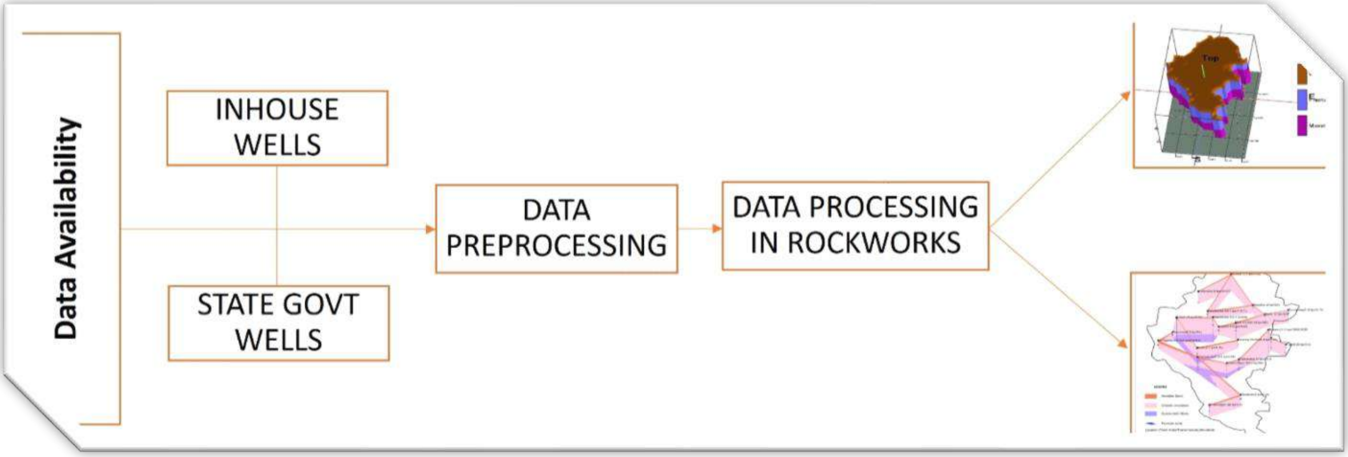
Decision- making regarding aquifer disposition objectives also involves considerations for ground water flow and contaminant transport analyses. By setting clear objectives, users can tailor Rock Works to generate visual representations, cross-sections, and volumetric calculations that align with specific project goals. Ultimately, the chosen objectives should align with the overarching aim of enhancing the understanding of aquifer disposition for informed groundwater resource management and exploration.

The goal of an aquifer test is often to determine key aquifer properties, such as hydraulic conductivity, transmissivity, and storativity. These objectives guide the selection of appropriate testing methods, including pumping rates, well configurations, and monitoring well locations. Additionally, aquifer tests may aim to assess the aquifer's response to stress, such as variations in pumping rates, to understand its dynamic behavior and recharge capacities.

The objectives of an aquifer test canal so extend to evaluating well efficiency, identifying potential aquifer boundaries, and estimating sustainable pumping rates for water supply wells. Clear objective s help in choosing the appropriate mathematical models for data analysis and interpretation, ensuring that the test out comes align with specific project goals. Furthermore, aquifer tests may serve to validate conceptual hydrogeological model so refine existing ones, contributing to a more accurate understanding of ground water flow within the aquifer system. Ultimately, well-defined objectives are integration the success of an aquifer test, providing a road map for data collection, analysis, and interpretation to derive meaningful insights into the aquifer's hydraulic properties and behavior.

5.2.2 MATERIAL AND METHODS

CGWB has taken up drilling operation in Raipur district in the past years. All the available datasets were collected. In the present AAP 2023-24 drilling of additional 9 new wells were undertaken. Additionally details of State Govt. wells were also collected so as to incorporate the detailed lithological variation in the block. All these data set were processed and arranged to prepare 2D cross sections and 3D Models representative of the subsurface aquifers disposition in the block.



5.3 RESULT AND DISCUSSION

5.3.1 GROUNDWATER EXPLORATION

A total of 12 exploratory wells were drilled in NAQUIM-I and prior studies and under NAQUIM-2.0 studies 12 nos of piezometric wells were drilled. The details of the wells area are as follows:

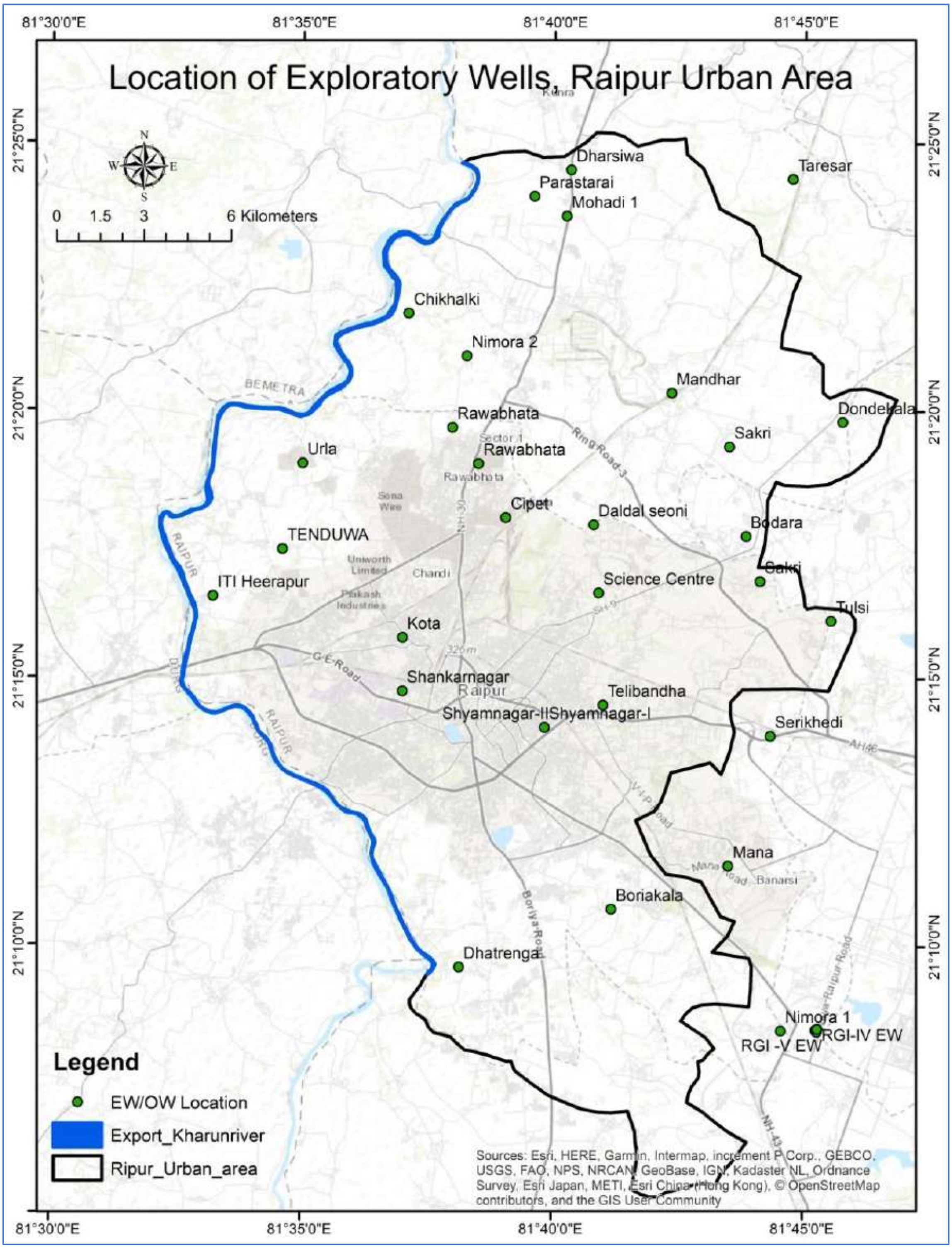


Figure 25 Location of Exploratory wells

5.3.2 AQUIFER DISPOSITION

There is major two types of aquifer system in Raipur Urba area i.e. Chandi Formation and Gunderdehi shale.

Chandi Formation:

Limestone: The Pendri member of Chandi formation comprising mostly of Karstic & Dolomitic Limestone in overall area. The areal extent of Chandi Sandstone is 64.48 %

Shale: Shales are thinly laminated to bedded having irregular thickness and few patches of sandstone in central part and eastern edge of the block boundary. The areal extent of Chandi Shale is 10 %

Sandstone: The sandstones are highly brittle, silicified, ferruginous, glauconitic, 01tho-quartzitic in nature and are thinly bedded to laminated occupying generally the elevated parts in the area (Shobhnath et. all, 2000). The areal extent of Chandi Sandstone is 25.50 %.

Gunderdehi Formation:

This comprises of shale intercalated with limestone with areal extent of 2-3 %.

Doleritic Intrusive: Subsurface dolerite intrusive is running roughly E-W to NE-SW direction in Kota-Samata colony area.

Topsoil:

Topsoil is composed of buff colored sand, silt, and clay particles. Topsoil depth varies depending on factors such as erosion, deposition, and parent material. Porosity of top soil influences water retention, drainage, and aeration

Vertically the aquifer can be categorized into two group viz.

1. Top Unconfined weathered Aquifer.
2. Bottom Fractured Aquifer

Exposure of Stromatolitic limestone in Semariya and Amlidih, Raipur

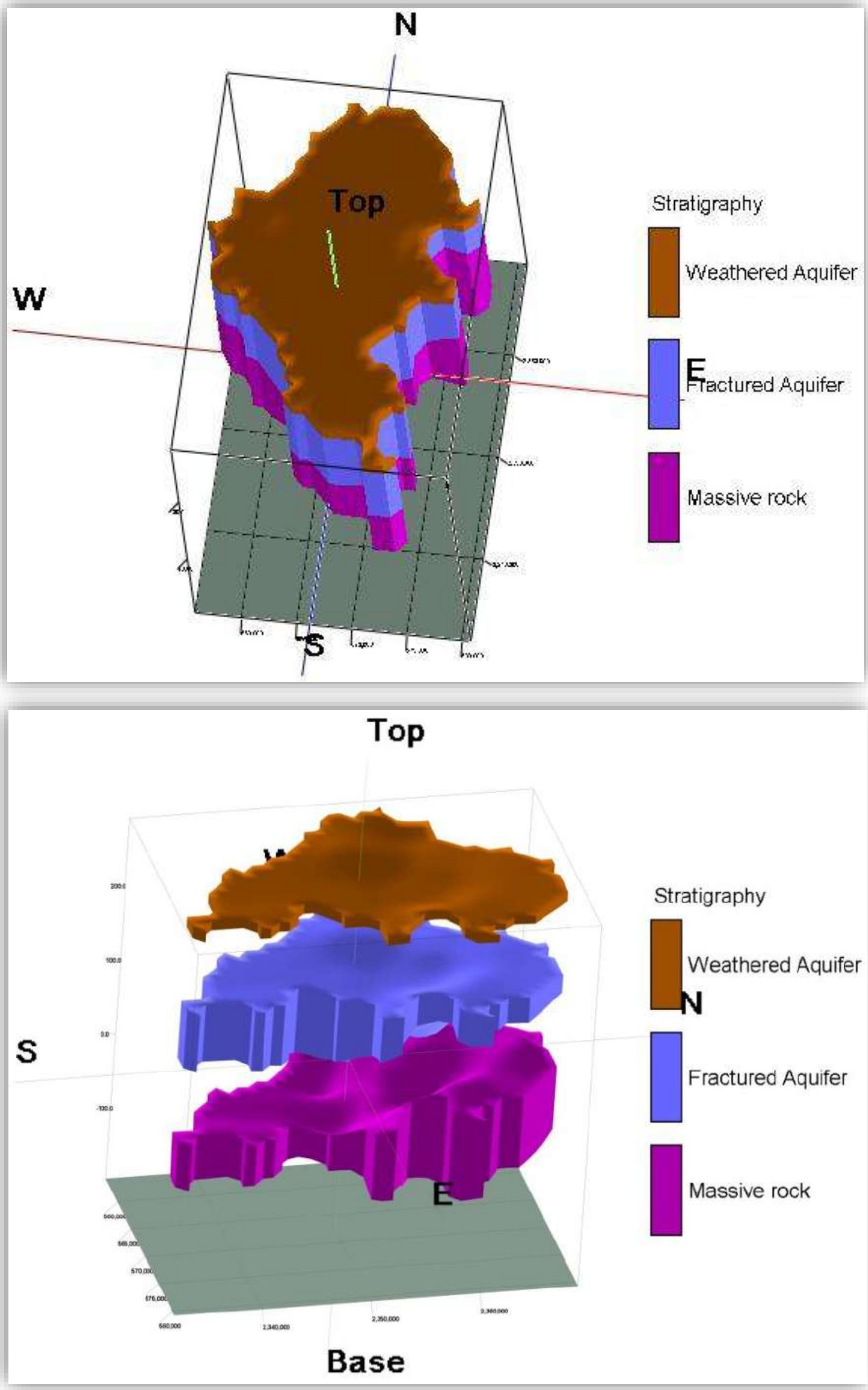


Figure 26 3D Disposition of aquifer

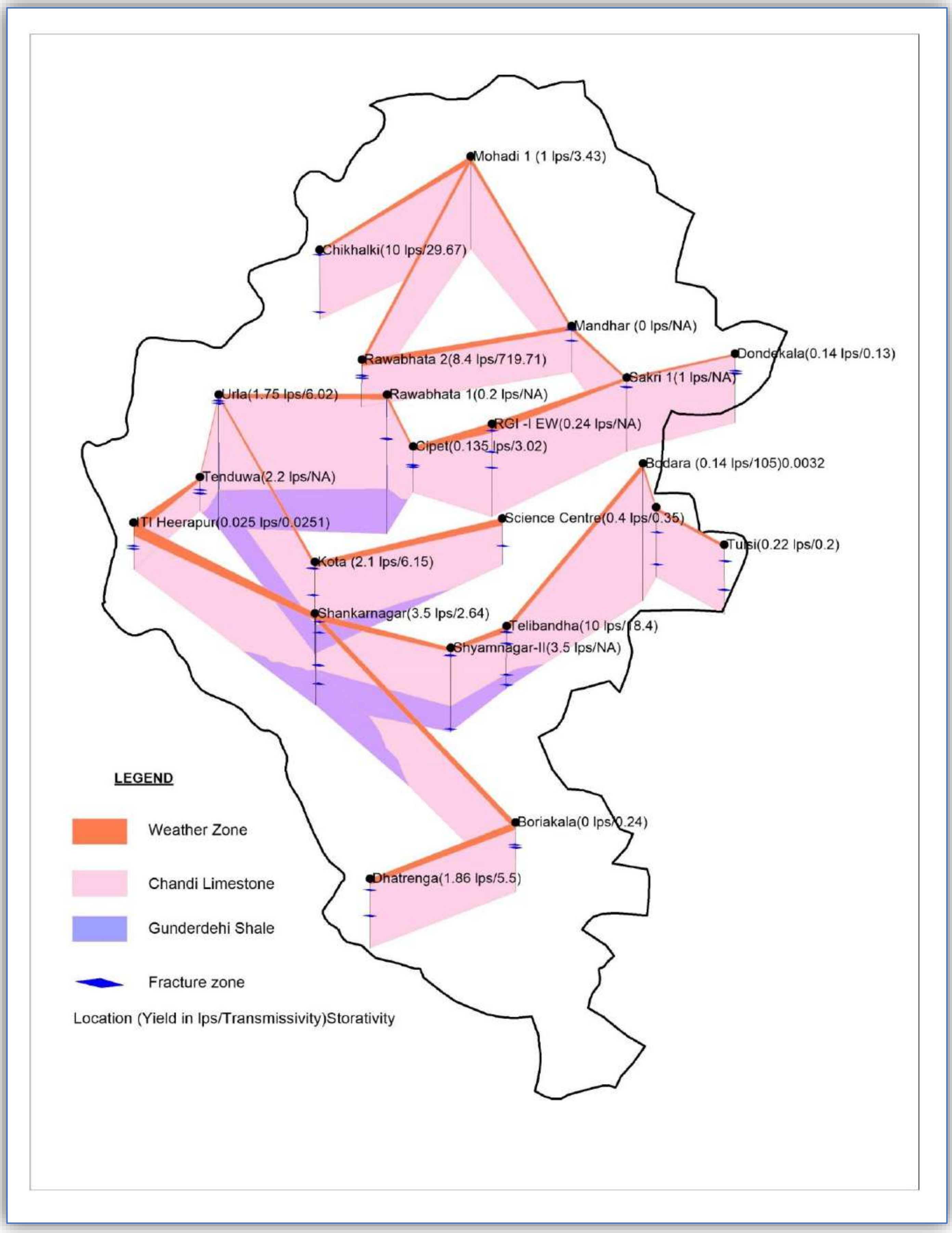


Figure 27 2D Fence Diagram of the Study Area

5.3.3 AQUIFER CHARACTERISTICS

The Chandi Formation

The Chandi Formation comprises two members namely Pendri limestone and Deodonger shales and sandstone. Ground water in these rocks occurs both under phreatic and semi-confined to confined condition. The depth of the dug wells in the area varies from 7 to 21m with diameter ranging from 2 to 6m whereas the depth of the bore wells in the area ranges from 30 to 120 m with the diameter varying from 0.10 to 0.15m.). In general, water-bearing horizons are encountered in depth ranges of 13 to 45m and 65 to 85m. The yield of bore wells tapping these horizons ranges from 3.6 to 45 m3/hr with drawdown ranging from 7 to 60 m. The T & S calculated for Chandi Formation varies from I to 120 m /day and 2 X 10-3 to 8.3 X 10-5 respectively. The phreatic depth to water level ranges from 2 to 15 m bgl during pre-monsoon period and 0.5 to 6m in post- monsoon period. However, a very shallow, discontinuous perched water table condition prevails in the central pan of Raipur town covering Ashram-Rajatalab-Shankamagar-Devendra nagar area due to the presence of impermeable shale, where the water table rernains within 3m bgl through out the year.

Gunderdehi Formation

Aquifer characteristics of Genderdehi Shale: - Gunderdehi Shale is not exposed in the area only 2-3 % area is exposed. subsurface geology as revealed by borehole data of the area shows that the contact of Chandi Formation and Gunderdehi Formation is sharp. Occasionally, the upper zone of the Gunderdehi Shale is fractured yielding meager amount of water but, in general, these formations are devoid of any water-bearing horizon in the area. The shale is hard massive formation underlying the Chandi Formation. It is not much productive as compared to other formations. Only in areas where shale has higher calcareous nature or transition with limestone it shows minor productivity. The weathered zone here ranges to about 9 m. The wells mostly drilled in these areas are either dry or has negligible discharge.

The topography of Raipur city is flat with elevated land at a few places with general slope of land towards northwest. The groundwater recharge occurs mainly through canal seepage and direct infiltration of precipitation. Groundwater flows from eastern side having canal network (constant recharging boundary) towards northwest and southwest. The Kharun river in the western side of the city forms the discharging boundary. The joints pattern and caverns mainly govern the flow.

The flow from the reservoir and ponds in the city is also towards northwestern and southwestern sides. Wherever the underlying veneer of hard shale pinches out, the inflowing surface water contaminates the surrounding groundwater. The situation at places is aggravated due to excessive exploitation of groundwater causing induced flow of surface water to the groundwater.

Table 15 Raipur Geology

<table>
<tr><th>Formation</th><th>GEOLOGY</th><th>Lithology</th><th>Area
(in Sq km)</th><th>Discharge (lps)</th></tr>
<tr><td rowspan="4">RAIPUR GROUP
Chandi Formation</td><td rowspan="2">Deodongar member</td><td>SST</td><td>128.73
(25.5%)</td><td>0 to 8.4
(11 EW/PZ)
(8.4 Rawabhata)</td></tr>
<tr><td>Shale</td><td>50
(10 %)</td><td>0 to 10
(3 EW/PZ)
(10 lps telibandha)</td></tr>
<tr><td>Pendri member</td><td>LST
(Karstic & Dolomitic nature)</td><td>325
(64.48%)</td><td>0 to 10
(12 EW/PZ)
(10 lps Chikhali)</td></tr>
<tr><td colspan="2">Total area</td><td>504
(100 %)</td><td></td></tr>
</table>

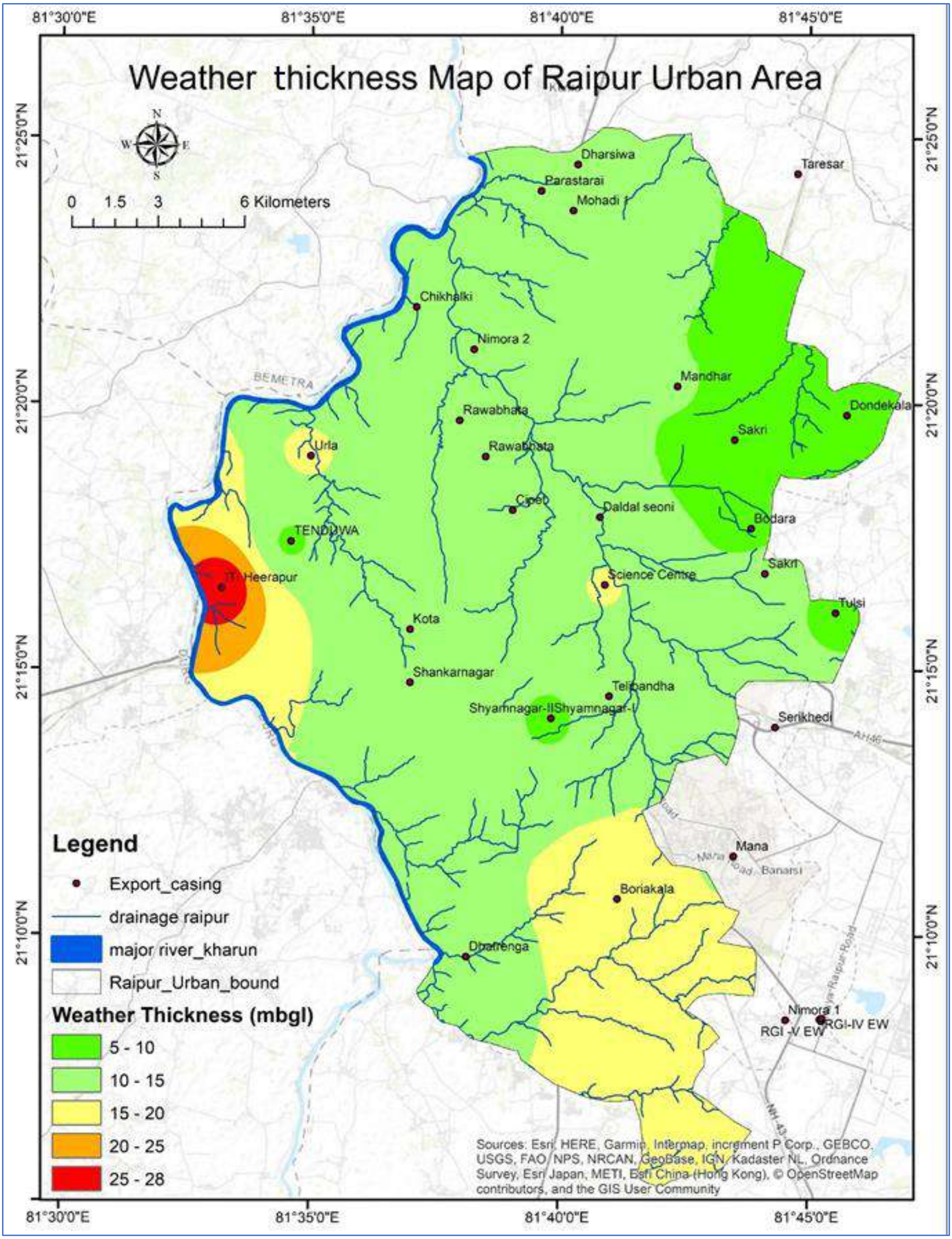


Figure 28 Weather Thickness map of Raipur Urban Area

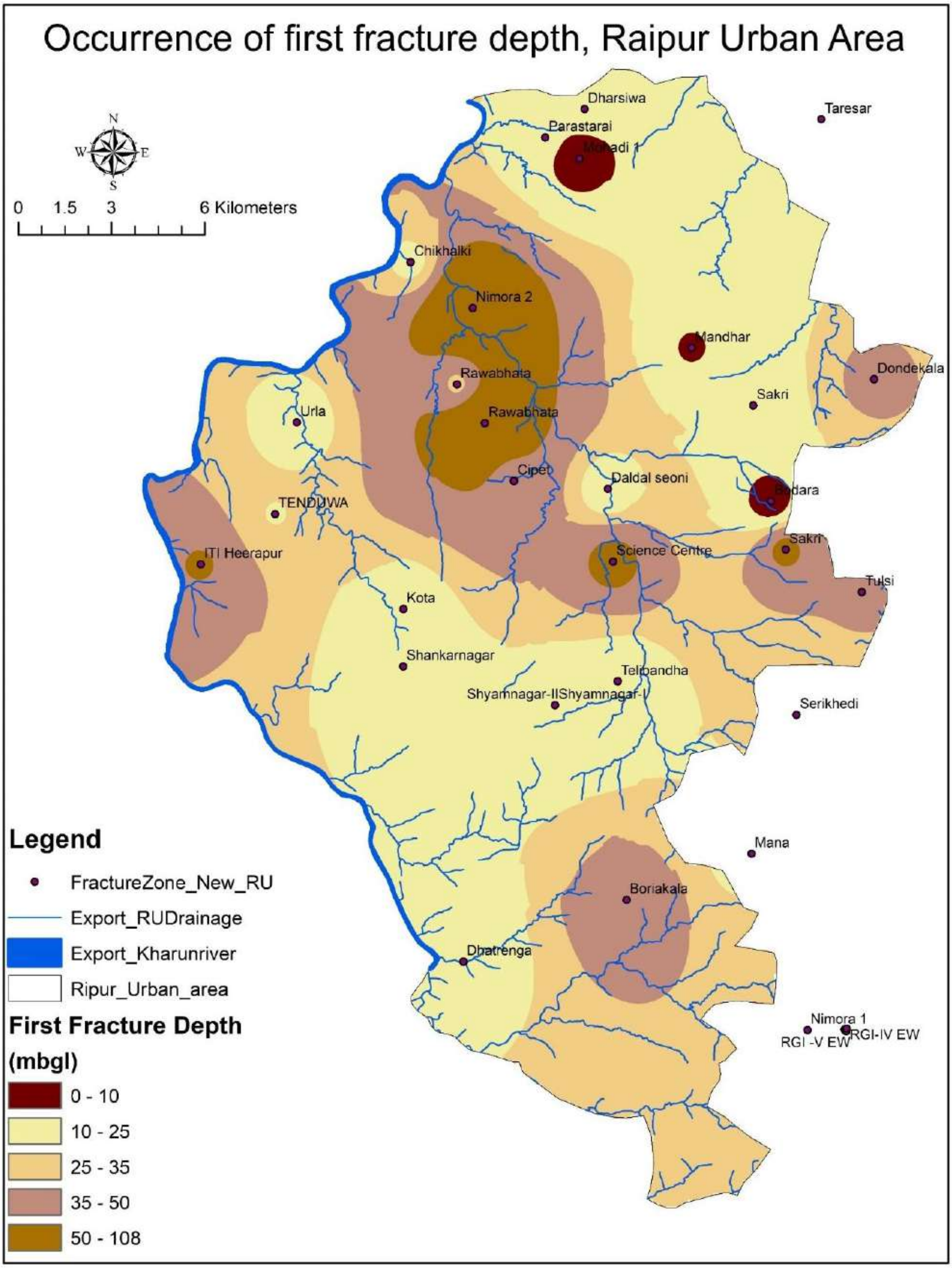


Figure 29 Occurrence of First Fracture Depth in Raipur Urban Area

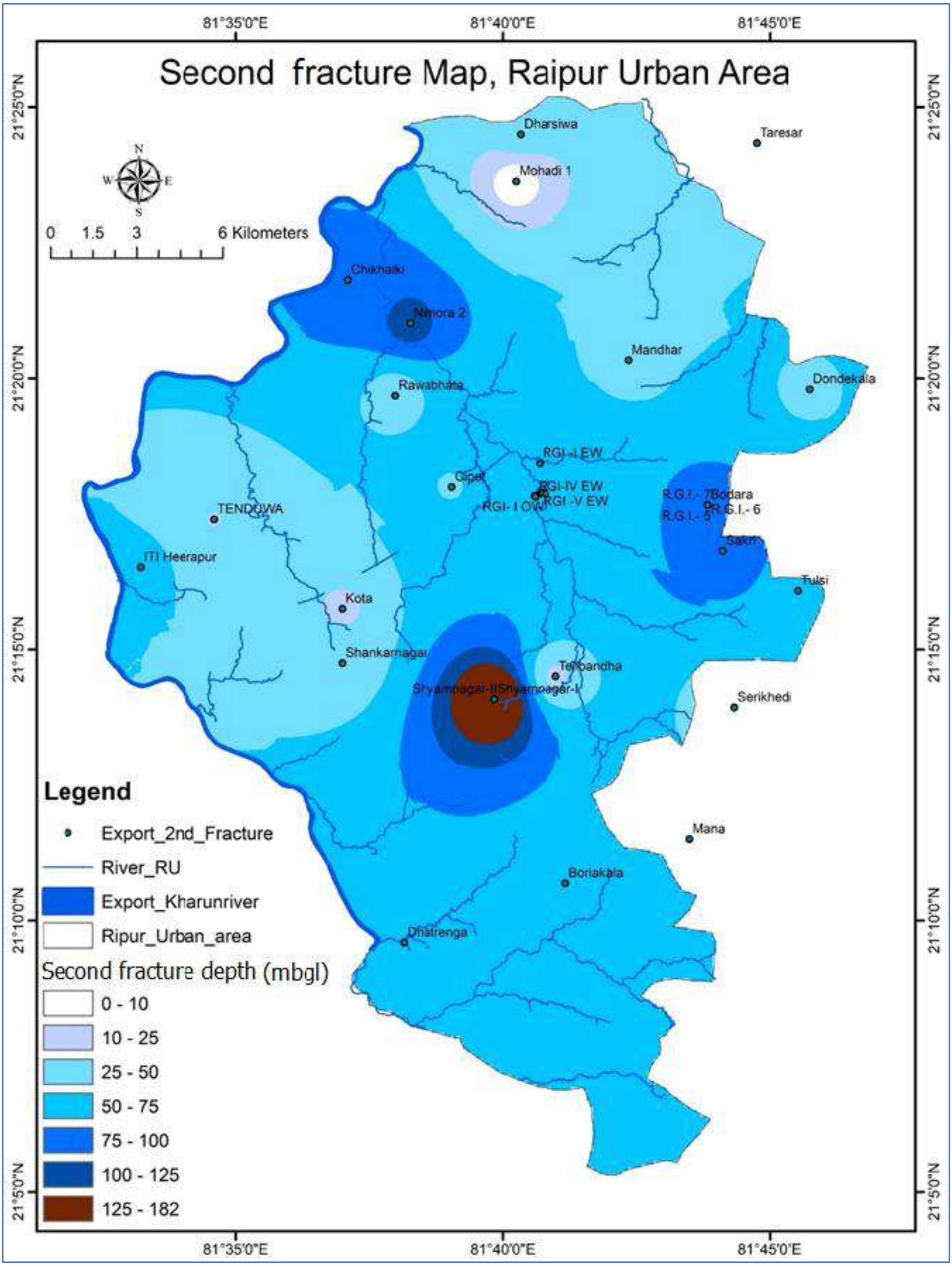


Figure 30 Occurrence of Second Fracture Depth in Raipur Urban Area

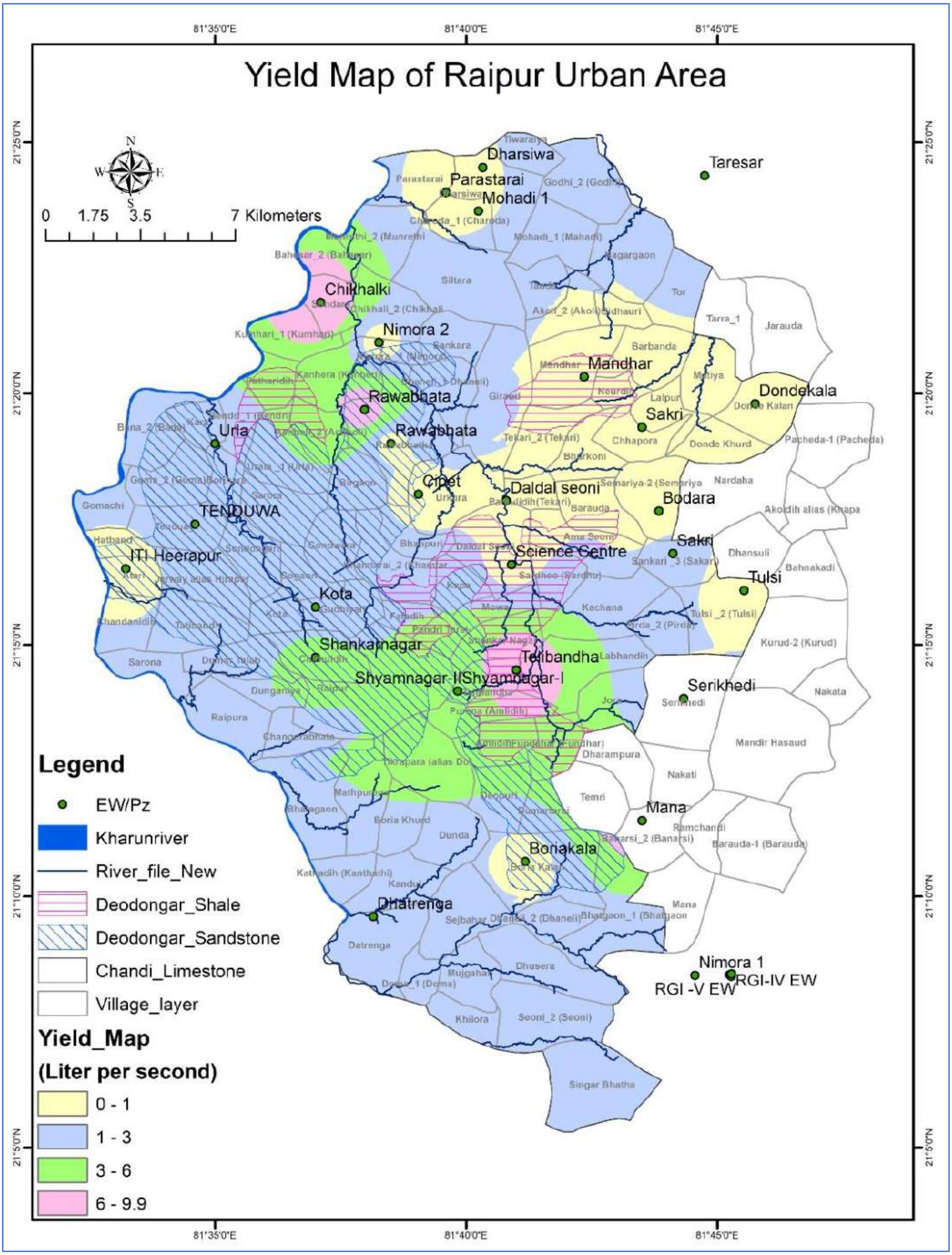


Figure 31 Yield Map of Raipur Urban Area

Subsurface geology observed during the course of ground water exploration in the area shows that Chandi limestones are intercalated with purple to gray calcareous shales at places. The thickness varies from 56-136 m in the area. Chandi limestones are followed by Gunderdehi shale and Charmuria limestones.

The Gunderdehi shales are purple in colour, calcareous, with fractured zones in upper part. The minimum thickness observed in the area is 227m. The Charmuria limestones are gray, flaggy, thinly laminated and non-stromatolitic. Subsurface dolerite intrusive is running roughly E-W to NE-SW direction in Kota-Samata colony area.

Table 16 Aquifer Type and properties

Belt	Prominent Lithology	Characteristics of Aquifer	Suitability of Drilling Rig	Suitability for Drinking /Irrigation	Remarks
Weathered zone	Soil, Laterite, Alluvium	shallow water table.	DTH	Yes	Shallow water tables
Sandstone	sandstones	Secondary porosity. Low-yielding wells.	DTH	Yes	Low weathering depth. Deep water tables
Shale	Shale				
Limestone	Limestone intercalation with clay.	Cavernous and fractured. Sustainable yield from the cavernous and fractured portion.	DTH	Yes	Deep water tables due to over-pumping

Table 17 Aquifer Characteristics in Spatial Extent

Belt	Explored Depth (m bgl)	Maximum depth drilled range (mbgl)	Static Water Level range (mbgl)	Fluctuation (meter)	Yield Potential range (lpm)	Trans-emissivity (m^2/day)	Remarks
Limestone	0-205	301.6	**Pre** 0.30-30.48 **Post** 0.37-27.71	**Range** -9 to 26.86 **Mean** 9.7	12-600	29.67 at EW Chikhali	Low-Moderate Discharge
Sandstone	9.25-154.6	154.6	**Pre** 1.65-21.34 **Post** 1-13.72	**Range** -10.58 to 15.71 **Mean** 10.58	12-504	719.7 at Rawabhata	Low to Moderate with occasional high discharge
Shale	15.92-100.01	100.01	**Pre** 0.61-12.19 **Post** 0.8-12.80	**Range** -0.64 to 10.51 **Mean** 0.64	24	Science center	Very low

Table 18 Vertical Aquifer Disposition Ranges

Aquifer Type	Weathered Thickness Range (mbgl)	Average Weathered Thickness (mbgl)	1st Fracture Depth Range (mbgl)	2nd Fracture Depth range (mbgl)
Weathered zone	6-31.9	25.9	---	----
Limestone	6-24	18	9.8-27.5	21.7-116
Sandstone	10-20	9.5	12.9-16.9	62.8-70.45
Shale	6-15	9	49.77-53.77	131.5-133.5

5.4 AQUIFER WISE WATER LEVEL

5.4.1 OBJECTIVE

Groundwater level data is a critical component in understanding and managing groundwater resources, offering valuable information about the depth and variability of the water table in aquifers. Monitoring changes in groundwater levels over time provides insights into the health of aquifers, helping to make informed decisions about sustainable water use, especially in areas where groundwater is a primary source of freshwater.

One key aspect of groundwater level data is its role in assessing aquifer recharge and depletion. By observing fluctuations in groundwater levels, hydrologists can identify patterns related to natural recharge from precipitation and potential stressors leading to depletion, such as excessive pumping or prolonged droughts. This understanding is crucial for implementing effective groundwater management strategies to maintain aquifer sustainability.

Groundwater level data is also instrumental in delineating groundwater flow patterns. By analyzing variations in water table elevations across different locations, hydrogeologists can map the direction and rate of groundwater movement within an aquifer. This information aids in the development of conceptual models for the subsurface, contributing to more accurate predictions of groundwater behavior and facilitating sustainable water resource planning.

Furthermore, real-time groundwater level data is essential for managing water infrastructure and mitigating potential risks. Monitoring wells equipped with sensors provide continuous updates on groundwater levels, enabling rapid response to changing conditions. This is particularly valuable in preventing over-extraction, land subsidence, and other adverse impacts associated with improper groundwater management.

