Additional Annexure-16

Comprehensive Hydrogeological Report
on
Ground Water Conditions in Core and Buffer Zones
for
Sahapur East UG Coal Mine,
Sohagpur Coalfield,
M/s. Chowgule & Company Private Limited.

Address of the Industry

Villages-Chunia, Senduri, Kathotia, Khamaria Kala, Kholhar,
Tehsil-Sohagpur, District-Shahdol and
Village Khamariya Khurd, Tehsil-Pali, District Umaria, Madhya Pradesh

Prepared By

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EXECUTIVE SUMMARY

All new/existing industries, industries seeking expansion, infrastructure projects and mining projects abstracting ground water, unless specifically exempted under Para 1.0 of THE GAZETTE OF INDIA: EXTRAORDINARY notification on dated 24.09.2020, will be required to seek No Objection Certificate from Central Ground Water Authority or, the concerned State/ UT Ground Water Authority as the case may be. The entire process of grant of No Objection Certificate shall be online through a web-based application system. Water management plans shall be prepared by all the State Ground Water Authorities/ Organizations for all Over-exploited, Critical and Semi-critical assessment units starting with Over-exploited units. Water management plans shall be reviewed and updated periodically. Water management plans, data on water availability and scarcity and policy framed in this regard shall be placed on the websites of Central Ground Water Authority/ State Ground Water Authority.

The Chowgule Group has always been at the forefront of providing better value to its customers since its establishment in 1916. With over 70 years' experience in open cast mine development and operation, Chowgule and Company Private Limited (CCPL) was the first in India to mechanize mining operation in 1952 at Sirigao Mines, Goa. At present, the Company owns 36 mining leases in Goa, 1 mining lease in Karnataka and has signed an agreement with the central government for commercial coal mining in the Shahpur (East) coal mine in Shahdol and Umaria districts of Madhya Pradesh.

Sahapur East Underground Coal Mine lease area located at villages Chunia, Senduri, Kathotia, Khamaria Kala, Kholhar villages of Sohagpur Tehsil of Shahdol District and Khamariya Khurd village of Pali Tehsil of District Umaria (Madhya Pradesh) over an area of 659 Ha. M/s. Chowgule & Company Private Limited proposes the Sahapur East Underground Coal Mine Project (ML Area: 659 Ha), for 0.70 MTPA Coal Production. The project location doesn't fall within 15km radius from any National Park, eco-sensitive zone etc. The nearest Shahdol Railway Station in 3.7 Km NE. The nearest Airport is Jabalpur Airport in 130 km south from the project site. No National Park/sanctuary falls within 15 km of the coal block.

Coal extraction from the site includes methods like mechanized and semi-mechanized board and pillar underground mining with continuous miner and shuttle cars combination for mechanized method and LHDs with solid blasting method for semi-mechanized. Total reserves that are extractable accounts to 22.187 MT with a percentage extraction of 35.01%.

Total water requirement for mining and other activities like rest shelters, canteen are estimated as 394 m^3/day. The requirement of potable water will be 33 m^3/day for the allied services i.e., canteen, rest shelters, offices colony etc. The water demand will be met from the ground water abstraction structures (Bore Wells) after obtaining the NOC permission of Central Groundwater Authority (CGWA). A total of 18 wells are monitored by doing one time monitoring in pre-monsoon, 2022 to understand the groundwater scenario in the study area. The depth to water level in and around the study area in the month of April 2022 (pre-monsoon) varies from 5.6 m bgl to 10.6 m bgl whereas during post monsoon season, it varies from 2-7.88 m bgl.

This report is revised and updated as per the SOP template issued in February 2022 and the query raised in the EAC meeting held on 10th November 2022. The proponent has applied as a fresh application for the quantum of 1130 m^3/day, out of which 394 m^3/day is the domestic requirement and 736 m^3/day is the estimated mine seepage in the second year of mine development plan. The report is made towards the fulfilment of the conditions stipulated by the CGWA to obtain NOC pertaining to the above-mentioned quantum with an objective to provide an appropriate measure for the ground water withdrawal and mining activities.

1 SALIENT FEATURES OF THE PROPOSAL

S. No.	Particulars	Information
1.	Application No.	New Application
2.	Submission Date	30th June 2022
3.	Fresh or Renewal	Fresh
4.	Existing or New/ Proposed	New
5.	If Renewal, date of validity of existing/ last NOC	NA
6.	CTE Issue Date	
7.	Name of Project with Address	Sahapur East UG Coal Mine, Sohagpur Coalfield, Villages-Chunia, Senduri, Kathotia, Khamaria Kala, Kholhar, Tehsil-Sohagpur, District-Shahdol and Village Khamariya Khurd, Tehsil-Pali, District Umaria, Madhya Pradesh.
8.	State	Madhya Pradesh
9.	District	Shahdol & Umaria
10.	Block/ Taluka	Sohagpur & Pali
11.	Category of Block/ Taluka (as per prevailing GWRE)	Safe
12.	Quantum of GW applied (KLD)	1130 m3/day (394 m^3/day borewell abstraction + 736 m^3/day mine seepage in first two years)
13.	Quantum of GW applied (m^3/Year)	4,12,450 m3/day
14.	Alluvium/ Non-alluvium	Non-alluvium
15.	GW Modelling Required (Yes/ No)	Yes
16.	Name of Authorized Signatory of Project & Designation	
17.	Consultant Details with Name of Authorized Signatory (If Institution)	
18.	In case report is prepared jointly by accredited institute and individual consultant, name details of chapters prepared by the individual consultant	No
19.	Accreditation Certificate No. and Date/ Validity (In case jointly as per Point No. 14, No. and validity of both institution and individual are to be given)	CGWA/RGI/005 Date- 15.02.2021 Validity upto-14.02.2026

2 ABOUT THE PROJECT

The Shahpur East Underground Coal mine is a Greenfield project holding an area of about 659 Ha in the western part of the Sohagpur Coalfields under the administrative control of M/s. Chowgule & Company Private Limited. The project is located at villages Chunia, Senduri, Kathotia, Khamaria Kala, Kholhar Villages of Sohagpur Tehsil of Shahdol District and Khamariya Khurd Village of Pali Tehsil of District Umaria, Madhya Pradesh. The location map of the project area is given as **Figure 2.1**.

The project area is bounded between latitudes 23°14'19" and 23°15'33" N and longitudes 81°18'48" and 81°20'30" E. The area is covered in Survey of India toposheet No. 64 E/7 and 64 E/8 (R.F. 1:50,000). The toposheet map of the area considered for carrying out the hydrogeological study is given as

Figure 2.2.

The area is well connected by both rail and road. The Shahdol and Sohagpur towns are both close to the project area and are connected through metalled road. The Shahdol town is located at about 12 kms from the project. The nearest railway station to the project area is also at Shahdol lying 3.7Km Northeast of the Project area. The nearest Airport is Jabalpur Airport lying 128 Km, WSW from the project site with a road distance of about 200Km.

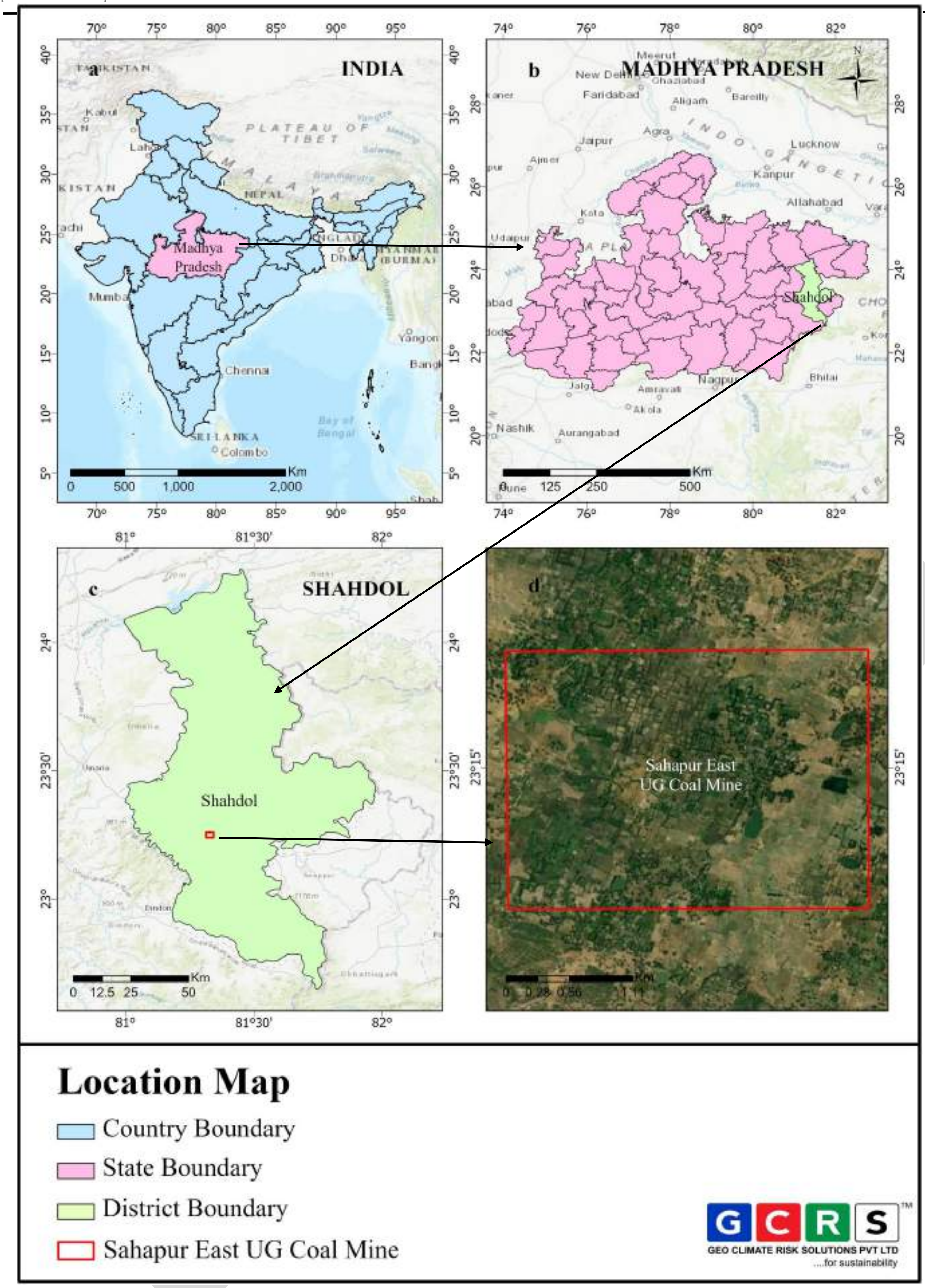

Figure 2.1: Location map of the Project area.