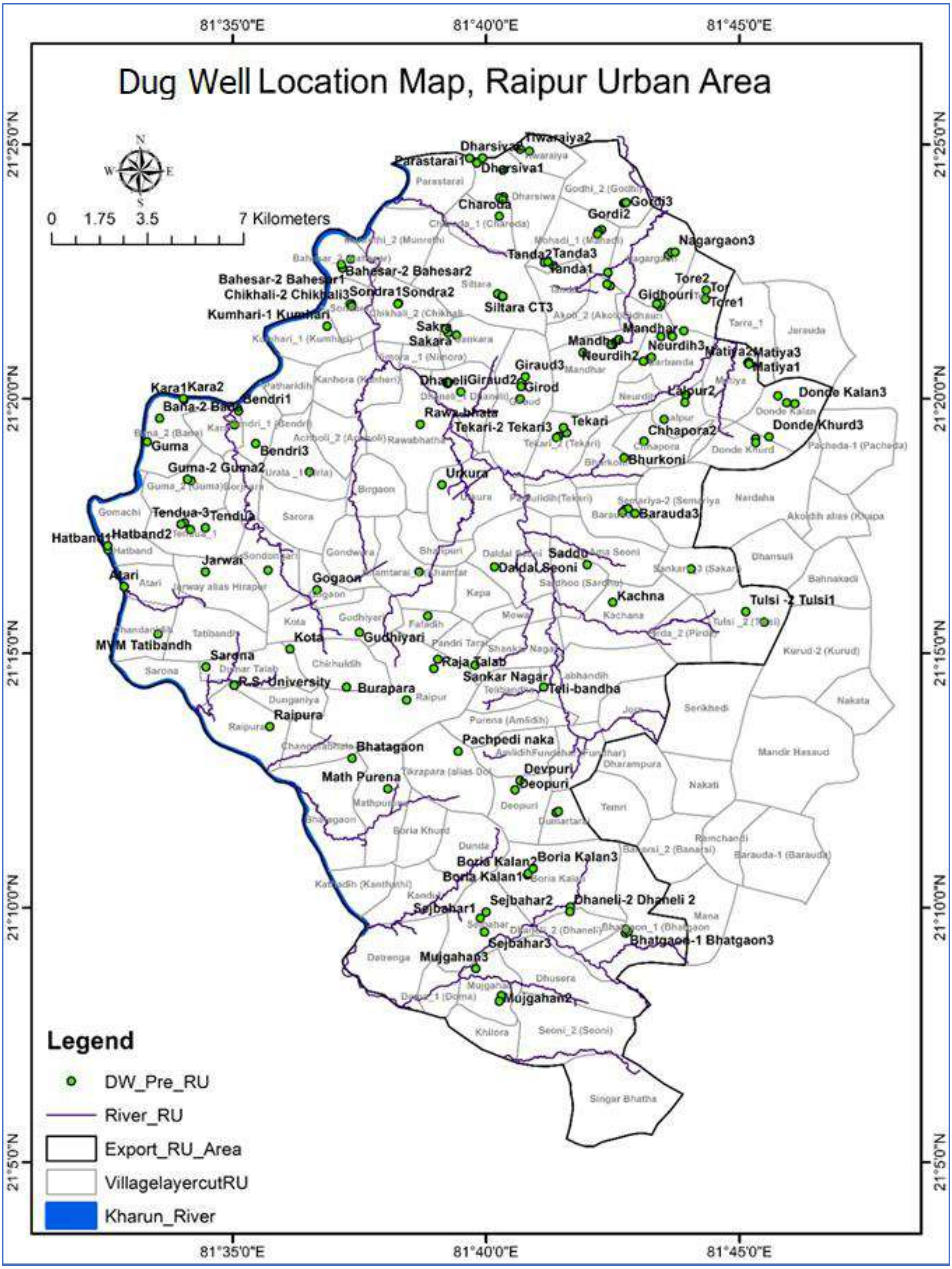


Figure 32 Dug Well Location map, Raipur Urban Area

Figure 33 Hand pump/Bore Well location Map of the study area

5.4.2 RESULTS AND DISCUSSION

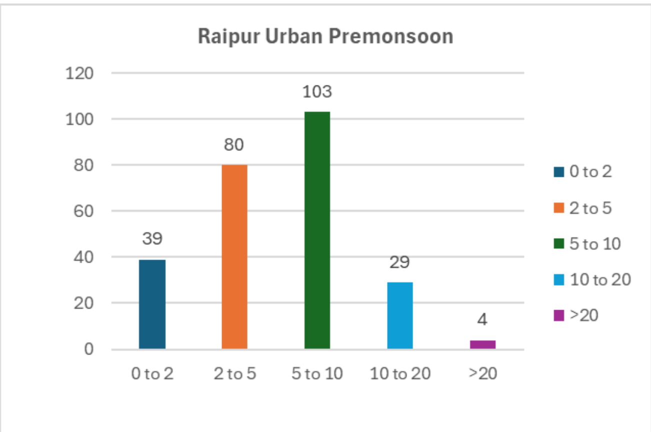
The depth to the water levels in the block were monitored two times a year in the month of Pre-monsoon (May) and Post Monsoon (November) through key wells establishments. In both seasons along with the water level measurements, the water samples were also collected from these observation wells for quality analysis.

5.4.2.1 Phreatic Aquifer (weathered aquifer)

Pre-monsoon and post-monsoon water-level measurements were conducted to analyze the behavior of the water level in the phreatic aquifer. A total of 119 nos of monitoring stations were utilized for water-level delineation.

Pre-Monsoon Water Level

The pre-monsoon water level ranges from 0.30 to 21.61 mbgl having an average water level of 5.78 mbgl and standard deviation of 4.48 indicating a greater variation in groundwater level in the study area. In general, the depth to water level ranges ranges 0 to 2 m bgl is observed in approximately 15 % of the wells, 2 to 5 m bgl is observed in approximately 31.25 % of the wells and depth to water level range between 5 to 10 m bgl is observed in 40.2 % of the wells in the state. Deeper water levels ranging between 10 - 20 m bgl occur respectively in 12.8% wells. The deepest water level of 24.38m bgl was monitored in Bendri 2 & Gidhauri 2 well in RUA.



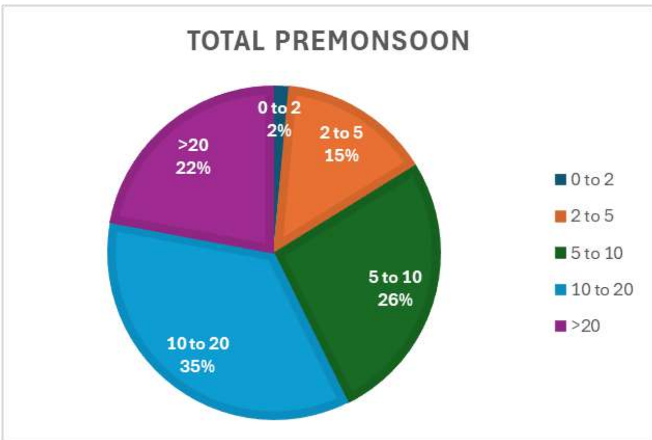


Figure 34 Pre-Monsoon Phreatic Aquifer Data in Percentage

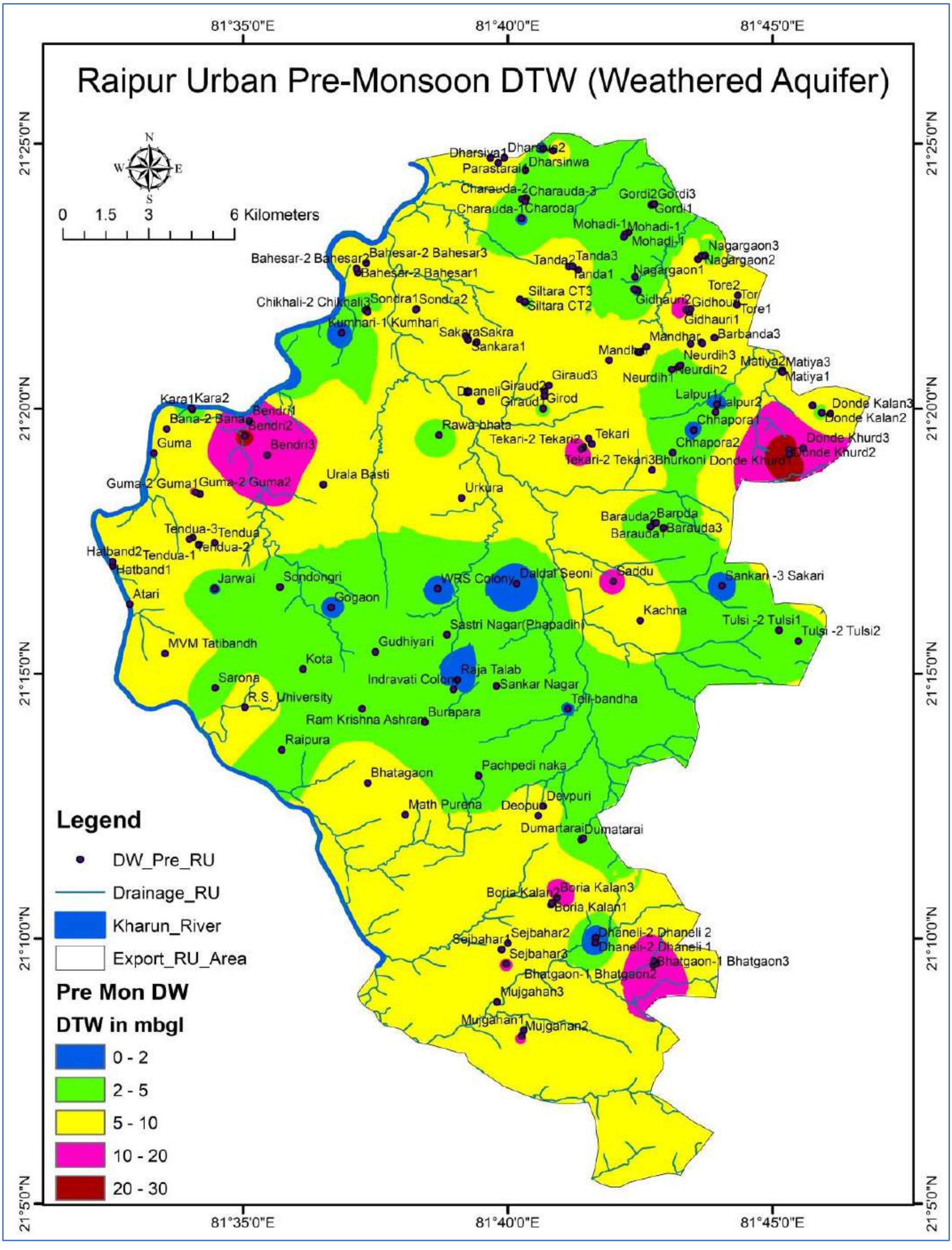


Figure 35 DTW Map of Pre-monsoon Weather Aquifer in Study Area

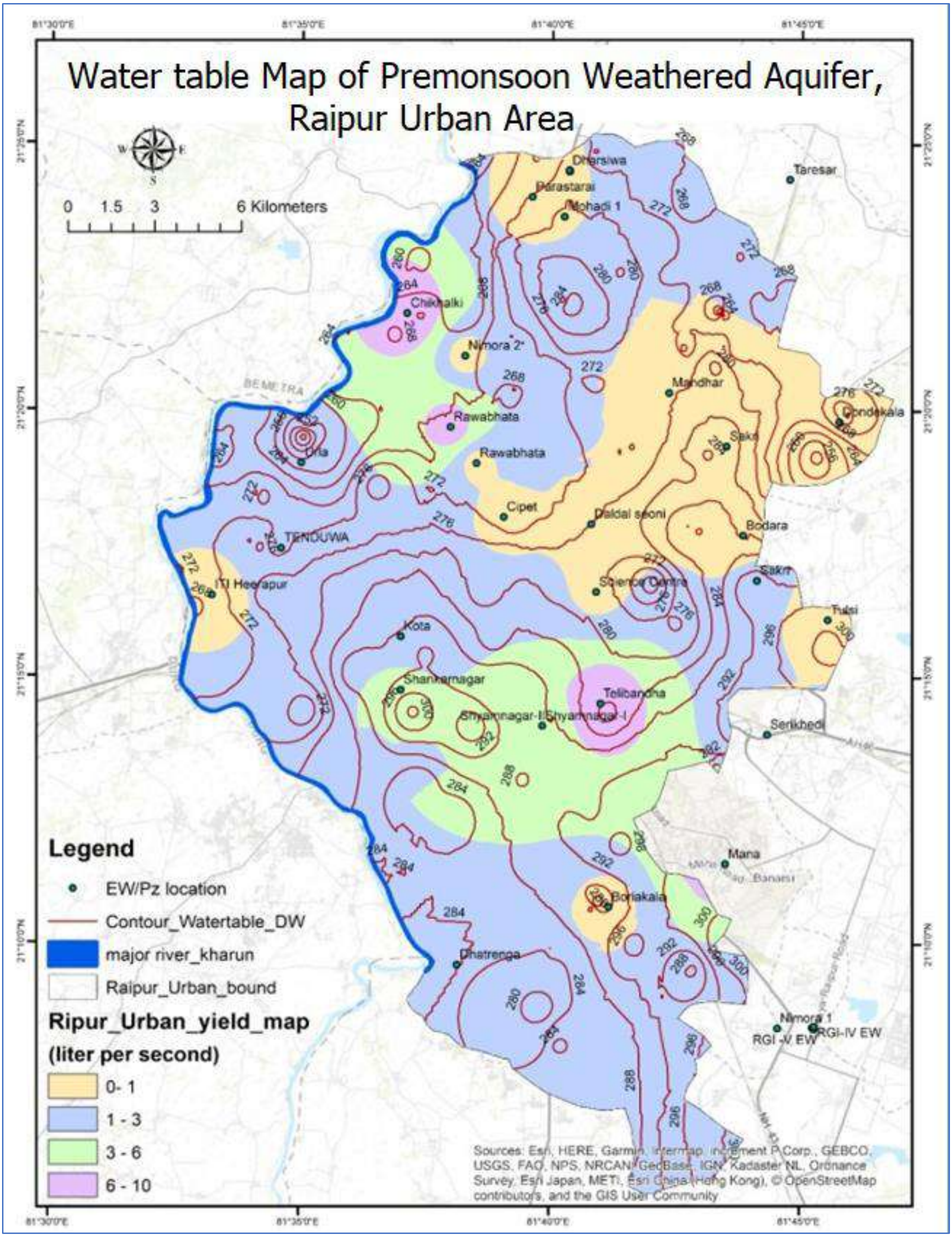
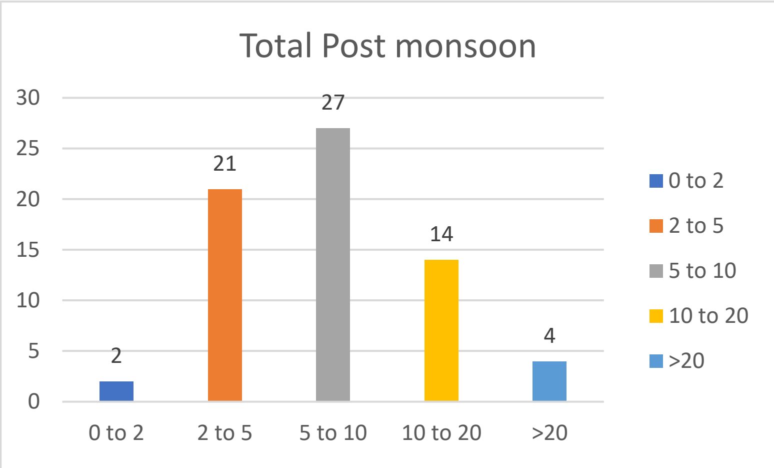


Figure 36 Water Table Map of Pre-monsoon Weather Aquifer in Study Area

Post-Monsoon Water Level

The post-monsoon water level ranges from 0.37 to 15.24 mbgl having an average water level of 4.76 mbgl and standard deviation of 3.08 indicating a greater variation in groundwater level in the study area. In general, the depth to water level ranges ranges 0 to 2 m bgl is observed in approximately 32.4 % of the wells, 2 to 5 m bgl is observed in approximately 39 % of the wells and depth to water level range between 5 to 10 m bgl is observed in 24 % of the wells in the state. Deeper water levels ranging between 10 - 20 m bgl occur respectively in 4.2% wells. The deepest water level of 24.38m bgl was monitored in Bendri 1 well in RUA.



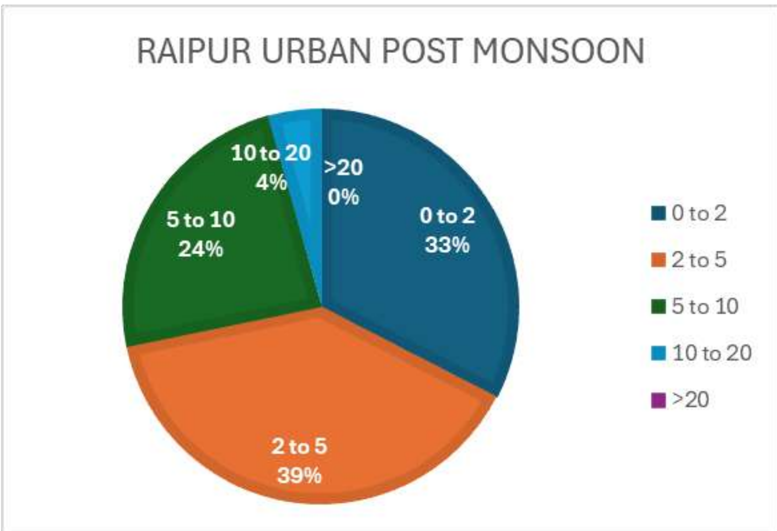


Figure 37 Post-Monsoon Phreatic Aquifer Data in Percentage

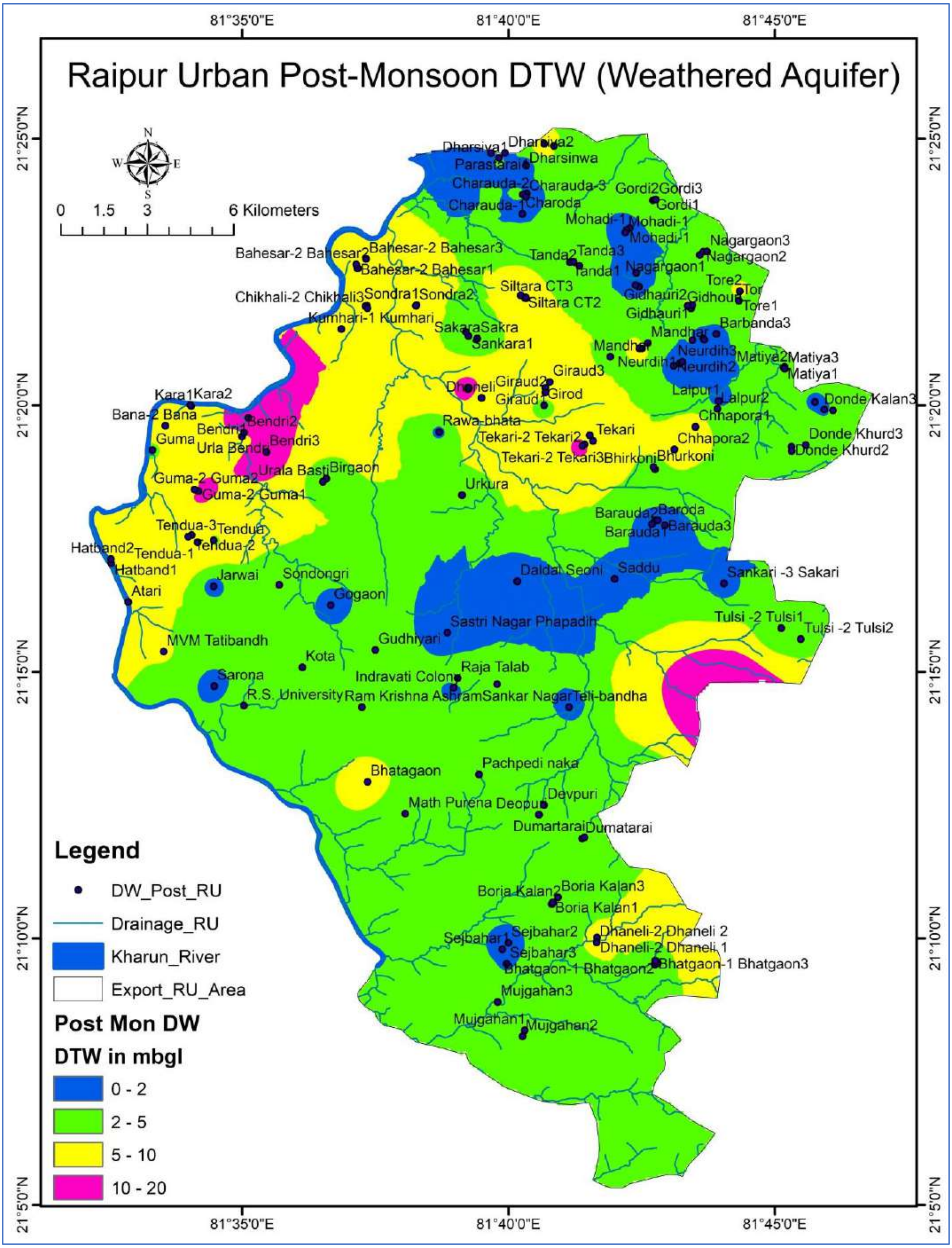


Figure 38 DTW Map of Post-monsoon Weather Aquifer in Study Area

Seasonal Ground Water Fluctuation in Phreatic Aquifer

There is mostly a rise in water level in November when compared to water level in May. About 71% of the monitored wells exhibit falls in the water level. Out of this, about 31% of the monitored wells exhibit rise in the water level in the range of 0-2 m in parts of all the districts. In 18% of the monitored wells, the water levels show rise in the range of 2-5 m the remaining 18% of the observation wells show rise in 5-10 m while 3 % observation wells shows of more than 10 m in the water level. Fall of water level as compared to May is observed in about 27.3 % of the observation wells monitored. Most of the wells exhibit falls in the range of 0-5m.

Moreover, the wells are never dried up in many areas during extreme climatic conditions. 39 nos of wells shows water level < 2 m in Pre-monsoon which shows that there is a possibility of a perched aquifer in the top weathered zone which holds significant quantity of water to cater the needs of common people.

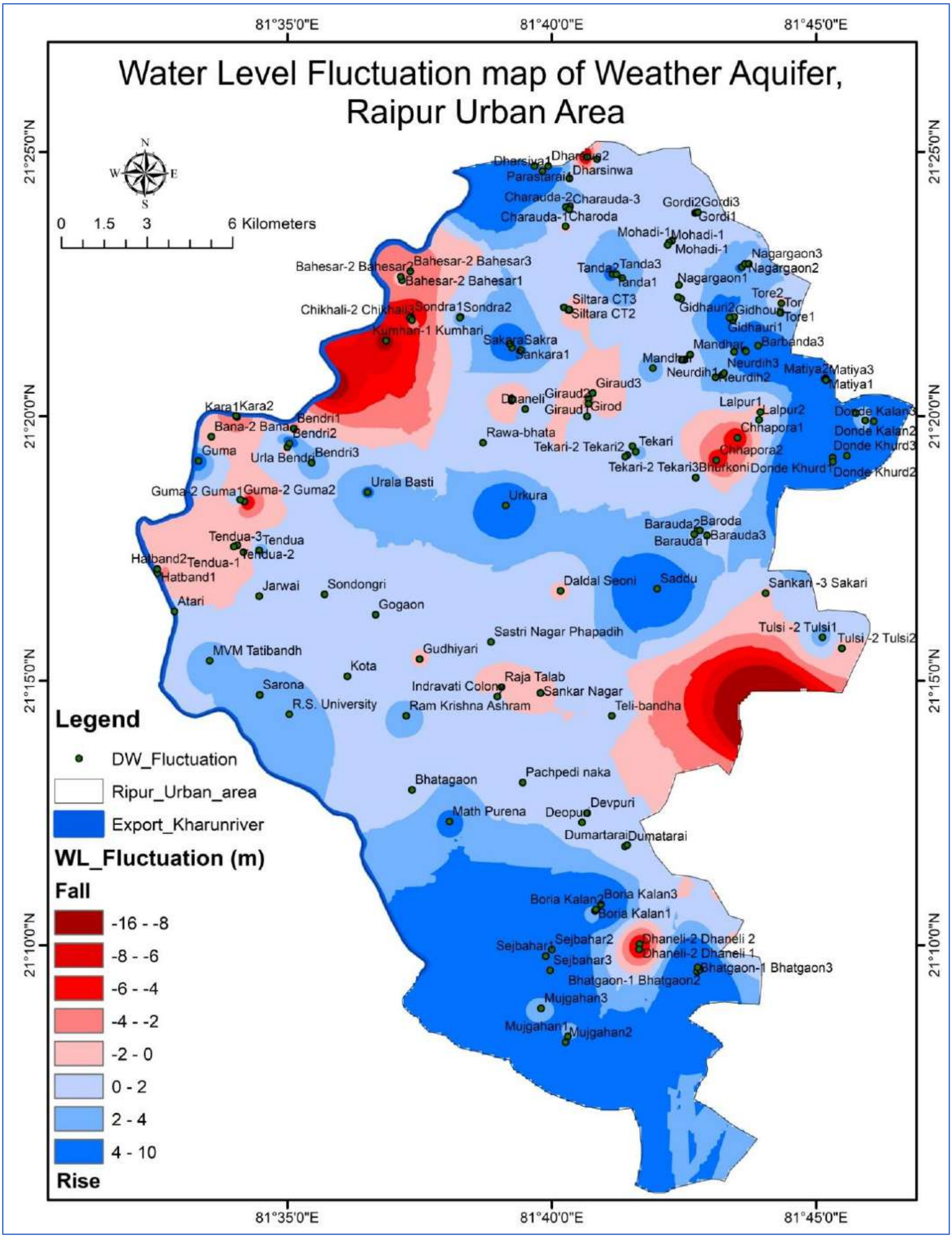


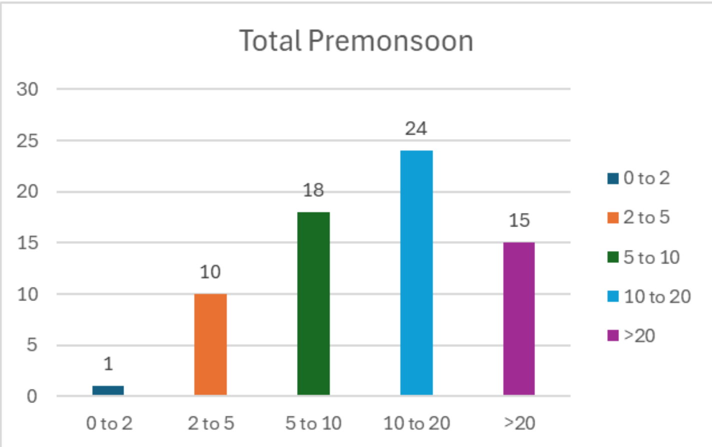
Figure 39 Water level fluctuation of phreatic aquifer

5.4.2.2 Fracture Aquifer

Pre-monsoon and post-monsoon water-level measurements were conducted from the deeper fractured aquifer depicts a seasonal fluctuation of 45 m . It shows the dynamic of the groundwater system is complex and as well as unique based on factors like lithology, porosity permeability, and topographical controls. A total of 69 monitoring stations were used for the delineation of water levels.

Pre-Monsoon Water Level

The pre-monsoon water level ranges from 2 to 61 mbgl having an average water level of 15.25 mbgl and standard deviation of 7.9 indicating a greater variation in groundwater level in the study area. In general, the depth to water level ranges ranges 0 to 2 m bgl is observed in approximately 1 % of the wells, 2 to 5 m bgl is observed in approximately 14 % of the wells and depth to water level range between 5 to 10 m bgl is observed in 26 % of the wells in the state. Deeper water levels ranging between 10 - 20 m bgl occur respectively in 56% wells and > 20 in 21% wells. The deepest water level of 45 m bgl was monitored in Daldal seoni well in RUA.



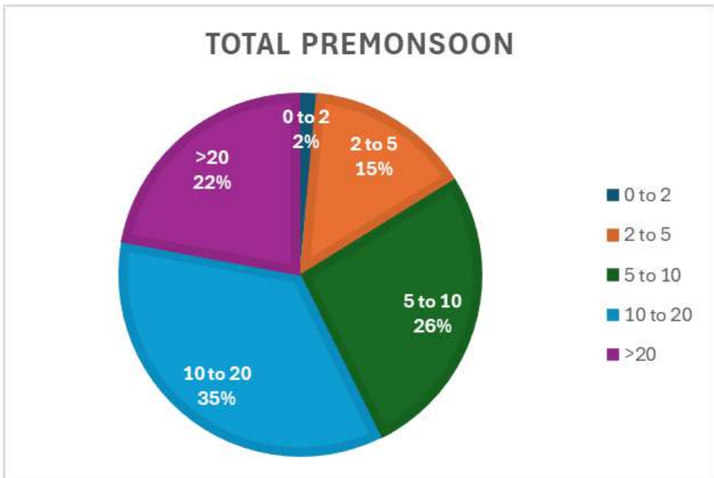


Figure 40 Pre-Monsoon Phreatic Aquifer Data in Percentage

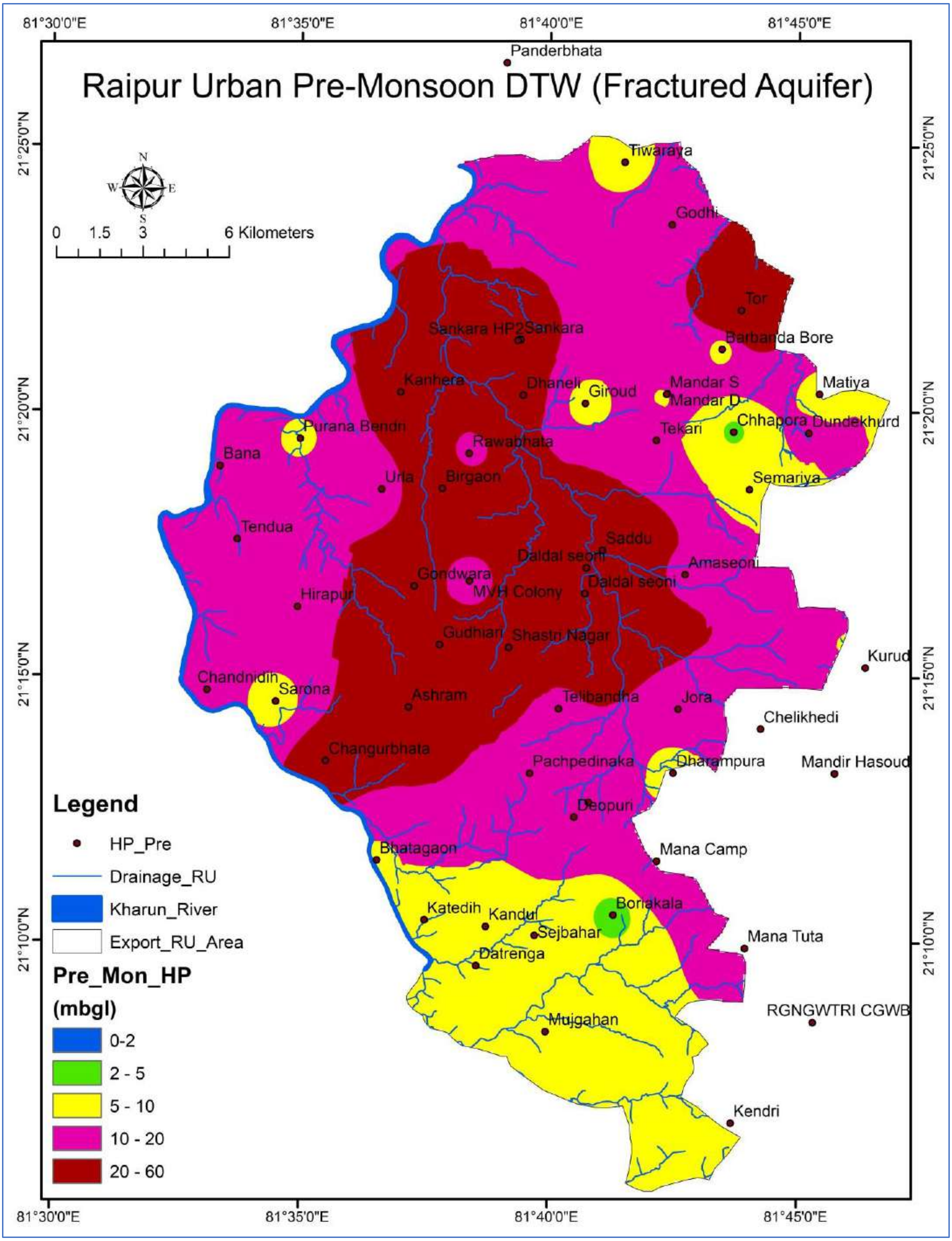


Figure 41 Pre monsoon Water Level Maps of Fractured Aquifer

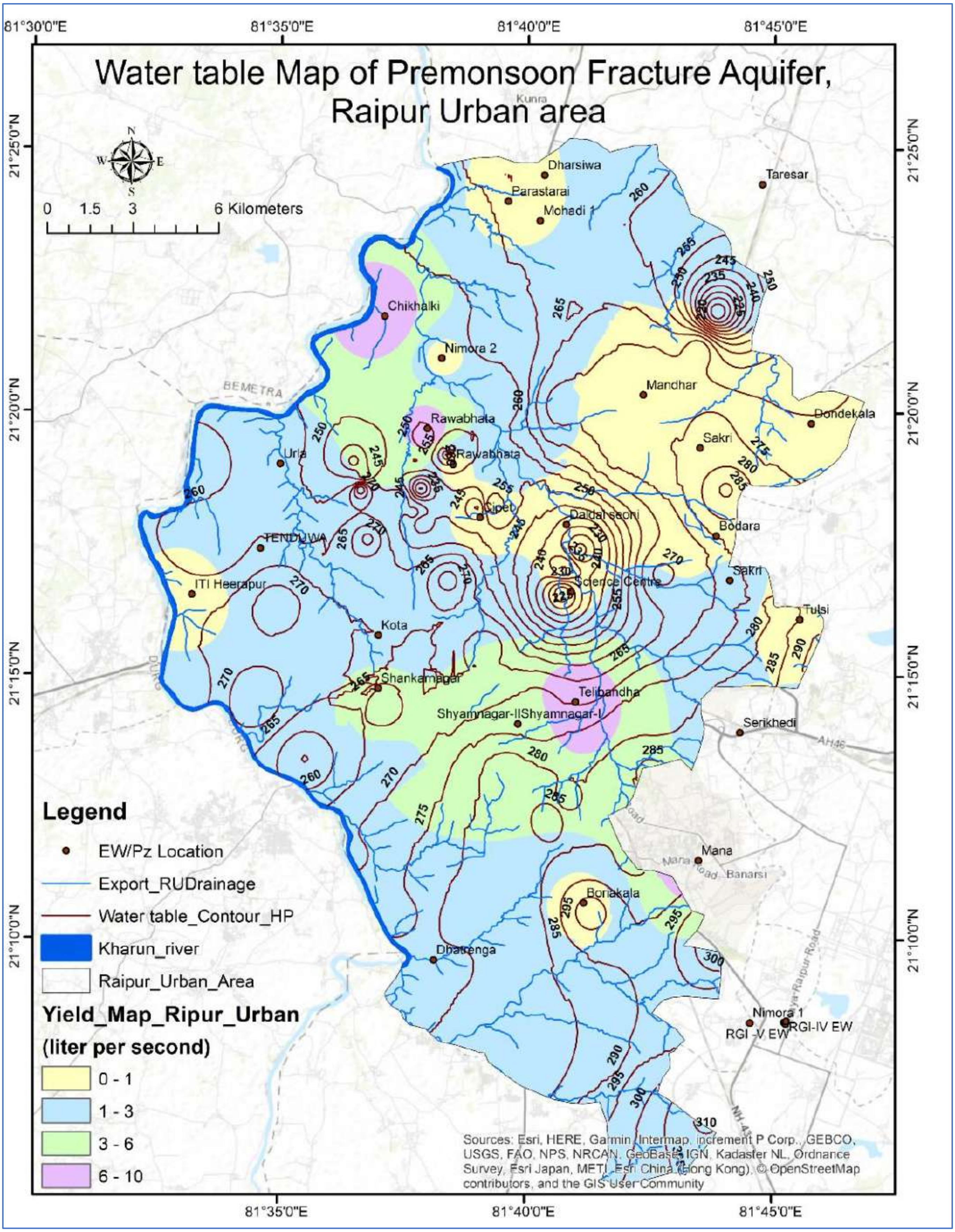
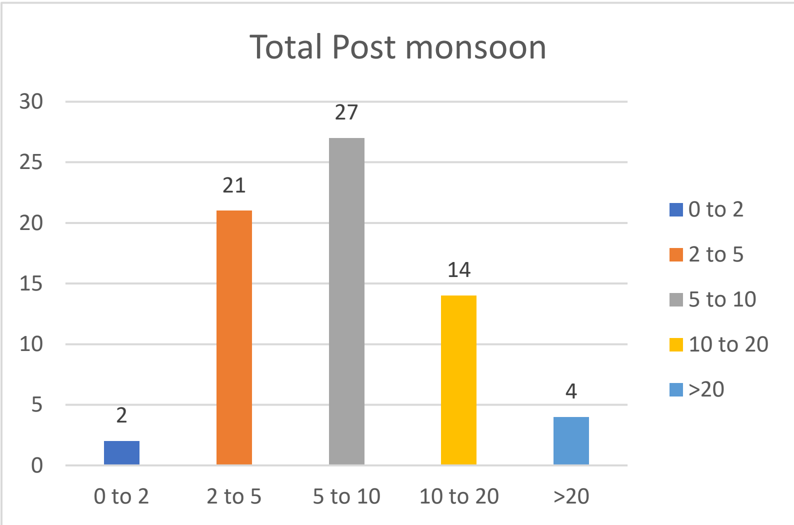


Figure 42 Pre-monsoon Water Table Map of Fractured Aquifer in Raipur Urban Area

Post-Monsoon Water Level

The post-monsoon water level ranges from 1.6 to 28.1 mbgl having an average water level of 7.9 mbgl and standard deviation of 4.13 indicating a greater variation in groundwater level in the study area. In general, the depth to water level ranges ranges 0 to 2 m bgl is observed in approximately 2 % of the wells, 2 to 5 m bgl is observed in approximately 30% of the wells and depth to water level range between 5 to 10 m bgl is observed in 39% of the wells in the state. Deeper water levels ranging between 10 - 20 m bgl occur respectively in 26% wells. The deepest water level of 28.1m bgl was monitored in Birgaon well in RUA.



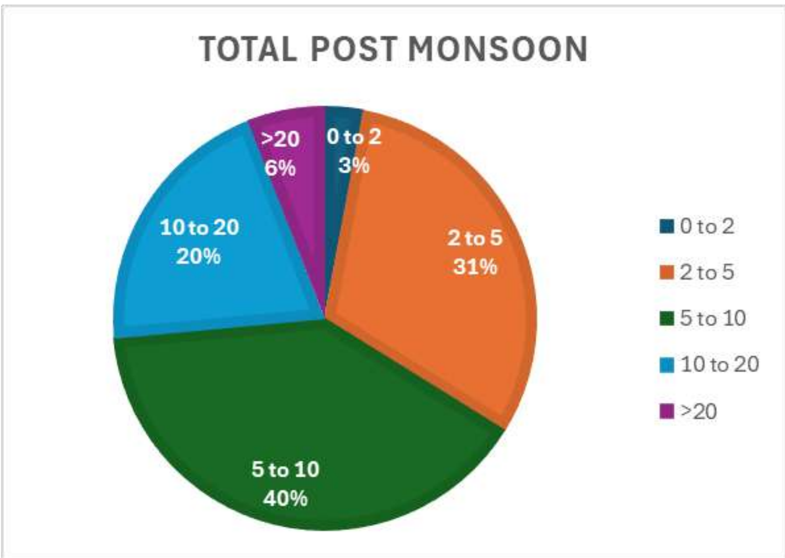


Figure 43 Post-Monsoon Phreatic Aquifer Data in Percentage

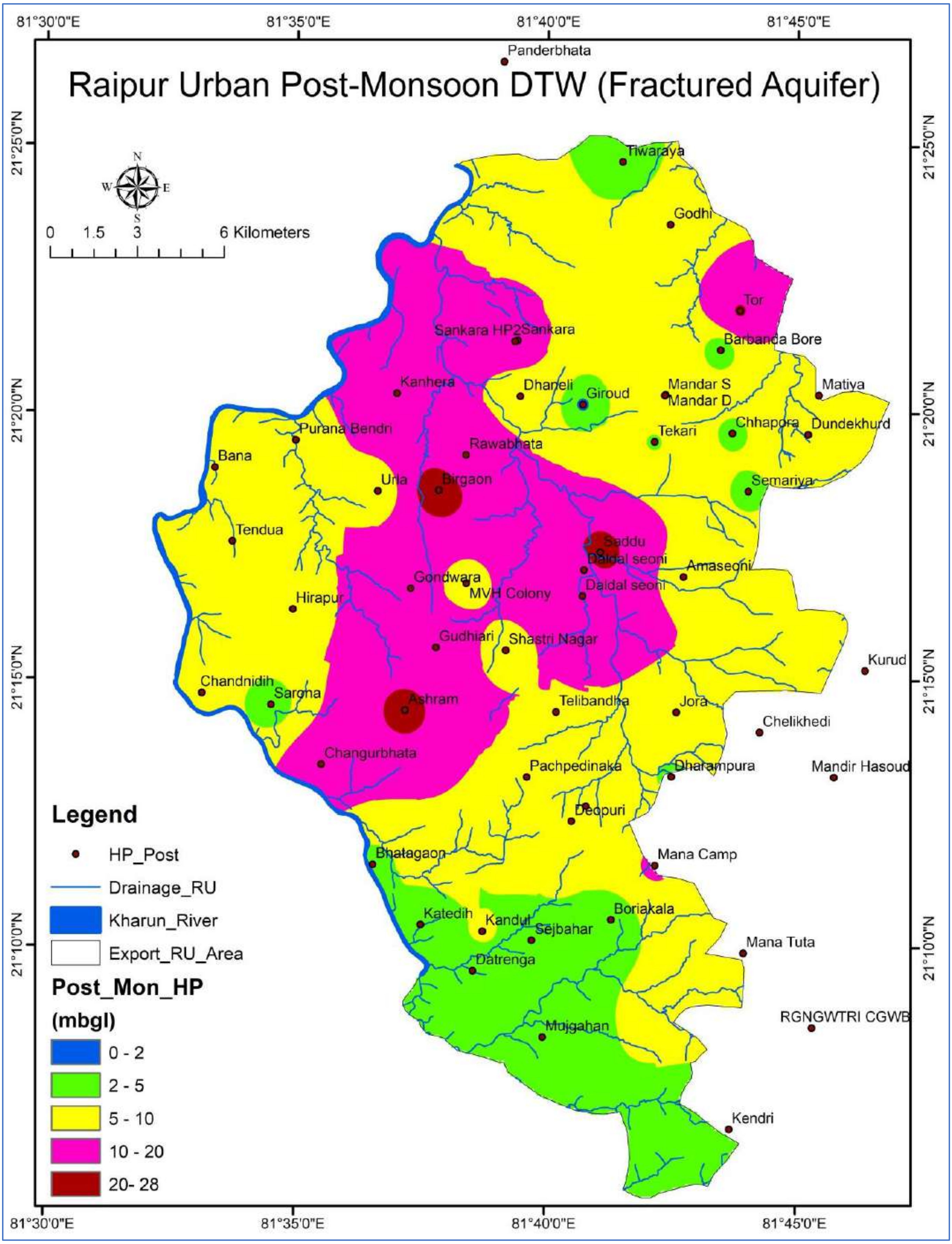


Figure 44 Post monsoon Water Level Maps of Fractured Aquifer

Seasonal Ground Water Fluctuation in Deeper/Fractured Aquifer

There is mostly a rise in water level in November when compared to water level in May. About 90% of the monitored wells exhibit falls in the water level. Out of this, about 18% of the monitored wells exhibit rise in the water level in the range of 0-2 m in parts of all the districts. In 24% of the monitored wells, the water levels show rise in the range of 2-5 m the remaining 28% of the observation wells show rise in 5-10 m while 20 % observation wells shows of more than 10 m in the water level. Fall of water level as compared to May is observed in about 4 % of the observation wells monitored. Most of the wells exhibit falls in the range of 0-2m.

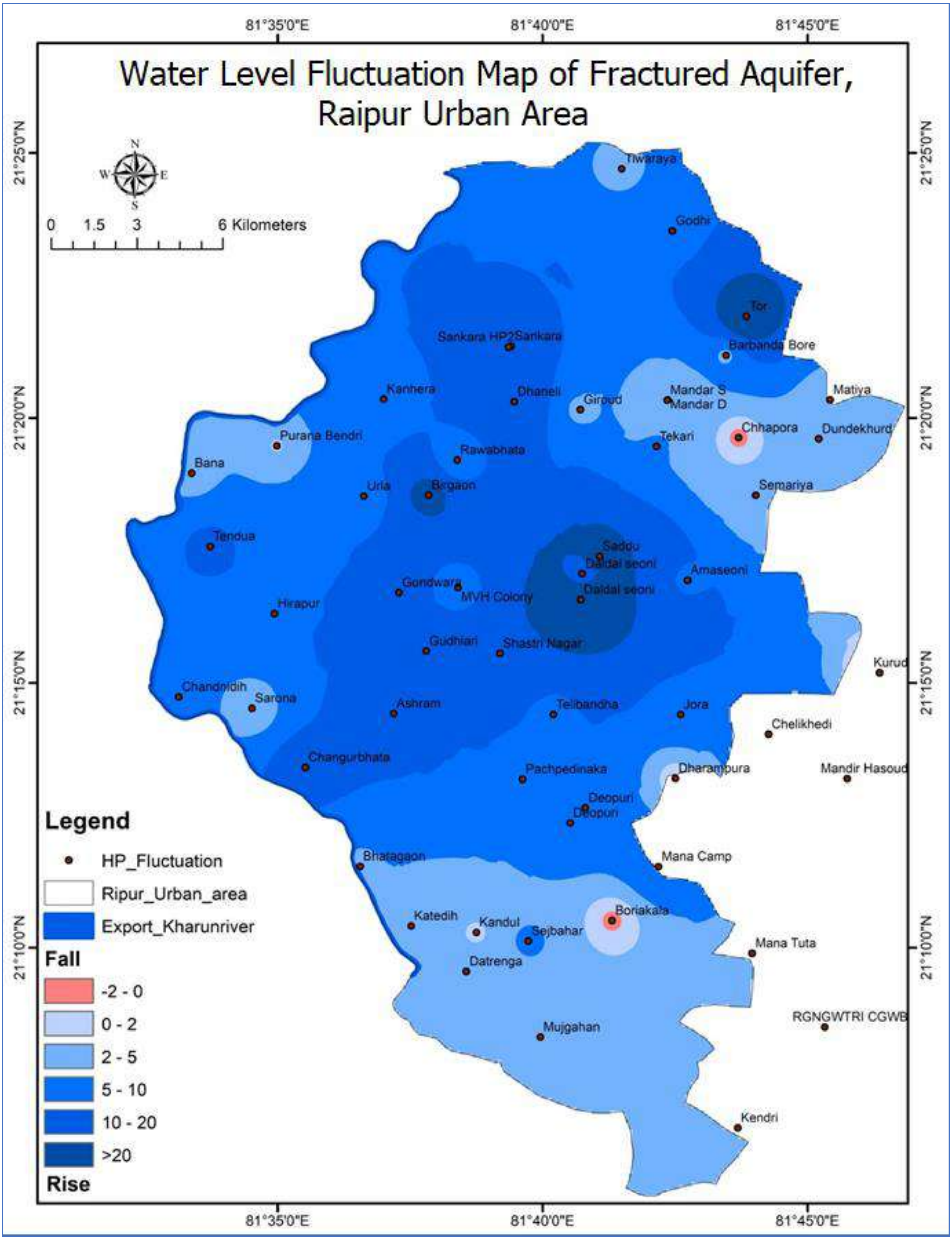


Figure 45 Water Level Fluctuation Map of Fractured Aquifer, Raipur Urban Area

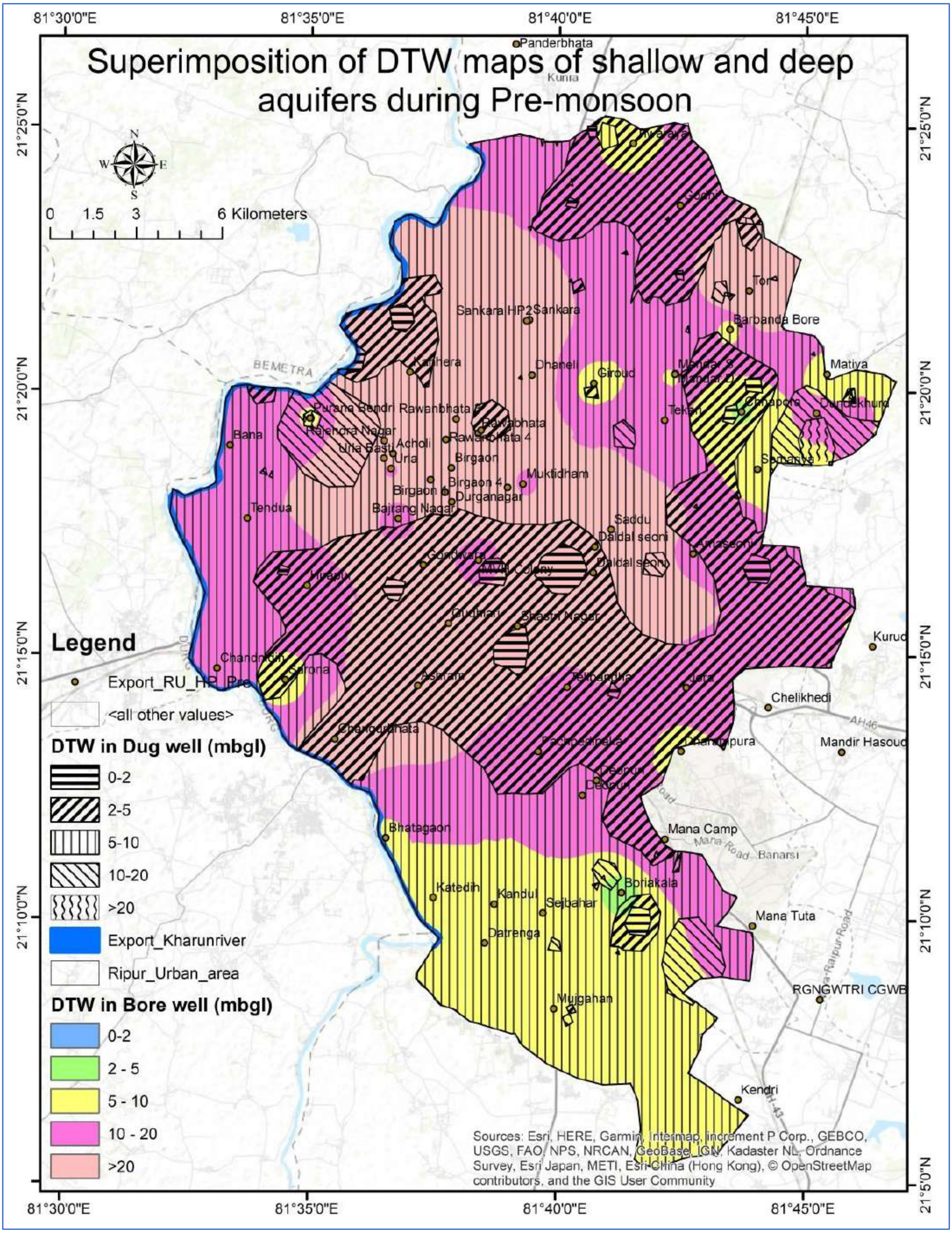


Figure 46 Superimposition of Shallow and Deep Aquifers during Pre-monsoon

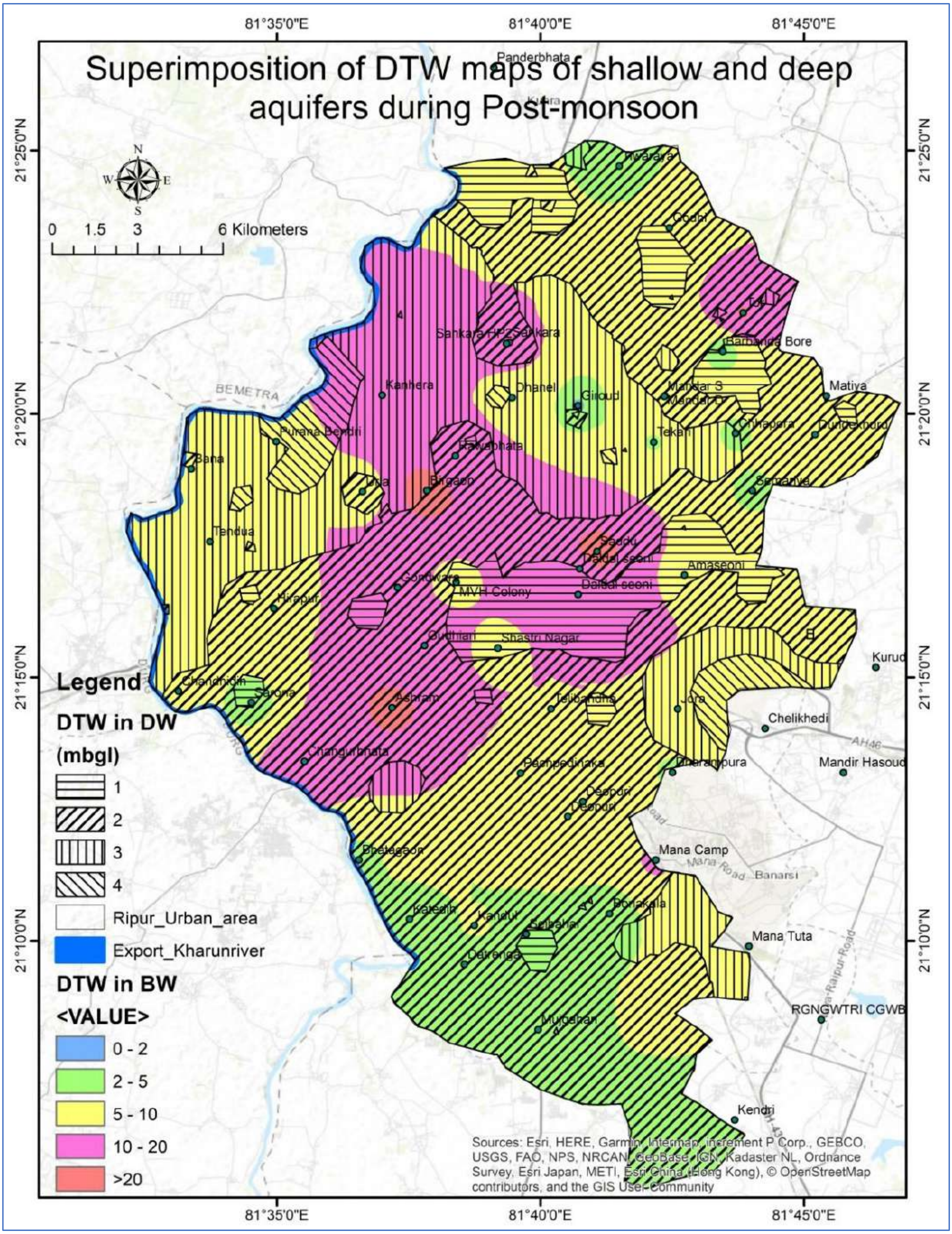


Figure 47 Superimposition of Shallow and Deep Aquifers during Post-monsoon

5.4.3 Hydrogeology

From the hydrogeological map, it is clear that groundwater flow is from south to north. There is a strong topographical, lithological, and irrigation control on the flow of groundwater in the central part.

The post monsoon water table shows clear water flowing towards the Kharun river towards west direction. Precipitation is the main source of Ground water recharge along with minor recharge from canal in canal command area. Out flow through the drainage system and drawal for different purposes are the principal sources of ground water discharge.

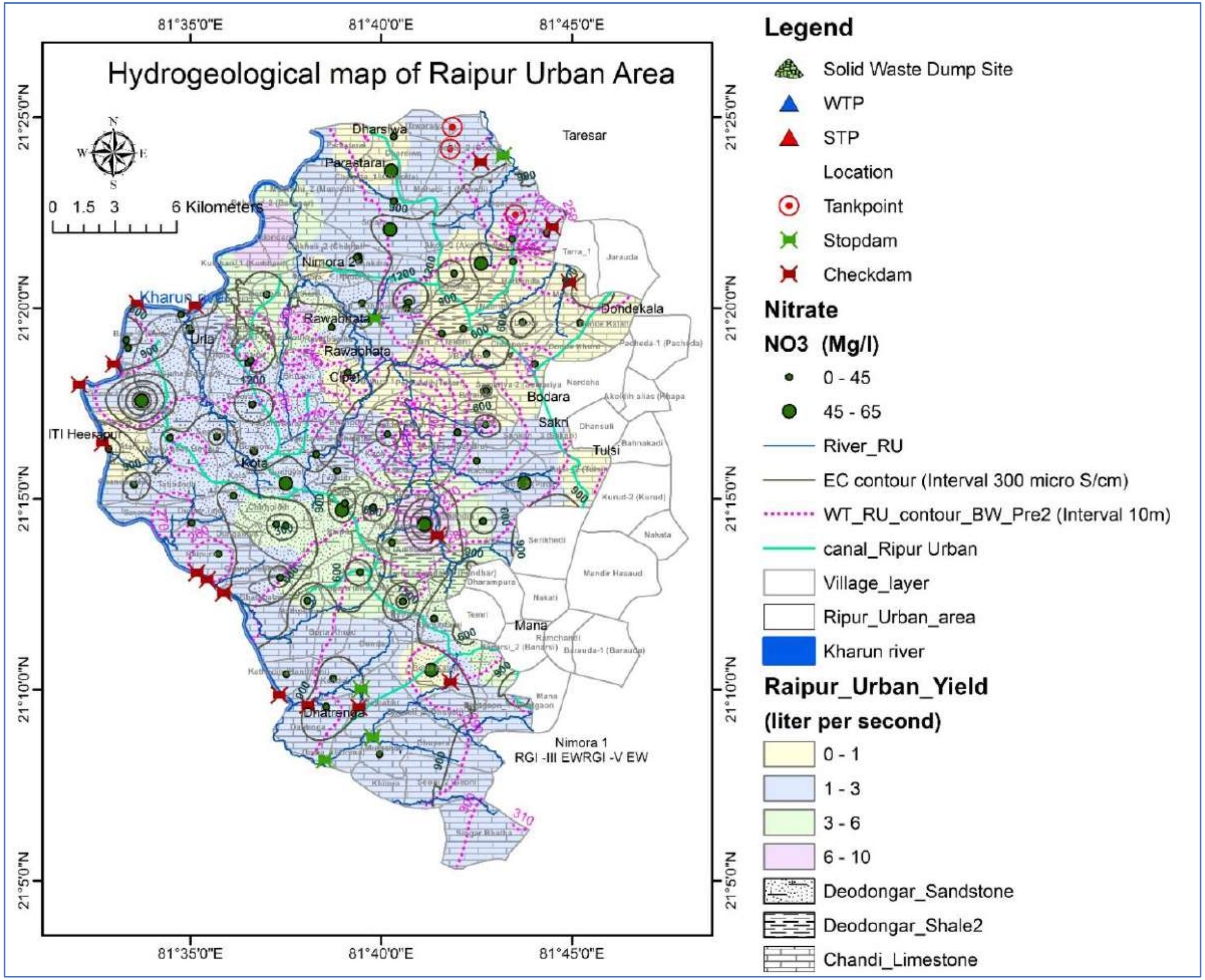


Figure 48 Hydrogeological map of Raipur Urban Area

Decadal Trend and Water level Behavior Pheratic Aquifer

1. Premonsoon
2. Postmonsoon

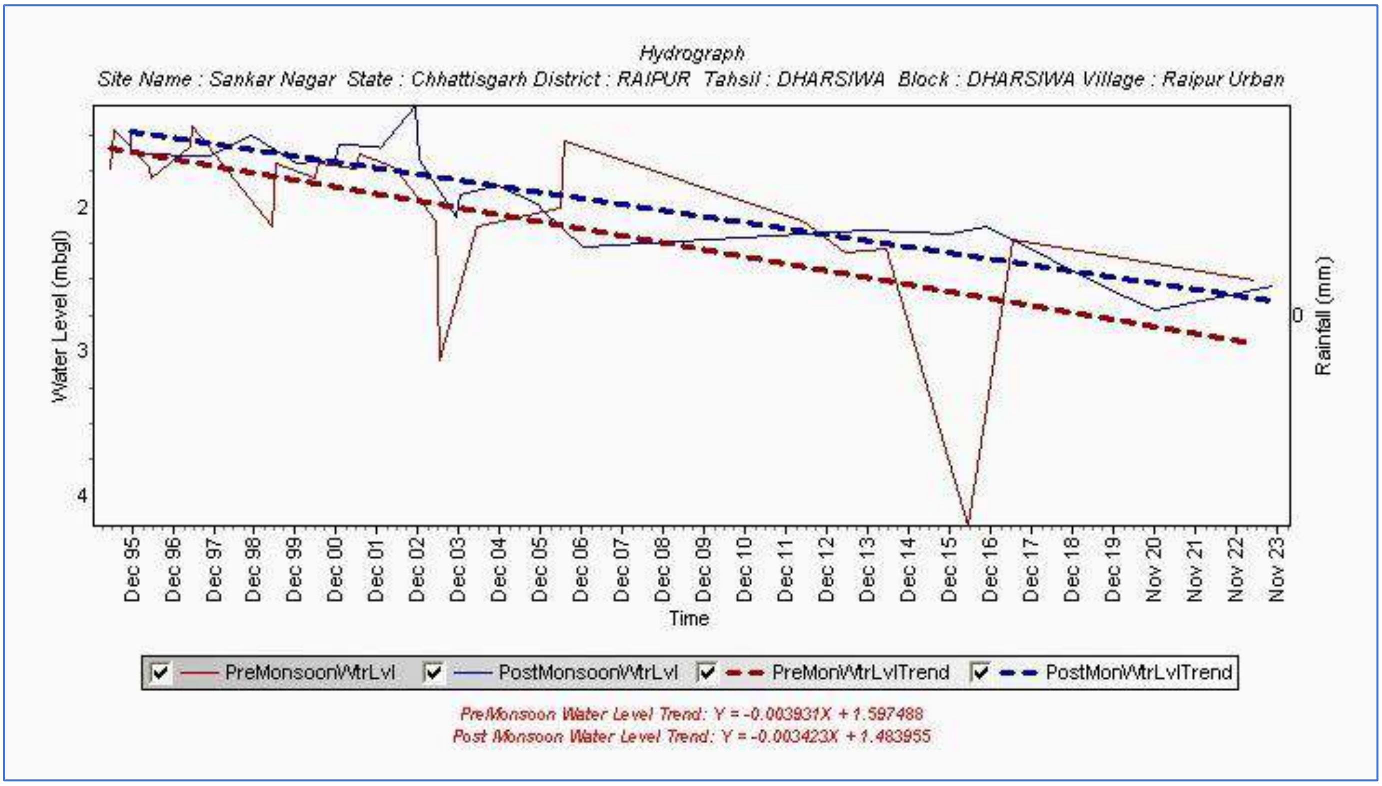


Figure 49 Hydrograph of Sankar Nagar Pz

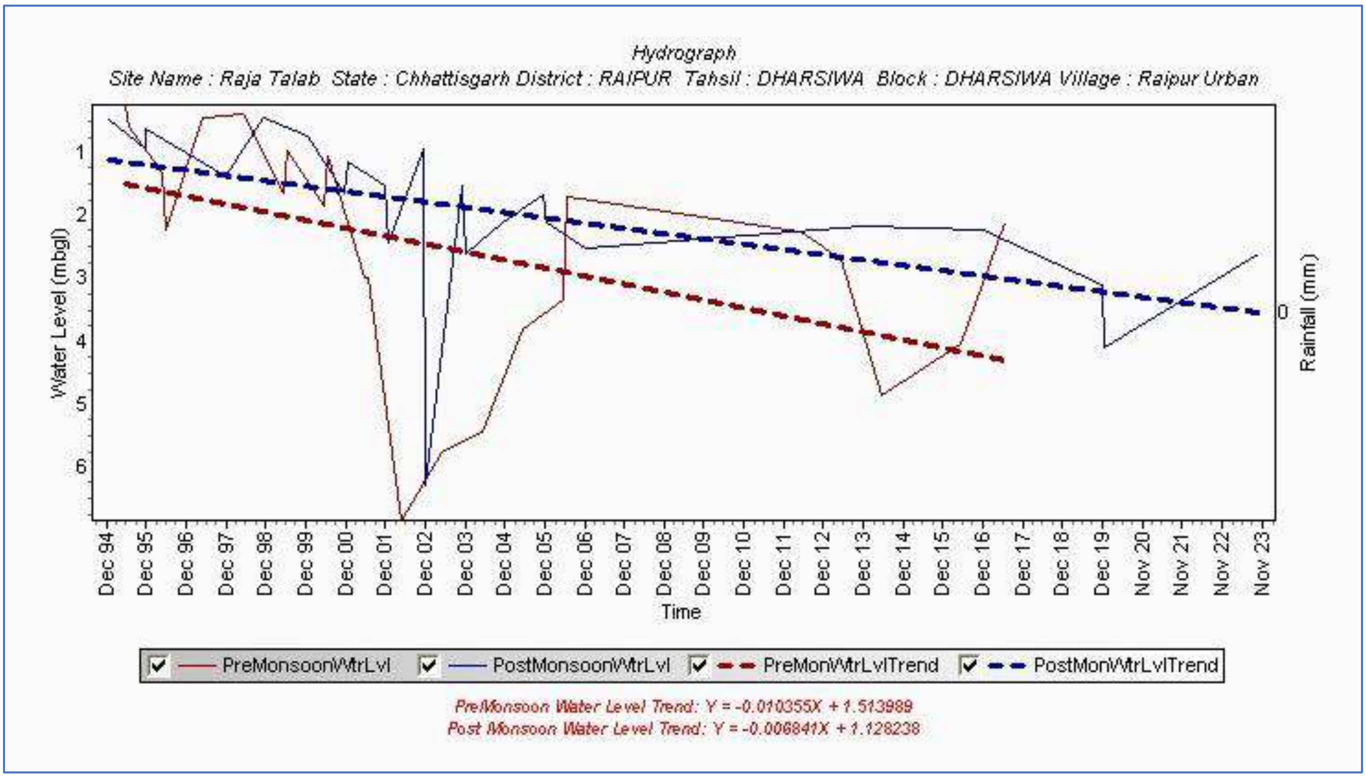


Figure 50 Hydrograph of Raja Talab Pz

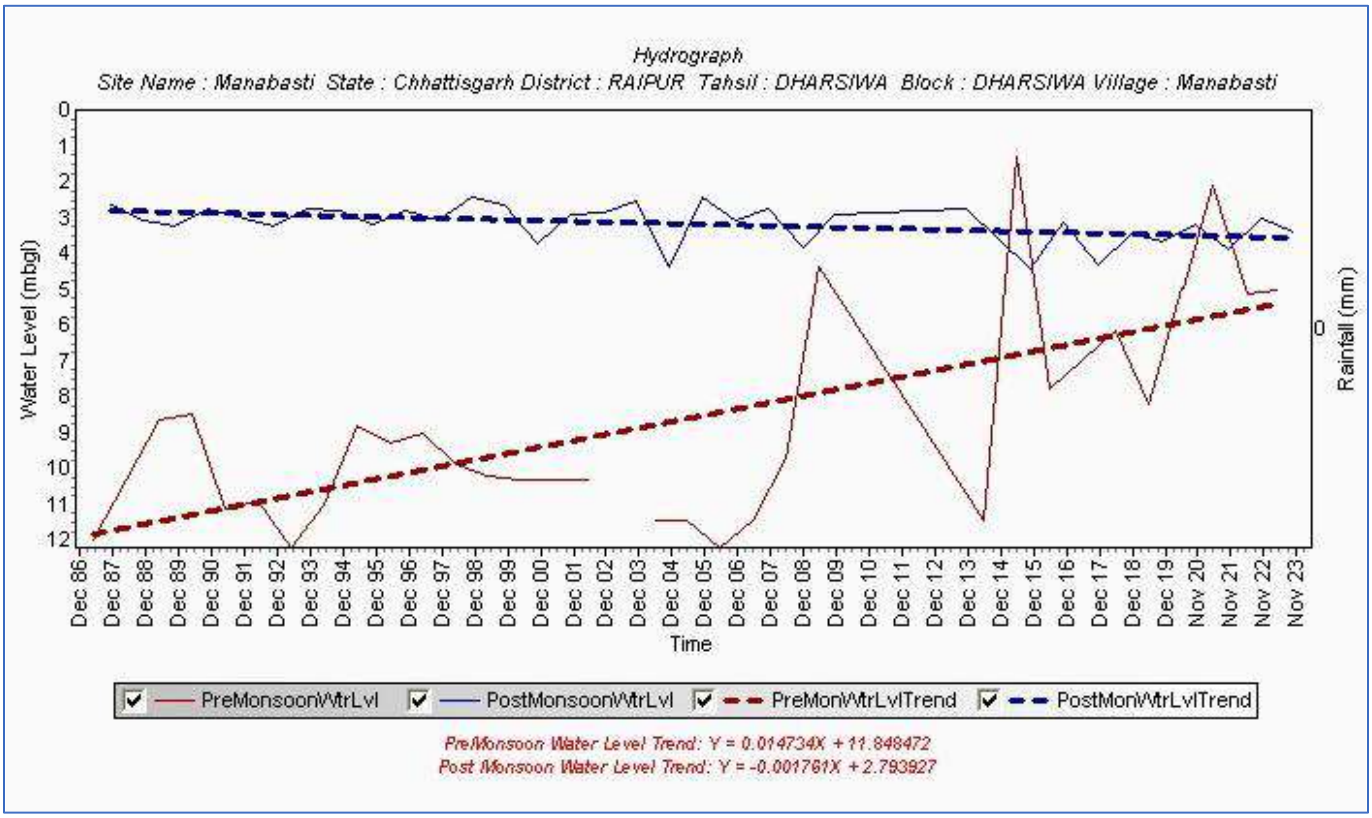


Figure 51 Hydrograph of Manabasti Pz

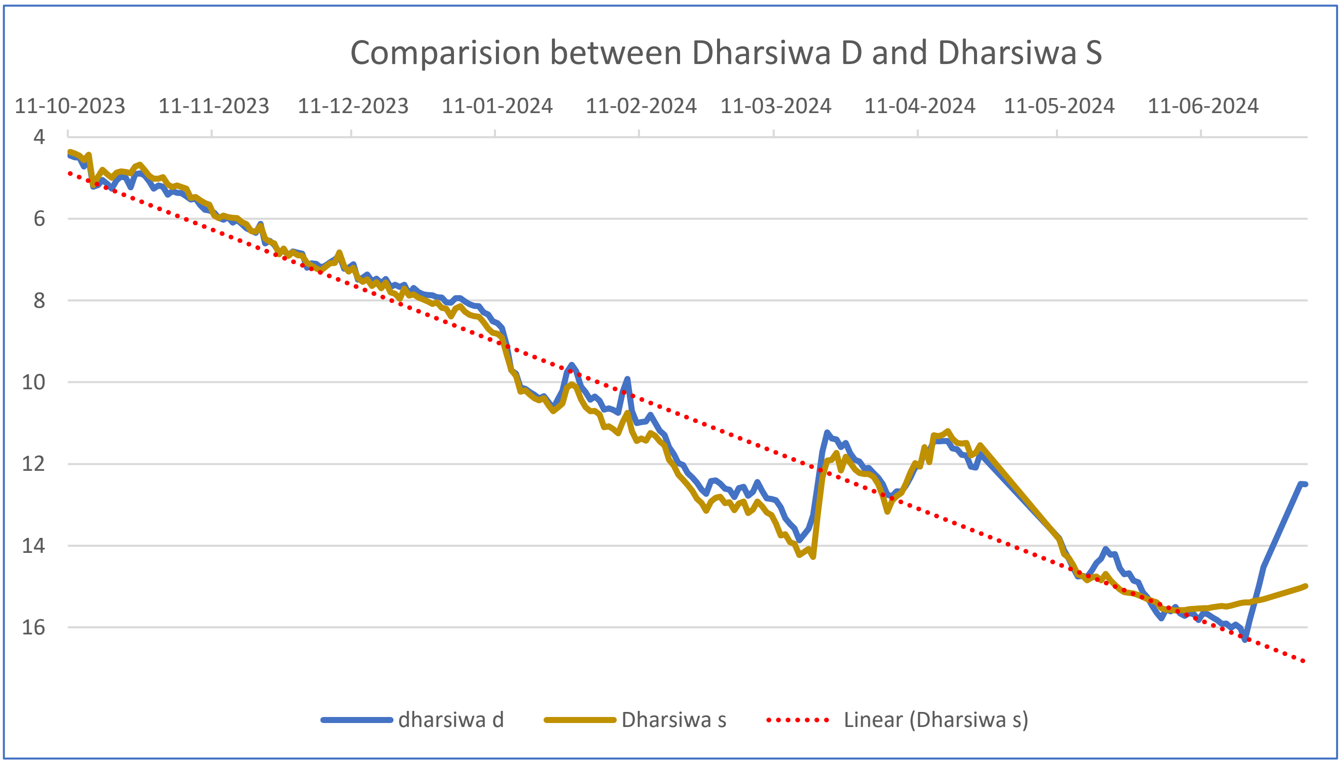


Figure 52 Hydrograph of Dharsiwa D and S Pz

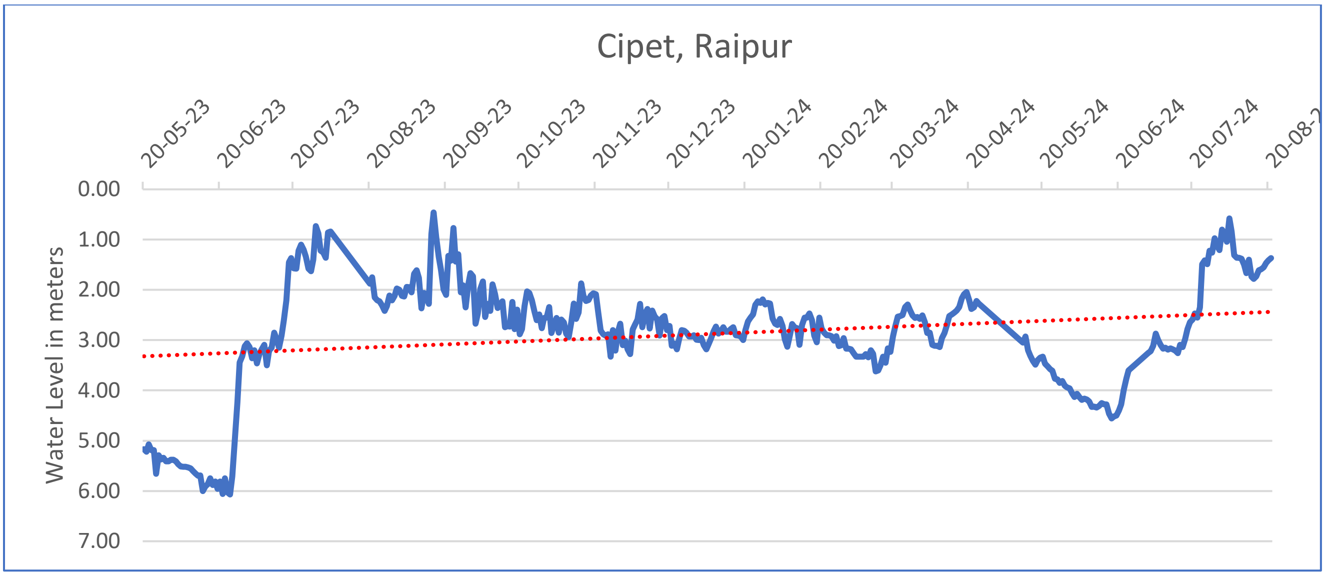


Figure 53 Hydrograph of Cipet Piezometer

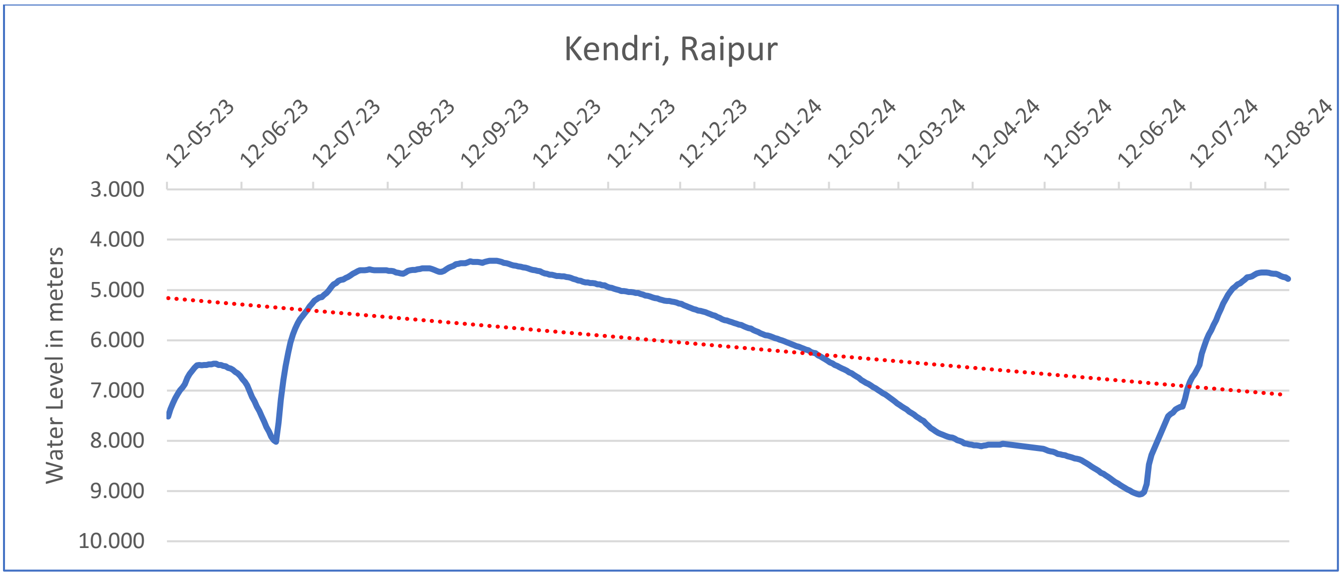


Figure 54 Hydrograph of Kendri Piezometer

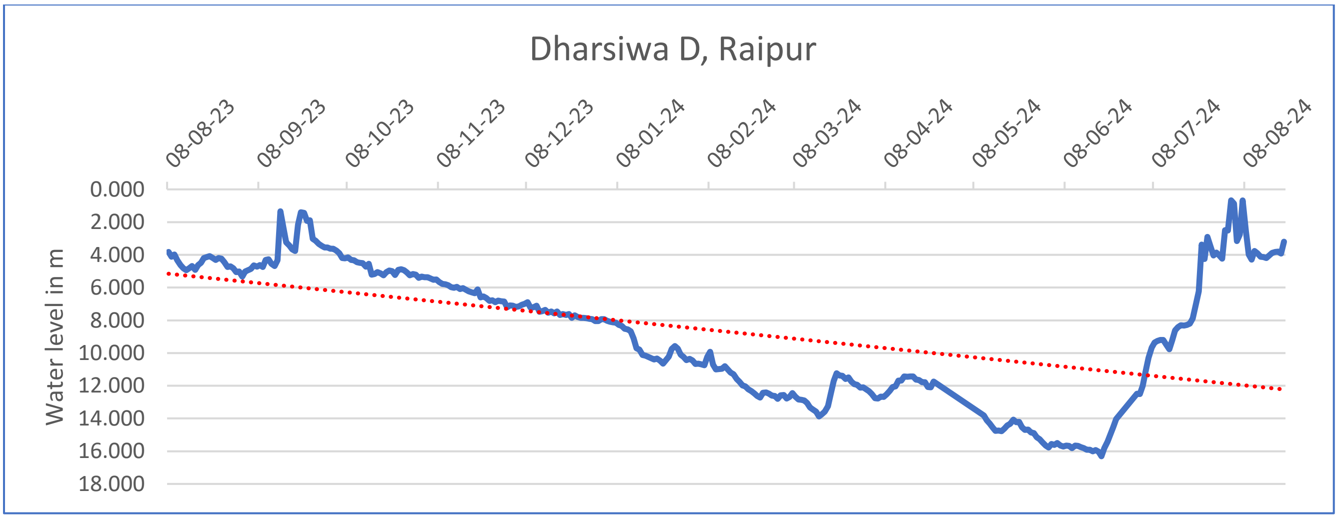


Figure 55 Hydrograph of Dharsiwa D Piezometer

Recession curve analysis is a powerful tool for understanding the behavior of aquifers, assessing groundwater sustainability, and making informed decisions about water resource management. It plays a crucial role in ensuring the long-term availability and reliability of groundwater supplies for both human and environmental needs.