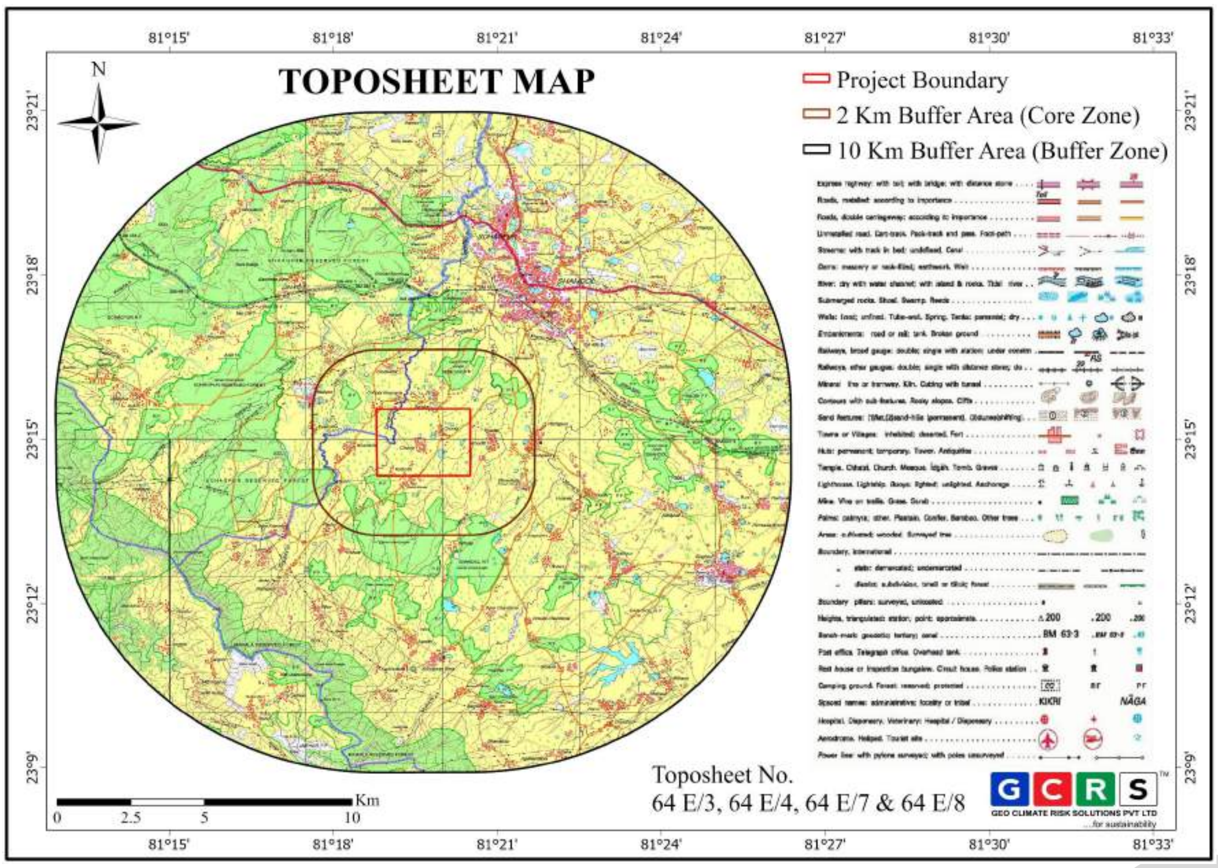

Figure 2.2: Toposheet map of the study area (Source: Survey of India).

OBJECTIVE

The overall objective of the study is to provide a coherent statement of the potential impacts of ground water withdrawal and seepage from mining activities in and around the ground water regime and suggest appropriate measures that can be taken to mitigate them.

This report is prepared to fulfil the following objectives:

- To understand the ground water dynamics of the area through detailed primary and secondary hydro-geological datasets
- Assessment of likely impacts of ground water withdrawal on ground water regime, water quality, and surface water bodies of the study area (10 km buffer area).
- Understanding and evaluation of optimum utilization of the groundwater abstracted for different mining activities. The break-up of total water requirement is explained in detail.
- The field monitoring was carried out for the preparation of comprehensive hydrogeological reports of core and buffer zones in the radius of 2 and 10 km respectively as per the CGWA new guidelines notified on 24.09.2020 and revised SOP issued on 14th Feb, 2022 for obtaining approval from the Central Ground Water Authority.

SCOPE OF WORK

Preparation of Comprehensive Hydrogeological Report along with Ground Water Modelling Study.

- Generation of baseline data, monitoring a network of observation wells, conducting aquifer performance test.
- To carry out Hydrogeological studies viz. general topography, drainage analysis, and geology,
- Meteorology & rainfall analysis, aquifer geometry; surface and ground water potentiality,
- Aquifer characteristics, quality of water; Ground water resources estimation and categorization, seepage calculations of ground water in mine workings
- Mining impact on surface and ground water environment and remedial measures**.**
- Detailed mathematical modelling of computed data.

- Suggested mitigation measures on impact of mining.
- Impact of Ghinachunia Nala on the underground mining work and its mitigation measures
- Obtaining 'statutory approval/NOC' from Central Ground Water Board/Authority to Carry out mining operations.
- Geo-physical aspects and drawing the Highest Flood level line at a suitable place near the proposed opening of the shaft and inclines.

APPROACH AND METHODOLOGY

In order to achieve the objectives hand in hand with the scope of work outlined above, a multidisciplinary approach has been adopted dovetailing the domain skills of hydro-geological and ground water modelling giving equal opportunities so as arrive at an optimal strategy addressing the issues holistically. The methodology encompasses detailed hydro-geological investigation in and around the lease area, establishing aquifer extent and an optimal ground water monitoring network for the surveillance of changes in water quantity and quality. Estimation of mine seepage in time and space has been attempted along with evaluating the influence on ground water in terms of space and quantification of contribution from ground water. Further, the recommendations are proposed to establish artificial recharge structures and water conservation structure in or around the mine lease area following standard norms and guidelines within the statutory frame work of various regulatory authorities.

To carry out the hydrogeological study for the project, core zone of 2 km and buffer zone of 10 km from the mine lease boundary has been assigned as per the statutory guidelines stipulated by the Central Ground Water Authority. The Google map of the study area demarcating the core and buffer zones is shown as **Figure 2.3**.

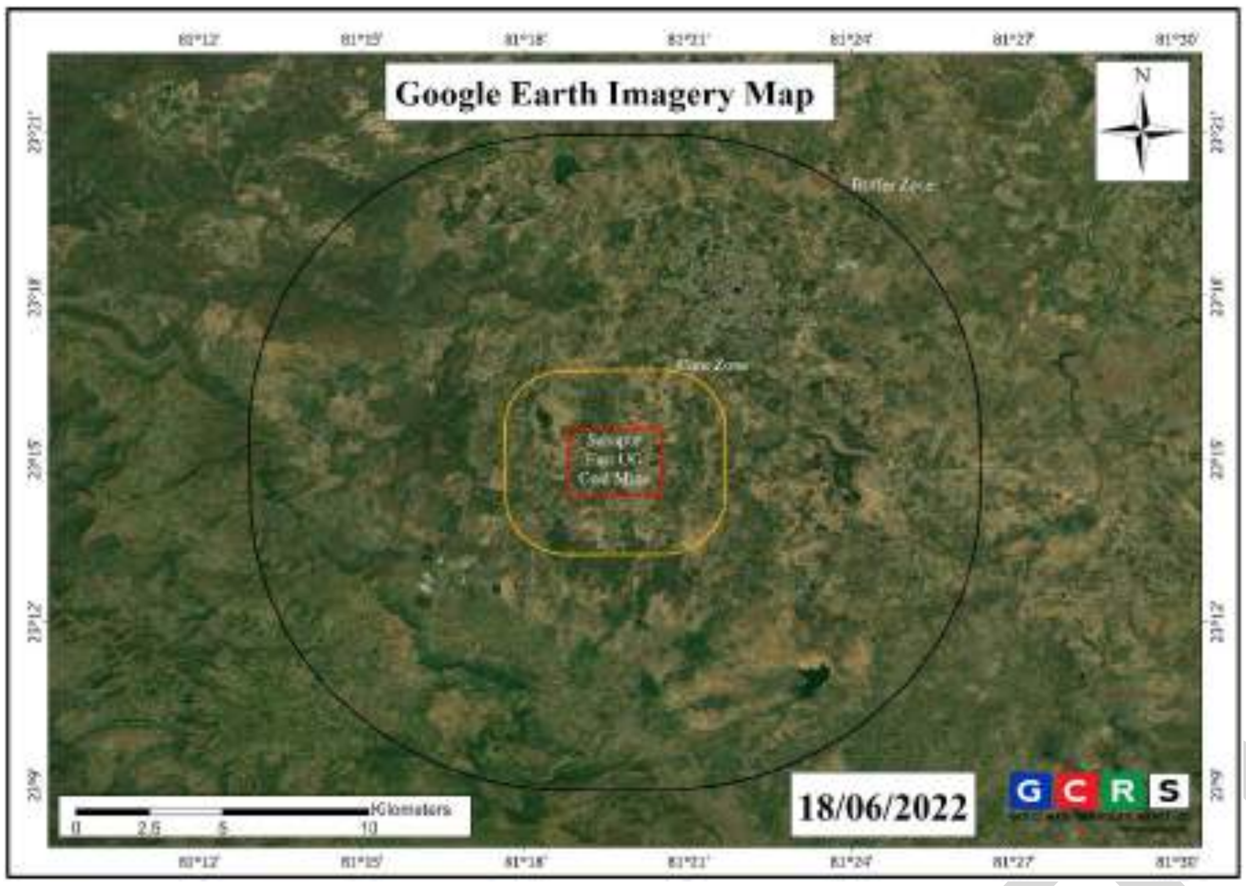

Figure 2.3: Google earth imagery of the study are demarcating core and buffer zones.

2.1 LANDUSE / LAND COVER OF THE SURROUNDING AREA

The land use and landcover (LULC) maps are the fundamental data source for land management and planning. The accurate mapping of LULC classes is a valuable tool for understanding the relationship between humans and the environment (Pratico et al., 2021; Schulz et al., 2021; Viana et al., 2019; Qian and Zhang, 2022). The LULC maps for the present study were prepared using Sentinel-2 data on Google Earth Engine (GEE) platform. The GEE platform is widely used to shorten the processing time, which helps the user store decades of data and removes the need to download the satellite imagery one by one. The spatial resolution of LULC classes in the present study is mainly related to the topographic factors/conditions.