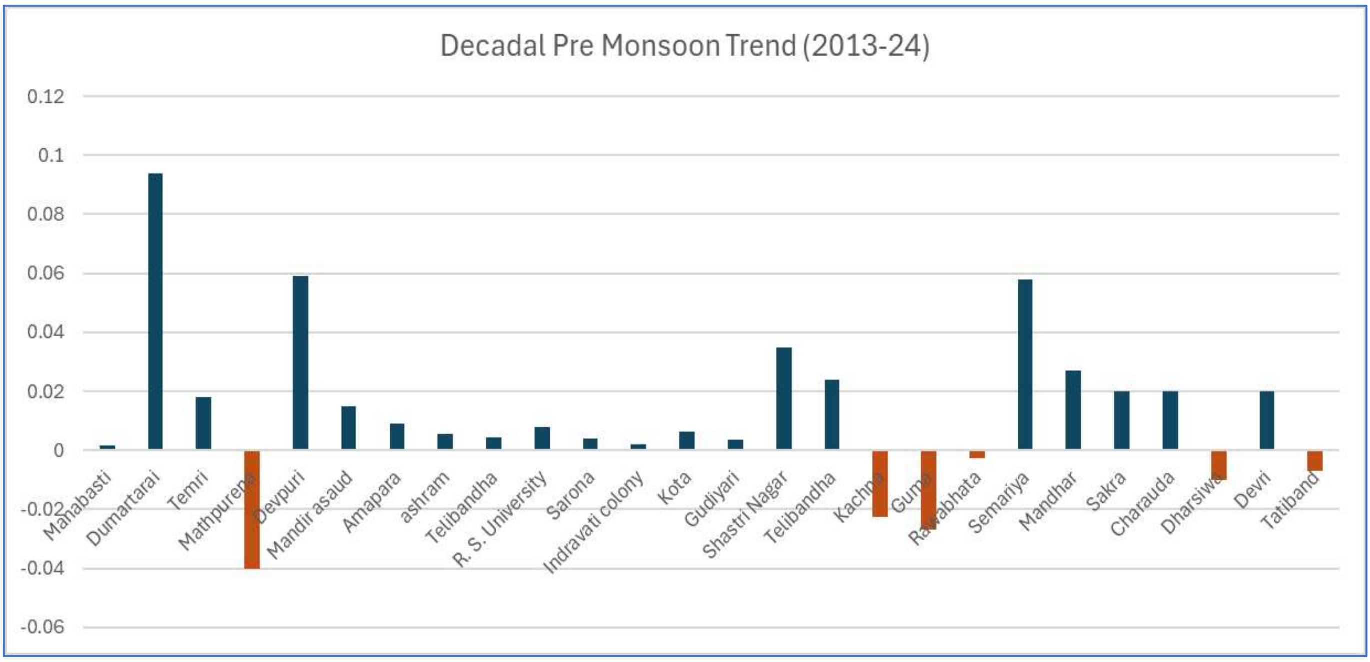


Figure 56 Decadal Pre-Monsoon Trend (2013-2024)

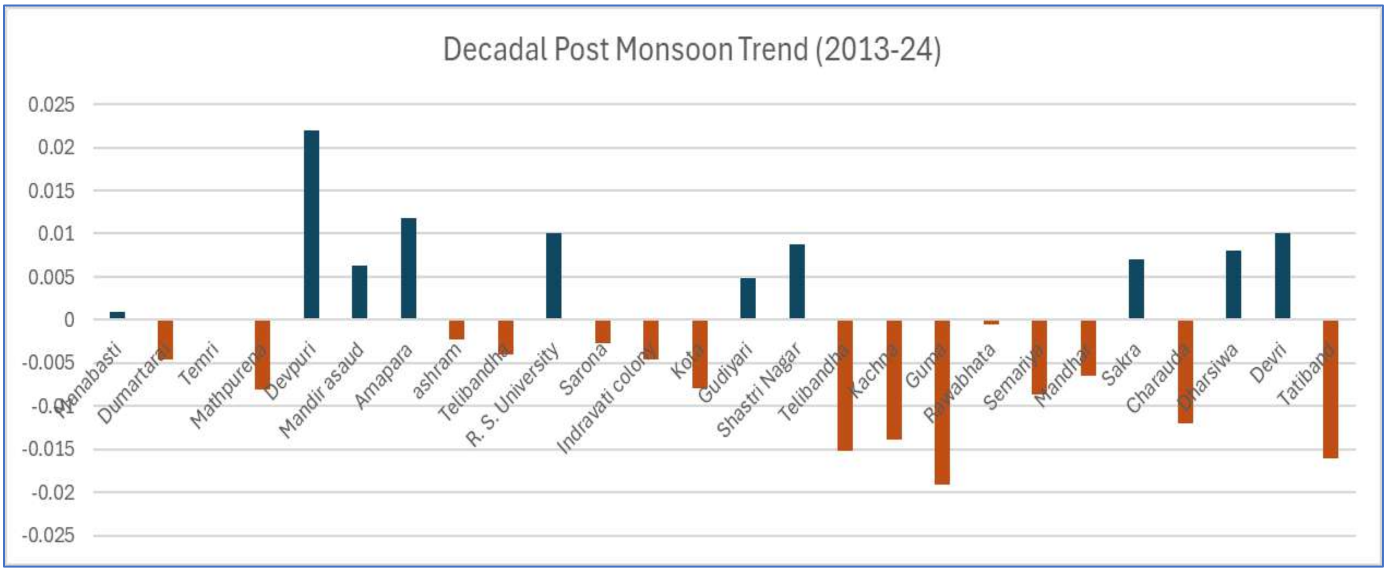


Figure 57 Decadal Post-Monsoon Trend (2013-2024)

5.5 RECHARGE AND DISCHARGE AREA DELINEATION

5.5.1 OBJECTIVE

Groundwater movement within a groundwater basin typically initiates from the recharge area and progresses towards the discharge area. The recharge area constitutes a vital segment of the watershed where groundwater diverges. This region is characterized by a vertically downward flow of groundwater, signifying the direction in which water traverses through the geological formations.

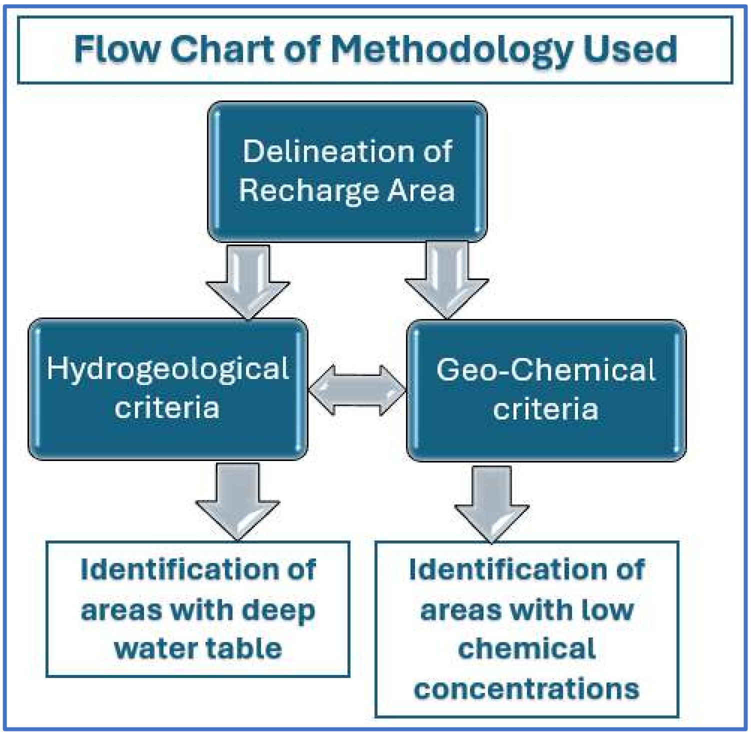
In the recharge area, the water surface permeates through the topsoil to reach the groundwater level, marking a crucial process in the replenishment of groundwater resources. This infiltration mechanism plays a pivotal role in sustaining the aquifer by allowing water to seep through various layers of soil and rock, contributing to the overall health of the groundwater basin.

Furthermore, the characteristics of the recharge area encompass a deep phreatic water level, typically situated below the piezometric surface in normal conditions. This configuration highlights the depth at which the groundwater is present and emphasizes the significance of understanding the vertical distribution of water within the aquifer. The interplay between the phreatic water level and the piezometric surface provides valuable insights into the dynamics of groundwater flow in this region.

Another distinctive feature of the recharge area is the relatively low concentration of chemical constituents in the groundwater. This aspect is crucial for assessing the quality of the replenishing water and its potential impact on the overall groundwater composition. The lower chemical load in this area contributes to the maintenance of water quality as it percolates through the soil, preserving the integrity of the aquifer.

Lastly, the recharge area is characterized by groundwater with a younger age compared to other parts of the groundwater basin. The age of groundwater refers to the time elapsed since it entered the aquifer. In the recharge area, the relatively younger age of groundwater indicates a more recent influx, reflecting the ongoing process of replenishment and emphasizing the dynamic nature of groundwater flow within the basin.

5.5.2 MATERIAL AND METHODS



5.5.3 RESULTS AND DISCUSSION

5.5.3.1 Hydrogeological Characteristics

From the topographic and water level map it is observed that there is strong lithological and anthropogenic control on the behavior of the water level. The water level in both phreatic and deeper aquifers shows a similar pattern with deeper water levels in the central portion and comparatively shallower water levels in the southern watershed divide and perched aquifer areas. This behavior is generally due to the presence of high aquifer thickness in the central and western areas which can be attributed to the presence of highly weathering resistant rocks in the western area. Whereas in the central areas, the weathering zone is deep and can extend to as high as 35 meters. It can be attributed to weathering-prone lithology which is chiefly limestone overlain by weathered material in the western fringes. However, the study area forms the western act like like a discharge area and showing shallow water level and eastern and middle part is behaving like a recharge area and showing deeper 62 water level due to presence of urban area, mining area in that part.

5.5.3.2 Geochemical Characteristics

Chadha's plot (1999) was used to identify the groundwater provenance. From the graph, it is clear that most of the samples fall in field-I showing Recharge water type with few samples with Base Ion Exchange and reverse ion exchange.

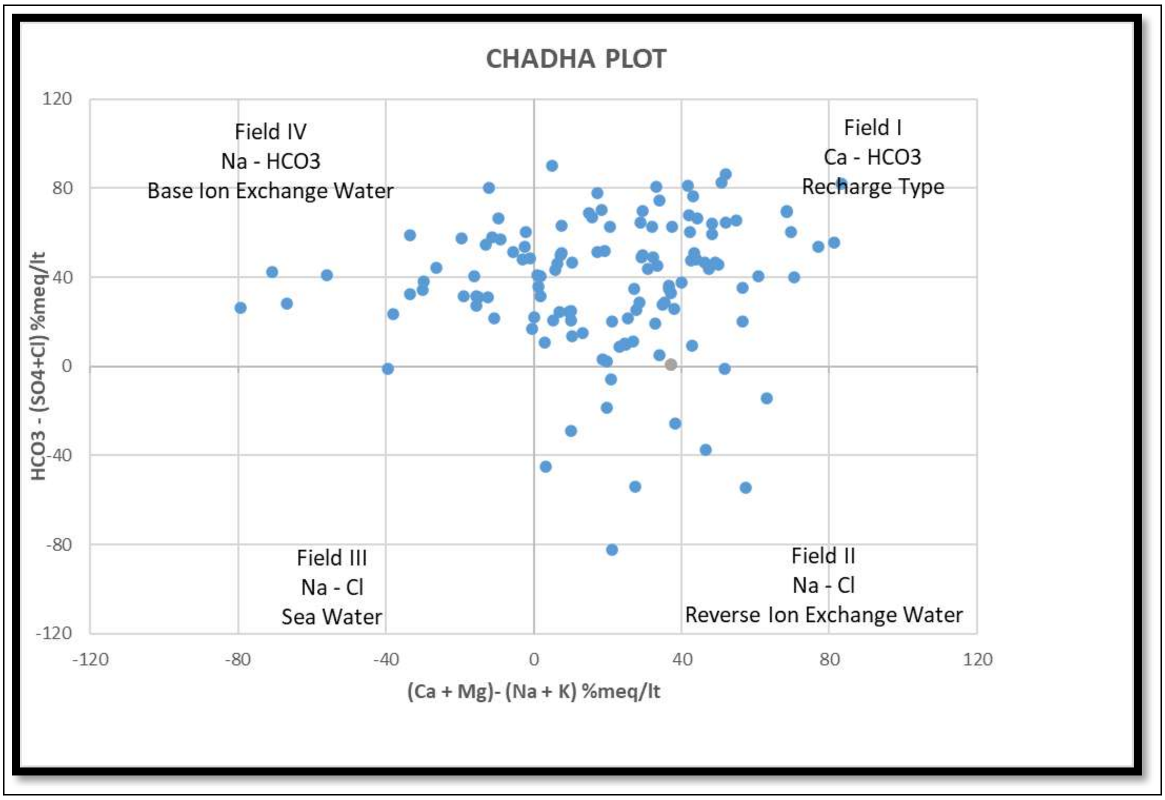


Figure 58 Chadha Plot for Premonsoon data

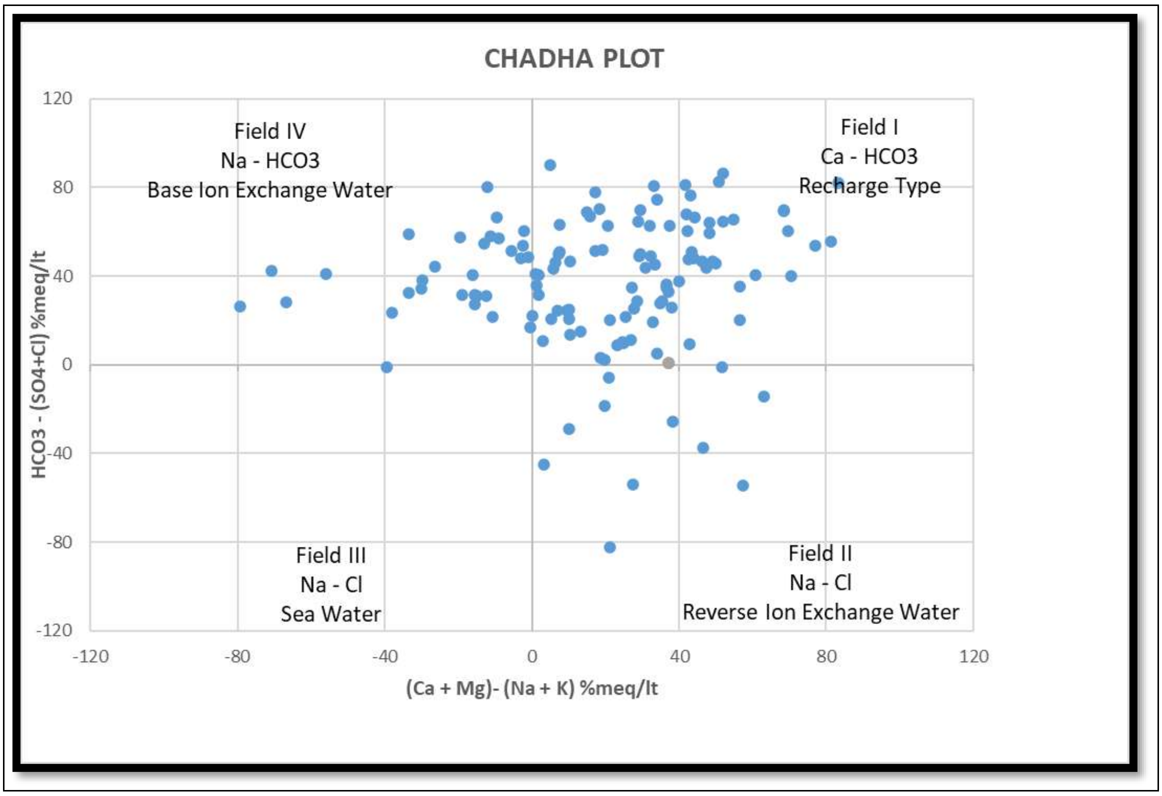


Figure 59 Chadha Plot for Postmonsoon data

Geochemical Criteria for identification of recharge area using Chadha Plot.

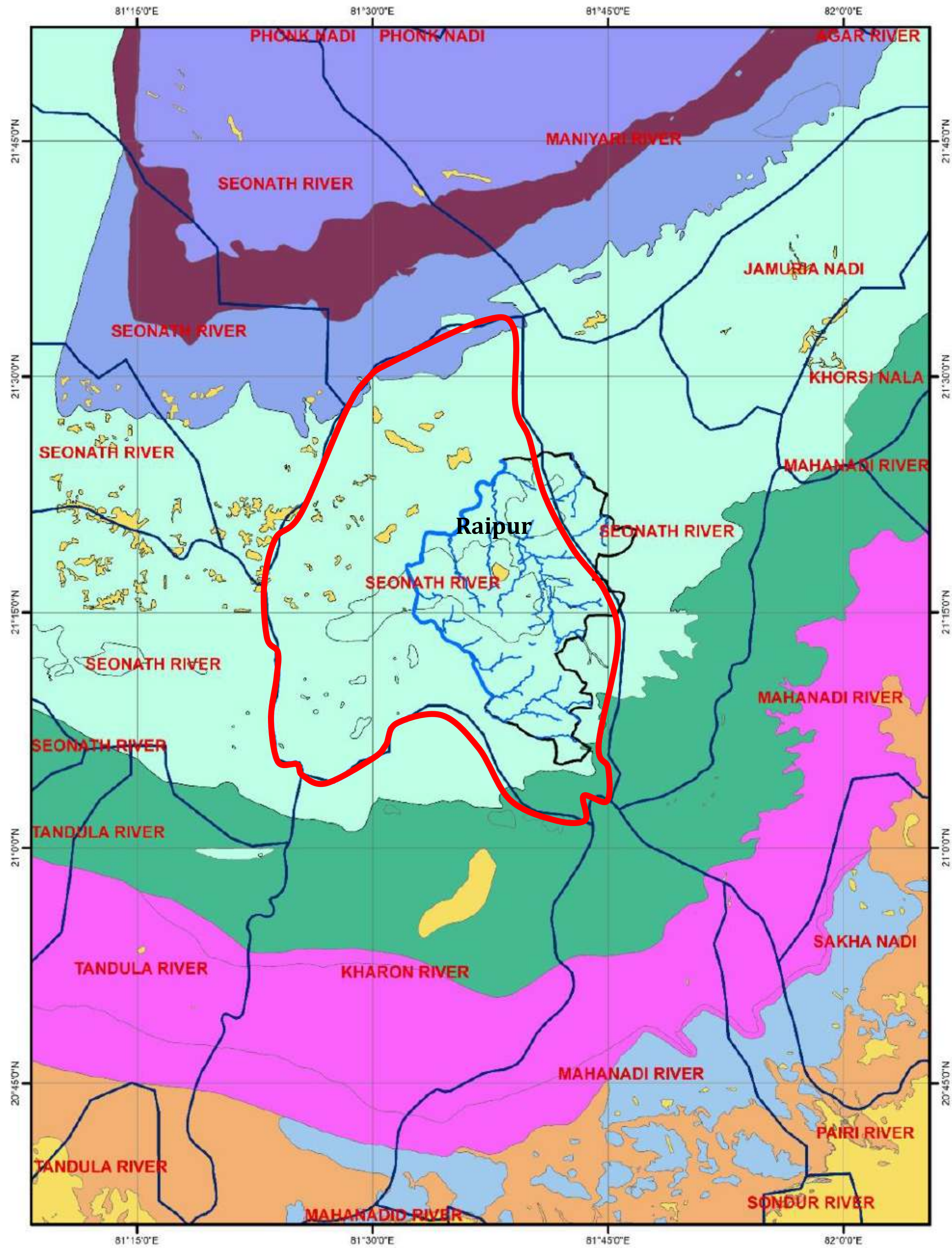


Figure 60 Watershed wise study area

Recharge Potential: A Recharge area potential map was prepared by overlaying the post-monsoon water level of both the first and second aquifers. The water-level was categorized into the area with water levels less than 3 mbgl and belo w 3 mbgl. The water level in 99% area is greater than 3 mbgl in the post-monsoon in the second aquifer (deeper) whereas in the first aquifer, the first area identified for recharge potential occur in the north eastern area were Birhaon, Urla and Siltara industrial areas and Giroud, Tekari, Daldal seoni, Dhaneli, Sankara, Changorabhata, Tendua etc are there which have lithological units of limestone and shale and some upper parts covered by sandstone, the second area is in the southern eastern side of city with lithology limestone and Shale in Deopuri, Joras areas . Third area have Some patches that fall in the Northeastern side of city which have limestone geology like Tor Tekari Tiwariya Matiya etc. The recharge potential of the whole of the study area is very high however availability of unsaturated aquifer thickness of the first aquifer is moderate which limits the area for recharge interventions.

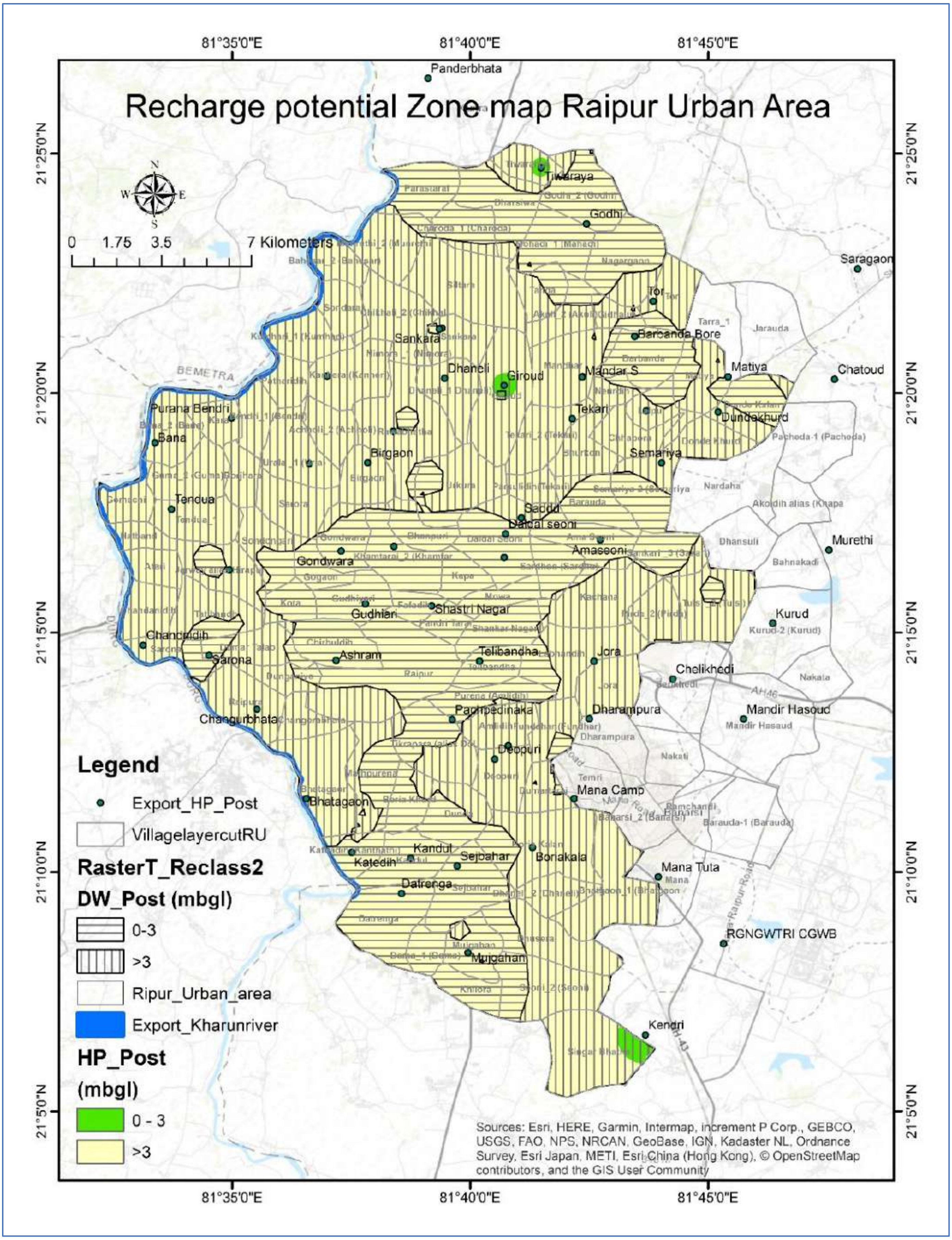


Figure 61 Recharge Potential Zonation Map

Identification of potential aquifers (Perched aquifer) for drinking water supply

Objective

Perched aquifers are formed by recharge that accumulates on aquitards. *Perched groundwater* forms above a layer of lower permeability material within the vadose zone where the migration of percolating recharge is slowed to the extent that it saturates the porous material above an aquitard (Figure51). If sufficient water is available for the development of water supplies, then this is referred to as a *perched aquifer*.

The Lower permeable layer in Raipur Urban is Deodongar shale unit and the water is saturated above in Deodongar Sandstone and weathered lateritic units which forms Perched conditions in Raipur Urban Area. Due to the localize recharge system water level fluctuation is very low in these units ranges up to 3.0 m bgl in Raipur City during Premonsoon season and post monsoon. Geophysical techniques along with the water level and geology of that area create a perched aquifer system.

The main objective is to demarcate the aquifer is to provide safe drinking water and irrigation water at the local level. In perched aquifer areas type of recharge structure will be different. In hard rock terrain, these are important sources of water in the lean season because they are not connected with the regional aquifer system. These aquifer systems also do not depict the original scenario of a particular area so also very important to demarcate perched aquifers.

Results and Discussion

The ground water occurs under phreatic to semi-confined condition in the urban agglomerate. The Deodongar shale behaves like confining layer and locally develop perched water table, where ground water level remains within 3m depth and can be seen at Parastarai, Mohadi in Northern part, Kota, Tendua, IIT Heerapur, Rawabhata, Shankar Nagar, Cipet, Mandhar, Shamnagar and Telibandha area in the middle part of the city and Datrenge, kandul, Sejbahar in the Southern part of the City forms the perched shallow aquifer as per the Geophysical and water level data of the area.

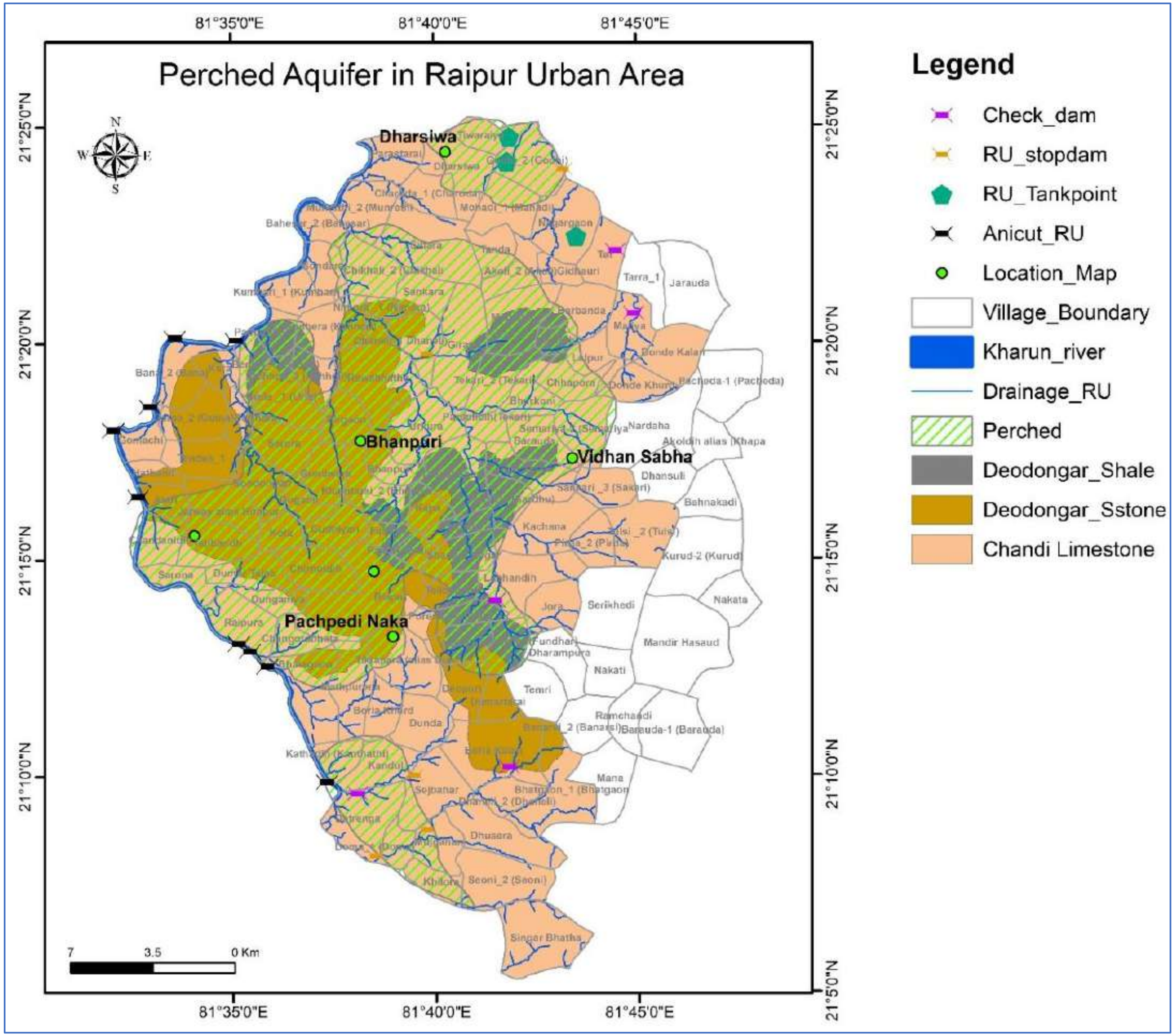


Figure 62 Perched Aquifer Map

5.8 GROUNDWATER QUALITY

5.8.1 OBJECTIVE

Water quality assessment is crucial for ensuring the safety and sustainability of water sources across various sectors, including drinking water, irrigation, and industrial processes. In the context of drinking water, assessing water quality is essential to safeguard public health. Contaminants such as bacteria, viruses, heavy metals, and chemicals can pose serious health risks if present in drinking water. Regular monitoring and assessment help identify and address potential hazards, ensuring that water treatment facilities can effectively remove or mitigate these contaminants, thus providing safe and clean drinking water to communities.

In agriculture, water quality assessment is pivotal for irrigation purposes. Poor water quality can have detrimental effects on soil health and crop productivity. High levels of salts, sediments, or toxic substances in water can lead to soil degradation, affecting the fertility and structure of the land. By monitoring water quality, farmers can make informed decisions about irrigation practices, selecting appropriate water sources, and optimizing resource utilization to enhance agricultural productivity while minimizing environmental impacts.

In industrial settings, water quality assessment is crucial for ensuring the efficiency and sustainability of manufacturing processes. Many industries rely on water for various purposes, including cooling, cleaning, and as a component in the production of goods. Poor water quality can lead to equipment corrosion, scaling, and fouling, impacting the overall efficiency of industrial operations.

Regular water quality assessments enable industries to implement appropriate treatment measures, reduce environmental impact, and comply with regulations, ultimately contributing to sustainable and responsible industrial practices. Overall, water quality assessment plays a pivotal role in safeguarding human health, promoting agricultural productivity, and supporting sustainable industrial development.

The objective of the water quality analysis is to categorize areas with poor water quality for drinking, irrigation, and industrial purposes and find out the mechanism controlling the dissemination of the toxic elements.

5.8.2 MATERIAL AND METHODS

The methodology for assessing drinking water quality typically involves a comprehensive approach that considers a range of physical, chemical, and microbiological parameters. Water quality testing is conducted using standardized methods and guidelines established by regulatory bodies, such as the Bureau of India (BIS). Parameters assessed include pH levels, turbidity, dissolved oxygen, total dissolved solids, heavy metals, pesticides, and microbial contaminants. Samples are collected at various points in the water supply chain, from the source to the tap, to identify potential contamination sources and assess the effectiveness of water treatment processes.

The collected data are then compared to established water quality standards and guidelines to determine compliance. Additionally, drinking water quality indexing often involves the development of a composite index that combines multiple parameters into a single numerical value, simplifying the communication of overall water quality and aiding in the identification of potential health risks.

This approach ensures a systematic and thorough evaluation of drinking water quality, helping authorities and water management agencies make informed decisions to ensure the provision of safe and reliable drinking water to the public.

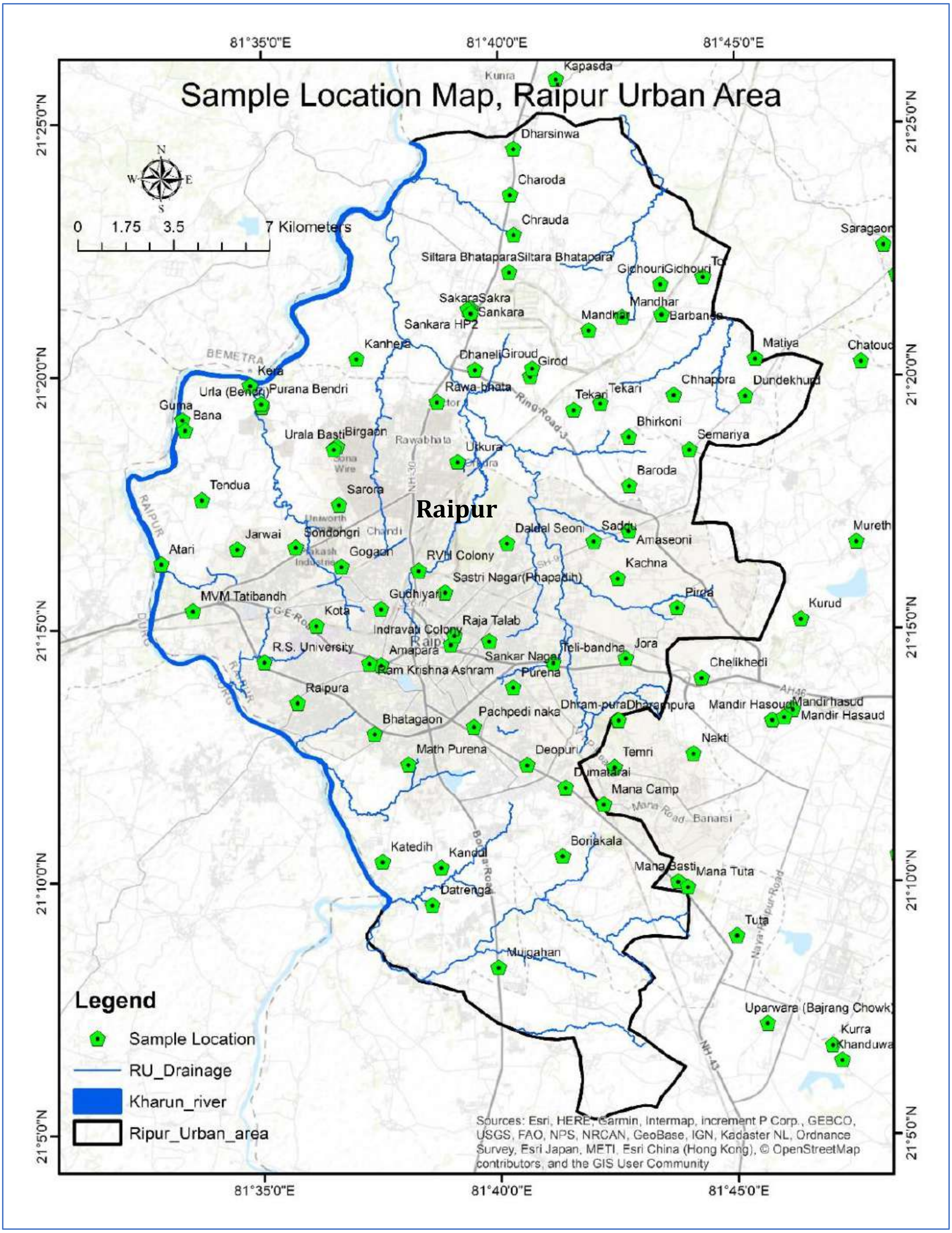


Figure 63 Groundwater Sampling Location Map

5.8.3 RESULTS AND DISCUSSION

5.8.3.1 Drinking water quality

pH:

Both pre-monsoon and post-monsoon water samples exhibit a slightly alkaline pH, with average values of 7.7 and 7.76, respectively. The narrow range and proximity to the neutral pH (7) suggest stable and acceptable conditions for drinking water. These consistent pH levels indicate a balanced acid-base environment, crucial for maintaining water quality.

EC (Electrical Conductivity):

The pre-monsoon period shows a wider range of electrical conductivity (EC) values, ranging from 162.00 to 2360 µS/cm, suggesting variability in ion content. Post-monsoon data shows the broader range 192 to 2090 µS/cm indicates the potential dilution effects from increased water flow during the monsoon, impacting the EC of water sources.

Chloride (Cl):

Chloride concentrations in both periods fall within the acceptable limits (250 mg/lt), with averages of 94.28 mg/l in Premonsoon and 98.42 mg/lt in postmonsoon respectively. The stable and low chloride levels indicate minimal contamination, contributing to the overall safety of the water for consumption.

Sulfate (SO4):

Sulfate levels show consistency, with average concentrations of 31.06 mg/l and 53.33 mg/l during pre and post-monsoon, respectively. These values remain well below the permissible limit of 200 mg/l, indicating a low sulfate presence and stable water quality.

Nitrate (NO3):

While nitrate concentrations 86% Samples in premonsoon and 85.3% falls in postmonsoon periods are within acceptable limits (45 mg/l) whereas, 14% samples are found above acceptable limit in premonsoon with maximum nitrate concentration of 65.4 mg/l and 15.49 % in postmonsoon with 59.2 maximium concentration. The variability suggests potential agricultural runoff or other sources contributing to nitrate levels, emphasizing the need for ongoing monitoring.

Total Hardness (TH)

Total Hardness (TH) in both pre-monsoon and post-monsoon water falls within acceptable limits (200 mg/l) with two locations showing more than permissible limit. However, the pre-monsoon period shows a broader range (45 to 945 mg/l) compared to post-monsoon (40 to 675 mg/lt), indicating potential changes in water composition.

Calcium (Ca):

Calcium levels remain consistent, with averages of 64.04 mg/l and 58.45 mg/l, contributing to water hardness in premonsoon and postmonsoon respectively.

Magnesium (Mg):

Magnesium concentrations display variations, with pre-monsoon levels ranging from 1.22 to 115.9 mg/l (average 26.2 mg/l) and post-monsoon ranging from 3.6 to 86.4 mg/l (average 31.3 mg/l). The wider range post-monsoon suggests dilution effects, while the lower average concentration may indicate reduced anthropogenic inputs during this period.

Fluoride (F):

Fluoride concentrations remain consistently low in both pre and post-monsoon periods, with averages of 0.33 mg/l and 0.12 mg/l, respectively. All samples fall within the acceptable limit (1 mg/l), indicating minimal risk of fluorosis. The stability in fluoride levels suggests a consistent source or lack of significant anthropogenic influence.

Phosphate (PO4):

Phosphate concentrations are consistently zero in both pre and post-monsoon periods, indicating a lack of detectable phosphate in the water samples. This absence suggests minimal contamination from agricultural runoff or other sources contributing to phosphate levels.

Silica (SiO2):

Silica levels show stability, with averages of 11.37 mg/l and 8.51 mg/l in pre and post-monsoon, respectively. The range in pre-monsoon is 2.93 to 34.49 mg/l and in post-monsoon is 2.5 to 19.2 mg/l.

Sodium (Na):

Sodium concentrations in both pre and post-monsoon periods fall within the acceptable limit, with an average of 57.17 mg/l and 66.2 mg/l, respectively. The consistent levels suggest minimal variation in sodium content, contributing to the overall stability of water quality.

Potassium (K):

Potassium levels remain within acceptable limits (1.5 mg/l) in both pre and post-monsoon periods, with averages of 6.23 mg/l and 7.66 mg/l, respectively. The low and stable potassium concentrations indicate a limited impact on water quality, emphasizing its suitability for drinking purposes.

Total Dissolved Solids (TDS):

Total Dissolved Solids (TDS) exhibit variations, with averages of 523.34 mg/l in pre-monsoon and 579.55 mg/l in post-monsoon. In pre-monsoon, 44.5% of samples exceed the acceptable limit of 500 mg/l and in post monsoon 63.7 %. High Total Dissolved Solids (TDS) in post-monsoon water samples typically indicate an increased concentration of dissolved substances in the water.

The analysis of water quality parameters during both pre and post-monsoon periods indicates that the water from the monitored sources generally meets the criteria for suitability in terms of drinking and irrigation purposes. The slightly alkaline pH levels, consistently low chloride and sulfate concentrations, and acceptable nitrate levels underscore the water's safety for consumption.

Electrical conductivity values, while exhibiting some variability, generally fall within acceptable limits, with the post-monsoon period potentially indicating dilution effects. Total hardness and calcium levels, though occasionally exceeding permissible limits, remain generally suitable for drinking water.