In the present study, 5 LULC classes were prepared pre-monsoon during 2022 (Figure **2.4**). The percentage area covered under different LULC classes, and their seasonal variations is presented below as **Table 2.1**.

It can be conferred from the data that the predominant land use in the study area is agriculture land followed by forest area (green area) with 69.15% and 27.92% coverage area respectively in the pre – monsoon season, 2022. The built up, water body and barren land covers the least percentage in the study area in a descending order of coverage area sequence with 1.51%, 0.77% and 0.63% respectively. Variations in the coverage area of the same has also been observed between the pre and post monsoon seasons in the study area.

Table 2.1: Year wise seasonal LULC percentage coverage of the study area.

Sl. No.	**Class**	**2021-Post monsoon**		**2022-Pre monsoon**	
		Area(ha)	**Percentage**	**Area(ha)**	**Percentage**
1	Waterbody	427.289	1.008	329.424	0.777
2	Agriculture	27477.226	64.835	29309.132	69.158
3	Green area	12645.936	29.839	11836.119	27.928
4	Barren land	1256.888	2.966	266.056	0.628
5	Built-up	572.925	1.352	639.533	1.509

As per the land use details of mine lease area, total 12.73 Ha land is reserved for forest, 522.79 Ha and 123.47 Ha is reserved for private land and government land respectively (**Table 2.1).**

Table 2.2: Land use details of Mine lease area.

Forest	
Reserve Forest	0 Ha
Protected Forest	0 Ha
Revenue Forest	12.733 Ha
Total Forest land	12.733 Ha
Non- Forest	
Private land	522.794 Ha
Government land	123.473 Ha
Total Non- Forest land	646.267 Ha
Total Land (A+B) = 659 Ha	

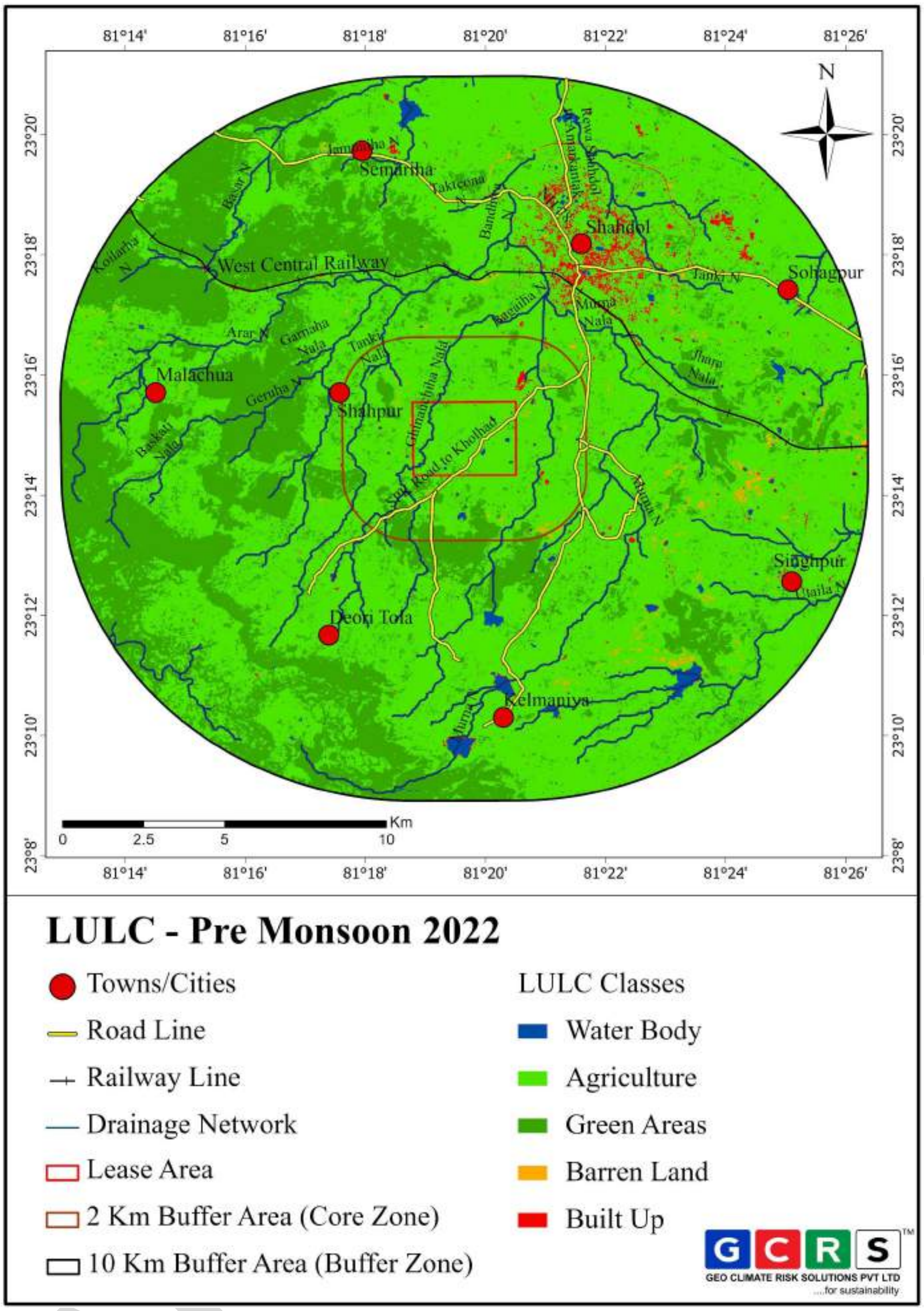

Figure 2.4: LULC map of the study area, (pre-monsoon) 2022,

2.2 DEM / TOPOGRAHY

Digital Elevation Model (DEM) is the digital representation of the land surface elevation with respect to any reference datum. It reflects the physical surface of the earth helps us to understand the nature of terrain by means of interpreting the landscape using modern techniques and high-resolution images. It is profitable to comprehend the nature of topography, address the practical problems and fix them by applying new insights, upcoming high resolutions satellite images and techniques. Whereas, topography is the physical and natural features of land surfaces. A topographic map shows natural features and manmade features (Balasubramanian, 2017).

The study area shows higher elevations of the order of 600 to 1000 mamsl towards the southwestern portion sloping down gently through the study area from the southwest to the northeast. The project area lies at about 475-504 mamsl (**Figure 2.5**).

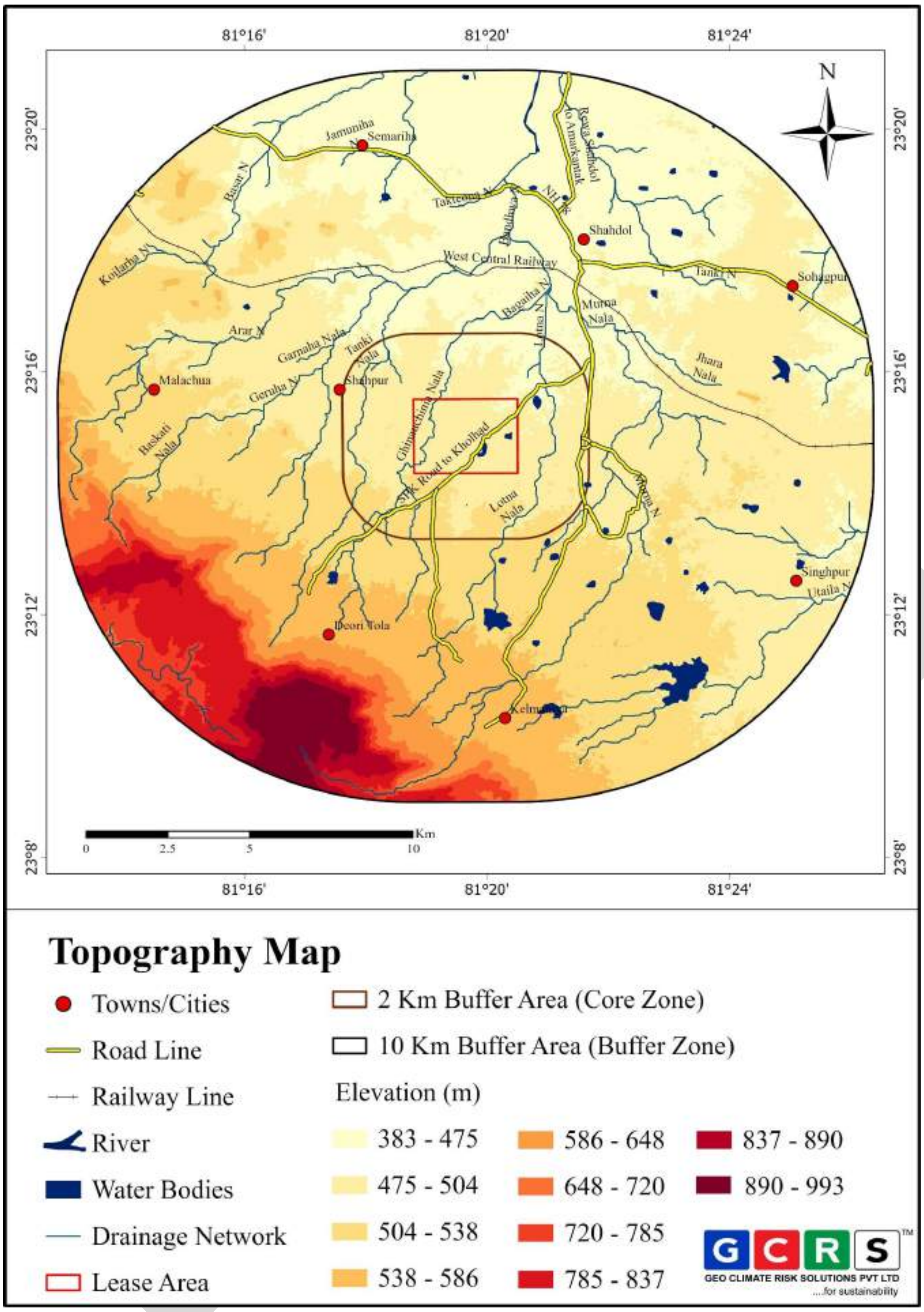

Figure 2.5: Topography map of the study area.

2.3 GEOMORPHOLOGY AND DRAINAGE

The predominant geomorphology of the study area is characterized by pediment pediplain complex with moderately dissected plateaus towards southwest and minor dissected hills and valleys (**Figure 2.6**).

The study area is characterized by pediplain-pediment complex and water bodies such as ponds. Major area is covered with pediplain-pediment complex and water bodies scattered in SE region in the buffer zone. The SW portion of the buffer zone is covered with pediment-corestone, bench, and scarps. All these landforms are formed due to the wind erosion. They also mark the presence of the water bodies such as rivers.