In terms of irrigation, the stable pH, low sulfate and nitrate concentrations, and generally acceptable electrical conductivity levels suggest the water's compatibility with agricultural practices. While occasional variations and exceedances call for ongoing monitoring, the overall findings support the conclusion that the water from these sources is, in general, suitable for both drinking and irrigation purposes.

Table 19 Statistical analysis of Pre-Monsoon water quality for drinking purpose

Parameters	**min**	**max**	**Avg**	**Sdev**	**No of wells above acceptable limit**	**No of wells above permissible limit**	**Acceptable limit**	**Permissible limit**	**% of samples above acceptable limit**	**% of samples above permissible limit**
pH	7.05	8.58	7.7336719	0.2048012	**0**	1	6.5	8.5	0	1
EC	162	2360	795.4375	360.25591	**NA**	**NA**	NA	NA	0	0
HCO3 in mg/lt	30.5	585.6	260.37969	95.368866	**NA**	**NA**	NA	NA	0	0
Cl in mg/lt	10.65	386.95	94.280078	72.476127	**0**	0	250	1000	0	0
SO4 in mg/lt	0	140.3	31.066016	30.332739	**0**	0	200	400	0	0
NO3 in mg/lt	0	65.4	20.227344	17.873746	**NA**	18	NA	45	0	14
F in mg/lt	0.01	1.29	0.3375781	0.2232038	**0**	0	1	1.5	0	0
SiO2 in mg/lt	2.93	34.49	11.372422	8.2476431	**NA**	**NA**	NA	NA	0	0
TH in mg/lt	45	945	267.30469	125.26207	**86**	2	200	600	67	1.5
Ca in mg/lt	10	356	64.046875	39.890056	**40**	1	75	200	31.2	1
Mg in mg/lt	1.22	115.9	26.200313	18.975709	**41**	1	30	100	32	1
Na in mg/lt	2.86	213.3	57.17457	39.791872	**NA**	**NA**	NA	NA	0	0
K in mg/lt	0.12	45.75	6.231301	8.4534071	**NA**	**NA**	NA	NA	0	0
TDS in mg/lt	103.68	1581.2	523.34758	238.01752	**57**	0	500	2000	44.5	0
No of Samples =128		NA= Not applicable								

Table 20 Statistical analysis of post-monsoon water quality for drinking purpose

Parameters	**min**	**max**	**Avg**	**Sdev**	**No of wells above acceptable limit**	**No of wells above permissible limit**	**Acceptable limit**	**Permissible limit**	**% of samples above acceptable limit**	**% of samples above permissible limit**
pH	7.05	8.84	7.7630392	0.2952061	0	4	6.5	8.5	0	0
EC	192	2090	865.0098	338.51523	**NA**	**NA**	NA	NA	0	0
HCO3 in mg/lt	73.2	408.7	246.21275	68.129372	**NA**	**NA**	NA	NA	0	0
Cl in mg/lt	14.2	273.35	98.42549	52.63895	**0**	0	250	1000	0	0
SO4 in mg/lt	0	451.9	53.335588	70.434956	**0**	1	200	400	0	0
NO3 in mg/lt	0	59.2	21.825196	16.702473	**NA**	15	NA	45	0	15
F in mg/lt	0	1.22	0.1131373	0.1820148	**0**	0	1	1.5	0	0
SiO2 in mg/lt	2.5	19.2	8.517451	100.00327	**NA**	**NA**	NA	NA	0	0
TH in mg/lt	40	675	276.66667	2.5223455	**79**	2	200	600	77.4	2
Ca in mg/lt	10	134	58.45098	23.085361	**17**	0	75	200	16.6	0
Mg in mg/lt	3.6	86.4	31.329412	17.114623	**44**	1	30	100	43	1
Na in mg/lt	6.22	282.9	66.204598	51.189171	**NA**	1	NA	NA	0	1
K in mg/lt	0.21	57.95	7.6691176	9.8741977	**NA**	1	NA	NA	0	1
TDS in mg/lt	128.64	1400.3	579.55657	226.8052	**65**	0	500	2000	63.7	0
No of Samples =102		NA= Not applicable								

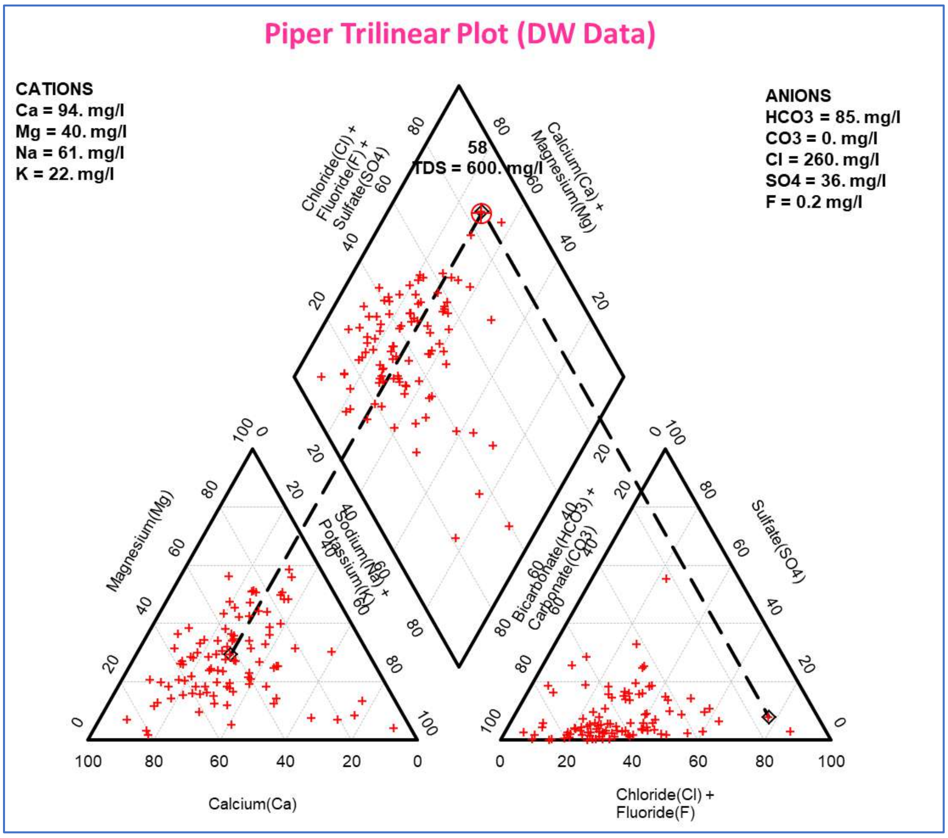


Figure 64 Piper Plot showing DW water characteristics

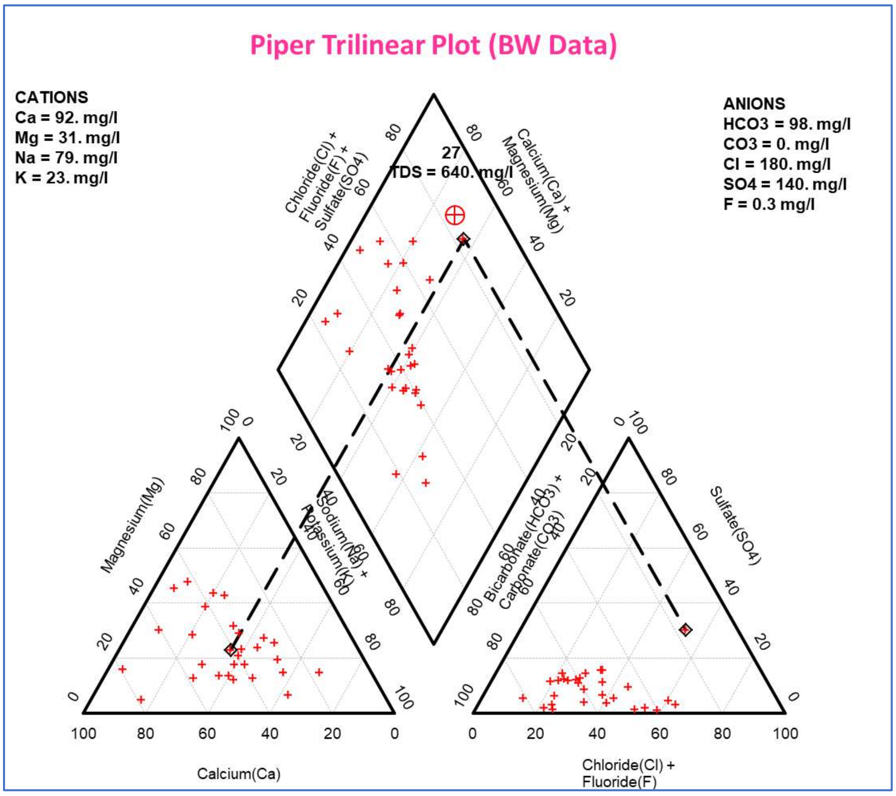


Figure 65 Piper Plot showing BW water characteristics

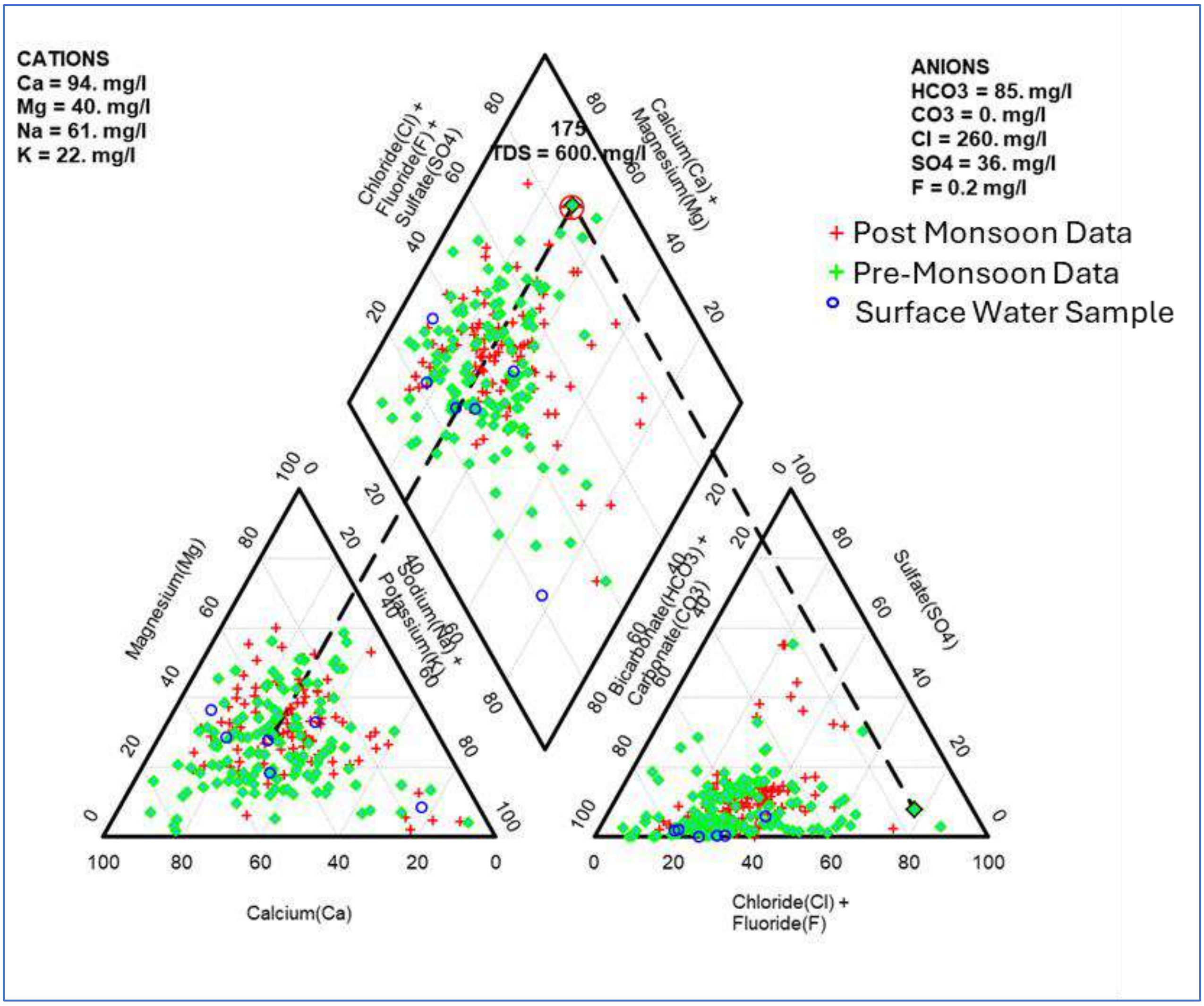


Figure 66 Piper Plot showing Pre vs Post monsoon variation in water characteristics

The Piper diagram indicates that the ground water of shallow aquifer of Raipur is mostly characterized by calcium-bicarbonate (Ca-HCO_3) type. However mixed type i.e. (Ca+Mg) & (SO_4+Cl) type ground water also observed at some places. The deeper aquifer is characterized by Na-K-bicarbonate type (Na, K-HCO_3) type.

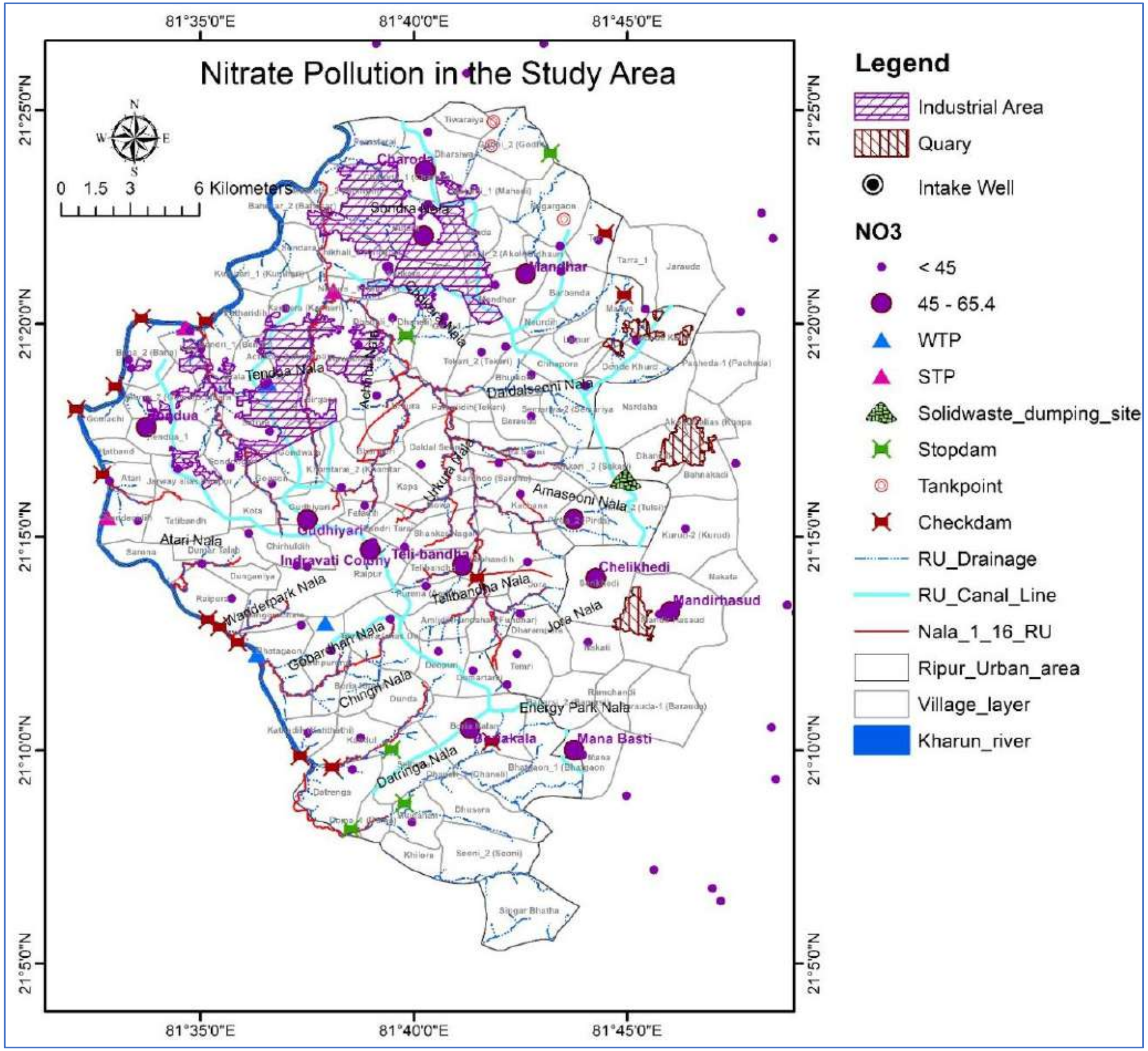


Figure 67 Nitrate Distribution Map

Table 21 Correlation analysis of Basic Parameters (Pre-monsoon)

	pH	*EC*	*CO3*	*HCO3*	*Cl*	*SO4*	*NO3*	*F*	*Ca*	*Mg*	*TH*	*Na*	*K*	*Sio2*	*PO4*	*u (µg/ml)*	*TDS*
pH	1.00																
EC	-0.13	1.00															
CO3	0.37	0.04	1.00														
HCO3	-0.05	0.65	0.11	1.00													
Cl	-0.14	0.88	0.05	0.29	1.00												
SO4	-0.11	0.52	-0.05	0.30	0.33	1.00											
NO3	-0.09	0.43	-0.10	0.09	0.39	0.26	1.00										
F	0.06	0.10	0.25	0.05	0.07	0.20	-0.07	1.00									
Ca	-0.10	0.68	-0.12	0.36	0.58	0.47	0.44	0.02	1.00								
Mg	-0.33	0.55	-0.10	0.43	0.50	0.19	0.26	-0.05	-0.01	1.00							
TH	-0.29	0.88	-0.16	0.55	0.77	0.48	0.51	-0.01	0.79	0.60	1.00						
Na	0.13	0.64	0.35	0.55	0.57	0.31	0.07	0.26	0.12	0.27	0.26	1.00					
K	0.03	0.39	-0.03	0.00	0.50	0.15	0.27	-0.12	0.20	0.17	0.27	0.19	1.00				
Sio2	0.04	0.07	0.02	-0.12	0.04	0.32	0.04	0.19	0.23	-0.18	0.07	-0.03	0.02	1.00			
u (µg/ml)	-0.09	0.36	-0.05	0.21	0.41	-0.09	-0.01	-0.11	-0.06	0.62	0.34	0.20	0.19	-0.06	0.00	1.00	
TDS	-0.13	1.00	0.04	0.64	0.87	0.55	0.43	0.11	0.70	0.53	0.88	0.63	0.39	0.09	0.00	0.33	1.00

Table 22 Correlation analysis of Basic Parameters (Post-monsoon)

	pH	*EC*	*HCO3*	*Cl*	*SO4*	*NO3*	*F*	*Ca*	*Mg*	*TH*	*Na*	*K*	*Sio2*	*u (µg/ml)*	*TDS*
pH	1.00														
EC	-0.13	1.00													
HCO3	-0.05	0.65	1.00												
Cl	-0.14	0.88	0.29	1.00											
SO4	-0.11	0.52	0.30	0.33	1.00										
NO3	-0.09	0.43	0.09	0.39	0.26	1.00									
F	0.06	0.10	0.05	0.07	0.20	-0.07	1.00								
Ca	-0.10	0.68	0.36	0.58	0.47	0.44	0.02	1.00							
Mg	-0.33	0.55	0.43	0.50	0.19	0.26	-0.05	-0.01	1.00						
TH	-0.29	0.88	0.55	0.77	0.48	0.51	-0.01	0.79	0.60	1.00					
Na	0.13	0.64	0.55	0.57	0.31	0.07	0.26	0.12	0.27	0.26	1.00				
K	0.03	0.39	0.00	0.50	0.15	0.27	-0.12	0.20	0.17	0.27	0.19	1.00			
Sio2	0.04	0.07	-0.12	0.04	0.32	0.04	0.19	0.23	-0.18	0.07	-0.03	0.02	1.00		
u (µg/ml)	-0.09	0.36	0.21	0.41	-0.09	-0.01	-0.11	-0.06	0.62	0.34	0.20	0.19	-0.06	1.00	
TDS	-0.13	1.00	0.64	0.87	0.55	0.43	0.11	0.70	0.53	0.88	0.63	0.39	0.09	0.33	1.00

Pearson Correlation:

The Pearson correlation coefficient is a correlation coefficient that measures linear correlation between two sets of data. It is the ratio between the covariance of two variables and the product of their standard deviations; thus, it is essentially a normalized measurement of the covariance, such that the result always has a value between −1 and 1. If the correlation coefficient is closed to +1 or -1 predicts a good relationship between two variables x and y, and the correlation coefficient r = 0 predicts no relationship between two variables. The correlation between the parameters is considered as strong, when it is in the range of +0.8 to 1.0 and -0.8 to -1.0, moderate when it is having a value in the range of +0.5 to 0.8 and -0.5 to -0.8, weak when it is in the range of +0.0 to 0.5 and -0.0 to -0.5.

The idea of bearing a single parameter analyzed has a relationship with other parameters. A highly positive correlation is observed between EC and HCO_3, Chloride, Calcium, Total Hardness, Siodium and TDS. Similarly, HCO_3 has good positive correlation with TDS. Like wise Cl also has good correlation with TH (R- 0.77) and TDS (R- 0.87).

Hardness plays a role in heart diseases in humans. Hardness above approximately 200 mg/l may cause scales in water pipes and distribution systems. According to this report, drinking water in the study area is hard for all samples. The TDS concentrations more than 1,000 mg/l can make scales in water pipes, heaters, boilers and household appliances. It is important to notice that pH has negative correlation with almost all the cations and anions. Carbonate, phosphate and silica are such parameters who does not have any correlation with any of the parameters analyzed.

No significant correlation among most of the parameters was observed in the water of study area. However, some of the parameters having correlation coefficients with $p < 0.05$ are detailed in Table. These correlations suggests that the heavy and trace metals behave independently of physical parameters, anions and major cations in the water samples collected from the study area, while some of the major cations, anions and physical parameters were found interrelated.

5.8.3.2 Irrigation Water Quality

The irrigation water quality is summarized in table-24. Overall, from the US-Salinity plot and Wilcox diagram it is clear the gross water quality is suitable for irrigation purpose.

Table 23 Statistical analysis of Irrigation water quality

Parameter	Min	Max	Average	Std
Na%	5.04	91.23	31.45	
SAR	0.71	43.13	5.67	5.00
RSC	-56.5	55.8	-9.04	20.67
Mg Ratio	2.05	86.4	39.13	17.63
Permeability Index	12.16	98.8	37.8	15.18
CR				
SSP	4.9	90.28	29.4	14.97
Kelly Ratio	0.05	10.30	0.59	1.00

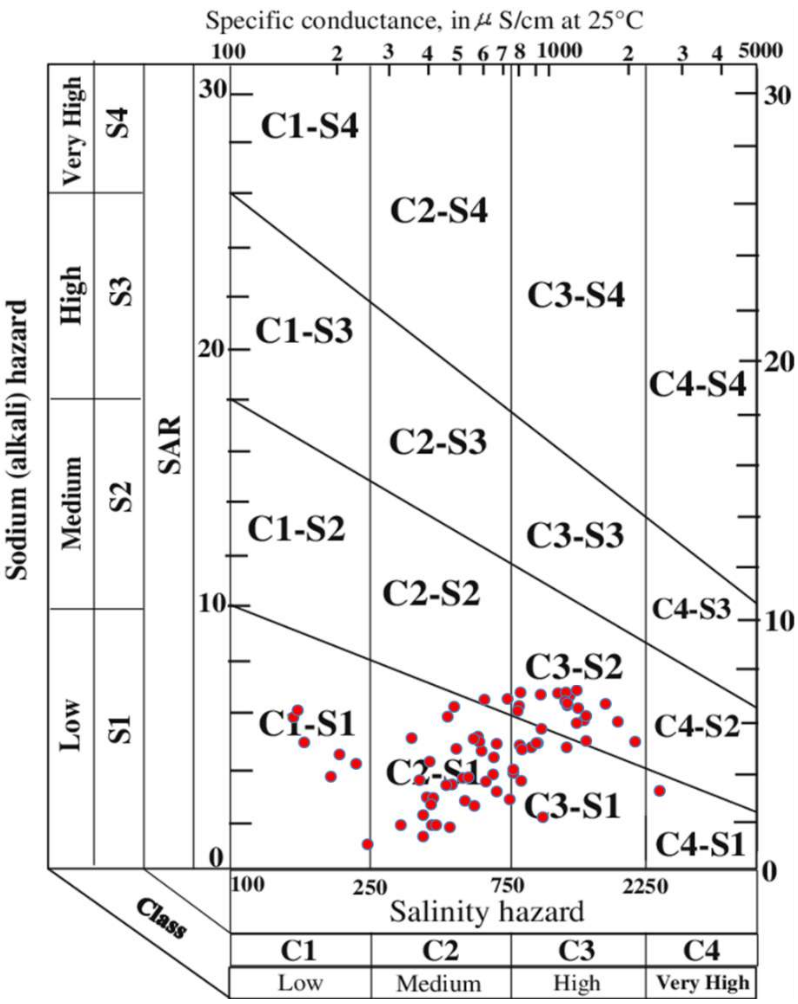


Figure 68 US Salinity Plot

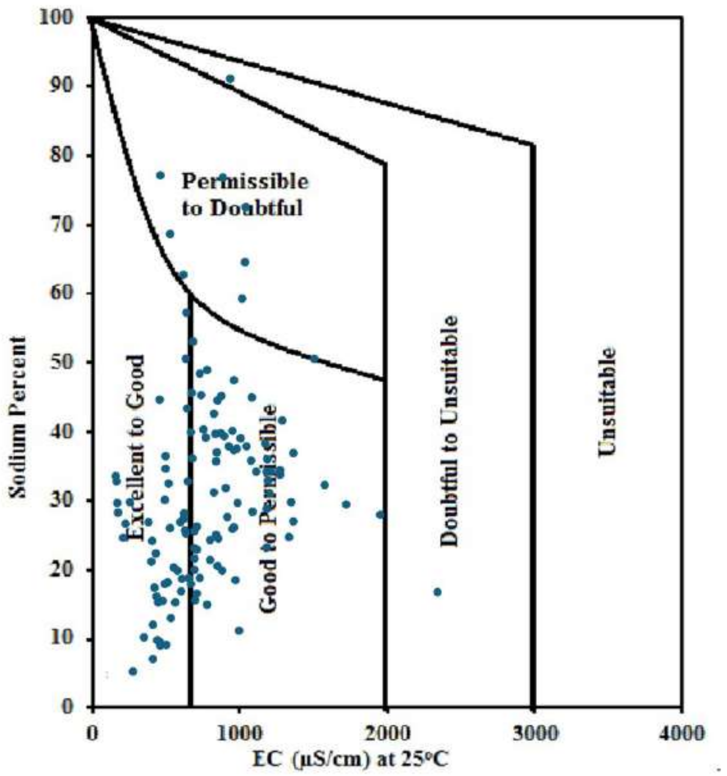


Figure 69 Wilcox diagram

CHAPTER 6

GROUNDWATER RESOURCES

6.1 OBJECTIVE

The quantitative estimation of various inputs to ground water resources and their temporal variation in space and time is imperative for a planned management and development of ground water resources. The resources in the surveyed area are computed on the basis of methodology recommended by the Ground Water Estimation Committee of Ministry of Water Resources, Govt. of India, 2015.

The entire aquifer mapping area falls under command area and has been covered under ground water resource assessment. The estimation of ground water resource in the surveyed area is taken as on March 2024.

The prime objective of groundwater resource estimation is Refinement of Parameters and lithology wise groundwater resource estimation.

The primary source of recharge of groundwater in Raipur Urban area is rainfall. Therefore, water table balance method has been used for estimating the resources. Rainfall recharge factor or Infiltration factor is a recharge parameter that indicates a quantum of water recharged to the groundwater system in relation to the rainfall. It is a function of rate of infiltration and ability of the system to accept the infiltrated water. The infiltration factor can be expressed as follows

$IF = (Qi/Qa) \times SY$,

Where,

IF = Infiltration Factor

Qi = Quantum of water infiltrated over the test period in m

Qa = Quantum of water applied in m

SY = Specific Yield

Recharge of ground water involves several components and rainfall being the major one. The other components are return irrigation flow from surface water and ground water.

Rainfall infiltration factor for alluvial formations is taken as 20%. The Return Flow Factor for recharge from surface water irrigation has been taken as 15-25 % for non-paddy crops and 50-60 % for paddy crops. In case of ground water irrigation, the return flow factor has been taken as 15-25 % for non-paddy crops. Canal seepage factor, for lined and unlined canals, has been taken as per GEC' 2015 norms. The recharge from other sources i.e. ponds and lakes have also been estimated based on the spread area of the water bodies.

6.2 RESULTS AND DISCUSSION

6.2.1 SOIL INFILTRATION STUDIES

Soil infiltration testing is a crucial component of hydrological studies, providing insights into water movement through the soil profile. One widely used method for conducting infiltration tests is the double ring infiltrometer technique. Soil infiltration tests with double ring infiltrometers provide valuable insights into soil-water interactions, infiltration dynamics, and hydraulic conductivity.

Understanding soil infiltration helps in managing water resources effectively, especially in areas prone to drought or water scarcity. It helps in estimating groundwater recharge rates and designing efficient irrigation systems. Soil infiltration studies aid in predicting and mitigating floods by assessing how quickly the soil can absorb rainfall and reduce surface runoff. It plays a crucial role in erosion control.

Higher infiltration rates reduce surface runoff, preventing soil erosion and sedimentation in rivers, lakes, and reservoirs. The data obtained from these tests contribute to watershed management, irrigation scheduling, soil conservation, and flood control efforts. By understanding the infiltration characteristics of soils, stakeholders can make informed decisions regarding land use planning, agricultural practices, and water resource management strategies.

Soil infiltration test was conducted by falling head method and mean hydraulic conductivity was calculated by using the formula.

$$k = \frac{A_i \cdot h_0}{A \cdot t} \ln\left(\frac{h_0}{h_t}\right)$$

where:

- A_i is the cross-sectional area of the inner ring,
- A is the cross-sectional area of the infiltration surface (area of the outer ring minus the area of the inner ring),
- h_0 is the initial water level at the start of the time interval,
- h_t is the water level at the end of the time interval,
- t is the time duration of the interval in seconds.

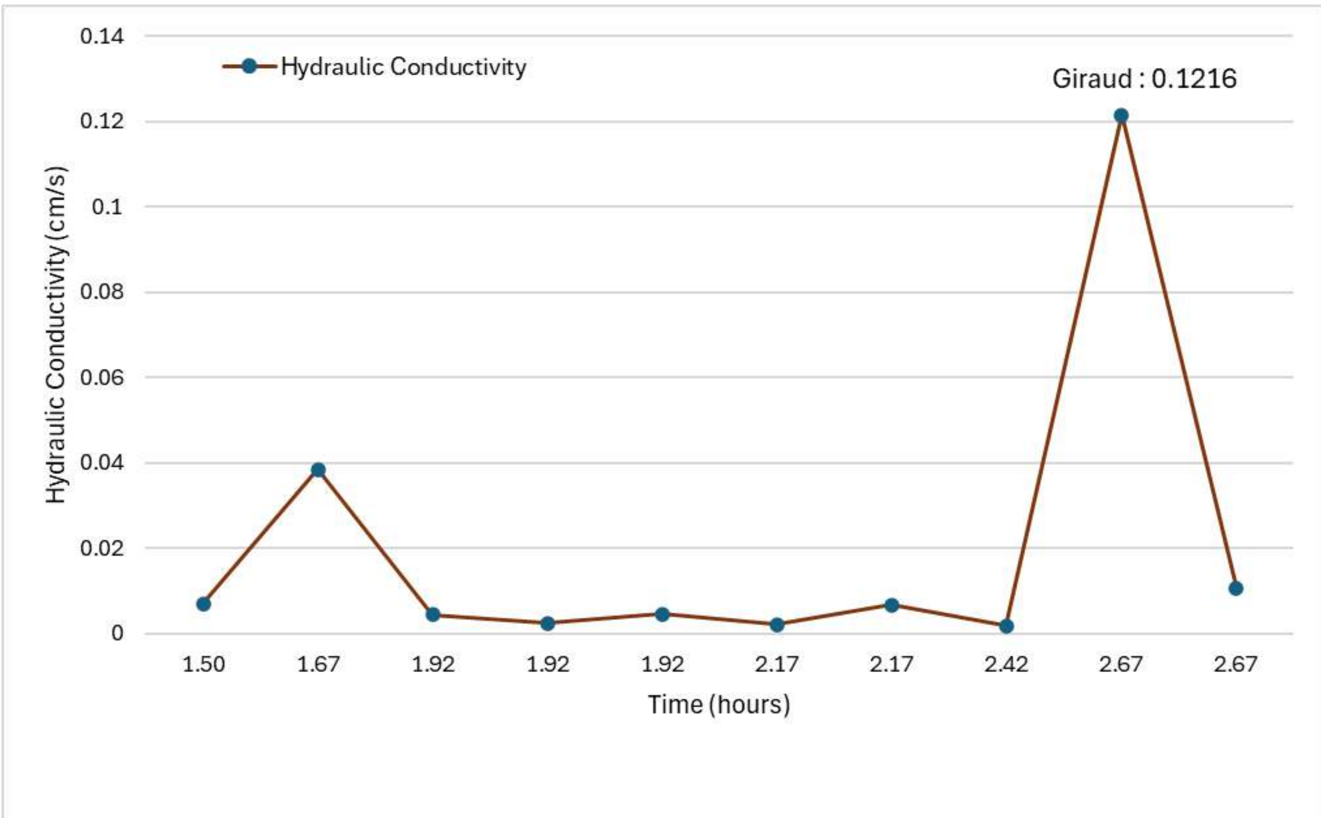


Figure 70 Hydraulic Conductivity Vs Time

Table 24 Average Infiltration rate during one hour

Sl.No.	Name	Average infilteration rate during one hour (cm)	time Hour	Hydraulic Conductivity
1	Mandhar	11.6	1.50	0.007
2	Bahesar-2	27.6	1.67	0.0385
3	Tulsi	6.7	1.92	0.00432
4	Airport Mana	3.4	1.92	0.0024
5	Kamal Vihar	6.8	1.92	0.00459
6	Semaria-2	3.2	2.17	0.00215
7	Chicha	10.2	2.17	0.0067
8	Mujgahan	2.7	2.42	0.00174
9	Giraud Raipur	15.6	2.67	0.1216
10	Pirda	13.5	2.67	0.01069

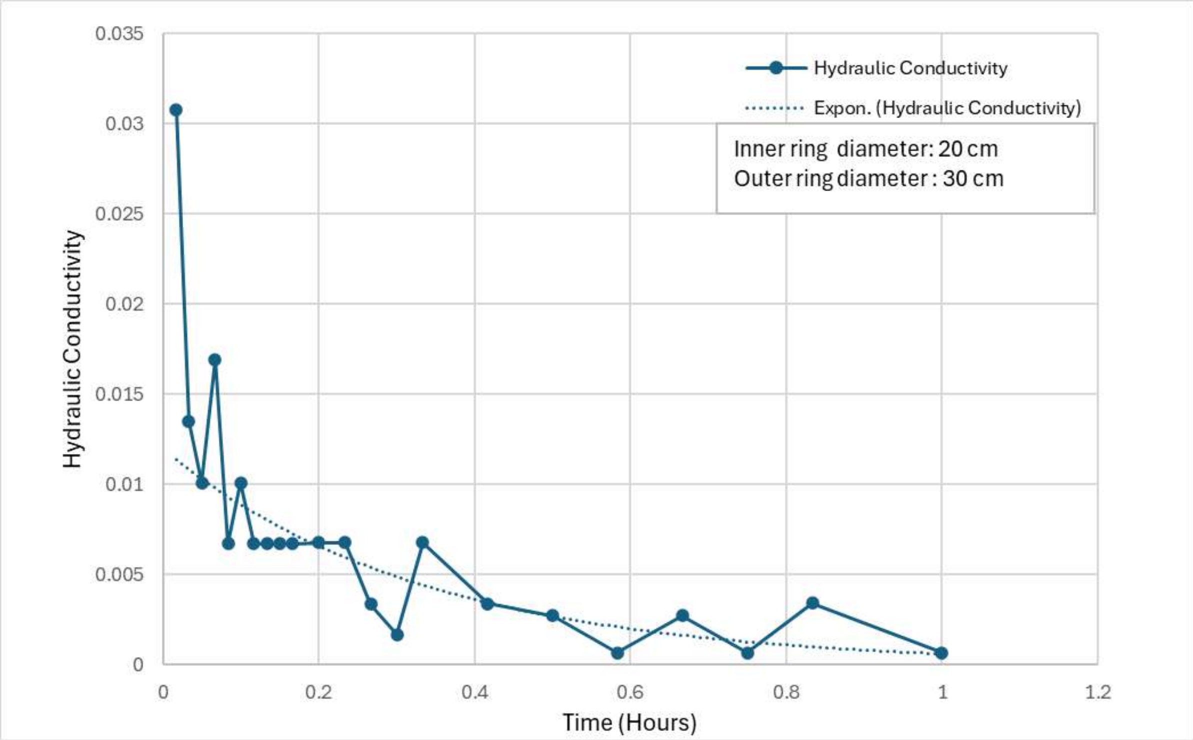


Figure 71 Hydraulic Conductivity Vs Time Plot of Mandhar

Table 25 Infiltration test conducted in the study area

Sr. no	Name	Latitude	Longitude	Average infilteration rate (cm/hr)	Geology	Land use	Soil type
1	Mandhar	21.3590887	81.6829101	11.6	Stromatolitic Dolomitic Limestone	Barren land	medium black soil
2	Giraud Raipur	21.332900	81.678982	15.6	Stromatolitic Dolomitic Limestoneand deodongar shale	Barren land	medium black soil
3	Bahesar-2	21.3788115	81.6267778	27.6	Stromatolitic Dolomitic Limestone	Barren land	medium black soil
4	Tulsi	21.2662171	81.7561582	6.7	Stromatolitic Dolomitic Limestone	Barren land	medium black soil
5	Semaria-2 (Gautam) Raipur	21.310036	81.735808	3.2	Stromatolitic Dolomitic Limestone	Barren land	medium black soil
6	Airport Mana	21.1989616	81.7553089	3.4	Stromatolitic Dolomitic Limestone	Barren land	Lateritic soil
7	Mujgahan	21.1499246	81.6638972	2.7	Stromatolitic Dolomitic Limestone	Barren land	medium black soil
8	Kamal Vihar VY-HOSPITAL	21.1888795	81.672660	6.8	Stromatolitic Dolomitic Limestone	Agriculture land	medium black soil
9	Pirda Ring Road Number 3	21.2678218	81.7327891	13.5	Stromatolitic Dolomitic Limestone	Agriculture land	medium black soil
10	Near sector 7 chicha atal nagar new raipur	21.2005239	81.7772289	10.2	Stromatolitic Dolomitic Limestone	Barren land	Lateritic soil

CALCULATION OF GROUNDWATER RESOURCES FOR RAIPUR URBAN AREA

Table 26 Formation wise Groundwater Resources of Raipur Urban Area (values in HAM)

Area Type and Aquifer	Total Area	Recharge Worthy Area	Recharge from rainfall	Recharge from other sources	Annual ground water recharge	Natural Discharge	Net ground water availability	Extraction			Total Draft	Stage of Extraction	Category
								Domestic Draft	Irrigation Draft	Industrial draft			
Raipur Urban Area	504	504	5136.9	869.95	6006.49	600.65	5405.84	4833.7589	564.514	592.9164	5991.19	110.8281	Over Exploited

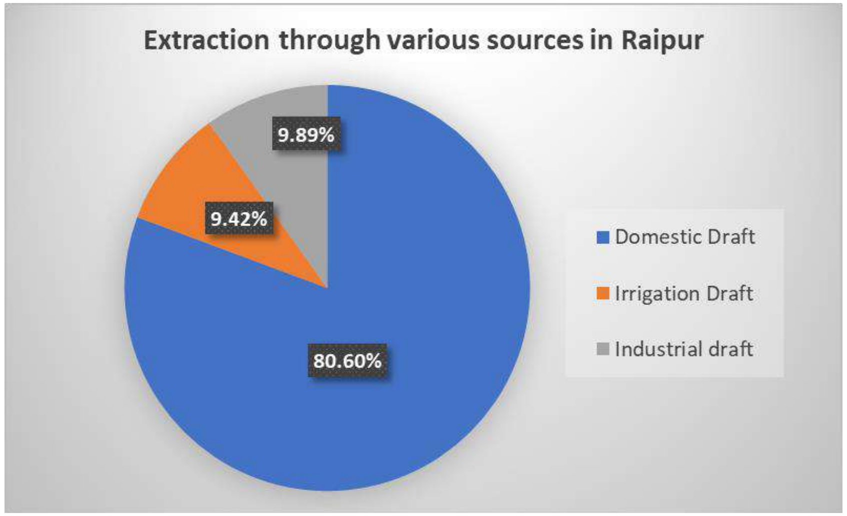


Figure 72 Extraction through various sources in Raipur

The stage of groundwater extraction is 110.82 % and the Raipur Urban Area falls under over exploited category. The Domestic extraction in the Raipur city is 4833.75, Industrial Extraction is 592.91 and Irrigation draft is 564.514 as shown in the following table no 27.