Drainage network of the study area is extracted from SRTM-DEM of 30 m spatial resolution (USGS website) by utilizing the Hydrology tool of ArcGIS software. The drainage in the concerned project area is predominantly dendritic in nature formed by the north- ward flowing Ghinachunia nala (**Figure 2.7**.) The Son River flowing on the northeast side of the study area at about 17 km forms the main drainage system of the Sohagpur Coalfield. All the major or minor streams passing through the study area flows towards the Son River flowing northwards.

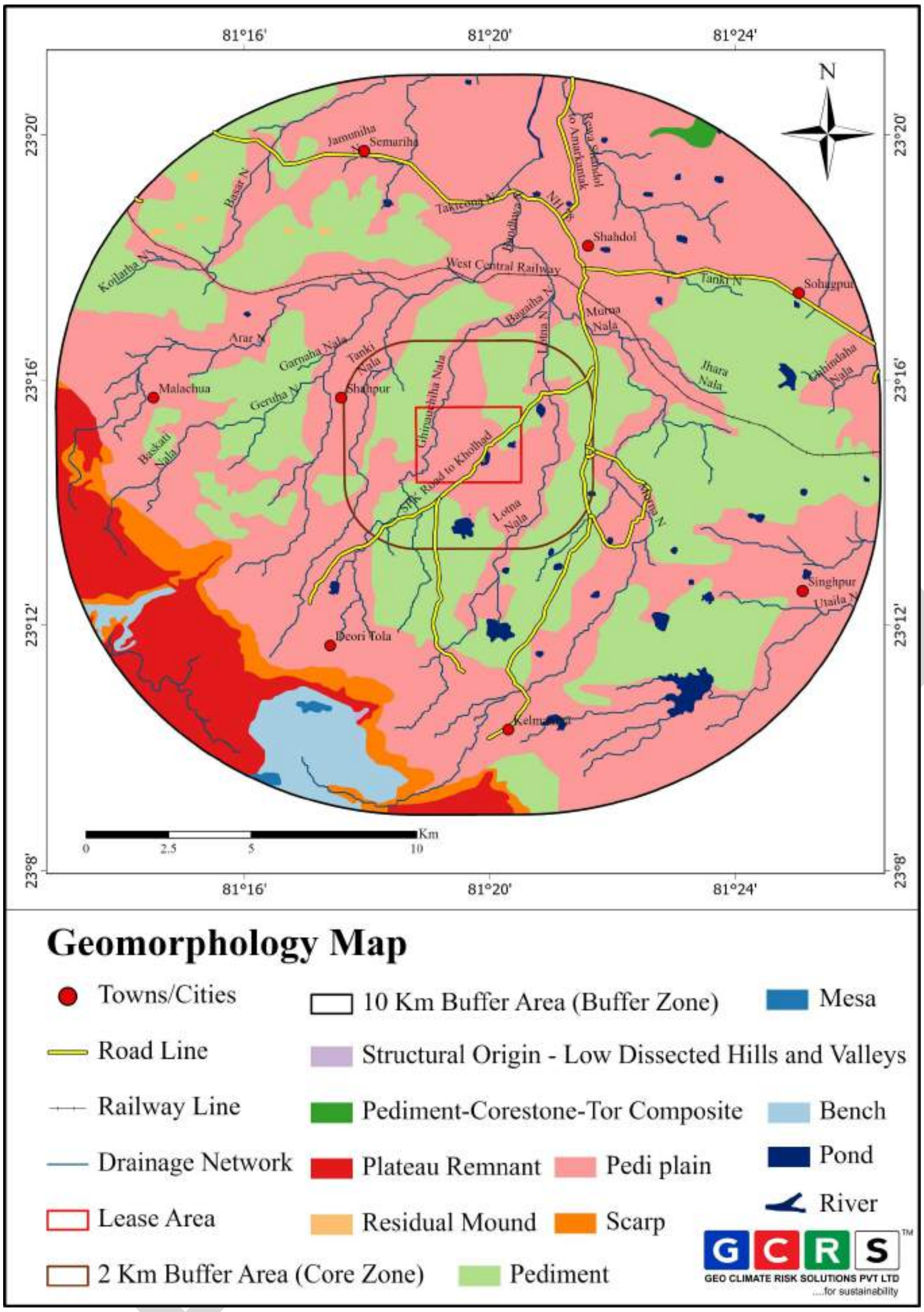

Figure 2.6: Geomorphology map of the study area (Source: https://bhukosh.gsi.gov.in).

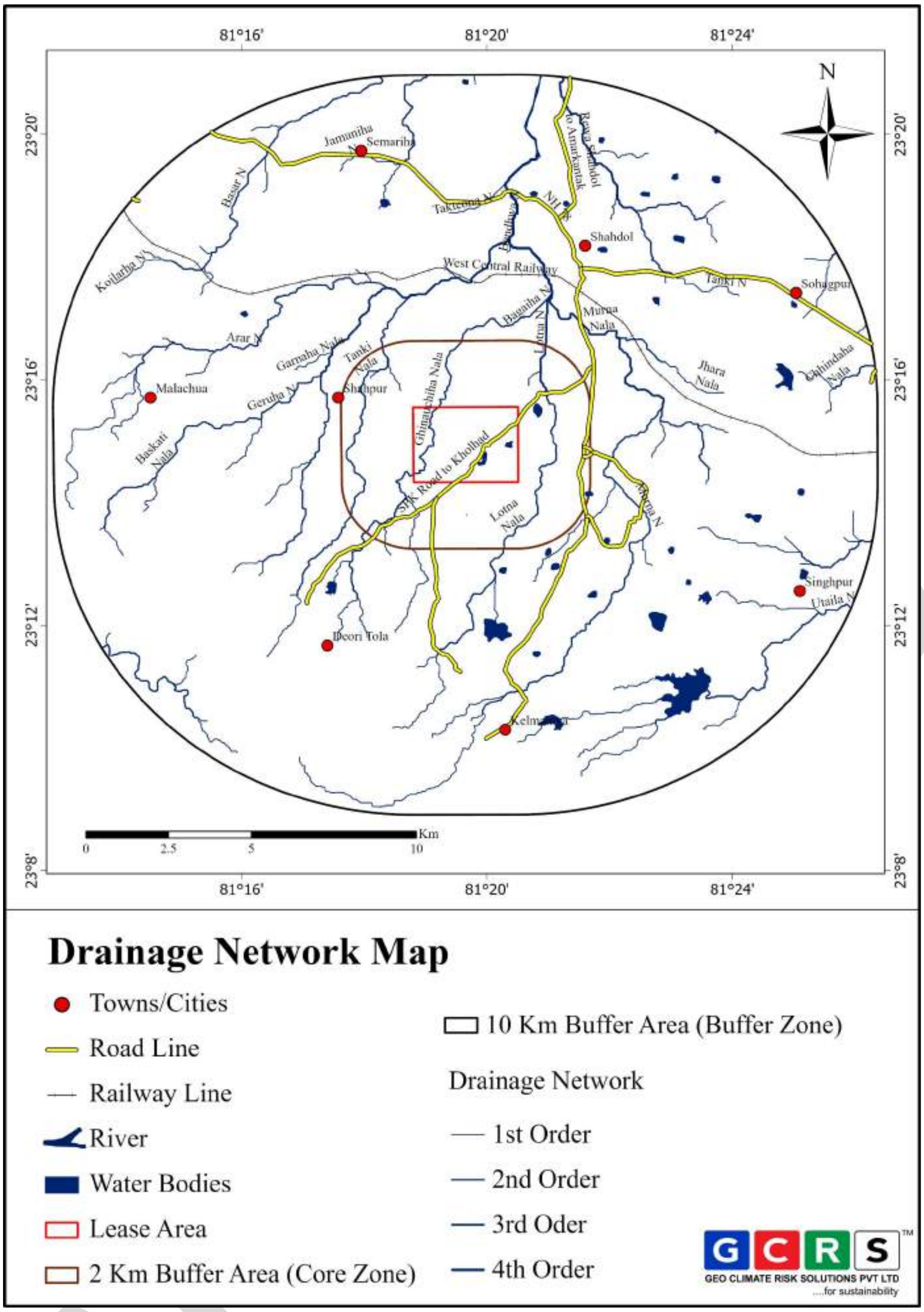

Figure 2.7: Drainage Map of the study area.

2.4 DETAILS OF WETLANDS / MAJOR WATER BODIES

A wetland is a distinct ecosystem that is flooded by water, either permanently or seasonally, where oxygen-free processes prevail. The primary factor that distinguishes wetlands from other landforms or water bodies is the characteristic vegetation of aquatic plants, adapted to the unique hydric soil. Any wetland site which has been listed under the Ramsar Convention that aims to conserve it and promote sustainable use of its natural resources is called a Ramsar Site. There are a total of 75 Ramsar wetland sites present in India as of August, 2022. (http://wiienvis.nic.in/Database/ramsar_wetland_sites_8224.aspx). The map and list showing the Ramsar sites existing in India is enclosed below as **Figure 2.8**. The Ramsar sites in the vicinity of the Project area is depicted in the

Figure 2.9.

From the above-mentioned figures, it is evident that, the Ramsar Wetland site nearest to the Project site is Samaspur Bird Sanctuary in Uttar Pradesh situated at an aerial distance of about 303.17 Km North of the project site. Hence, no Ramsar sites being present neither in the vicinity of 500m from the mine lease nor within the study area, Certificate regarding the same is not applicable for the proposal.

Further, there are no major water bodies found in the study area. However, it is conspicuous from the toposheet (Figure **2.5**) and LULC maps (Figure **2.4**) that, reservoirs of lesser magnitude formed by the small dams on the minor streams are prominent in the study area.