Table 27 Inflow/Outflow Components

Sr. no	Inflow/Outflow Components	Values in Ham (from NAQUIM 2.0)
1	Rainfall Recharge	5136.9
2	Groundwater Irrigation	203.92
3	Tanks and Ponds	635.91
4	Water Conservation Structures	29.76
5	Total Ground water Recharge	6006.49
6	Annual Extractable Ground Water Resources	5405.84
7	Domestic Extraction	4833.75
8	Industrial Extraction	592.91
9	Irrigation Draft	564.514
10	Total Draft	59991.17
11	Stage of Extraction	110.82%

CHAPTER 7

GROUNDWATER MANAGEMENT

7.1 OBJECTIVE

Groundwater management encompasses various strategies aimed at ensuring sustainable utilization of this vital resource. Two primary approaches to groundwater management are demand-side management and supply-side management, each addressing different aspects of groundwater use and conservation.

Demand-side management focuses on reducing the demand for groundwater by implementing measures to increase efficiency, promote conservation, and manage consumption. This approach often involves implementing water-saving technologies, promoting water-efficient practices in agriculture, industry, and urban areas, and raising awareness about the importance of water conservation. By reducing the overall demand for groundwater, demand-side management helps to alleviate pressure on groundwater resources, mitigate the risk of overexploitation, and ensure long-term sustainability.

Supply-side management, on the other hand, involves strategies aimed at increasing the availability of groundwater resources to meet existing and future demand. This approach includes measures such as artificial recharge, rainwater harvesting, groundwater banking, and conjunctive use of surface water and groundwater. By enhancing the recharge of aquifers and optimizing the utilization of available groundwater resources, supply-side management aims to maintain adequate groundwater levels, improve water security, and meet the diverse needs of society.

Results and Discussion

ISSUES

The issues identified in the study area are as follows:

I. Growing population and corresponding increase in groundwater draft.
II. Urbanization and reducing recharge area.
III. Depleting groundwater levels and quality and groundwater over exploitation.
IV. Drying of dug wells.
V. Ground Water Quality Management Interventions, including demarcation of safer aquifers.
VI. Waste disposal pattern and groundwater quality issues.
VII. Proper Management of treated Kharun River water.
VIII. Storm Water management.
IX. Nitrate contamination.

7.2 FINDINGS

1. Proper management of Treated water is not done in the urban area and the remaining water from WTP after supply through piped networks is left in the river itself. The remaining water can be provided to major industries through pipes/ canals in the Urla and Siltara area.
2. The existing canals in the city should not be filled with earth material for development/ beautification/ flattening. The canals in the area act like recharge structures and go through areas not covered by drainage/ nalas.
3. **Built-up area increased approximately 2.1 times** from 2013 to 2023 due to rapid urbanization.
4. A significant part of the area is under perched water conditions although this water is hardly being utilized due to underutilization of dug wells and more reliable on deeper wells Depth to Water Level during the pre-monsoon is in the range of 10-20 m in 49% of the area.
5. General Groundwater quality is good but **Nitrate concentration in 21% of sample is >45 mg/L is found**.
6. High Nitrate in parts of Jora, Kota, Mana Basti, Sarora, Tuta and Urla Basti due to over utilization of fertilizers and unscientific Sewage disposal.
7. Groundwater is of **Ca-Mg-HCO_3 type** indicating rock water interaction.
8. **E-Coliform contamination in almost 90%** of the samples analyzed.
9. Built up area may be utilized for rooftop rainwater harvesting. It has been found that since 2000 many RTRWH structures has been built but there has been no significant increase in water level conditions causing major challenge in managed aquifer recharge.
10. **Sarona dumping yard** is contaminating the Ground water with increased nitrate. It should be **shifted outside the urban area on impermeable strata.**
11. Limestone quarries are present in the area where **continuous dewatering is done which is contributing to the deepening of groundwater levels** in and around the area.
12. A Total 49 nos of major ponds along the city should be selected for de siltation/ deepening to increase water storage capacity.
13. Restoring and proper Utilization of canals.

7.3 WATER CONSERVATION PLAN

7.3.1 Supply side Management

Runoff Calculation

The Soil Conservation Service (SCS) Curve Number (CN) method is a widely used empirical approach for estimating direct runoff from rainfall events in watersheds. Developed by the United States Department of Agriculture's Natural Resources Conservation Service, this method considers the influence of soil, land use, and antecedent moisture conditions on runoff generation. The CN method assigns a curve number to each land cover type and soil condition, representing the watershed's hydrologic characteristics. These curve numbers range from 0 to 100, with lower values indicating high infiltration and lower runoff potential, while higher values correspond to reduced infiltration and increased runoff. By integrating factors such as soil permeability, land cover, and rainfall intensity, the CN method provides a simple yet effective means of estimating direct runoff volume, making it valuable for hydrological modeling, land use planning, and water resource management. Despite its simplicity and widespread application, the CN method requires careful consideration of local conditions and calibration to ensure accurate runoff predictions.

Table 28 Precipitation and Runoff Table

Year	Total precipitation mm	Total runoff mm	% Runoff
2020	1640.04	321.75	19.61
2021	1502.84	208.13	13.84
2022	1408.01	363.6	25.8

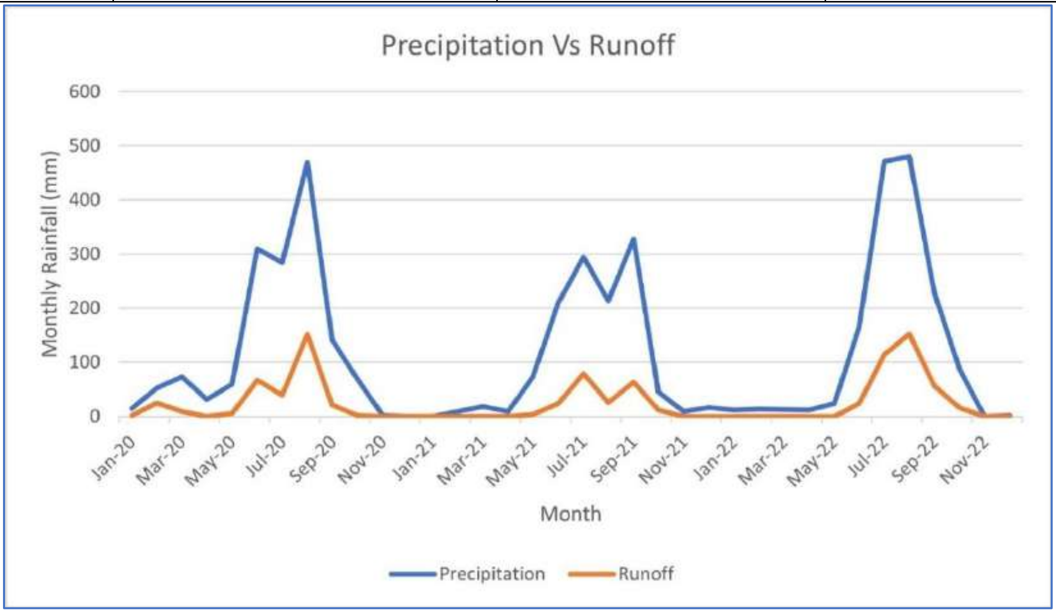


Figure 73 Precipitation Vs Runoff

7.3.1.1 Water Conservation for Urban Sprawl

The Urban Sprawl water resources is complicated due to lack of unpaved space. Hence, the paved areas which contain mainly the dense habitations are suitable for roof top rainwater harvesting and garden pond and urban ponds development and urban recharge structures which includes.

Raipur urban area is categorized as critical from ground water development point of view and the stage of development has already attained 92%. The dependence on ground water is bound to increase more in the future. Thus, it is imperative to plan for augmentation of ground water resource in the city area. Keeping in view the land availabilities and feasibilities, the following interventions are recommended

1. Roof top rainwater harvesting at building level.

Out of a total area of 504 km2 areas, the paved area is 189.14 sq. km for rooftop rainwater harvesting in urban. Normal no monsoon rainfall in RUA is 0.143m. There are nearly 264427 households in the city.

Assuming a total roof area of 500.0000 ha and a harvesting efficiency of 20%, total volume of harvested water will be nearly 14 mcm, which is a significant amount. Hydrogeological investigation is a prerequisite for groundwater recharge. Further, close-net telemetry monitoring of rainfall and weather forecasts over the city will enable harvesting runoff at suitable sites. It is needed to implement measures to make sure that rainwater falling must be tapped to maximum possible extent. These RTRWH can be connected through proper pipes and filters to recharge existing dug wells and bore wells. As on date only 9016 nos. of Buildings are completed with RTRWH structure in Raipur remaining buildings may be taken on priority to complete the RTRWH to catch the available rain water.

2. Pond Management Plan:

There are total of 49 nos. of surface water bodies in Raipur city, which covers 980-hectare area.

Limestone ponds: Ponds in the limestone covered areas are already effective recharge structures. Water in these ponds remains for nearly 180 days in a year. Desilting and deepening of these ponds by 6 meter will increase the water storage, but the increase in ground water recharge is expected to be only marginal.

Sandstone shale ponds: On the other hand, the ponds on the sandstone and shale covered areas practically do not contribute to ground water recharge in their present state. Thickness of the upper sandstone is not more than 2m in most parts, thus the base of all these ponds is shale, which does not allow percolation. Thickness of this shale layer is upto 30 m, below which stromatolitic limestone is encountered. This stromatoltic limestone is a potential aquifer. Thus it is suggested that to increase recharge efficiency, inverted wells or recharge shafts be constructed within these ponds. These ponds should also be desilted to increase the water storage and recharge efficiency. It is important to note that ponds in the urban areas in many cases are polluted by urban wastes, so special care should be taken to go for a complete hydrochemical and biochemical assessment of individual pond water, before constructing recharge wells. Unless the pond water is of suitable quality it should not be used for ground water recharge.

Further, though there are a total of 49 major such water bodies, it is recommended that only those water bodies, whose area is more than 1000 m2 be considered for construction of recharge wells and the recharge wells should be constructed in such a way that a minimum water column of 2m is maintained in the pond. This is to ensure that silt does not enter the recharge well and a minimum water level is maintained in the pond.

Construction of recharge wells and cost estimates

One bore well is to be constructed in each pond, which means 49 borewells are to be constructed. Each borewell may be of 70m depth and an associated insitu filter is to be constructed. Average rate of construction of a bore well is around Rs 1500 per m and the average cost of construction of the filter is 20000. Thus the unit cost of each installation will be around 125000. Total cost of construction of 49 bore wells will be 61,25,000 lakhs.

3. Rainwater harvesting at City level

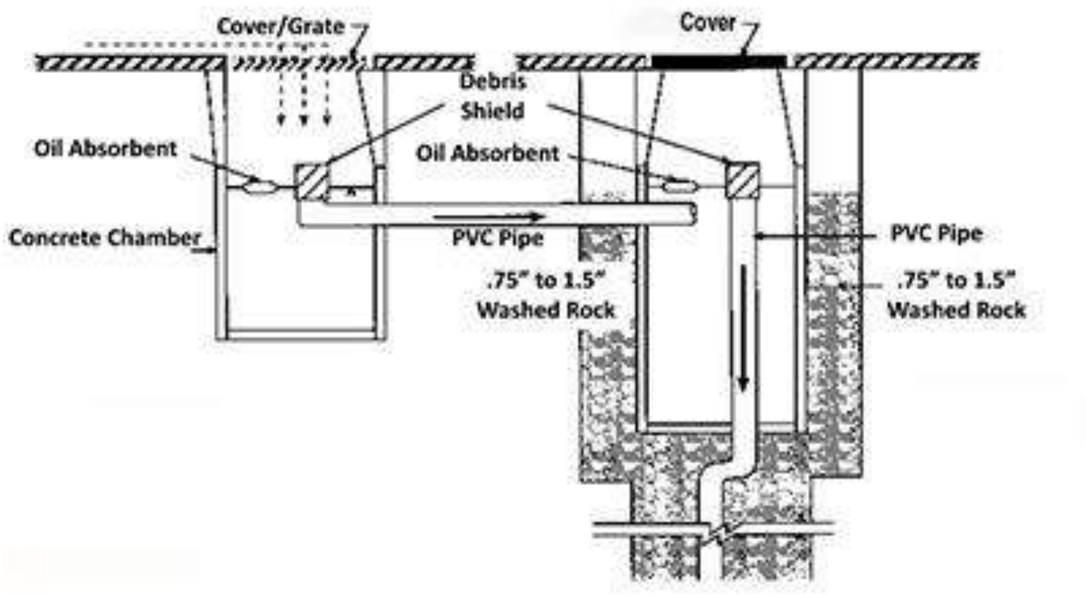
Attending the run of Urban runoff can be retained on site by certain design strategies and details such as green roofs to existing and new buildings, rain garden, permeable/ porous pavement, swales, filtered catch basins, tree grates, irrigation of public open space, storm water mitigations incorporated in street designs, maintenance of storm chambers and proper diversions to storm water.

In a typical community approximately 65% of the impervious surface is associated with transportation, which includes parking lots and roads. Run off from large parking lots can be retained and recycled for more greenery by use of porous surfaces

Water conservation and storm water drainage are two aspects of water management in cities. As these two areas overlap, water harvesting techniques will not succeed without a well- planned storm water drainage system.

3. Artificial Recharge through Stormwater Drains:

Stormwater can be utilized through drains to channel water by Modifying existing stormwater drains to direct excess runoff into recharge trenches, pits, or wells. Efficiently utilizes stormwater, which is often wasted, and helps in recharging groundwater. Storm water flows into a concrete chamber. The chamber allows time for the settling for solid. Storm water is passed through and oil absorbent matrix prior to entering the infiltration chamber where it may be subjected to additional pretreatment for recharge.



4. Soakaways:

These are essential structures in urban water management, particularly effective in areas with significant impervious surfaces like roads and pavements that prevent natural water infiltration. A hole is dug in the ground, typically ranging from 1 to 2 meters deep and 1 to 1.5 meters wide, depending on the volume of water it needs to handle. The pit is filled with coarse aggregate materials like gravel, crushed stones, or bricks. This filling creates void spaces that can hold water temporarily. Water from roofs, roads, or other catchment areas is directed into the soakaway through a pipe or channel. The inlet may include a silt trap to prevent debris from entering the soakaway. It helps in manage excess stormwater, reducing the risk of flooding.

5. Green Building for Water Conservation:

For efficient use, management, and recycling of water within the built environment. It can be achieved through various design strategies, technologies, and practices that minimize water consumption, reduce wastewater generation, and maximize the use of alternative water sources like rainwater and greywater.

Which includes Installation of low-flow faucets, dual-flush toilets, and water-efficient irrigation systems to reduce water consumption. Collecting and storing rainwater for non-potable uses like irrigation, flushing toilets, or cooling systems. Reusing water from sinks, showers, and washing machines for landscaping or toilet flushing.

6. Water Quality Considerations

Most important aspect of ground water development in the city is sustaining ground water quality. It has been pointed out in many reports that the karstic limestone terrain in Raipur Urban area is highly vulnerable to pollutions especially when the urban waste dump sites are located above them. It is recommended that all the urban waste dump sites be relocated to low lying shale covered areas. In addition to the above recommended interventions to increase the supply, it is also imperative to reduce groundwater demand by adopting water efficient lifestyle. The success of any programme finally depends on people's participation.

7. Public campaign and awareness sand participation

The people, NGO, and Government should work jointly together and implement the rainwater harvesting in a big way in all places in the years to come to achieve a sustainable goal. There is a suggestive need to study the policy formulation measures with the efficient management of available water, and legislative measures supporting them. Locals are to be sensitized on issues related to depleting of the ground water resources.

8. Abandoned mine Pit:

Utilizing the water from abandoned mine pits near Mandirhasaud, Dhansuli, Dondekala, Jarauda, Cherikhedi, Murethi, Mathiya, and Doundikhurud, which cover an area of 625.8876 hectares, for community purposes is a viable idea. Given the significant volume of water in these pits, it could indeed be beneficial for domestic uses and irrigation, provided that the water undergoes proper quality checks and necessary treatments. The treatment process could include filtration, chemical treatment, and disinfection (e.g., chlorination or UV treatment). After treatment, the water can be stored in overhead tanks constructed in the vicinity of these areas.

A piped network can be developed to supply the treated water from overhead tanks to nearby communities and agricultural lands. As well as the water can also be pumped in nearby canals which will ultimately recharge the areas near canals.

Sr. no	Mine Pit	Area in hectare
1	Quarry 1 (Dhansuli)	304.7781
2	Quarry 2 (Mandirhasaud)	178.480
3	Quarry 3 (Dondekala)	70.6448
4	Quarry 4(Dondekhurud)	33.6391
5	Quarry 5 (Jarauda)	12.102
6	Quarry 6 (Matiya)	26.2436

Table 29 Area of different Quarry near the study area

9. Bioremediation:

As per the remote sensing analysis the Kharun river stretches from river near Indraprath/ wonderland to Chandandih having stretch of 6,405.55 m second stretch starting near IIT Heerapur and third stretch near Atari to Parastarai area having stretch of 6356.46 is highly contaminated by algae which dissolve the oxygen of water body. The in-situ microbial techniques should be used for the treatment of river water are the plant-assisted floating bed technique in which plants like water hyacinths, reeds, and cattails are used to absorb, concentrate, and metabolize contaminants from the water.

10.Increasing water supply connections:

The water piped networks should be increased which will cover the areas with surface treated water supply, as on date 156151 nos. of piped connections are present in Raipur city. Many major societies are not covered under pipeline connections due to which stress on ground water is increased.

7.3.1.2 Suitable Structures for Water Conservation Measures

A detailed analysis of the overall hydrogeology, water consumption, and recession analysis reveals that being placed at the upper catchment of the Kharun watershed. The base flow of water from the upper catchment to the middle and lower catchment is not so fast due to the presence of Shale in the upper catchment so the water level is not much deeper in that part, while in the lower catchment due to the presence of limestone, urban area, industrial area and agriculture area depletion of water is very high. The water level depletion is at the rate of 0.007 meters per day. This depletion is recorded during October, November, and December when the water usage for agricultural purposes is at a bare minimum. An effective management plan will involve slowing the depletion rate. The Raipur city comprises of two types of units.

1. The Perched aquifer having water level at shallow depths suitable for recharge shaft/tank and pond.
2. The Limestone unit with a less uneven fracture distribution is suitable for Recharge Structures.

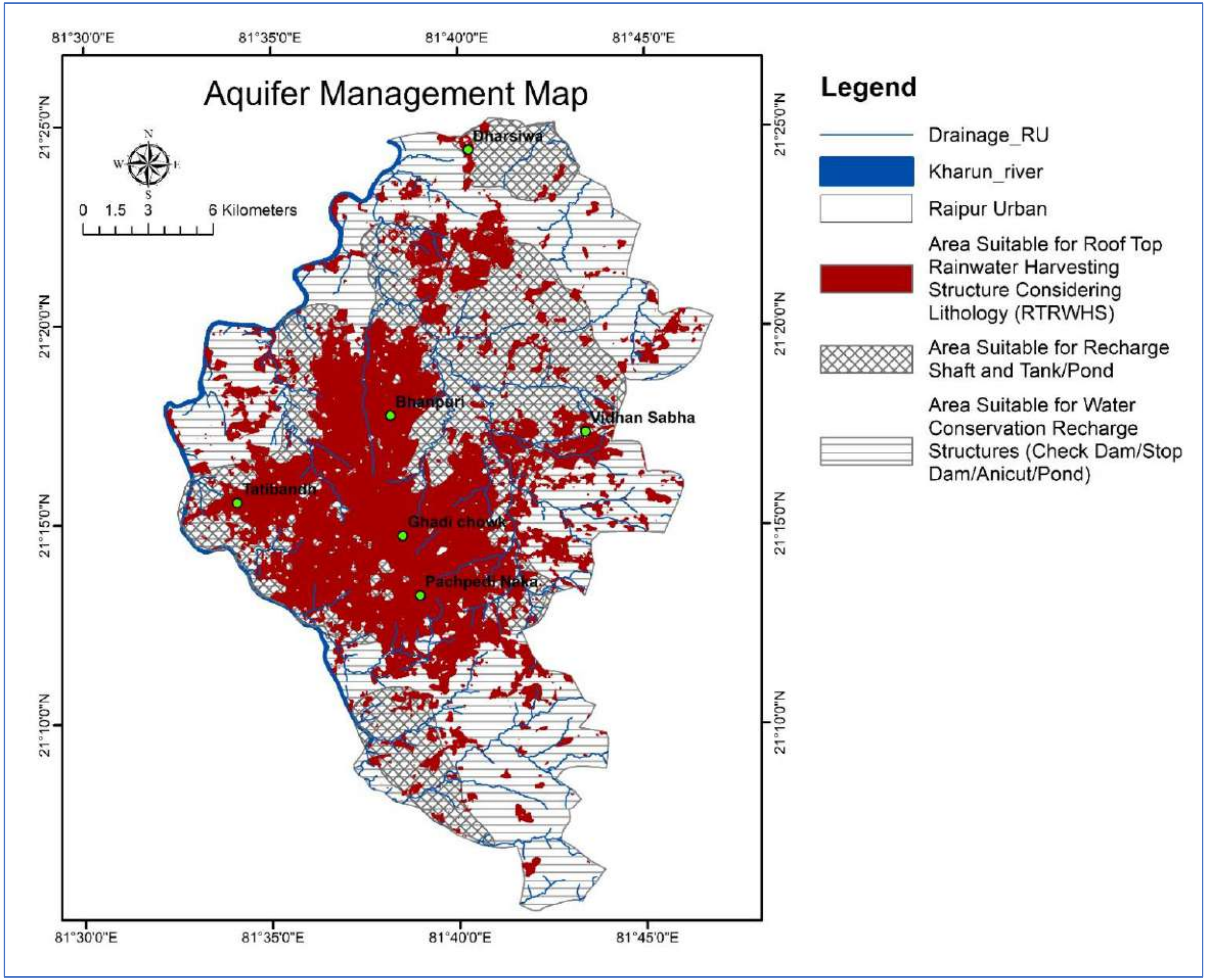


Figure 74 Aquifer Management Map

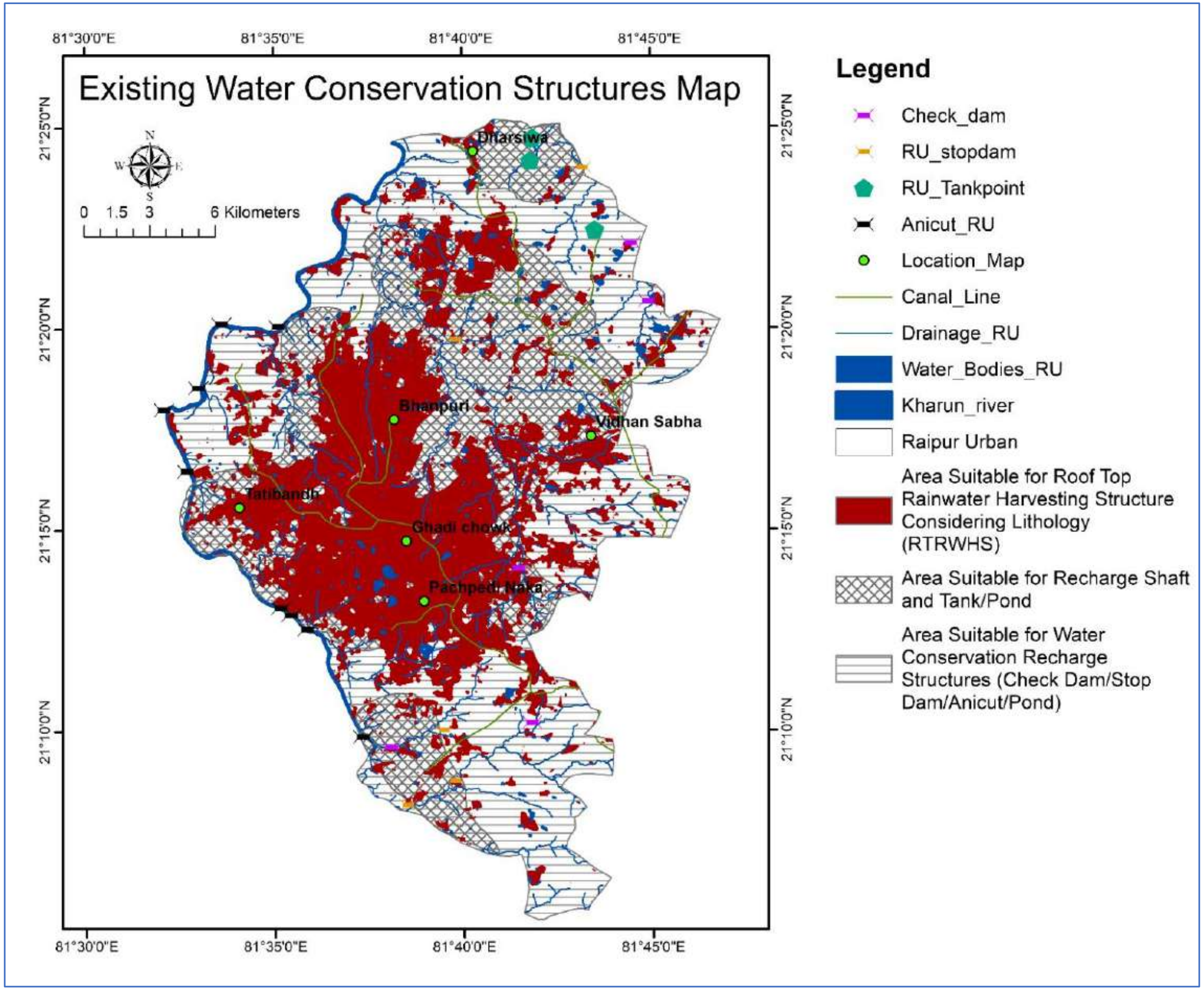


Figure 75 Existing Water Conservation Structures Map

7.3.1.3 Managed Aquifer Recharge (MAR)

From the detailed hydrogeological investigation, it is inferred that managed aquifer recharge is the prime requisite for tackling this scenario. Four objectives must be achieved through induced recharge for complete water security and overall economic development of the region:

1. Gravity Head recharge wells with Roof top rainwater harvesting.
2. Dug Cum Bore well recharge structure.
3. Reducing the depleting water level of the fractured Limestone Aquifer in the southern and northern portions by with recharge shafts or recharge wells.
4. Arresting the baseflow through Subsurface Dyke. But it can only be constructed after proper cleaning of drainage systems and construction of proper sewerage networks.

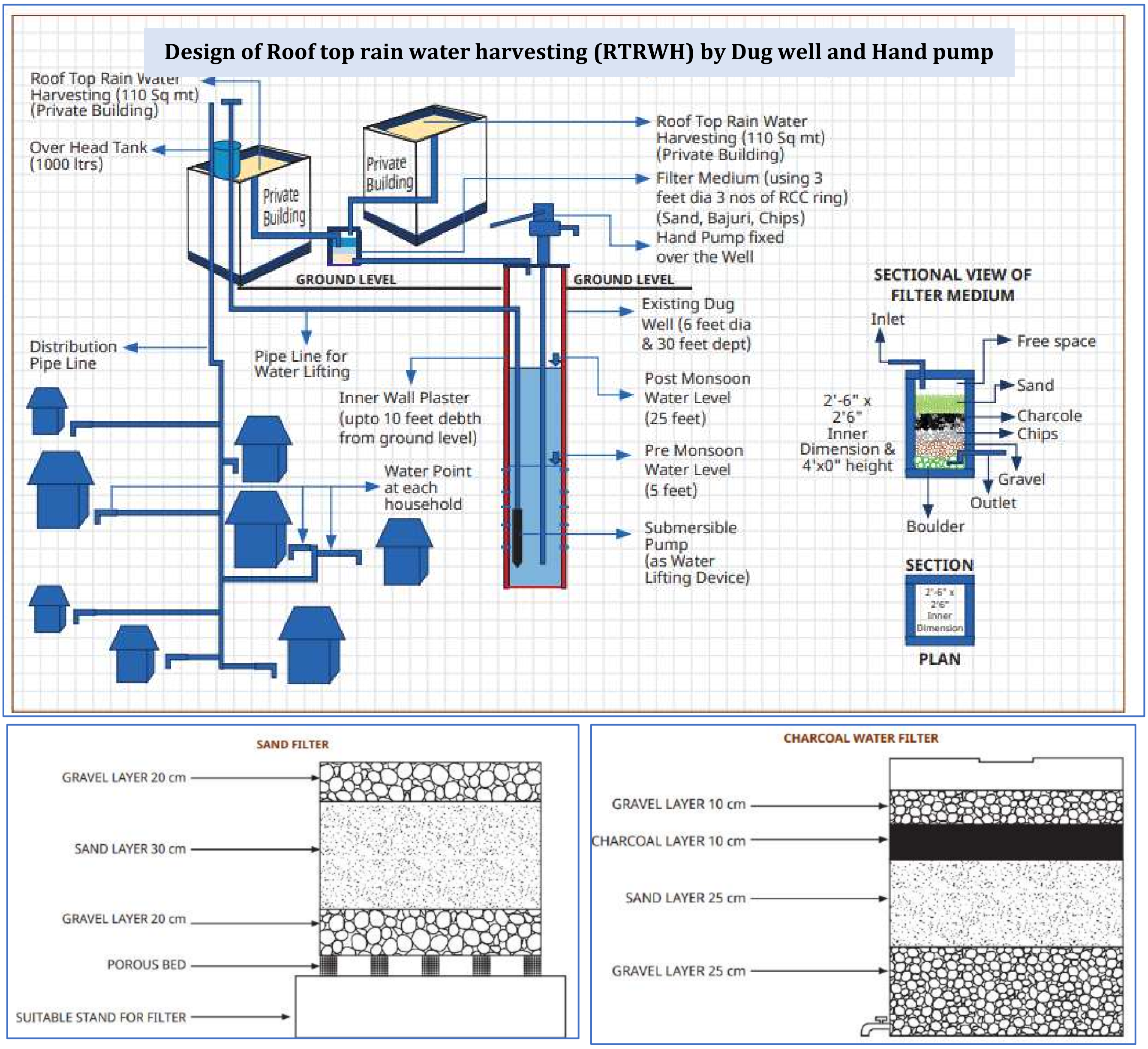


Figure 76 Design of Roof top rain water harvesting structure

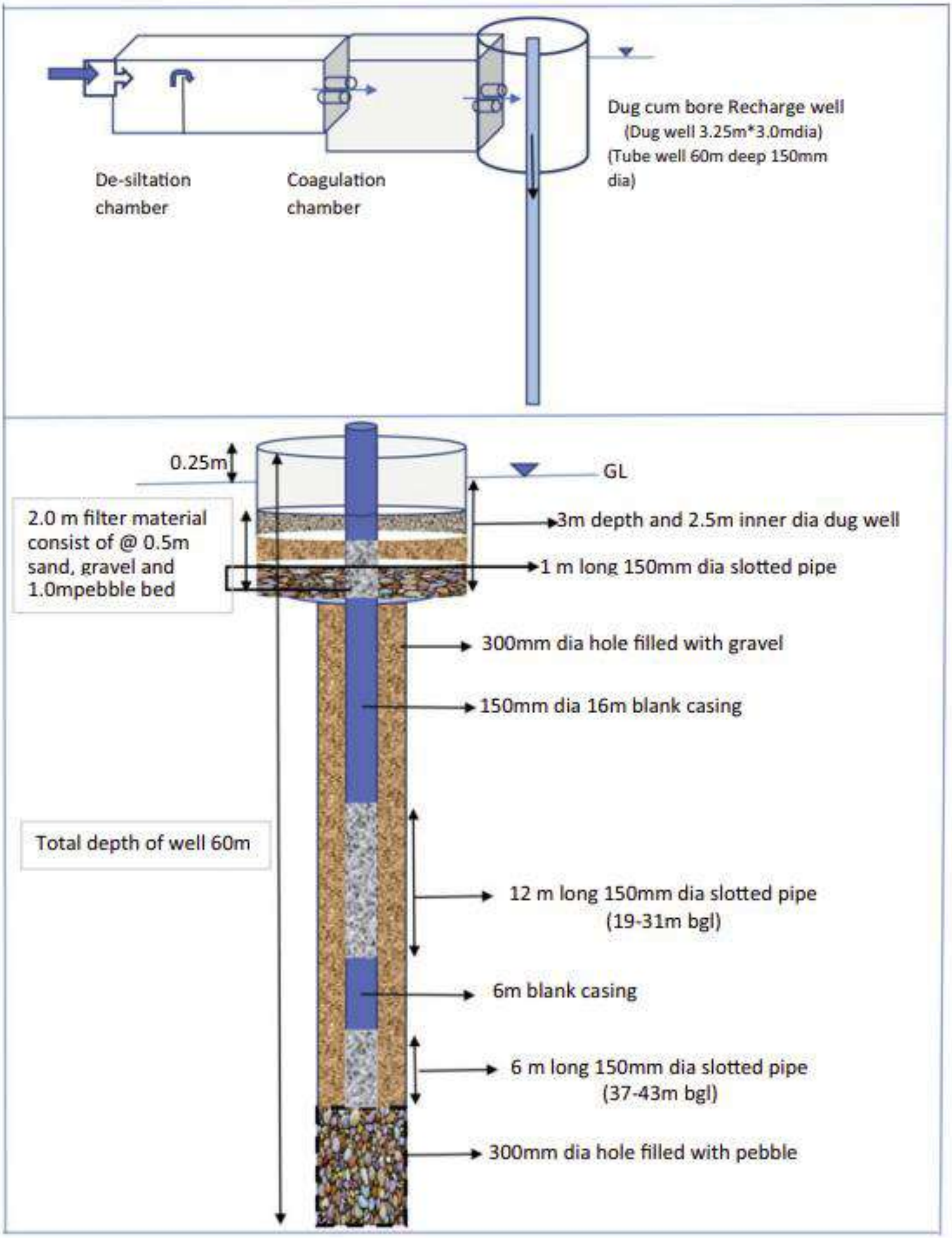


Figure 77 Dug Cum Bore well Recharge Structure

Proposed location of Percolation Tank in Raipur with tentative cost

The total 35 nos of village locations are proposed for construction of small to medium percolation tanks. Small to medium PT of dimension 20,000 sq feet or more may be made depending upon the availability of area in the particular villages.

Table 30 Proposed Percolation Tank (PT)

Sr. no	Village Name	Lat	Long
PT-1	Singar Bhatha	21.1071339	81.7113495
PT-2	Seoni_2 (Seoni)	21.1217403	81.6845856
PT-3	Dhusera	21.1463642	81.6946564
PT-4	Bhatgaon_1 (Bhatgaon	21.1559792	81.7193985
PT-5	Khilora	21.1253414	81.6718521
PT-6	Datrenga	21.148447	81.640686
PT-7	Temri	21.195652	81.7108078
PT-8	Daldal Seoni	21.2907639	81.6740112
PT-9	Giraud	21.3140736	81.6759109
PT-10	Barauda	21.2980862	81.7058487
PT-11	Chhapora	21.3138714	81.7243881
PT-12	Matiya	21.3349495	81.7414246
PT-13	Godhi_2 (Godhi)	21.3973312	81.7028961
PT-14	Boria Kalan	21.1724873	81.6851425
PT-15	Akoli_2 (Akoli)	21.35783	81.7022476
PT-16	Parastarai	21.3973522	81.6567001
PT-17	Tiwaraiya	21.4097576	81.6892166
PT-18	Tendua_1	21.289753	81.5591583
PT-19	Gomachi	21.2934818	81.5521622
PT-20	Sarora	21.2927246	81.5988388
PT-21	Guma_2 (Guma)	21.3108635	81.5727615
PT-22	Kachana	21.262846	81.7185135
PT-23	Sankari _3 (Sakari)	21.2764549	81.7430191
PT-24	Kumhari_1 (Kumhari)	21.3504658	81.6047363
PT-25	Kanhera (Kanheri)	21.3439026	81.6195755
PT-26	Giraud	21.352457	81.6823883
PT-27	Mohadi_1 (Mahadi)	21.3880596	81.6957397
PT-28	Dharsiwa	21.40382	81.6789551
PT-29	Nagargaon	21.374218	81.725708
PT-30	Barbanda	21.3502502	81.7277527
PT-31	Tor	21.3732624	81.7445831
PT-32	Bhatgaon_1 (Bhatgaon	21.1732903	81.719841
PT-33	Sejbahar	21.1639271	81.6765213

Calculating recharge by Percolation Tanks

Table 31 Calculation of recharge and costing

Sr no	Type	Calculation	Tentative Cost (in Lakh)	Tentative Recharge
1	Percolation Tank	Percolation Tanks= 33 nos. Dimension= 20,000 feet width X 10 feet Hight	13,20,000 @ 40,000/ PT (small to medium)	1,32,000 Cubic Meter = 0.132 MCM

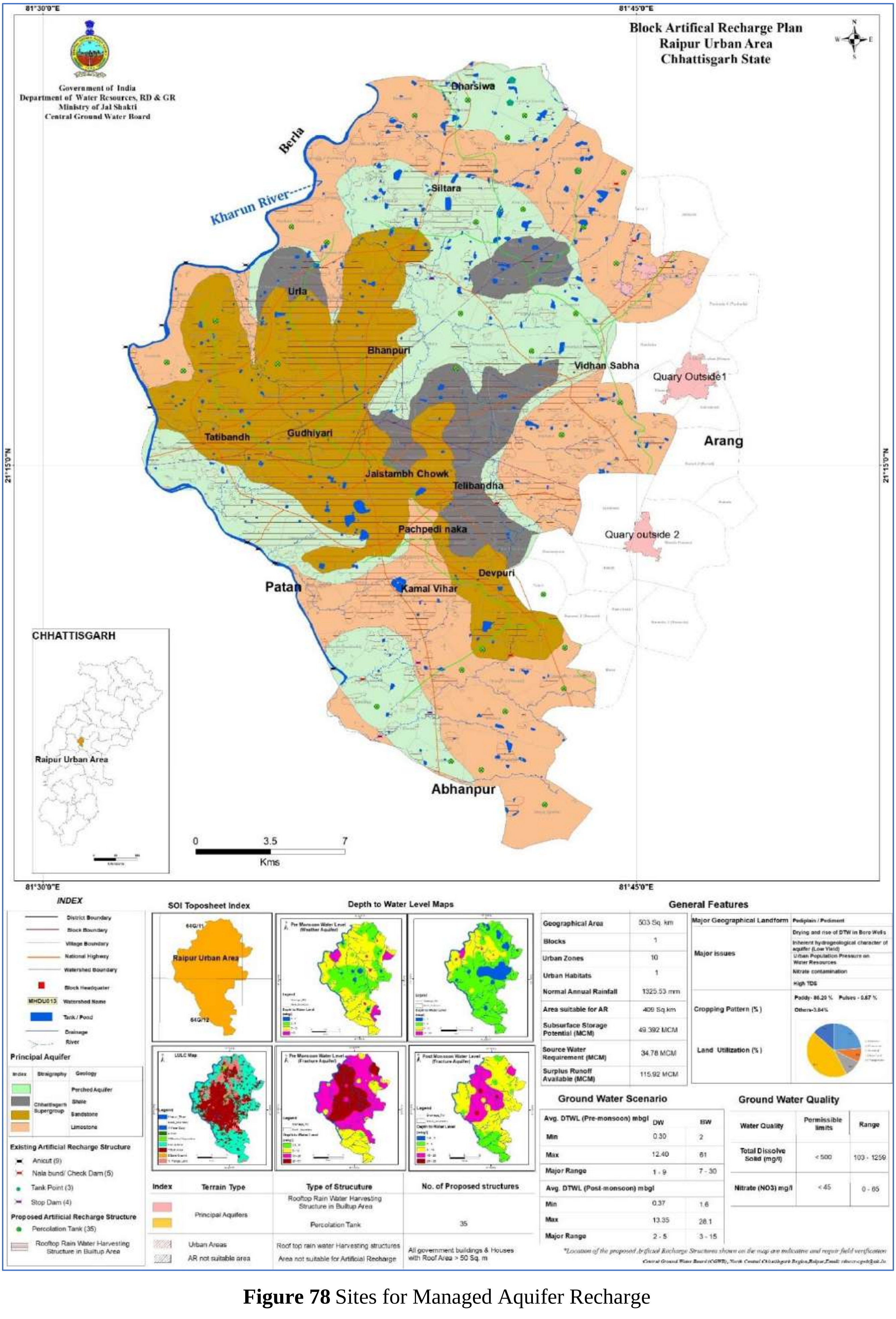


Figure 78 Sites for Managed Aquifer Recharge

7.3.2 Demand Side Management

The behavior analysis of farmers was carried out through farmer feedback forms which yielded the following results.