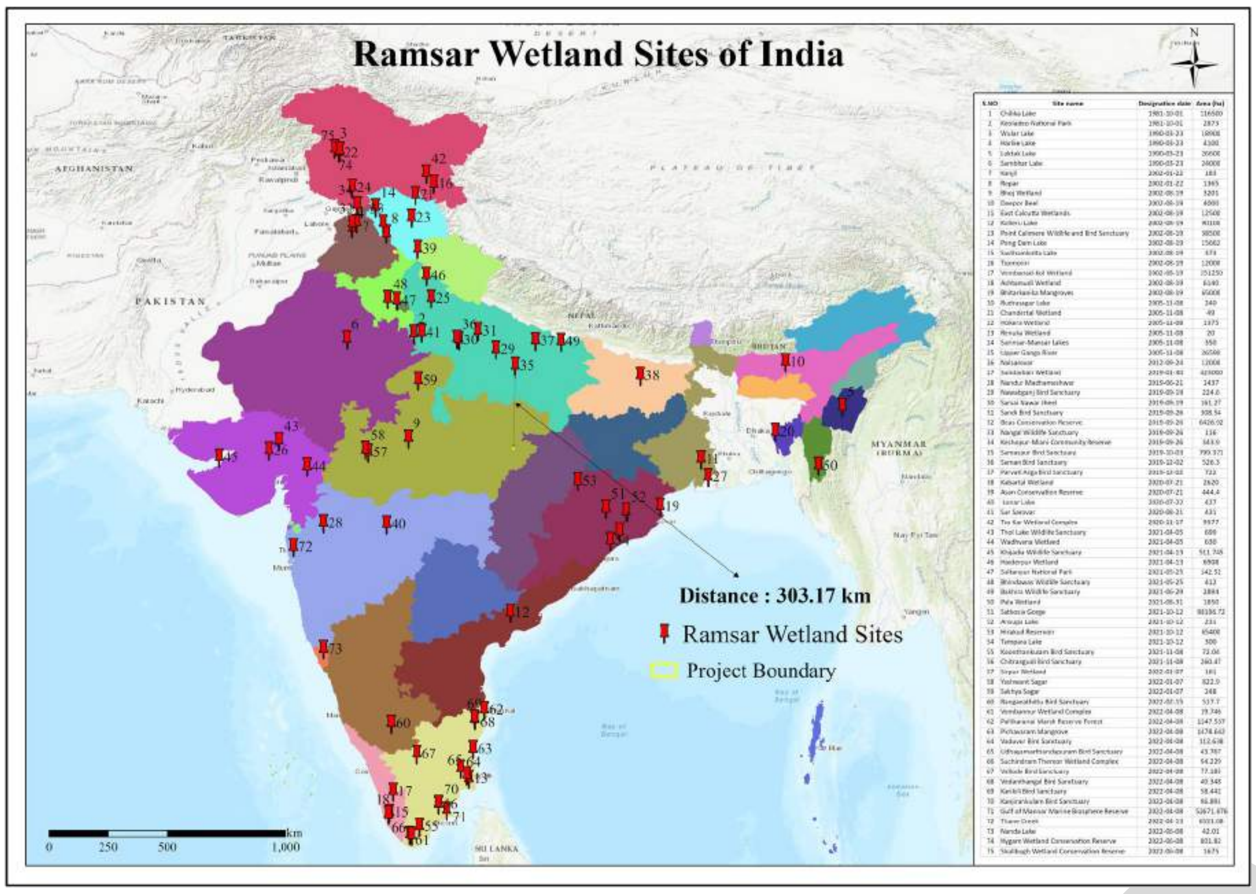

Figure 2.8: Map showing Ramsar Wetland Sites of India

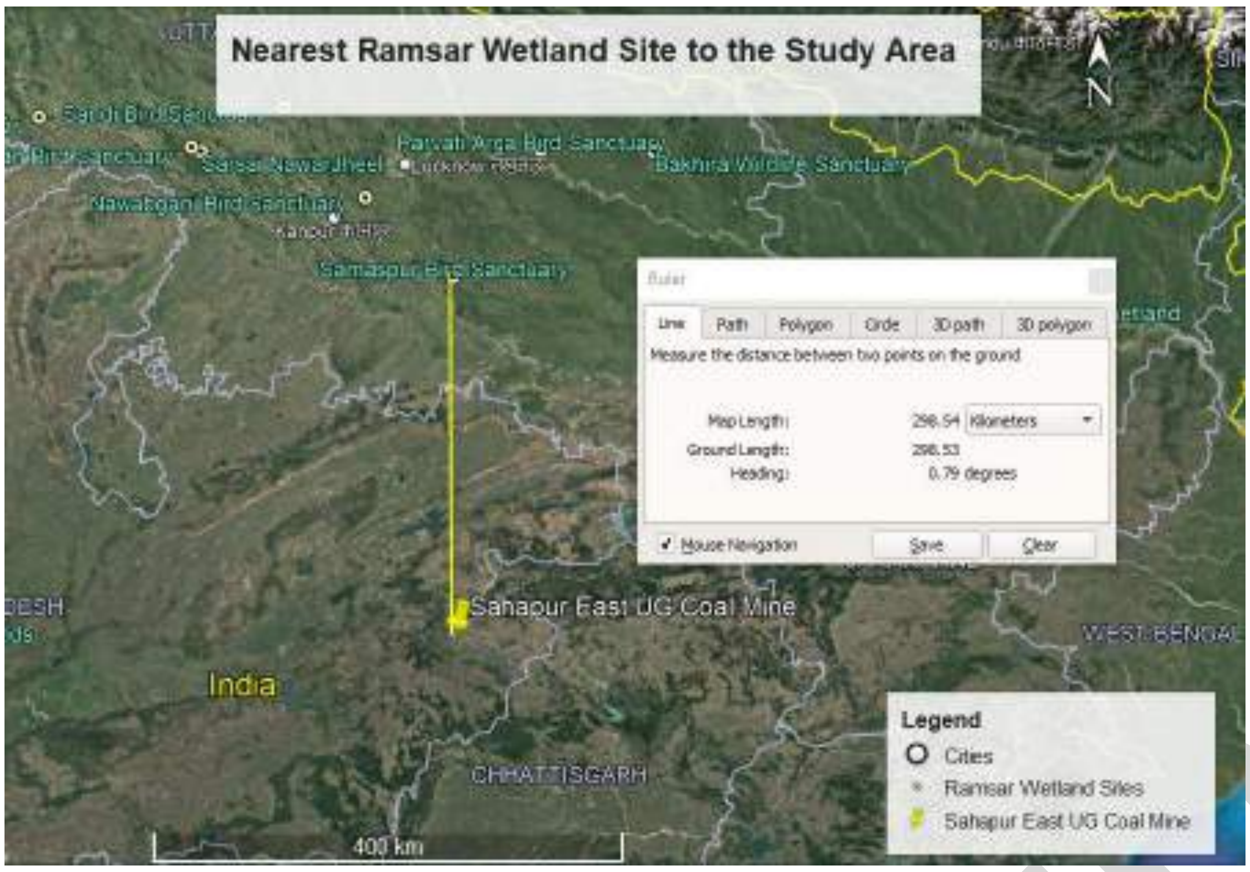

Figure 2.9: Nearest Ramsar Wetland site to the Project .

3 HYDROGEOLOGY

Details pertaining to the ground water scenario in the core and buffer zones of the study area, brief of the regional and local geology, hydrogeological set up, water level trends, fluctuations and quality data including relative maps have been discussed in the underlying sections.

3.1 GEOLOGICAL SET UP

The Sohagpur Coalfield forms one of the main coal bearing areas of the Rewa-Gondwana basin and comprises an area of nearly 3100 sq. km of Barakar strata within the Shahdol district of Madhya Pradesh. GSI regional exploration conducted between 1994 to 1999 in the western part of Shogpur reported that the coalfield is elongated roughly in the East-West direction and extends over 103 Km from Ghunguti (230 29': 810 13') in the west to the Hasia nala located between latitude 23^0 20' and longitude 82^0 15' in the east. The maximum width of the coalfield along North-South is approximately 45 Km. It can be broadly divided into two parts i.e., the North and South Sohagpur, along the E-W trending intrabasinal Bahmni - Chilpi fault. The North Sohagpur represents the down thrown block of the Sohagpur basin where coal measures are inferred to occur at depth, under a thick cover of younger Upper Triassic sediments termed as Supra-Barakars. The coal horizons in South Sohagpur are either exposed or occur under a thin cover of younger sediments; except in the South-West where it is overlain by a thick Lameta Formation and Traps. In South Sohagpur, three sub basins namely Jhagrakhand, Jamuna - Kotma & Amlai- Burhar, from east to west, have been recognised. Sohagpur Coalfield has been a traditional source of superior quality, low rank, high volatile coals. Such coals have been under active exploitation in the entire tract in South Sohagpur.

The Sohagpur Coalfield is the biggest coal–producing area of South Rewa Gondwana Basin, Shahdol District, Madhya Pradesh and covers an area of 3100 km2. The coalfield has 1000 m thick sedimentary strata and the Gondwana rocks strike WNW–ESE to E–W and dip upto 5° towards the north (Pareek, 1987). The Gondwana sediments in the area are known as Talchir (early Permian), Barakar (early Permian), Pali (middle Permian–middle Triassic) and Parsora (early Jurassic) formations as well as Lameta beds (late Cretaceous) (Raja Rao, 1983). The Talchir Formation unconformably overlies the basement rocks and contains shale, siltstone and boulder beds. The Barakar Formation overlies the Talchir Formation and is approximately 450 m thick. The Barakar Formation is the only coal bearing sequence and is divided into lower, middle and upper members. The lower member is composed of greyish–white feldspathic garnetiferous sandstone, siltstone and shale, the middle member comprises cross–bedded feldspathic sandstones with garnet, and thick workable coal seams in the lower portion while the upper member of the Barakar Formation contains ferruginous sandstones, shales, and siltstones. The Pali Formation is also divided into three members, lower, middle and upper and is about 350 m thick (Gautam et al., 2016). The Parsora Formation comprises coarse grained to pebbly ferruginous sandstones and shales and the Lameta beds include greenish and reddish, poorly consolidated sandstones and shales with nodular limestone at the top. An unconformity is marked between the Parsora Formation and Lameta beds. The coalfield is intruded by dykes and sills (Deccan Trap–late Cretaceous–Eocene). Dolerites are also placed along the faults (Dhanam et al., 2013).

The regional stratigraphic succession of Sohagpur basin as per GSI is provided in **Table 3.1**

LOCAL GEOLOGY:

The Shahpur East block falls in the Nort western part of Sohagpur Coalfield. The area explored by MECL (Mining Exploration Corporation Limited) explains that mostly the area is covered by sandy soil and minor exposures of Barren measure sandstones are discovered alonh the Ghinachunia Nala. The study area conforms to the regional geology of the area (**Figure 3.4**).

Table 3.1: Geological sequence of the area.

Age	Formation (max. recorded thickness)	Lithology
Early Eocene To Late Cretaceous	Deccan Trap (100m)	Dolerite dykes and basic flows
Late Cretaceous	Lameta (25m)	Calcareous sandstone & sandy limestone
Early Jurassic To Late Triassic	Parsora (100m)	Mature well sorted arenite interbedded with lavender coloured clay beds (Not found in the area)
Early Triassic To Late Permian	Pali (+250m)	Immature sandstone with varying amount of clay matrix. Decrease in feldspar content towards top (Not found in the area)

Late Permian	Raniganj (+550m)	Fine to medium grained feldspathic, cross-bedded immature and poorly sorted sandstone alternating with gray claystone, shale and coal.
Local disconformity (scoured contact, Coal & caliche development), may be conformable in the deeper parts of the basin		
Late Permian	Barren Measures (250m)	Medium to coarse grained arkosic, immature and poorly sorted sandstone interbedded with siltstone, shale and variegated claystone.
Local disconformity (palaeosol), may be conformable in the deeper parts of the basin		
Early Permian	Barakar (265m)	Medium to coarse grained arkosic, immature and poorly sorted sandstone alternating withsiltstone, shale, variegated claystone and coal.
		Medium to fine grained arkosic, immature and poorly sorted sandstone alternating withsiltstone, shale and grey claystone.
Early Permian	Talchir (+120m)	Medium to coarse grained pebbly sandstone with argillaceous matrix; angular pebbles of quartz, rock fragments, claystone and shale
-UNCONFORMITY-		
Precambrian	Surguja crystalline Complex	Granite

In order to understand the local geology of the study area, a detailed study has been carried out using borehole lithology data (Figure **3.1**). The detailed litholog data provide a clear understanding of the stratigraphy and thickness of the formation available in the study area. The proponent has shared borehole lithology data inside the mine lease area. The fence diagram has been prepared using available litholog data. A fence diagram is simply a 3D graphical representation of 2D subsurface geometry. A fence diagram can be drawn using various data such as borehole lithology and stratigraphy, geophysical data, geochemical data, and structural data. Fence diagrams are applied in multiple fields of geology, for example, inferring the extension of aquifers and the extension of a plume in aquifers to infer the lithology and various structures across the defined area.

Method

For the present study, a fence diagram and cross-sections have been prepared with the Rockworks software using the Lateral Blending technique to understand the lateral extension of various rocks. In the Lateral Blending technique, a fence diagram can be established by building a solid lithology model, which is achieved by automatically assigning values (interpolating) to voxels (i.e., a point or circle with three-dimensional information of a model) in a horizontal manner. At first, the software assigns values to the voxels enveloping near the borehole concerning the nearest lithology or any real numbers. Then the model assigns values to the next voxel concerning the closest lithology value to the first point. The model will then assign values to the voxels until it reaches a voxel around a third of the way to the adjacent borehole or nearest lithology. In the middle point of two boreholes, the model will assign random values to the voxels to avoid sharp change or contact. In this way, a fence diagram can be obtained by slicing the solid model based on the desired outlines of the fence that is selected in the fence selection map of the software. Similarly, the sliced solid model creates cross-sections and profiles between the desired points in the project area.

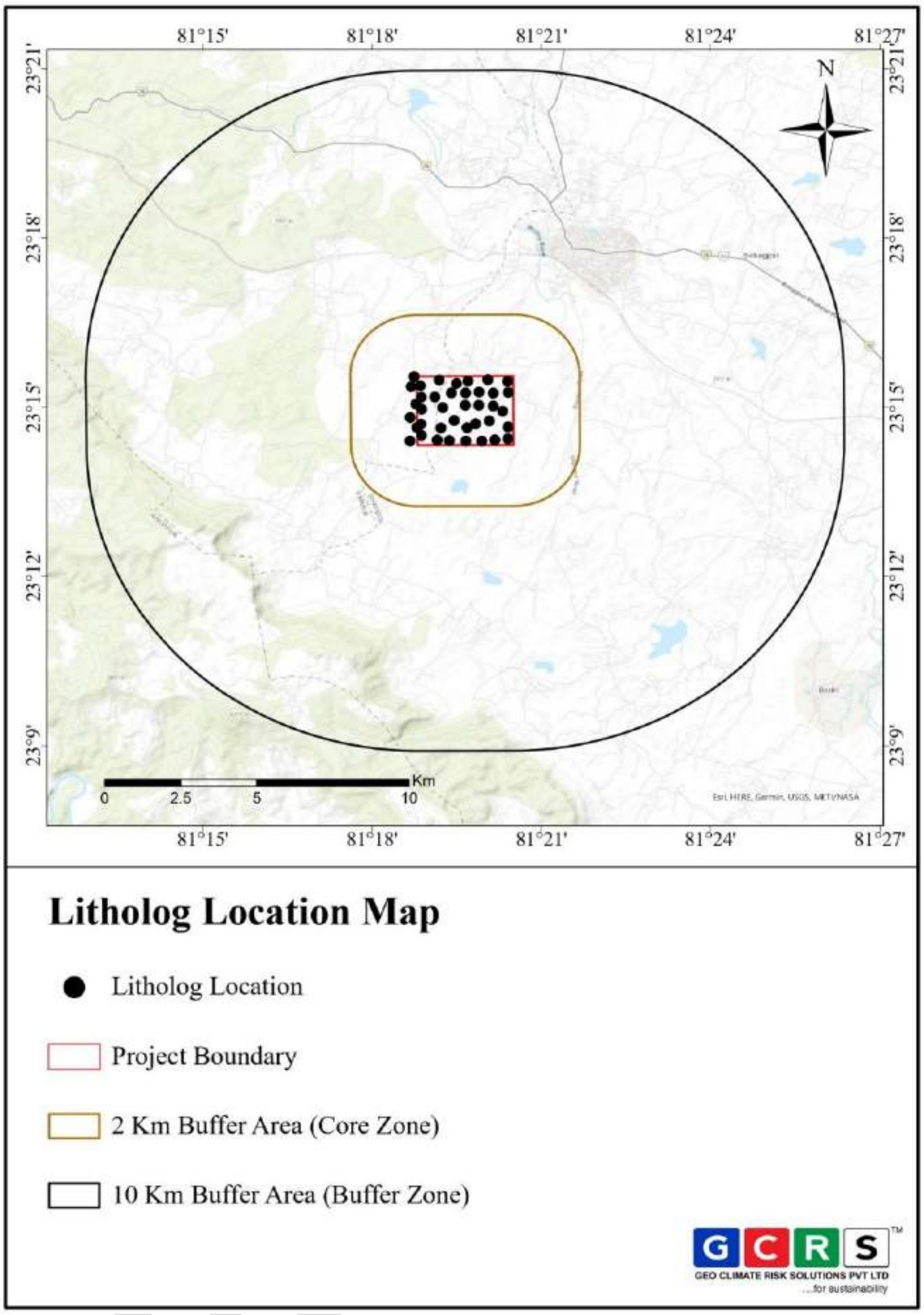

Figure 3.1: Lithology Borehole locations of the project area.

Figure 3.2 represents the depth-wise and lateral variation of lithologies on the project boundary in a fence diagram based on the available borehole data. Based on the fence diagram, soil, lamprophyre/dolerite intrusive, sandstone, shale, shaly coal, claystone, and coal beds are found in the project boundary. Among these lithology units, sandstone covers much of the study area. The project area has both semi-confined and unconfined aquifers. The project area consists of eight comparable and workable coal seams: Local Seam L1, Seam I, Seam II, Seam III, Local Seam L2, and Seam IV from bottom to top. Further, Seam III of the project area was found to occur as three sub-sections from the bottom, namely IIIL and IIIB, which are less continuous. In contrast, the top sub-section IIIA was continuous and obvious all over the project area. The coal seams IV, IIIA, IIIB, IIIL, and II are visible in the fence diagram. Due to their lower thickness, coal seams L1, I, and L2 are not visible in the fence diagram. The dolerites are found below the topsoil in the northwestern and southwestern parts of the project area. The first and last occurrence of dolerites is generally found between 3 to 18 m bgl along the above-mentioned project area. A 30 m thick layer of dolerite found in the borehole MSSE-34 lies on the southwestern part of the project area. Like, dolerites in the north and southwestern parts of the project area, claystone is found below the topsoil in the north and southeastern parts of the project area. The occurrence of the claystone is generally found between 4.5 to 14.13 m bgl. Claystone is also found in the deeper levels of the project area.

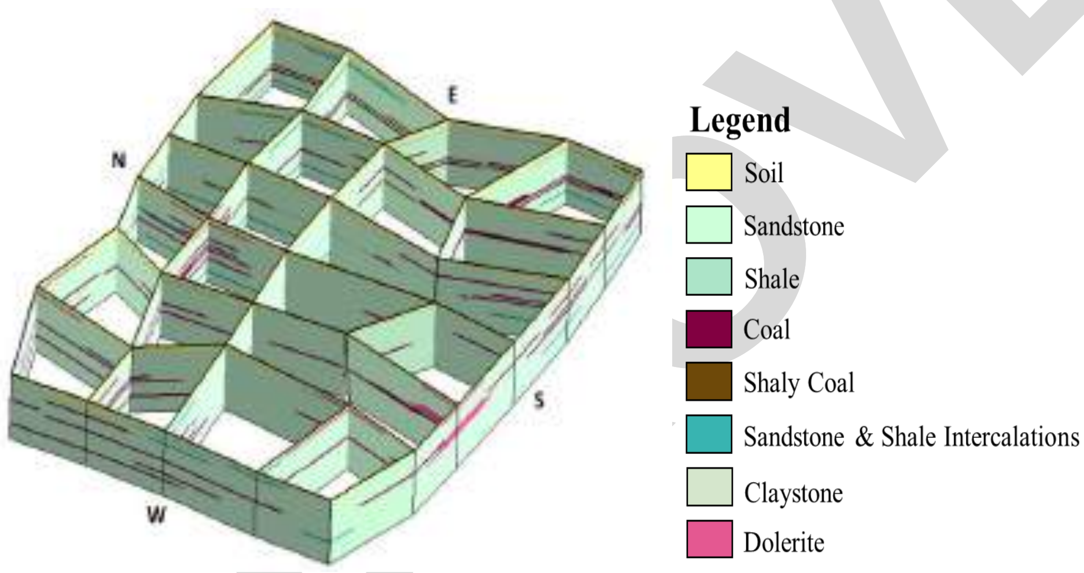

Figure 3.2 Fence diagram of the project area

Figure 3.3 represents the lithologic profile section along AA' that is the north-south direction of the project area. Based on the lithologic profile, the top layer is occupied by soil followed by a minor occurrence of dolerite in the northern part of the study area. It is also evident that the topmost or first appearance of the coal seam in the southern part of the profile of AA' represents the coal seam IV, while the appearance of a coal seam in the middle of the profile AA' represent the coal seam III which includes its sub-sections IIIA, IIIB, and IIIL as isolated patches in the middle northern part of the profile. Similarly, the bottom-most or last appearance of a coal seam in the north part of the profile represents the coal seam II. Shale is found above the coal seam II in the northern part of the profile. Also, minor occurrences of shaly coal beds are found in the bottom center part of the profile.