1. Model Building Bye Laws (MBBL) 2016 circulated by Ministry of Housing & Urban Affairs include provisions for Rainwater Harvesting and it has been shared with all the States / UTs. So far 35 States / UTs have adopted the provisions of rainwater harvesting of MBBL2016.
2. Central Ground Water Authority (CGWA) has been constituted under Section 3(3) of the “Environment (Protection) Act, 1986” for the purpose of regulation and control of ground water development and management in the Country. CGWA has advised States/UTs to take measures to promote/adopt artificial recharge to ground water / rainwater harvesting. CGWA grants No Objection Certificates (NOCs) for ground water abstraction to Industries, Infrastructure units and Mining projects in feasible areas in certain States/UTs where regulation is not being rainwater harvesting respective State/UTs. The latest guidelines for control and regulation of groundwater extraction with pan-India applicability was notified by the Ministry on 24 September 2020.
3. Installation of low flow taps, showerheads, and toilets in households, offices, and commercial buildings to reduce water usage.
4. Implementing a pricing structure where higher water consumption leads to higher rates, encouraging conservation among urban users.
5. Groundwater Extraction charges should be charged from users, particularly large-scale extractors like industries and large residential complexes, to discourage excessive groundwater withdrawal.
6. Regular audits of groundwater usage in agriculture, industry, and urban sectors to identify inefficiencies and opportunities for reduction.
7. Installing smart meters to monitor groundwater extraction in real-time, providing data for better management and control.
8. Encouraging or mandating the installation of greywater recycling systems in new buildings. Greywater from sinks, showers, and washing machines can be reused for irrigation, flushing toilets, and other non-potable purposes. Providing incentives or subsidies for retrofitting existing buildings with greywater systems.
9. Incorporating water efficiency and conservation criteria in green building certifications and urban planning regulations.
10. Upgrading old and leaking water distribution networks to reduce water loss, which indirectly reduces the demand on groundwater.

11. Developing infrastructure to capture and store stormwater for groundwater recharge or non-potable use.
12. Providing financial incentives for purchasing and installing water-saving appliances and fixtures.
13. Regulating and limiting groundwater extraction by industries, commercial establishments, and large residential complexes through a permit system.
14. Hydrogeological studies and chemical analysis of groundwater samples to be carried out around industrial clusters to analyse the groundwater conditions at regular time intervals. In industrial areas, strict monitoring and regulation of industries should be done.
15. As the Karun River is present along the boundary of Raipur City the dependency on groundwater sought through conjunctive use, strategies should focus on optimizing the use of surface water and managing both resources effectively to ensure sustainability.
16. The treated water from water treatment plant if in excess may be supplied to the major industries through proper piped networks or canals. The excess treated water should no be diverted again in the river as practice.
17. Ultimately the proper usage and Management of Surface water through proper planning may be done to reduce the stress.
18. Conjunctive use of water resources like creation of more ponds may be given importance. Deepening of existing ponds.
19. Protection of wetlands from encroachment may be taken on priority.
20. The source of nitrate in ground water is mostly anthropogenic. Hence, dug wells in the affected areas are to be substituted by borewells or tubewells to avoid the phreatic aquifer.
21. Creation of Sewage Treatment Plant (STP) in urban should be given due importance to prevent ground water contamination.
22. Recycle/reuse of ground water in urban area may be strongly encouraged particularly in Raipur town.
23. Under the Smart City Project the renovation work of city ponds Raipur should be done. In which pathways, peaching works, electrification, gardens, land scrapping, should be built.

CHAPTER 8

CONCLUSION AND RECOMMENDATIONS

8.1 CONCLUSION

1. The Raipur Urban area is 504 km^2 within the Chhattisgarh basin, has a diverse geography characterized by structural plains and a well-drained river system conducive to industrialization, the area supports an urban majority of its 11,58,462 population and nearby villages, primarily engaged in farming.
2. Geologically the area comprises of Chandi limestone of the Paleoproterozoic Chhattisgarh Supergroup covering 57.14% area of the central and southern region. The rest 42.86% area is covered by Deodongar Sandstone and Deodongar Shale which forms the Perched Aquifer condition in the Raipur City.
3. The climate is subtropical and the block receives substantial rainfall, averaging 1,398.2 mm annually with rainfall showing a rising trend of 0.48 mm/year.
4. Fractured Chandi limestone and Deodongar Sandstone and Deodongar Shale form the major aquifer system of the study area. The transmissivity of these aquifer ranges from 0.2 m2/day to 121.7 m2/day.
5. The depth range of the weathered aquifer is 6-31.95 m with an average yield lying upto 10 LPS and the first fracture depth ranged from 14 to 64.7 m mbgl with an average yield upto as high as 10 LPS, whereas the depth of second fracture ranged between 19.8 to 182 mbgl with average yield upto 2 LPS.
6. The pre-monsoon water level in Phreatic Aquifer ranged from 0.30 to 21.61 mbgl and postmonsoon water level ranged from 0.37 to 15.24 mbgl whereas the seasonal fluctuation ranged from -7.10 t0 7.16 meters.
7. The pre-monsoon water level in Fractured Aquifer ranged from 2 to 61 mbgl and post monsoon water level ranged from 1.6 to 28.1 mbgl whereas the seasonal fluctuation ranged from -6.11 t0 37.31 meters. One high-yielding well was drilled in Chikhali, Raipur with transmissivity 29.67 m2/day and a yield of 10LPS.
8. As per Ground Water Resource Estimation calculated in 2023 the stage of groundwater development was 94.07% and as per the calculation of resources for the study for Raipur city the ground water resource calculated is 110.82 % which makes the city over exploited in year 2024.
9. The decadal ground water trend showed a falling trend for most of the wells.
10. The water quality is suitable for drinking and agricultural use except in a few areas where nitrate has been found above the permissible limit. The range varies up to 73 mg/l.

8.2 RECOMMENDATIONS

1. All buildings should have proper Roof Top Rain Water harvesting (RTRWH) System with annual maintenance as per the Model Building Bye Laws (MBBL) 2016 circulated by Ministry of Housing & Urban Affairs include provisions for Rainwater Harvesting .
2. All infrastructure projects like (Apartments/Hotels/Educational institutions/Hospitals) must have connections of Nagar Nigam water supply for surface water.
3. Hon'ble Prime Minister launched Amrit Sarovar Mission on 24th April 2022. The Mission is aimed at developing and rejuvenating 75 water bodies in each district of the country as a part of celebration of Azadi ka Amrit Mahotsav. Urban ponds can be developed under this mission.
4. All new industries should come up with 100 % utilisation of surface water as Dharsiwa block is in Critical Category to check depletion of ground water level.
5. All existing industries must partially use treated or recycled water to reduce draft of Ground Water and check the decline of ground water resources
6. A detailed inventory of Raipur municipal, industrial, and commercial water wells/ BW/ TE (including up-dating the administrative status of their use rights and socio-economic profile of users).
7. Registering all multi-residential, commercial, and industrial users, and charging (directly or indirectly) should be done for abstraction to constrain use.
8. Implement strict regulations to prevent the use of septic systems in areas where sewer systems are available or planned. Alternative sanitation solutions should be provided such as composting toilets in slum areas.
9. Conjunctive use of water resources may be given priority.
10. Urban Canals in must be revived, maintained and protected as they play a significant role in groundwater recharge.
11. The source of nitrate in ground water is mostly anthropogenic. Hence, dug wells in the affected areas are to be substituted by borewells or tubewells to avoid the phreatic aquifer.
12. Recycle/reuse of ground water in urban area may be encouraged particularly in Raipur town.
13. Creation of more Sewage Treatment Plant (STP) in urban areas should be given due importance to prevent ground water contamination.
14. Community level Mass awareness programs about conservation and protection of water to be generated through media campaigns, seminars etc.

15. Central Government supports construction of water harvesting and conservation works primarily through Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) and Pradhan Mantri Krishi Sinchayee Yojana – Watershed Development Component (PMKSYWDC).
16. Banning of Summer Paddy. Summer paddy could only allow if surface water irrigation sources are available.
17. The ponds present in the limestone already act as a percolation tank. It may deepen to increase the storage.

Annexure 1 Details of key wells established in Raipur Block

Sl. No	Village	Block	District	Longitude	Latitude	WL Pre M May (m)	WL Post M Nov (m)	Fluctuation	Year	Source
1	Chelikhedi	Dharsiwa	Raipur	81.7377036	21.2337989	16.7	13.7	3	2024	HP
2	Deori	Dharsiwa	Raipur	81.6907284	21.4695301	2.85	2.87	-0.02	2024	DW
3	Kapasda	Dharsiwa	Raipur	81.687281	21.431246	1.8	2.02	-0.22	2024	DW
4	Kukera	Dharsiwa	Raipur	81.7123077	21.4528521	4.2	1.95	2.25	2024	DW
5	Charoda	Dharsiwa	Raipur	81.6709809	21.3931685	1.15	1.9	-0.75	2024	DW
6	Chelikhedi	Dharsiwa	Raipur	81.7377036	21.2337989	16.4	10.02	6.38	2024	HP
7	Kurud	Dharsiwa	Raipur	81.7726953	21.2531582	7.72	9.14	-1.42	2024	HP
8	Murethi	Dharsiwa	Raipur	81.792365	21.2786834	16.63	10.46	6.17	2024	HP
9	Nagpura	Dharsiwa	Raipur	81.8387216	21.3090734	2	1.98	0.02	2024	HP
10	Semariya	Dharsiwa	Raipur	81.7337071	21.3090037	6.63	4.42	2.21	2024	HP
11	Saragaon	Dharsiwa	Raipur	81.8024159	21.3765124	6.74	5.27	1.47	2024	HP
12	Matiya	Dharsiwa	Raipur	81.7570477	21.3390101	8.13	5.98	2.15	2024	HP
13	Dundekhurd	Dharsiwa	Raipur	81.7535484	21.3267313	10.78	7.3	3.48	2024	HP
14	Tekari	Dharsiwa	Raipur	81.7024546	21.324363	10.2	4.73	5.47	2024	HP
15	Giroud	Dharsiwa	Raipur	81.6785424	21.3359072	5.71	1.68	4.03	2024	HP
16	Sankara	Dharsiwa	Raipur	81.6567978	21.3558576	25.6	12	13.6	2024	HP
17	Sankara HP2	Dharsiwa	Raipur	81.6559136	21.3555531	25.7	11.89	13.81	2024	HP
18	Kanhera	Dharsiwa	Raipur	81.6166508	21.3392528	21.7	15.6	6.1	2024	HP
19	Purana Bendri	Dharsiwa	Raipur	81.5830672	21.3245404	8.27	6.4	1.87	2024	HP
20	Bana	Dharsiwa	Raipur	81.556223	21.3159341	11.44	7.95	3.49	2024	HP
21	Tendua	Dharsiwa	Raipur	81.5621071	21.2929178	19.46	8.29	11.17	2024	HP
22	Urkura	Dharsiwa	Raipur	81.6521381	21.3052086	9.4	2.05	7.35	2024	DW
23	Amaseoni	Dharsiwa	Raipur	81.7122296	21.2822781	16.46	7.07	9.39	2024	HP
24	Mana Tuta	Dharsiwa	Raipur	81.7325836	21.1649296	12.01	8.2	3.81	2024	HP
25	Mujgahan	Dharsiwa	Raipur	81.6659179	21.1385775	7.1	4.69	2.41	2024	HP
26	Sejbahar	Dharsiwa	Raipur	81.6621514	21.1687637	9.9	4.36	5.54	2024	HP
27	Siltara Bhatapara	Dharsiwa	Raipur	81.6704981	21.3676747	12.2	8	4.2	2024	DW
28	Mandhar	Dharsiwa	Raipur	81.6985059	21.3484857	7.3	3.9	3.4	2024	DW
29	Gidhouri	Dharsiwa	Raipur	81.7237618	21.36359	1.1	1.15	-0.05	2024	DW
30	Tor	Dharsiwa	Raipur	81.7388009	21.3660014	10.45	2.63	7.82	2024	DW
31	Barbanda	Dharsiwa	Raipur	81.7241775	21.3536568	4.6	2.18	2.42	2024	DW
32	Chhapora	Dharsiwa	Raipur	81.7283209	21.3271014	3.8	4.44	-0.64	2024	HP
33	Chatoud	Dharsiwa	Raipur	81.7942921	21.3380989	4.65	3.82	0.83	2024	HP
34	Katedih	Dharsiwa	Raipur	81.6252654	21.1735053	7.52	4.08	3.44	2024	HP
35	Datrenga	Dharsiwa	Raipur	81.6426313	21.1591853	5.34	3.16	2.18	2024	HP
36	Kandul	Dharsiwa	Raipur	81.645804	21.1714922	6.99	5.27	1.72	2024	HP
37	Boriakala	Dharsiwa	Raipur	81.6885239	21.175223	2.65	3.09	-0.44	2024	HP
38	Mandir Hasoud	Dharsiwa	Raipur	81.7624855	21.2198532	17.23	3.41	13.82	2024	HP
39	Dharampura	Dharsiwa	Raipur	81.7084249	21.2199107	4.89	4.4	0.49	2024	HP

Annexure 2 Water Quality parameter analysis Raipur Urban

S.No.	District	Village	Latitide	Longitude	Sample Source	PH	EC	CO_3	HCO_3	Cl	SO_4	NO3	F	TH	Ca	Mg	Na	K	Si	Po_4	u	TDS
1	Raipur	Amapara	21.23833	81.625	DW	7.5	162		67.1	17.75	0.11	0.98	0	55	16	3.66	10.87	3.16	2.93	0	0.84	103.68
2	Raipur	Atal Nagar(Sector-18)	21.17555	81.80633	DW	7.7	446	0	170.8	49.7	0.11	27.4	0	200	48	19.5	9.34	0.72	5.87	0	2.06	285.44
3	Raipur	Atari	21.2718	81.5477	DW	8.1	467	0	244	35.5	4.06	0.28	0	55	14	4.88	83.67	3.37	6.73	0	0.75	298.88
4	Raipur	Baroda	21.29722	81.7125	DW	7.9	932	0	280.6	124.3	23.7	31.8	0	305	58	39	77.2	13.5	5.4	0	4.75	596.48
5	Raipur	Bhatagaon	21.2156	81.6226	DW	7.8	175	0	85.4	17.75	0	1.96	0.1	65	16	6.1	10.33	2.41	3.42	0	0.96	112
6	Raipur	Bhirkoni	21.31333	81.7125	DW	7.8	428	0	207.4	31.95	4.3	8.63	0.1	175	46	14.6	14.43	4.01	4.92	0	2.11	273.92
7	Raipur	Birgaon	21.31043	81.60965	DW	8	623	0	280.6	46.15	11	9.27	0.1	225	48	25.6	37.13	2.78	6.76	0	2.95	398.72
8	Raipur	Daldal Seoni	21.27833	81.66944	DW	7.7	523	0	274.5	42.6	2.14	10	0.1	180	36	22	37.88	3.07	5.89	0	1.83	334.72
9	Raipur	Deopuri	21.2053	81.6762	DW	7.6	1589	0	475.8	237.9	42.9	11	0.2	550	30	116	118.1	4.17	9.28	0	45.07	1017
10	Raipur	Dhaneli	21.33556	81.65833	DW	7.6	685	0	274.5	71	8.17	22.9	0	215	34	31.7	52.81	5.41	5.73	0	3.52	438.4
11	Raipur	Dhram-pura	21.22	81.7081	DW	7.6	1373	0	390.4	181.1	24.4	21.5	0.1	460	94	54.9	73.26	7.53	7.68	0	10.60	878.72
12	Raipur	Dumatarai	21.19778	81.68972	DW	7.5	640	0	250.1	74.55	6.45	17.6	0.1	240	42	32.9	34.7	4.08	5.24	0	3.74	409.6
13	Raipur	Girod	21.33333	81.67778	DW	7.4	1016	0	305	170.4	9.1	3.81	0.1	315	44	50	90.8	3.44	5.24	0	5.12	650.24
14	Raipur	Gogaon	21.27083	81.61111	DW	7.4	1221	0	372.1	170.4	51.4	14.2	0.1	425	42	78.1	97.15	7.66	7.68	0	17.34	781.44
15	Raipur	Gudhiyari	21.2568	81.625	DW	7.8	775	0	268.4	85.2	10.4	46.2	0.1	240	54	25.6	55.8	25.55	11.3	0	2.55	496
16	Raipur	Guma	21.3193	81.5553	DW	7.9	213	0	109.8	24.85	0.33	1.19	0.1	90	22	8.54	10.1	5.67	3.74	0	0.86	136.32
17	Raipur	Indravati Colony	21.245	81.6495	DW	7.5	967	0	244	145.6	6.23	46.8	0.1	345	50	53.7	53.7	3.89	7.12	0	2.98	618.88
18	Raipur	Jarwai	21.27667	81.57444	DW	7.9	853	0	353.8	88.75	4.64	12	0.1	275	26	51.2	65.5	15	7.87	0	4.24	545.92
19	Raipur	Jora	21.24028	81.71111	DW	8	417	0	170.8	39.05	0.56	13.9	0.1	185	42	19.5	10.98	0.83	6.41	0	1.90	266.88

S.No.	District	Village	Latitude	Longitude	Sample Source	PH	EC	CO3	HCO3	Cl	SO4	NO3	F	TH	Ca	Mg	Na	K	Si	Po4	u	TDS
20	Raipur	Kachna	21.26667	81.70833	DW	7.5	632	0	262.3	71	9.48	9.22	0.1	230	62	18.3	35.96	0.56	5.4	0	3.01	404.48
21	Raipur	Kera	21.33056	81.57917	DW	7.5	698	0	298.9	63.9	8.61	22.9	0.3	280	46	40.3	31.13	1.29	6.76	0	5.11	446.72
22	Raipur	Khanduwa	21.10773	81.78658	DW	7.7	714	0	323.3	63.9	15.8	4.93	0.4	285	36	47.6	44.19	3.95	7.68	0	6.02	456.96
23	Raipur	Kota	21.25139	81.60222	DW	8.1	499	0	280.6	28.4	0	3.8	0.3	175	26	26.8	33.95	1.12	7.12	0	3.06	319.36
24	Raipur	Kuhera	21.15536	81.80799	DW	7.8	567	0	219.6	67.45	2.99	15.1	0.3	235	32	37.8	18.12	2.04	5.56	0	2.27	362.88
25	Raipur	Mana Basti	21.1667	81.7292	DW	7.7	986	0	292.8	127.8	15.1	47.1	0.2	295	50	41.5	69.6	19.9	5.56	0	2.75	631.04
26	Raipur	Mana Camp	21.19222	81.70306	DW	7.3	459	0	146.4	74.55	7.53	2.17	0.3	135	30	14.6	43.95	10.16	3.74	0	1.56	293.76
27	Raipur	Mandir Hasaud	21.22336	81.76973	DW	7.4	847	0	256.2	120.7	11	34.2	0.5	330	42	54.9	50.14	0.9	5.73	0	5.31	542.08
28	Raipur	Math Purena	21.20556	81.63444	DW	7.5	1282	0	311.1	191.7	54.6	34.8	1.3	435	26	90.3	102.8	4.07	7.3	0	7.36	820.48
29	Raipur	MVM Tatibandh	21.2563	81.5588	DW	8	924	0	378.2	92.3	23.4	33.7	0.1	325	68	37.8	49.3	12.6	9.49	0	5.44	591.36
30	Raipur	Nakti	21.20889	81.73472	DW	7.9	892	0	353.8	99.4	23.6	0	0.2	105	18	14.6	159.5	3.1	5.73	0	1.07	570.88
31	Raipur	Nawagaon(Durga Chowk)	21.22041	81.81594	DW	7.6	533	0	207.4	42.6	5.8	25.8	0.4	195	46	19.5	28.83	4.49	5.7	0	2.32	341.12
32	Raipur	Pachpedi naka	21.2179	81.6575	DW	7.7	438	0	237.9	14.2	0.07	3.72	0.5	180	30	25.6	23.18	0.96	7.49	0	4.47	280.32
33	Raipur	Parsada	21.20353	81.84666	DW	8.1	385	0	170.8	31.95	2.75	5.44	0.4	140	42	8.54	22.68	1.47	4.31	0	1.78	246.4
34	Raipur	Pirda	21.25694	81.72917	BW	7.6	861	0	213.5	134.9	4.93	45.6	0.4	320	56	43.9	46.63	1.45	8.02	0	7.03	551.04
35	Raipur	Purena	21.23083	81.67139	DW	7.4	970	0	427	113.6	11.5	12.7	0.3	260	42	37.8	101	12.2	6.06	0	5.48	620.8
36	Raipur	R.S. University	21.23944	81.58389	DW	7.6	844	0	329.4	78.1	18.1	25.3	0.3	280	28	51.2	60.9	18.2	10.5	0	4.70	540.16
37	Raipur	Raipura	21.22597	81.59553	DW	7.6	655	0	274.5	67.45	8.62	1.19	0.2	230	32	36.6	50.8	1.14	7.68	0	3.69	419.2
38	Raipur	Raja Talab	21.248	81.6508	DW	7.5	1122	0	262.3	191.7	43.2	11.5	0.2	385	36	72	89.43	4.51	6.73	0	8.63	718.08
39	Raipur	Ram Krishna Ashram	21.23889	81.62083	DW	7.9	227	0	97.6	42.6	4.64	0.6	0.4	95	30	4.88	13.46	3.97	4.46	0	1.08	145.28
40	Raipur	Rawa-bhata	21.325	81.645	DW	7.6	1022	0	402.6	152.7	5.8	3.37	0.2	230	24	41.5	139.8	24.45	10.4	0	3.39	654.08

S.No.	District	Village	Latitide	Longitude	Sample Source	PH	EC	CO3	HCO3	Cl	SO4	NO3	F	TH	Ca	Mg	Na	K	Si	Po4	u	TDS
41	Raipur	RVH Colony	21.26944	81.63833	BW	8.1	1091	0	451.4	142	22.9	0	0.6	305	62	36.6	111.7	4.63	8.86	0	10.50	698.24
42	Raipur	Saddu	21.27899	81.69993	DW	8	677	0	244	81.65	8.89	25.5	0.5	185	40	20.7	69.35	3.08	6.76	0	2.38	433.28
43	Raipur	Sakra	21.35417	81.65694	DW	8	881	0	341.6	85.2	46	11.1	0.2	240	52	26.8	88.39	3.94	4.02	0	4.83	563.84
44	Raipur	Sankar Nagar	21.24611	81.66306	DW	8.1	256	0	128.1	17.75	0.48	0.93	0.3	90	26	6.1	11.96	9.39	4.16	0	1.06	163.84
45	Raipur	Sarora	21.29124	81.61036	DW	7.7	1517	0	268.4	326.6	43.6	4.38	0.3	385	110	26.8	179.5	2.4	4.17	0	3.10	970.88
46	Raipur	Sastri Nagar(Phapadih)	21.26222	81.6475	DW	7.8	807	0	262.3	103	6.2	43.1	0.4	315	96	18.3	36.65	16.3	6.41	0	3.58	516.48
47	Raipur	Sondongri	21.27722	81.595	DW	7.6	515	0	237.9	42.6	7.76	14.8	0.3	245	96	1.22	23.91	1.41	4.46	0	2.32	329.6
48	Raipur	Tekari	21.32222	81.69306	DW	8	604	0	256.2	46.15	11.5	9.36	0.1	230	52	24.4	37.1	2.73	6.41	0	4.43	386.56
49	Raipur	Teli-bandha	21.23889	81.68556	DW	7.5	1968	0	384.3	365.7	22.3	48	0.4	700	188	56.1	111.3	22.05	10.6	0	10.95	1259.5
50	Raipur	Temri	21.20444	81.70694	DW	8	661	0	231.8	85.2	4.73	31.5	0.2	290	96	12.2	29.47	1.83	6.56	0	3.83	423.04
51	Raipur	Tuta	21.14888	81.74972	DW	8	451	0	231.8	24.85	0.56	25.9	0.2	200	68	7.32	15.96	0.69	7.12	0	2.41	288.64
52	Raipur	Uparwara (Bajrang Chowk)	21.11992	81.76043	DW	8.1	442	0	195.2	46.15	0.33	35.1	0.5	210	66	11	15.29	5.11	8.02	0	1.89	282.88
53	Raipur	Urala Basti	21.30944	81.60861	DW	8	1051	0	317.2	142	41.7	26.8	0.7	160	48	9.76	190.9	6.25	6.23	0	1.57	672.64
54	Raipur	Urla (Bendri)	21.32361	81.58333	DW	7.5	958	0	256.2	131.4	27.5	44.4	0.3	360	74	42.7	56.01	2.57	6.1	0	3.81	613.12
55	Raipur	Deori	21.46953	81.690728	DW	7.8	1189	0	280.6	170.4	71.3	4.5	0.9	390	82	45.1	90.81	3.94	11.3	0	0.11	796.63
56	Raipur	Kapasda	21.431246	81.687281	DW	7.8	746	0	347.7	60.35	28.1	3.03	0.9	240	64	19.5	89.04	3.87	11.8	0	0.08	499.82
57	Raipur	Kukera	21.452852	81.712308	DW	8	1003	0	292.8	78.1	57.1	64.3	0.3	370	96	31.7	20.66	0.89	11.2	0	0.32	672.01
58	Raipur	Charoda	21.393169	81.670981	DW	8	902	0	207.4	99.4	68.1	65.4	0.4	290	76	24.4	84.21	3.66	12.4	0	0.49	604.34
59	Raipur	Chelikhedi	21.233799	81.737704	BW	7.6	1357	0	353.8	134.9	86.3	53.5	0.4	480	144	29.3	90.76	3.94	13.2	0	0.22	909.19
60	Raipur	Kurud	21.253158	81.772695	BW	7.9	688	0	219.6	60.35	31.6	33.7	0.3	170	40	17.1	86.04	3.74	13.6	0	0.45	460.96

S.No.	District	Village	Latitude	Longitude	Sample Source	PH	EC	CO3	HCO3	Cl	SO4	NO3	F	TH	Ca	Mg	Na	K	Si	Po4	u	TDS
61	Raipur	Murethi	21.278683	81.792365	BW	7.9	417	0	189.1	31.95	3.8	18.6	0.1	185	38	22	6.18	0.26	16.4	0	0.09	279.39
62	Raipur	Nagpura	21.309073	81.838722	BW	7.6	735	0	231.8	63.9	38.9	65.4	0.3	205	62	12.2	86.19	3.74	10.3	0	0.21	492.45
63	Raipur	Semariya	21.309004	81.733707	BW	7.8	621	0	262.3	42.6	34.2	23.5	0.2	115	38	4.88	86.63	3.76652	12.5	0	0.82	416.07
64	Raipur	Saragaon	21.376512	81.802416	BW	8	278	0	61	28.4	5.1	40.2	0.5	120	40	4.88	2.86	0.12	11.3	0	0.71	186.26
65	Raipur	Matiya	21.33901	81.757048	BW	7.8	460	0	189.1	35.5	13.3	0.7	0.5	195	52	15.9	9.13	0.39	11.4	0	0.04	308.2
66	Raipur	Dundekhurd	21.326731	81.753548	BW	7.7	855	0	298.9	67.45	44.4	14.6	0.3	245	56	25.6	87.97	3.82	11.3	0	0.51	572.85
67	Raipur	Tekari	21.324363	81.702455	BW	7.7	762	0	335.5	63.9	46.6	17.5	0.2	285	88	15.9	86.16	3.74	22.6	0	0.84	510.54
68	Raipur	Giroud	21.335907	81.678542	BW	7.6	1734	0	445.3	174	108	22	0.8	450	148	19.5	83.98	3.65	14.7	0	0.32	1161.8
69	Raipur	Sankara	21.355858	81.656798	BW	7.9	833	0	274.5	81.65	54.9	20.6	0.5	260	82	13.4	86.15	3.74	18.6	0	0.62	558.11
70	Raipur	Sankara HP2	21.355553	81.655914	BW	7.8	643	0	305	28.4	15.8	6.54	0.9	145	38	12.2	87.06	3.78	13.4	0	0.13	430.81
71	Raipur	Kanhera	21.339253	81.616651	BW	7.8	960	0	341.6	88.75	54.4	5.72	0.7	290	82	20.7	86.74	3.77	18.2	0	0.49	643.2
72	Raipur	Purana Bendri	21.32454	81.583067	BW	7.7	967	0	378.2	74.55	67.4	14.6	0.6	345	108	18.3	91.62	3.98	12.8	0	0.02	647.89
73	Raipur	Bana	21.315934	81.556223	BW	7.8	787	0	268.4	81.65	30.8	17.7	0.3	210	42	25.6	90.12	3.91	11.8	0	0.42	527.29
74	Raipur	Tendua	21.292918	81.562107	BW	7.8	2360	0	585.6	340.8	98.1	62.3	0.2	945	356	13.4	84.64	3.68	26.6	0	0.33	1581.2
75	Raipur	Urkura	21.305209	81.652138	DW	7.8	1054	0	323.3	103	70.3	8.94	0.4	340	86	30.5	92.52	4.02	13.7	0	0.13	706.18
76	Raipur	Amaseoni	21.282278	81.71223	BW	7.9	534	0	225.7	42.6	7.2	34.9	0.5	85	18	9.76	83.67	3.63	13.6	0	0.23	357.78
77	Raipur	Mana Tuta	21.16493	81.732584	BW	7.7	878	0	280.6	113.6	26.6	22.7	0.4	290	76	24.4	85.83	3.73	12.3	0	0.29	588.26
78	Raipur	Mujgahan	21.138578	81.665918	BW	7.7	1085	0	439.2	92.3	67.4	21.8	0.2	365	80	40.3	90.98	3.95	9.4	0	0.99	726.95
79	Raipur	Siltara Bhatapara	21.367675	81.670498	DW	7.7	1192	0	85.4	262.7	36.3	58.2	0.2	400	94	39.6	60.75	22.2	7.75	0	4.68	798.64
80	Raipur	Siltara Bhatapara	21.367675	81.670498	DW	7.7	1282	0	219.6	220.1	48.9	52.1	0.2	425	120	30	80.7	30.5	8.36	0	4.64	858.94
81	Raipur	Mandhar	21.348486	81.698506	DW	7.8	1374	0	79.3	387	17.6	31.7	0.5	425	138	19.2	86.6	45.75	26.8	0	6.52	920.58

S.No.	District	Village	Latitude	Longitude	Sample Source	PH	EC	CO3	HCO3	Cl	SO4	NO3	F	TH	Ca	Mg	Na	K	Si	Po4	u	TDS
82	Raipur	Gidhouri	21.36359	81.723762	DW	7.9	1182	0	201.3	220.1	54	11	0.3	370	96	31.2	83.75	35.7	11.5	0	6.56	791.94
83	Raipur	Gidhouri	21.36359	81.723762	DW	8	1297	0	317.2	127.8	78.1	10.2	0.2	230	84	4.8	51.4	40.2	9.28	0	7.31	868.99
84	Raipur	Tor	21.366001	81.738801	DW	7.7	992	0	219.6	170.4	8.56	13.1	0.2	340	90	27.6	60.05	9.25	7.66	0	5.44	664.64
85	Raipur	Barbanda	21.353657	81.724178	DW	7.7	607	0	250.1	53.25	4	1.45	0.5	260	100	2.4	18.52	9.26	6.19	0	5.96	406.69
86	Raipur	Chhapora	21.327101	81.728321	BW	7.8	557	0	219.6	42.6	2.8	10.7	0.8	225	46	26.4	24	3.48	29.1	0	7.52	373.19
87	Raipur	Chatoud	21.338099	81.794292	BW	7.9	649	0	189.1	81.65	9.97	35.1	0.7	190	52	14.4	62.43	6.6	28.9	0	5.91	434.83
88	Raipur	Katedih	21.173505	81.625265	BW	7.6	1202	0	201.3	202.4	20.8	31.7	0.6	370	78	42	78.34	7.07	9.47	0	5.69	805.34
89	Raipur	Datrenga	21.159185	81.642631	BW	7.6	806	0	158.6	134.9	2.8	3.16	0.2	275	70	24	32.38	2.74	7.32	0	5.28	540.02
90	Raipur	Kandul	21.171492	81.645804	BW	7.8	839	0	250.1	99.4	42.2	2.7	0.2	260	64	24	74.7	5.75	30.3	0	5.75	562.13
91	Raipur	Boriakala	21.175223	81.688524	BW	7.9	1197	0	97.6	181.1	140	50.2	0.3	360	92	31.2	79	23.1	34.5	0	5.35	801.99
92	Raipur	Mandir Hasoud	21.219853	81.762486	BW	7.8	856	0	128.1	142	9.57	40.2	0.5	290	52	38.4	29.81	7.16	30.8	0	5.00	573.52
93	Raipur	Dharampura	21.219911	81.708425	BW	7.9	354	0	79.3	56.8	2.6	16.3	0.4	150	28	19.2	6.94	1.17	30.1	0	5.43	237.18
94	Raipur	Ghodari (Ghorari)	20.168	82.025	DW	7.3	786	0	274.5	67.45	57.5	15.1	0.3	330	114	11	25.89	0.84	32.1	0	0.00	526.62
95	Raipur	Godhi	21.2968	81.4545	DW	7.8	507	0	286.7	10.65	6.06	2.43	0.3	245	76	13.4	10.73	0.69	8.32	0	0.13	339.69
96	Raipur	Nawagaon	21.223376	81.812523	DW	7.8	494	0	262.3	10.65	50.8	5.94	0.2	220	66	13.4	21.26	1.08	32.7	0	0.26	330.98
97	Raipur	Nawagaon	21.098611	82.236389	DW	7.1	167	0	61	17.75	3.51	0	0.7	55	18	2.44	11.33	1.59	32.5	0	0.15	111.89
98	Raipur	Bajrangpur	20.9833	81.8111	DW	7.9	640	0	292.8	17.75	49.6	0	0.4	160	48	9.76	74.33	1.54	32.2	0	0.10	428.8
99	Raipur	Bhaisa	21.405556	82.027778	DW	7.7	832	0	329.4	67.45	19.5	8.6	0.5	255	80	13.4	51.74	2.19	7.66	0	0.10	557.44
100	Raipur	Bhatia	21.4266	82.0348	DW	7.5	716	0	238.4	56.8	59.7	17.4	0.4	275	76	20.7	24.22	1.18	32.5	0	0.00	479.72
101	Raipur	Biladi	21.572778	81.783056	DW	7.6	699	0	388.1	24.85	6.03	0.02	0.3	285	64	30.5	38.4	1.46	6.04	0	0.15	468.33
102	Raipur	Chicholi	21.4658	81.865	DW	8	407	0	122	49.7	53.3	1.19	0.3	165	48	11	17.35	5.02	30.3	0	0.00	272.69

S.No.	District	Village	Latitude	Longitude	Sample Source	PH	EC	CO3	HCO3	Cl	SO4	NO3	F	TH	Ca	Mg	Na	K	Si	Po4	u	TDS
103	Raipur	Chrauda	21.38	81.6722	DW	7.8	584	0	237.9	17.75	9.32	9.93	0.2	200	60	12.2	21.56	1.87	5.87	0	0.00	391.28
104	Raipur	Devri	21.466	81.6833	DW	7.6	698	0	176.9	81.65	56.3	34.3	0.2	255	82	12.2	30.39	2.81	29.8	0	0.00	467.66
105	Raipur	Dharsinwa	21.4083	81.6722	DW	7.6	613	0	244	56.8	10.6	2.96	0.3	250	58	25.6	25.41	1.28	6.91	0	0.00	410.71
106	Raipur	Ghivera	21.3691	81.9752	DW	7.8	410	0	152.5	17.75	57.3	1.12	0.2	145	46	7.32	18.14	5.18	29.8	0	0.00	274.7
107	Raipur	Gotiadih	21.018249	81.679096	DW	7.9	674	0	323.3	46.15	8.25	16.9	0.5	205	56	15.9	61.85	0.87	7.75	0	0.00	451.58
108	Raipur	Kanki	21.4003	81.992	DW	7.7	1093	0	341.6	117.2	80.8	22.6	0.3	355	110	19.5	63.34	2.04	33.1	0	0.00	732.31
109	Raipur	Kanki	21.3922	81.9507	DW	7.9	911	0	353.8	78.1	23.1	13.6	0.3	290	70	28.1	59.5	4.61	9.03	0	0.00	610.37
110	Raipur	Kasrangi	21.3651	81.9806	DW	7.7	1046	0	378.2	124.3	74.8	26.6	0.5	195	62	9.76	161.5	2.65	5.59	0	0.00	700.82
111	Raipur	Kharora	21.3875	81.9208	DW	7.5	464	0	201.3	31.95	8.44	15	0.3	200	74	3.66	8.45	0.78	7.42	0	0.00	310.88
112	Raipur	Kurra	21.1127	81.7833	DW	7.7	628	0	311.1	24.85	95.3	0	0.5	255	42	36.6	44.13	3.14	9.85	0	0.00	420.76
113	Raipur	Mandhar	21.352778	81.710278	DW	7.7	737	0	262.3	60.35	24.5	51.7	0.2	300	76	26.8	29	4.56	6.7	0	0.00	493.79
114	Raipur	Mandirhasud	21.2208	81.7667	DW	7.4	980	0	341.6	120.7	67.6	56.1	0.3	420	110	35.4	43.06	0.49	6.7	0	0.02	656.6
115	Raipur	Math	21.395	81.9026	DW	7.7	702	0	237.9	88.75	18.5	47.6	0.2	315	86	24.4	25.08	2.52	8.86	0	0.02	470.34
116	Raipur	Narra	21.263889	81.888889	DW	7.6	1213	0	274.5	230.8	86.6	21.9	0.7	430	104	41.5	87.21	2.93	11.2	0	0.01	812.71
117	Raipur	Palari	21.5292	82.1625	DW	7.6	675	0	262.3	71	17.7	36.3	0.2	310	74	30.5	25.19	9.73	7.75	0	0.02	452.25
118	Raipur	Pandan Bhata	21.4428	81.6519	DW	7.7	500	0	140.3	47.55	86.3	6.32	0.6	175	52	11	41.33	7.94	6.14	0	0.03	335
119	Raipur	Piparhatta	21.6228	82.1012	DW	7.7	500	0	134.2	78.1	36.9	6.28	0.6	185	54	12.2	40.2	7.92	3.87	0	0.01	335
120	Raipur	Raita (Satna ni para)	21.4428	81.7174	DW	7.6	715	0	213.5	88.75	97.6	5.59	0.5	285	72	25.6	37.91	1.22	6.77	0	0.00	479.05
121	Raipur	Ranisagar	21.2783	82.0281	DW	7.5	1191	0	353.8	149.1	90.4	60.6	0.2	455	92	54.9	37.5	43.2	6.09	0	0.00	797.97
122	Raipur	Sakara	21.354167	81.656944	DW	7.7	481	0	256.2	17.75	13.5	6.92	0.4	195	54	14.6	16.01	0.49	7.49	0	0.00	322.27
123	Raipur	Saragaon	21.3667	81.8069	DW	7.5	697	0	335.5	49.7	77.2	16	0.6	300	82	23.2	46.36	1.2	8.01	0	0.00	466.99