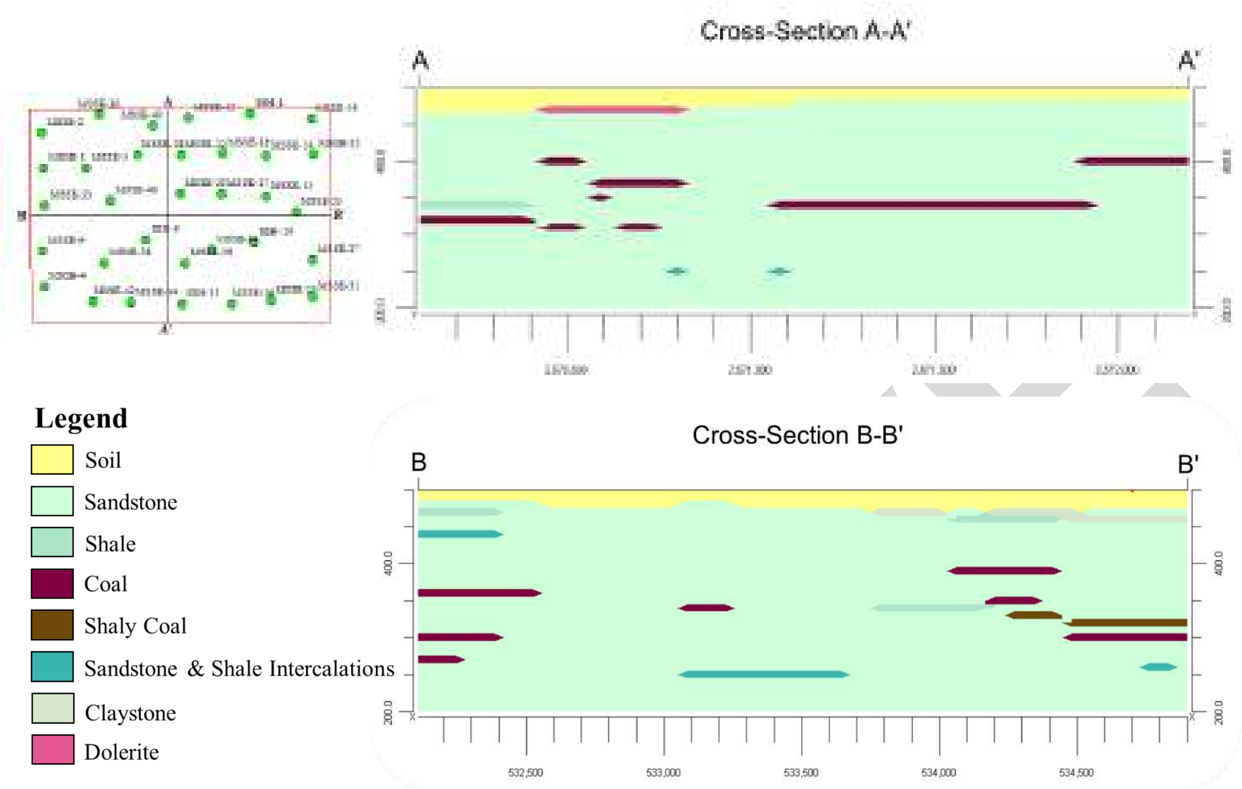

Figure 3.3 Lithologic Profile along with AA' and BB' in the project area

Figure 3.3 also represents the lithologic profile section along BB' that is the West-East direction of the project area. Based on the lithologic profile, the top layer is occupied by soil, followed by a minor claystone occurrence in the study area's eastern part. It is also evident that the topmost or first appearance of the coal seam in the southern part of the profile of BB' represents the coal seam IV. In contrast, the isolated appearance of a coal seam in the middle of the profile BB' represents the coal seam III. The bottom-most coal seam at the eastern part of the profile represents coal seam II. Similarly, the top coal seam at the western part of the profile BB' represents the coal seam II. Coal seams at the bottom of the coal seam II at the southern part of the profile represent coal seam L1. Due to their lower thickness, coal seams IV, III, and II are not visible in the profile. Also, minor intercalations of shale and sandstone beds are found in the bottom center and eastern part of the profile and the top northern part of the profile.

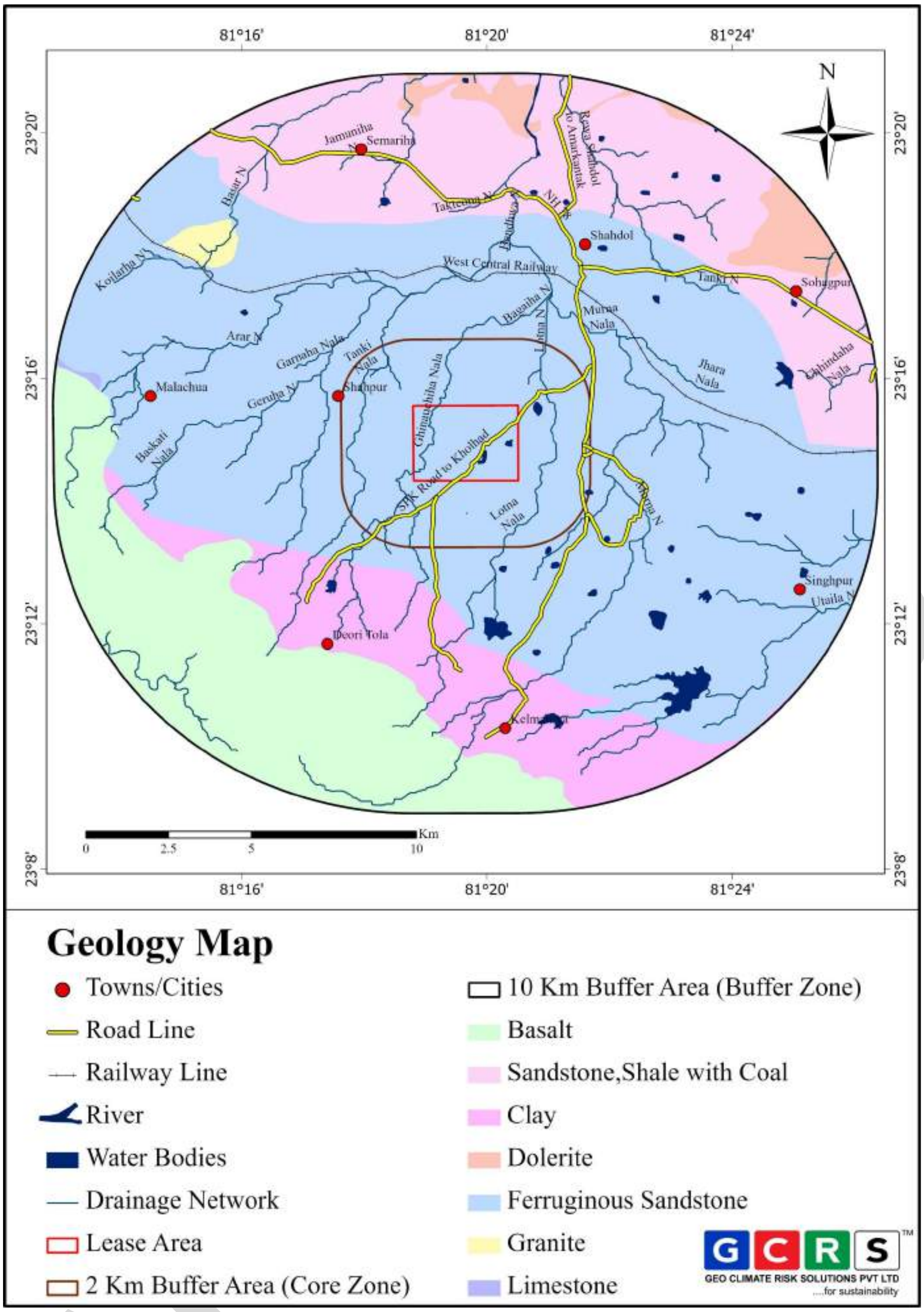

Figure 3.4: Geology map of the study area (Source: https://bhukosh.gsi.gov.in).

3.2 GEOPHYSICAL STUDIES

In order to reconstruct the sub-surface geometry of the study area, a detailed geophysical investigation has been carried out using Vertical Electrical Sounding (VES) survey (**Figure 3.5**). In the present study, the VES data were interpreted using the physical parameters, such as the thickness of the formation and resistivity. Then the parameters were correlated with available borehole lithological data to interpret the sub-surface stratigraphy. The present study used depth-wise resistivity variation in VES data to interpret the sub-surface stratigraphy (Telford et al., 1990; Reynolds, 2011). The apparent resistivity of the formation is calculated by measuring the change in the potential in the proximity of the applied external electric current to the electrodes, excluding the self-potential of the formation (Chandra, 2015).