S.No.	District	Village	Latitide	Longitude	Sample Source	PH	EC	CO3	HCO3	Cl	SO4	NO3	F	TH	Ca	Mg	Na	K	Si	Po4	u	TDS
124	Raipur	Tarpongi	21.4906	81.6892	DW	7.7	536	0	225.7	46.15	25.2	14.2	0.3	265	82	14.6	17.42	0.8	10.4	0	0.01	359.12
125	Raipur	Kurru	20.01883	81.50945	DW	7.7	889	0	274.5	103	86.3	44.4	0.3	370	68	48.8	41.1	1.65	9.81	0	0.02	595.63
126	Raipur	Baihar	21.1987	81.9492	DW	8.6	945	9	378.2	138.5	15.4	0.46	1	45	10	4.88	213.3	3.8	13.4	0	0.01	633.15
127	Raipur	Gatapaar Village	21.0273	81.770554	DW	7.7	170	0	30.5	17.75	60.6	0	0.4	75	26	2.44	13.41	1.82	12.4	0	0.00	113.9
128	**Raipur**	**Arang**	**21.19316**	**81.9702**	**DW**	**7.6**	**1341**	**0**	**421**	**134.9**	**102**	**45.8**	**0.3**	**505**	**72**	**91.5**	**78.94**	**7.71**	**7.86**	**0**	**0.00**	**898.47**

Annexure 3 Hydrogeological Information in Raipur City

Sl. No.	Location	Block	Latitude	Longitude	Depth	casing	Formation	Zone_encountered	SWL	Discharge	T (m2/day)	S
1	Bodara	Dharsiwa	21.2944	81.7306	200.17	8.5	Chandi limestone	nil	7.69	0	0.1453	
2	Deori	Dharsiwa	21.4662	81.6881	94.7	11	Chandi limestone	14-20,30				
3	Dharsiwa	Dharsiwa	21.4083	81.6722	50	11.7	Dolomite/Limestone	16-18, 34.35 to 41.00		1		
4	Kota	Dharsiwa	21.2625	81.6167	199	11.7	0.00-136.00 Chandi Fm 136-199 Gunderdehi Fm	16.8-18.60,19.8- 21.0,68.4-68.6	6.69	2.1	6.15	
5	Mana	Dharsiwa	21.1917	81.725	301.5	14	0.0- 48.77 Chandi Fm 10.4-225.5 Gunderdehi 225.5-301.48 Charmuria	15.77-19.77,49.77-53.77	14.43	10	98.86	
6	Mandhar	Dharsiwa	21.3389	81.7058	100	10.4	Dolomite/Limestone	8.40 to 9.00,32				
7	Mohadi 1	Dharsiwa	21.39386	81.67074	200.17	14.5	Chandi			1		
8	Pandarbhata	Dharsiwa	21.4628	81.6525	50	11.5	Dolomite/Limestone	3 to 5,25 26		0.5		
9	Pandarbhatta	Dharsiwa	21.4646	81.6623	200.17	16	Chandi Limestone	146.38-149.38	5.3	0.351	0.7818	
10	R.G.I- OW	Dharsiwa	21.2944	81.7306	110.5	14.9	Chandi	83.00-83.50		0.24		
11	R.G.I. -1	Dharsiwa	21.2944	81.7306	202	15.9	Chandi	16.30- 16.80, 61.00-61.50		1		
12	R.G.I.- 2	Dharsiwa	21.2944	81.7306	202	11.65	Chandi	63.00-63.50		0.37		
13	R.G.I.- 3	Dharsiwa	21.2944	81.7306	202	11.5	Chandi	10.00-10.50, 62.00-62.50		0.37		
14	R.G.I.- 4	Dharsiwa	21.2944	81.7306	128.9	15	Chandi	15.00-16.00, 84.00-85.00		4.5		
15	R.G.I.- 5	Dharsiwa	21.2944	81.7306	110.5	11.5	Chandi	83.50-84.00		SEEPAGE		
16	R.G.I.- 6	Dharsiwa	21.2944	81.7306	159.3	11.5	Chandi	85.50-86.10		0.24		
17	R.G.I.- 7	Dharsiwa	21.2944	81.7306	171.5	9.8	Chandi	15.40-15.90		0.24		
18	Rawabhata	Dharsiwa	21.3167	81.6417	301.6	11.5	0- 205 Chandi fm & 205-301.6 Gunderdehi Fm	9525	21.4	0.2		
19	RGI -I EW	Dharsiwa	21.3072	81.6781	202.1	16.9	Deodongar Chandi	15-32,61, 100.29	8	0.24		
20	RGI- I OW	Dharsiwa	21.2972	81.6764	110.5	15.9	Deodongar Chandi	15-32,61,83.5	4.86	0.24		
21	RGI -II EW	Dharsiwa	21.3	81.6869	202	12.65	Deodongar Chandi	125.8	5.57	0.5		
22	RGI -III EW	Dharsiwa	21.3006	81.6794	202	12.5	Deodongar Chandi	64.7	4.78	1		
23	RGI -V EW	Dharsiwa	21.2981	81.6783	110.5	12.5	Deodongar Chandi	14-16, 84	12	0		
24	RGI -VI EW	Dharsiwa	21.2981	81.6789	159.3	12.5	Deodongar Chandi	14-16, 86	13	0		
25	RGI, Daldalseoni	Dharsiwa	21.2978	81.68	171.5	10.3	Limestone	14-16,35		0		
26	RGI-IV EW	Dharsiwa	21.2969	81.6767	128.9	16	Deodongar Chandi	14-16, 85	5.49	4.5		
27	Sakri	Dharsiwa	21.3222	81.725	160	6	0.0- 18.50 Chandi Fm 18.50 - 160 Gunderdehi	18.5	1.2	1		
28	Saragaon	Dharsiwa	21.3667	81.8167	281.81	8.21	0-69.01 Chandi Fm 69.01-281.81Gunderdehi formation	27-28.5,166-168,190-195	3.95	1	2.47	

Sl. No.	Location	Block	Latitude	Longitude	Depth	casing	Formation	Zone_encountered	SWL	Discharge	T (m2/day)	S
29	Shankarnagar	Dharsiwa	21.2458	81.6167	198	14.7	0.0-120.5 Chandi Fm 120.5-198 Gunderdehi Fm	14-16,37.3-39,114-116,154-156	13.15	3.5	2.64	
30	Shyamnagar-I	Dharsiwa	21.2347	81.6639	135	8.5	0.0- 103 Chandi Fm103- 135 Gunderdehi Fm	21.5- 21.7,34.0-34.2,38.5-38.8,42.3-43.3,72.0-72.40	2.65	6	81.4	
31	Shyamnagar-II	Dharsiwa	21.2347	81.6639	182.4	9	0.0- 126.7 Chandi Fm 126.7-182.4 Gunderdehi	14-16,182	25.51	3.5		
32	Taresar	Dharsiwa	21.4056	81.7458	197	7.8	00-118.00 Chandi Fm 118-197 Gunderdehi Fm	9.8-12.89,17.99-18.99,67.66-70.66,159.9-162., 169-172	6.69	5	121.7	
33	Telibandha	Dharsiwa	21.2417	81.6833	135	13.25	0.00-103 Chandi Fm 103.-135 Gunderdehi Fm	13.25, 14-19.75, 25.85-26.00, 129.5,131.5-133.5	3.45	10	18.4	
34	Urla	Dharsiwa	21.3167	81.5833	290	15.4	Chandi limestone, Gunderdehi shale	15--16	5.89	1.75	6.02	
35	Nimora 1	Dharsiwa	21.140385	81.742582	101.00	24	Chandi Limestone	32.2	10.29mbgl	1.403		
36	Science Centre	Dharsiwa	21.2766	81.6817	100.01	15.92	Deodongar Shale	58.50mbgl	37	0.4	0.35	
37	Parastarai	Dharsiwa	21.4	81.66	70.65	12.4	Chandi Limestone	13-15mbgl	11.59		0.025	
38	Rawabhata	Dharsiwa	21.328	81.633	100.05	13.5	Deodongar Sstone	32.20-35.85mbgl, 35.85-39.85mbgl	25	8.4		
39	Cipet	Dharsiwa	21.299938	81.650803	100.05	10.62	Chandi L.stone & Deodongar Sstone	NA	5.17	0.135	3.02	
40	ITI Heerapur	Dharsiwa	21.27525	81.5537	100.05	28.79	Deodangar Sandstone	51.15-55.15mbgl	25.1	0.025	0.0251	
41	Tenduwa Ravanbhata chowk	Dharsiwa	21.2916348	81.5676951	101.05	31.95	Deodangar Sandstone	66.45-70.45 m bgl & 81.75-85.75	54.25	Nil	Nil	
42	TENDUWA	Dharsiwa	21.289951	81.576718	24.55	9.25	Deodangar Sandstone	20.55-24.55	11.16	2.2		
43	Sakri	Dharsiwa	21.28028	81.73525	154.6	12.6	Chandi Limestone	55.15	20.65	1.54	7.52	
44	Tulsi	Dharsiwa	21.2680243	81.7588987	154.6	9.25	Chandi Limestone	38	1.27	0.22	0.20	
45	Dondekala	Dharsiwa	21.3299697	81.7625153	154.6	6.03	Chandi Limestone	39.85	12.2	0.14	0.13	
46	Nimora 2	Dharsiwa	21.3502575	81.6377299	154.6	12.06	Chandi L.stone & Deodongar Sstone	108.7	6.84	Nil	0.49	
47	Serikhedi	Dharsiwa	21.2321797	81.7388462	154.6	13	Chandi Limestone	24.55	6.07	Nil	1.32	
48	Chikhalki	Dharsiwa	21.3635092	81.618365	154.6	14.5	Chandi Limestone	20.55	6.41	10	29.67	
49	Dhatrenga	Dharsiwa	21.1599207	81.6358021	154.6	12.06	Chandi Limestone	12.9	9.40	1.86	5.50	
50	Boriakala	Dharsiwa	21.178143	81.686284	154.6	20	Deodongar Sstone	47.5	30.83	Nil	0.24	

Annexure 4 Rainwater Harvesting installed in Municipal Corporation-owned properties

S. No.	Zone No.	Number of Rainwater Harvesting Systems Installed in Municipal Corporation-owned Buildings/Properties			Number of rain water harvesting systems installed in government buildings			Number of rain water harvesting systems installed in private building			Number of rain water harvesting systems installed in buildings over 150 square meters according to the applications received for regularization				Total number of buildings (3+6+9+12+14)	Total number of rain water harvesting completed (4-7+10+13+15)	Number of remaining rainwater harvesting (16-17)
		The total number of rain water harvesting systems installed in municipal corporation buildings/properties.	The number of completed rainwater harvesting systems installed in municipal corporation buildings/properties	The number of remaining rain water harvesting systems	The total number of rain water harvesting systems to be installed in government buildings	The number of completed rainwater harvesting systems installed in government buildings.	Number of rain water harvesting remaining	Total number of rain water harvesting units installed in private buildings	Number of completed rainwater harvesting systems installed in private buildings	Number of remaining rain water harvesting	Number of residential buildings constructed more than 150 sq.m.	Number of rain water harvesting systems installed in residential buildings	Number of non-residential buildings constructed more than 150 sq.m.	Number of rain water harvesting units installed in non-residential buildings.			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	15	15	0	15	7	8	746	605	141	213	53	214	93	1203	773	430
2	2	42	20	22	15	11	4	1989	1733	256	85	85	169	169	2300	2018	282
3	3	35	28	7	15	10	5	876	534	342	115	90	198	110	1239	772	467
4	4	19	17	2	32	18	14	195	85	110	100	66	196	113	542	299	243
5	5	22	21	1	10	5	5	483	315	168	268	268	138	138	921	747	174
6	6	107	107	0	34	34	0	1526	935	591	168	104	81	69	1916	1249	667
7	7	64	64	0	16	16	0	395	259	136	87	57	149	75	711	471	240
8	8	28	28	0	18	18	0	1210	979	231	183	123	138	111	1577	1259	318
9	9	18	5	13	41	11	30	702	428	274	449	258	133	87	1343	789	554
10	10	32	32	0	6	0	6	441	104	337	446	293	336	210	1261	639	622
TOTAL		382	337	45	202	130	72	8563	5977	2586	2114	1397	1752	1175	13013	9016	3997

Annexure 5 Farmer Feedback Form

Annexure-II

Stakeholder's Feedback Form

Photograph

Name	Doneshwar Sahu	
Village	दतरेंगा	
Block	धरसींवा	
District	रायपुर	
Address		
Mobile Number (optional)		
Type and number of structures	12	
Type	Borewell	
Number		
(coordinates of the structures are to be obtained by the field officer)		
Drill time discharge (lps)	1.5 – 2 inch	
Depth of installation of pump	30 meter	
Casing depth (Bore wells) HR		
Fracture encountered depth-HR	45 meter	
Slotted pipe depths (TW) SR		
Average water levels – pre-monsoon		
Average water levels – post-monsoon		
The well is used for	A खेती और पीने के लिए	
Is water available throughout the year	हाँ	
If not for how many months water is available		

Pumping Duration	Number of days pump is in operation (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	30	8	2.5 lps

Kharif (no of months to be specified)	90	10 hrs	1-5
Others (no of months to be specified)			
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)			
Khariff (no of months to be specified)			
Others (no of months to be specified)			
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	धान	धान	चना, दाल
Area under crop			
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	धान	चना	
Area under crop			
Reasons for change in cropping pattern in last 20 years.		पानी की उपलब्धता मे कमी	
If the cropping pattern is to be changed, which are the suitable crops that can be grown		दलहन तिलहन और सब्जी	
Available Market for the crop			
Average unit cost of production			
Average unit cost of selling			
Existing MSP(Minimum Support Price) and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.			
Source of Energy			
Solar	○ Is it connected to grid ○ If yes how much incentive do you get per month on an average for feeding electricity to the grid (Rs per month)		

Electric	○ Do you get free electricity for irrigation?
	○ Do you pay a fixed charges
	○ If a fixed charge is paid, what is the per month charge
	○ If unit-based charges are paid what is the average monthly charges in rupees
	  ○ During kharif----
	  ○ During Rabi-----
		हाँ
		नहीं	

Diesel	○ Average consumption of diesel (liters) per month ○ During Kharif ○ During Rabi	
Water Market*	○ Do you share the pumped water with other farmers ○ If yes ○ For how many days do you share pumped water in Kharif ○ For how many days do you share pumped water in Rabi Period ○ On an average how much do you charge per annum (in Rs)	नहीं
	○ Do you receive additional water from boreholes of nearby farmers ○ If yes ○ For how many days do you receive pumped water in Kharif ○ For how many days do you receive pumped water in Rabi Period ○ On an average how much do you pay per annum (in Rs)	नहीं
Other issues/Remarks e.g. common problems in drilling of wells, common health issues in the area etc	कम सिंचाई के कारण रबी की धान की फसल मे कम होती है	

- Feedback of the local stake holders will form an important input for problem identification and characterization. Feedbacks are to be obtained in case of Urban areas, Industrial clusters also. Feedback on drinking water availability, dependence on ground water etc are also to be obtained. The above feedback form can be customized to the type of priority area and objective of the study.

Annexure-II

Stakeholder's Feedback Form

			Photograph
Name	सुशीला साहू		
Village	बरडगी		
Block			
District	रायपुर		
Address	माता मंदिर के पास		
Mobile Number (optional)			
Type and number of structures			
Type	बोरवेल		
Number			
(coordinates of the structures are to be obtained by the field officer)			
Drill time discharge (lps)	1-3 इंची		
Depth of installation of pump	50 फिट		
Casing depth (Bore wells) HR	60		
Fracture encountered depth- HR	60 मिटर		
Slotted pipe depths (TW) SR			
Average water levels – pre-monsoon	10 - 30 मिटर		
Average water levels – post-monsoon	10 - 20 मिटर		
The well is used for	किसानी, खेती	पीने	
Is water available throughout the year	हाँ		
If not for how many months water is available			

Pumping Duration			
	Number of days pump is in operation (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	30	4-5	2-2.4 lps

Kharif (no of months to be specified)	40		
Others (no of months to be specified)			
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)			
Khariff (no of months to be specified)			
Others (no of months to be specified)			
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop			
Area under crop			
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	धान सब्जी	सब्जी	
Area under crop			
Reasons for change in cropping pattern in last 20 years.			
If the cropping pattern is to be changed, which are the suitable crops that can be grown			
Available Market for the crop	मंडी रायपुर		
Average unit cost of production			
Average unit cost of selling			
Existing MSP(Minimum Support Price) and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.			

Source of Energy		
Solar	○ Is it connected to grid ○ If yes how much incentive do you get per month on an average for feeding electricity to the grid (Rs per month)	नहीं.

Electric	○ Do you get free electricity for irrigation?
	○ Do you pay a fixed charges
	○ If a fixed charge is paid, what is the per month charge
	○ If unit-based charges are paid what is the average monthly charges in rupees
	    ○ During kharif----
	    ○ During Rabi-----
		हाँ

Diesel	○ Average consumption of diesel (liters) per month ○ During Kharif ○ During Rabi	
Water Market*	○ Do you share the pumped water with other farmers ○ If yes ○ For how many days do you share pumped water in Kharif ○ For how many days do you share pumped water in Rabi Period ○ On an average how much do you charge per annum (in Rs)	नहीं
	○ Do you receive additional water from boreholes of nearby farmers ○ If yes ○ For how many days do you receive pumped water in Kharif ○ For how many days do you receive pumped water in Rabi Period ○ On an average how much do you pay per annum (in Rs)	नहीं
Other issues/Remarks e.g. common problems in drilling of wells, common health issues in the area etc		

- Feedback of the local stake holders will form an important input for problem identification and characterization. Feedbacks are to be obtained in case of Urban areas, Industrial clusters also. Feedback on drinking water availability, dependence on ground water etc are also to be obtained. The above feedback form can be customized to the type of priority area and objective of the study.

Annexure-II

Stakeholder's Feedback Form

		Photograph
Name	मानकी बाई	
Village	धरसींवा	
Block	धरसींवा	
District	रायपुर	
Address		
Mobile Number (optional)		
Type and number of structures		
Type	बोरवेल	
Number		
(coordinates of the structures are to be obtained by the field officer)		
Drill time discharge (lps)	2 इंच	
Depth of installation of pump	50 फिट	
Casing depth (Bore wells) HR		
Fracture encountered depth-HR		
Slotted pipe depths (TW) SR		
Average water levels – pre-monsoon	20 फिट	
Average water levels – post-monsoon	16 फिट	
The well is used for	खेती किसानी पीने	
Is water available throughout the year	नही	
If not for how many months water is available	साल भर	

Pumping Duration

	Number of days pump is in operation (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	40	4	2

Kharif (no of months to be specified)	40		
Others (no of months to be specified)			
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)			
Khariff (no of months to be specified)			
Others (no of months to be specified)			
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	धान , सब्जी	सब्जी भाजी	
Area under crop			
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	भाजी	भाजी	
Area under crop			
Reasons for change in cropping pattern in last 20 years.			
If the cropping pattern is to be changed, which are the suitable crops that can be grown			
Available Market for the crop	मंडी		
Average unit cost of production			
Average unit cost of selling			
Existing MSP(Minimum Support Price) and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.			
Source of Energy			
Solar	○ Is it connected to grid ○ If yes how much incentive do you get per month on an average for feeding electricity to the grid (Rs per month)	नहीं	

Electric	○ Do you get free electricity for irrigation?
	○ Do you pay a fixed charges
	○ If a fixed charge is paid, what is the per month charge
	○ If unit-based charges are paid what is the average monthly charges in rupees
	    ○ During kharif----
	    ○ During Rabi-----
		हाँ	

Diesel	○ Average consumption of diesel (liters) per month
	  ○ During Kharif
	  ○ During Rabi	

Water Market*	○ Do you share the pumped water with other farmers ○ If yes ○ For how many days do you share pumped water in Kharif ○ For how many days do you share pumped water in Rabi Period ○ On an average how much do you charge per annum (in Rs)	नहीं
	○ Do you receive additional water from boreholes of nearby farmers ○ If yes ○ For how many days do you receive pumped water in Kharif ○ For how many days do you receive pumped water in Rabi Period ○ On an average how much do you pay per annum (in Rs)	नहीं
Other issues/Remarks e.g. common problems in drilling of wells, common health issues in the area etc		
- Feedback of the local stake holders will form an important input for problem identification and characterization. Feedbacks are to be obtained in case of Urban areas, Industrial clusters also. Feedback on drinking water availability, dependence on ground water etc are also to be obtained. The above feedback form can be customized to the type of priority area and objective of the study.		

Annexure-II

Stakeholder's Feedback Form

		Photograph
Name	घनश्याम पटेल	
Village	आटाडांड	
Block	धरसींवा	
District	रायपुर	
Address	भाटागांव चौक	
Mobile Number (optional)		
Type and number of structures	78	
Type	बोरवेल	
Number		
(coordinates of the structures are to be obtained by the field officer)		
Drill time discharge (lps)	1 – 3 lps	
Depth of installation of pump	50 feet	
Casing depth (Bore wells) HR		
Fracture encountered depth-HR	70 meter	
Slotted pipe depths (TW) SR		
Average water levels – pre-monsoon	15 – 40 meter	
Average water levels – post-monsoon	10 – 20 meter	
The well is used for	खेती	
Is water available throughout the year	हाँ	
If not for how many months water is available		

Pumping Duration

	Number of days pump is in operation (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	40	5	2.5 lps

Kharif (no of months to be specified)	50		
Others (no of months to be specified)			
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)			
Khariff (no of months to be specified)			
Others (no of months to be specified)			
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	धान, सब्जी	सब्जी भाजी	
Area under crop			
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	सब्जी	सब्जी	
Area under crop			
Reasons for change in cropping pattern in last 20 years.			
If the cropping pattern is to be changed, which are the suitable crops that can be grown			
Available Market for the crop	रायपुर मंडी		
Average unit cost of production			
Average unit cost of selling			
Existing MSP(Minimum Support Price) and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.			
Source of Energy			
Solar	○ Is it connected to grid ○ If yes how much incentive do you get per month on an average for feeding electricity to the grid (Rs per month)	नहीं	

Electric	○ Do you get free electricity for irrigation?
	○ Do you pay a fixed charges
	○ If a fixed charge is paid, what is the per month charge
	○ If unit-based charges are paid what is the average monthly charges in rupees
	  ○ During kharif----
	  ○ During Rabi-----
		हाँ	

Diesel	○ Average consumption of diesel (liters) per month
	  ○ During Kharif
	  ○ During Rabi	

Water Market*	○ Do you share the pumped water with other farmers ○ If yes ○ For how many days do you share pumped water in Kharif ○ For how many days do you share pumped water in Rabi Period ○ On an average how much do you charge per annum (in Rs)	नाही
	○ Do you receive additional water from boreholes of nearby farmers ○ If yes ○ For how many days do you receive pumped water in Kharif ○ For how many days do you receive pumped water in Rabi Period ○ On an average how much do you pay per annum (in Rs)	नाही
Other issues/Remarks e.g. common problems in drilling of wells, common health issues in the area etc		
- Feedback of the local stake holders will form an important input for problem identification and characterization. Feedbacks are to be obtained in case of Urban areas, Industrial clusters also. Feedback on drinking water availability, dependence on ground water etc are also to be obtained. The above feedback form can be customized to the type of priority area and objective of the study.		

Annexure-II

Stakeholder's Feedback Form

		Photograph
Name	श्याम लाल साहू	
Village	मोहदा	
Block	धरसींवा	
District	रायपुर	
Address		
Mobile Number (optional)		
Type and number of structures		
Type	बोरवेल	
Number	01	
(coordinates of the structures are to be obtained by the field officer)		
Drill time discharge (lps)	1.5 लीटर प्रति सेकंड	
Depth of installation of pump	90 फीट	
Casing depth (Bore wells) HR	40 फीट	
Fracture encountered depth-HR	—	
Slotted pipe depths (TW) SR		
Average water levels – pre-monsoon		
Average water levels – post monsoon		
The well is used for	कृषि उपयोग	
Is water available throughout the year	नहीं	
If not for how many months water is available	10 माह	

Pumping Duration

	Number of days pump is in operation (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	30-40 दिन	4 घंटे	

Kharif (no of months to be specified)	60 दिन	6 घंटे	
Others (no of months to be specified)			
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)		भाजी, दाल,	धान
Khariff (no of months to be specified)		धान	
Others (no of months to be specified)			
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	धान	भाजी, दाल, धान	
Area under crop			
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	धान	धान, दाल	
Area under crop			
Reasons for change in cropping pattern in last 20 years.			
If the cropping pattern is to be changed, which are the suitable crops that can be grown			
Available Market for the crop			
Average unit cost of production			
Average unit cost of selling			
Existing MSP(Minimum Support Price) and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.			
Source of Energy			
Solar	○ Is it connected to grid ○ If yes how much incentive do you get per month on an average for feeding electricity to the grid (Rs per month)	नहीं	
Electric	○ Do you get free electricity for irrigation? ○ Do you pay a fixed charges ○ If a fixed charge is paid, what is the per month charge ○ If unit-based charges are paid what is the average monthly charges in rupees 　○ During kharif---- 　○ During Rabi-----	हाँ	

Diesel	○ Average consumption of diesel (liters) per month
	  ○ During Kharif
	  ○ During Rabi	

Water Market*	○ Do you share the pumped water with other farmers ○ If yes ○ For how many days do you share pumped water in Kharif ○ For how many days do you share pumped water in Rabi Period ○ On an average how much do you charge per annum (in Rs)	
	○ Do you receive additional water from boreholes of nearby farmers ○ If yes ○ For how many days do you receive pumped water in Kharif ○ For how many days do you receive pumped water in Rabi Period ○ On an average how much do you pay per annum (in Rs)	
Other issues/Remarks e.g. common problems in drilling of wells, common health issues in the area etc		

- Feedback of the local stake holders will form an important input for problem identification and characterization. Feedbacks are to be obtained in case of Urban areas, Industrial clusters also. Feedback on drinking water availability, dependence on ground water etc are also to be obtained. The above feedback form can be customized to the type of priority area and objective of the study.

Annexure-II
Stakeholder's Feedback Form

		Photograph
Name	शिव सिंह यादव	
Village	आमासिवनी	
Block	धरसींवा	
District	रायपुर	
Address	—	
Mobile Number (optional)	—	
Type and number of structures		
Type	बोरवेल	
Number	01	
(coordinates of the structures are to be obtained by the field officer)		
Drill time discharge (lps)	1 लीटर प्रति सेकंड	
Depth of installation of pump	80 feet	
Casing depth (Bore wells) HR	30 फीट	
Fracture encountered depth-HR		
Slotted pipe depths (TW) SR		
Average water levels – pre-monsoon		
Average water levels – post-monsoon		
The well is used for	कृषि उपयोग	
Is water available throughout the year	नहीं	
If not for how many months water is available	08 माह तक	

Pumping Duration

	Number of days pump is in operation (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	30 से 40	4 से 5	

Kharif (no of months to be specified)	50से 60 दिन	6 घंटे	
Others (no of months to be specified)			
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)		सब्जी-भाजी, धान	
Khariff (no of months to be specified)		धान	
Others (no of months to be specified)			
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	धान	भाजी	
Area under crop			
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop			
Area under crop			
Reasons for change in cropping pattern in last 20 years.			
If the cropping pattern is to be changed, which are the suitable crops that can be grown			
Available Market for the crop			
Average unit cost of production			
Average unit cost of selling			
Existing MSP(Minimum Support Price) and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.			
Source of Energy			
Solar	○ Is it connected to grid ○ If yes how much incentive do you get per month on an average for feeding electricity to the grid (Rs per month)		नहीं.
Electric	○ Do you get free electricity for irrigation? ○ Do you pay a fixed charges ○ If a fixed charge is paid, what is the per month charge ○ If unit-based charges are paid what is the average monthly charges in rupees ○ During kharif---- ○ During Rabi-----		हाँ

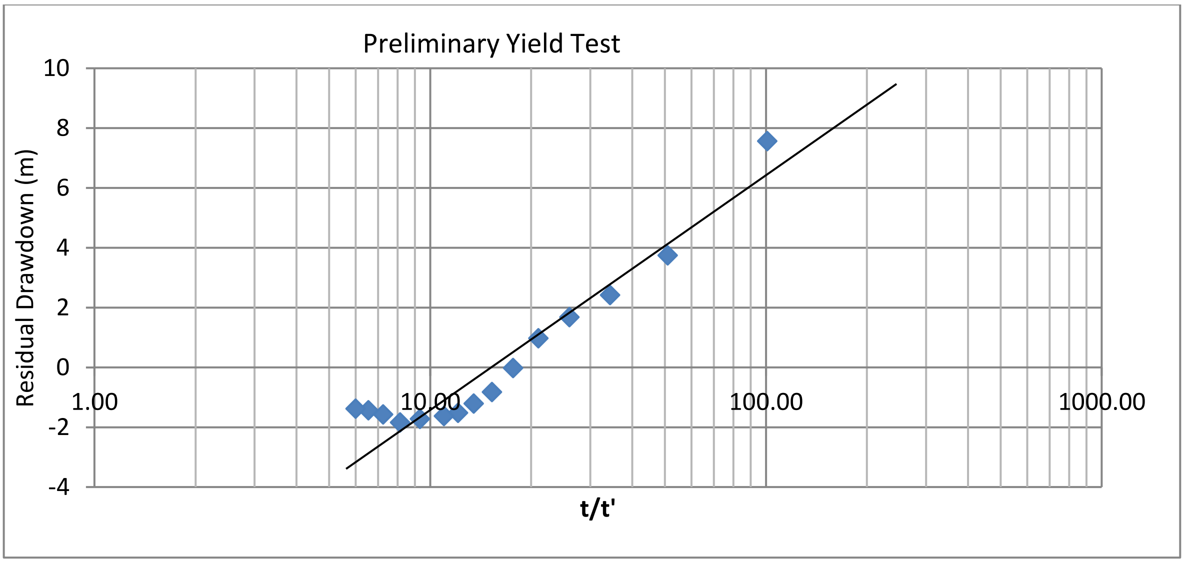
Diesel	○ Average consumption of diesel (liters) per month
	  ○ During Kharif
	  ○ During Rabi	

Water Market*	○ Do you share the pumped water with other farmers ○ If yes ○ For how many days do you share pumped water in Kharif ○ For how many days do you share pumped water in Rabi Period ○ On an average how much do you charge per annum (in Rs)	नहीं
	○ Do you receive additional water from boreholes of nearby farmers ○ If yes ○ For how many days do you receive pumped water in Kharif ○ For how many days do you receive pumped water in Rabi Period ○ On an average how much do you pay per annum (in Rs)	
Other issues/Remarks e.g. common problems in drilling of wells, common health issues in the area etc		
- Feedback of the local stake holders will form an important input for problem identification and characterization. Feedbacks are to be obtained in case of Urban areas, Industrial clusters also. Feedback on drinking water availability, dependence on ground water etc are also to be obtained. The above feedback form can be customized to the type of priority area and objective of the study.		

Annexure 6 Pumping Test / PYT Data of Raipur Urban Area

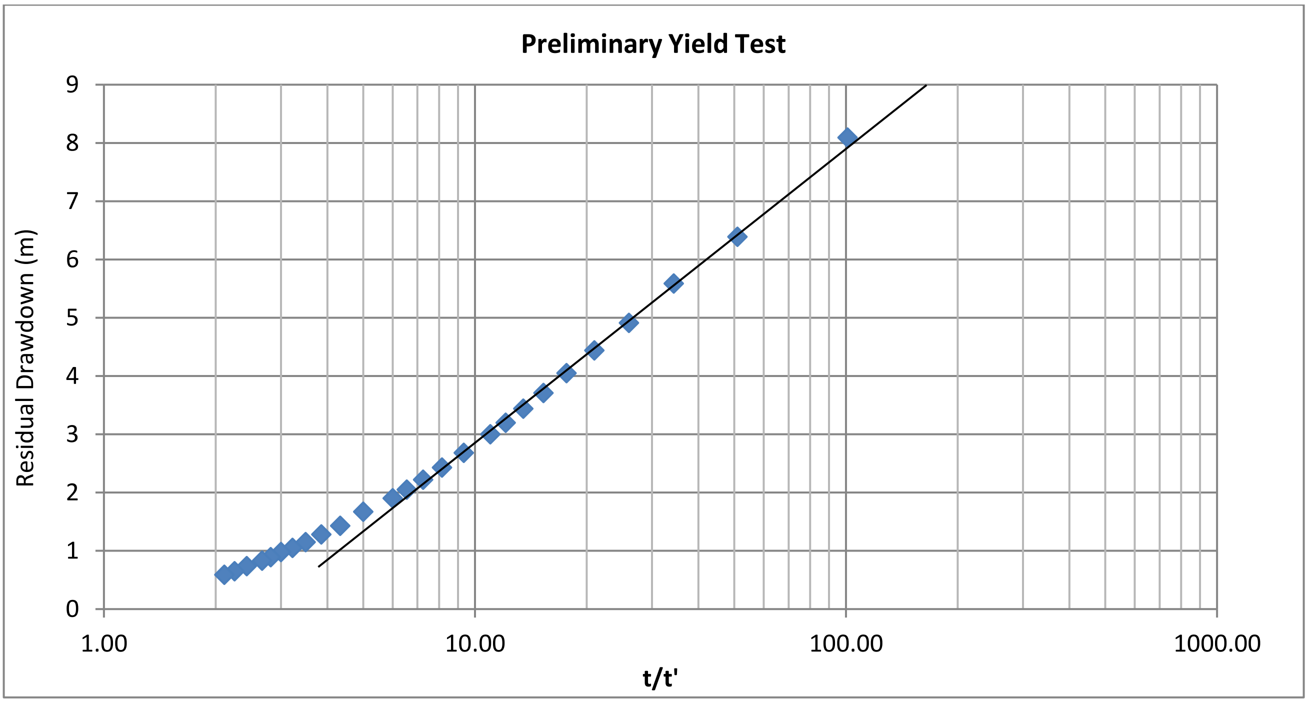
Datrenga, Raipur Latitude (21.1593157, Longitude 81.6357796)

Date/hrs	Time since pumping started (min) t	Time since pumping stopped (min) t'	Depth to water (m)	Residual Draw down (m)	t/t'
27/02/2024	100	0	16.96	7.56	0.00
	101	1	16.96	7.56	101.00
	102	2	13.14	3.74	51.00
	103	3	11.82	2.42	34.33
	104	4	11.08	1.68	26.00
	105	5	10.37	0.97	21.00
	106	6	9.38	-0.02	17.67
	107	7	8.57	-0.83	15.29
	108	8	8.19	-1.21	13.50
	109	9	7.88	-1.52	12.11
	110	10	7.77	-1.63	11.00
	112	12	7.68	-1.72	9.33
	114	14	7.56	-1.84	8.14
	116	16	7.82	-1.58	7.25
	118	18	7.96	-1.44	6.56
	120	20	8.02	-1.38	6.00
	125	25	8.16	-1.24	5.00
	130	30	8.24	-1.16	4.33
	135	35	8.31	-1.09	3.86
	140	40	8.38	-1.02	3.50
	145	45	8.48	-0.92	3.22
	150	50	8.56	-0.84	3.00
	155	55	8.62	-0.78	2.82
	160	60	8.69	-0.71	2.67
	170	70	8.74	-0.66	2.43
	180	80	8.79	-0.61	2.25
	190	90	8.82	-0.58	2.11
	200	100	8.9	-0.5	2.00
	210	110	9.12	-0.28	1.91



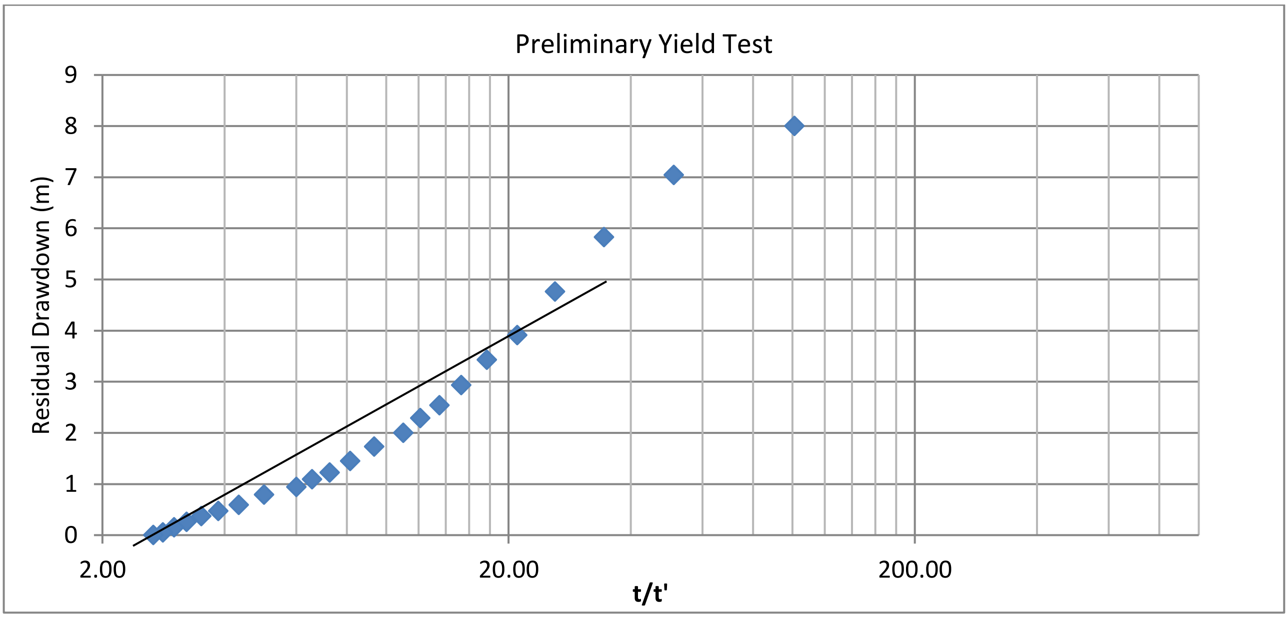
Chikhali, Raipur (Latitude 21.3635092, Longitude 81.6183650)

Date/hrs	Time since pumping started (min) t	Time since pumping stopped	Depth to water (m)	Residual Draw down	t/t'
		(min) t'		(m)	
22/01/2024	100	0	31.8	25.39	0.00
	101	1	14.5	8.09	101.00
	102	2	12.8	6.39	51.00
	103	3	12	5.59	34.33
	104	4	11.32	4.91	26.00
	105	5	10.85	4.44	21.00
	106	6	10.46	4.05	17.67
	107	7	10.12	3.71	15.29
	108	8	9.85	3.44	13.50
	109	9	9.61	3.2	12.11
	110	10	9.41	3	11.00
	112	12	9.09	2.68	9.33
	114	14	8.84	2.43	8.14
	116	16	8.63	2.22	7.25
	118	18	8.46	2.05	6.56
	120	20	8.31	1.9	6.00
	125	25	8.08	1.67	5.00
	130	30	7.84	1.43	4.33
	135	35	7.69	1.28	3.86
	140	40	7.56	1.15	3.50
	145	45	7.46	1.05	3.22
	150	50	7.39	0.98	3.00
	155	55	7.3	0.89	2.82
	160	60	7.24	0.83	2.67
	170	70	7.15	0.74	2.43
	180	80	7.06	0.65	2.25
	190	90	7	0.59	2.11



Sankari (Latitude 21.28028, Longitude 81.73525)

Date/hrs	Time since pumping started (min) t	Time since pumping stopped (min) t'	Depth to water (m)	Residual Draw down (m)	t/t'
30/11/2023	100	0	30.6	9.95	0.00
	101	1	28.65	8	101.00
	102	2	27.69	7.04	51.00
	103	3	26.48	5.83	34.33
	104	4	25.41	4.76	26.00
	105	5	24.56	3.91	21.00
	106	6	24.08	3.43	17.67
	107	7	23.58	2.93	15.29
	108	8	23.19	2.54	13.50
	109	9	22.94	2.29	12.11
	110	10	22.65	2	11.00
	112	12	22.38	1.73	9.33
	114	14	22.1	1.45	8.14
	116	16	21.87	1.22	7.25
	118	18	21.74	1.09	6.56
	120	20	21.59	0.94	6.00
	125	25	21.44	0.79	5.00
	130	30	21.24	0.59	4.33
	135	35	21.12	0.47	3.86
	140	40	21.02	0.37	3.50
	145	45	20.91	0.26	3.22
	150	50	20.8	0.15	3.00
	155	55	20.7	0.05	2.82
	160	60	20.65	0	2.67



Photographs

(Photographs taken during Field work and Meetings done during Study in Raipur Urban area)

Photograph Slide 1: Photographs taken during field work done in Raipur Urban Area

Photograph slide 2: Photographs taken during STP and Intake well visit and during Field Work done in Raipur Urban Area

Photograph slide 3: Photographs taken during Tier III Training with Industries in Siltara Industrial area and Interaction program (PIP) with Kendriya Vidyalaya in Raipur.

Photograph slide 4: Discussion of Ground Water Situation and Recharge Plan with Raipur Nagar Nigam

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