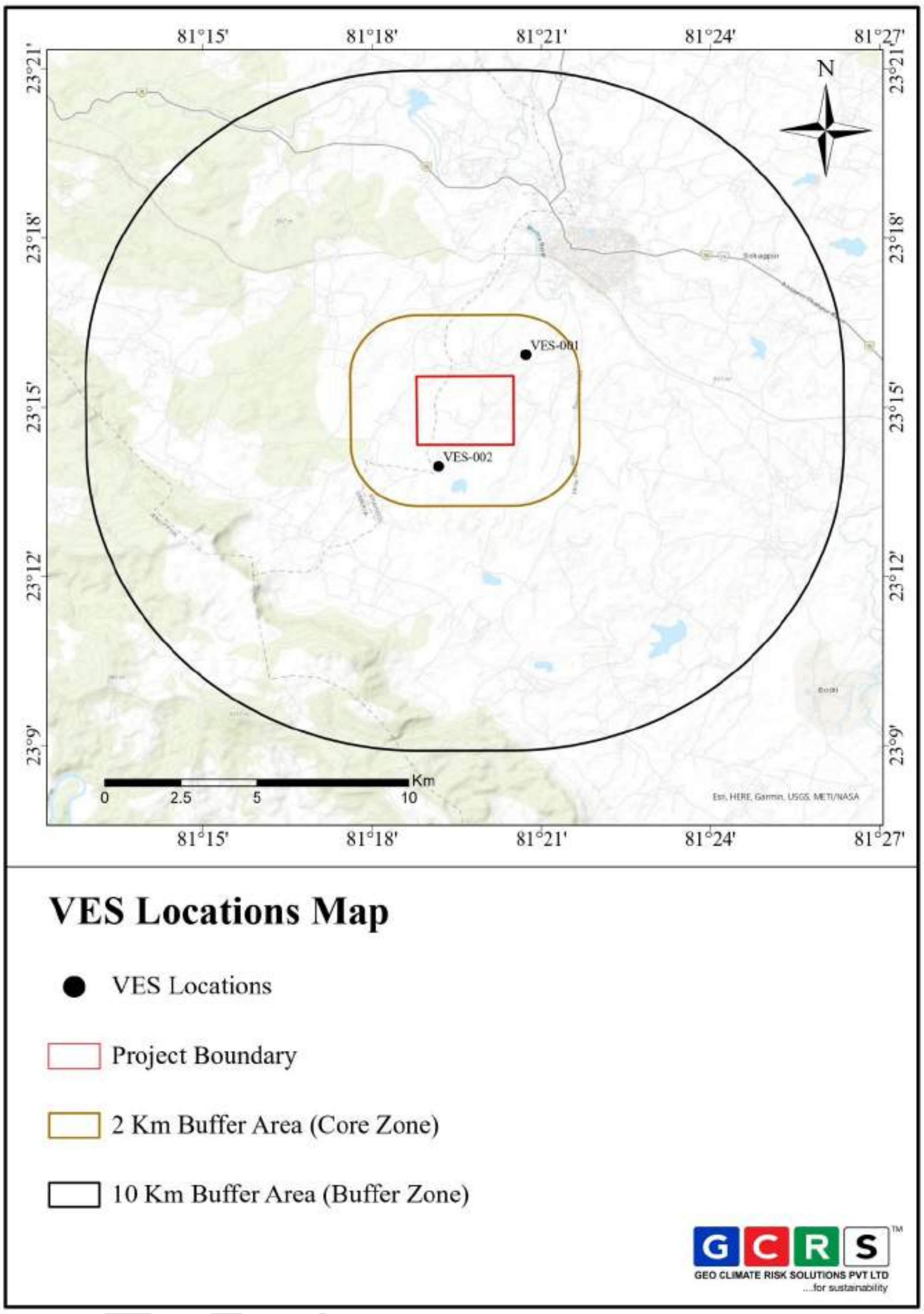

Figure 3.5: Spatial distribution of VES survey conducted in the study area.

METHODOLOGY

The resistivity soundings were carried out in the study area by applying Schlumberger configuration with possible current electrode separation to get the maximum depth of investigation. Apparent resistivity (ρ_a) can be measured at different depths in the form of the pseudo-depth section by using four electrodes (2 current and 2 potential) system by placing electrodes in different spacing. In this technique, the current electrode/ potential electrode separation is increased in a sequence and the depth of investigation is dependent on the total spread length and the array configuration used for data collection. The configuration of the VES technique is shown in Figure **3.6**.

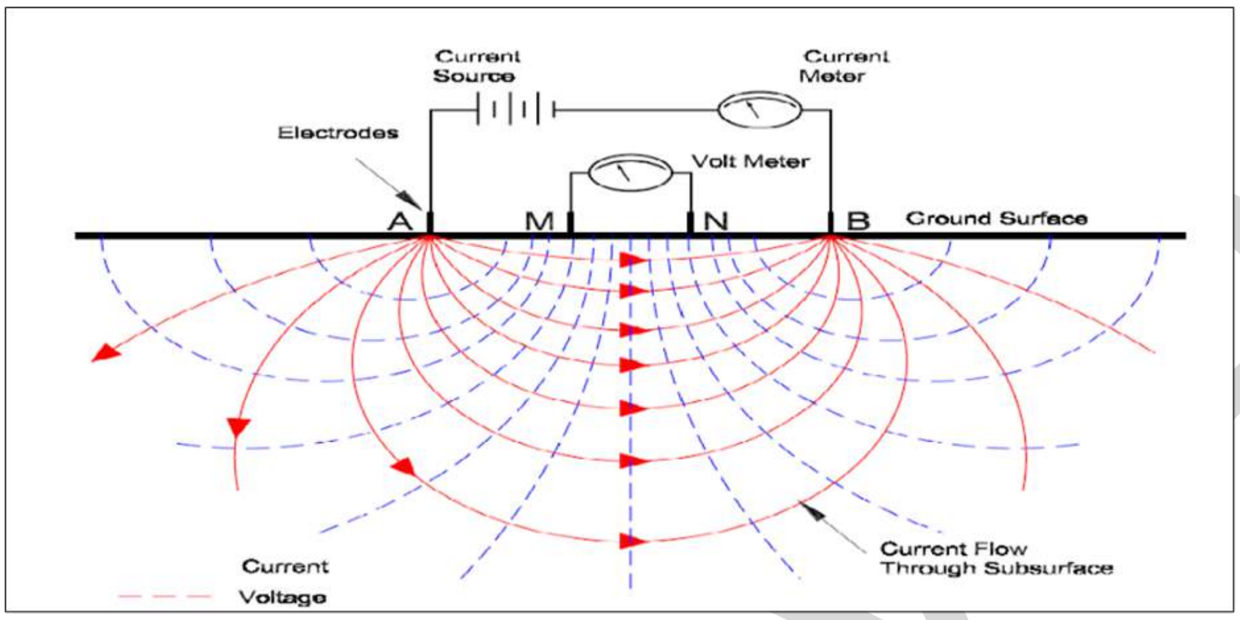

Figure 3.6: Schematic diagram of 2D resistivity imaging technique.

Schlumberger Array Configuration

In this array, four electrodes are placed in a line around a common midpoint. The two outer electrodes, A and B, are current electrodes, and the two inner electrodes, M and N, are potential electrodes, as shown in Figure 3. With the Schlumberger array, for each measurement, the current electrodes A and B are moved outward to a greater separation throughout the survey, while the potential electrodes M and N stay in the same position until the observed voltage becomes too small to measure (**Figure 3.7**; Bhattacharya, 2012). At this point, the potential electrodes M and N are moved outward to a new spacing. As a thumb rule, the reasonable distance between M and N should be equal or less than one-fifth of the distance between A and B at the beginning. This ratio goes about up to one-tenth or one-fifteenth, depending on the signal strength. The formula for the derivation of the apparent resistivity with the Schlumberger array is given below.

$$\rho_a = \frac{\pi}{4}\frac{V}{I}\frac{(L^2 - a^2)}{a}$$

Where, ρa is apparent resistivity; I is current intensity; V is potential difference between M and N Point, L is the distance between outer electrodes A and B and "a" is the distance between inner electrodes M & N.

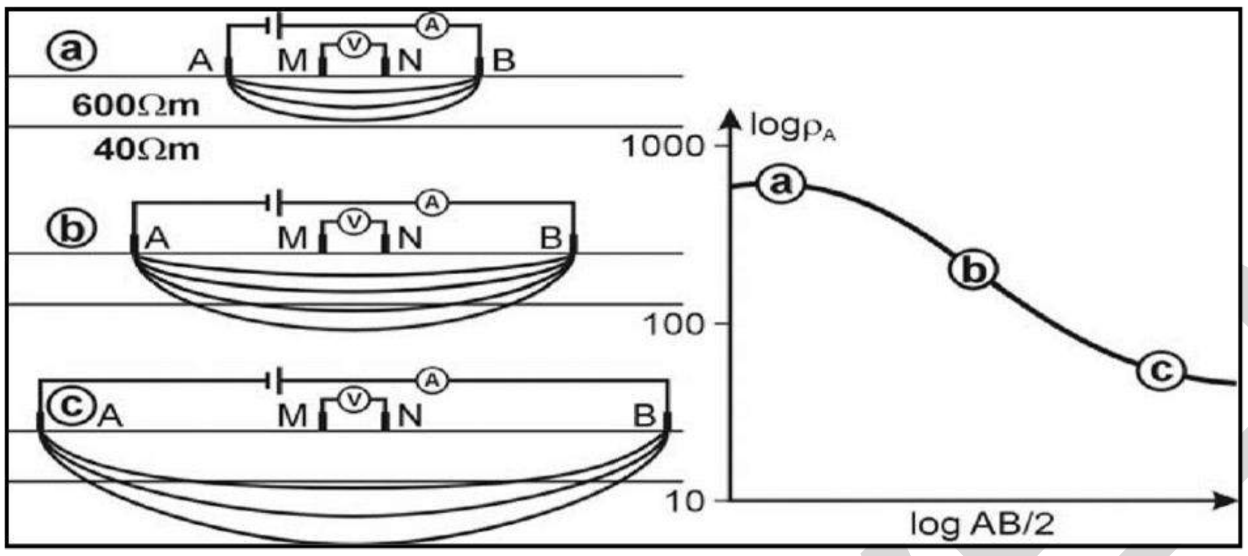

Figure 3.7: Schlumberger Array Configuration. From (a) to (c), A and B (current electrodes) are moved outward to a greater separation from the center.

Instruments used:

The resistivity soundings were carried out in the study area by applying the Schlumberger configuration using the SSR-MP-ATS resistivity meter (manufactured by IGIS, Hyderabad). The IGIS Signal stacking Resistivity Meter Model SSR-MP-ATS is a high-quality – data acquisition system incorporating several innovative features for earth resistivity. For example, the signal-to-noise ratio can be enhanced by √N where N is the number of stacked readings. SSR-MP-ATS is a microprocessor-based signal stacking resistivity meter in which running averages of measurements [1, (1+2)/2, (1+2+3)/3, ...(1+2+....+16)/16] up to the chosen stacks are displayed and the final average is stored automatically in memory utilizing the principle of stacking to achieve the benefit of high signal to noise ratio (SSR-MP-ATS-

Manual). Also, it works on the principle of direct measurement of ΔV and Current and direct division instead of the constant current mode, thus reducing the wastage of power. For the data acquisition, the instrument is powered by two 12V rechargeable batteries to send the current through current electrodes and measure the potential differences between potential electrodes. Further, the instrument calculates apparent resistivity using the geometrical factor corresponding to the chosen configuration. The SSR-MP-ATS is programmable through a user-friendly menu for its operation and entry of survey parameters like survey no., Electrode separations, no. of stacks, etc. (SSR-MP-ATS-Manual).

Data Processing and Interpretation:

The present study's interpretation of vertical electrical sounding data was carried out in two stages. In the first stage, the VES data were interpreted based on theoretical knowledge to establish the basic geoelectrical model. In the second stage, the interpreted results found in stage 1 were correlated with the available borehole lithological data and further validated accordingly to determine the resistivity range for different lithological units.

Initially, the raw VES data (AB/2, MN/2, apparent resistivity, AB/2 is the current electrode spacing, and MN/2 is the potential electrode spacing) obtained from the SSRMP-ATS instrument was imported into the processing software. The ZondIP resistivity sounding software was used to process the VES raw data. Further, the apparent resistivity data were plotted in the log-log graph to generate a computer-modeled curve (Figure 4). The log resistivity graph, resistivity-depth table, and pseudo section were also received after processing the software. The log resistivity graph illustrates the double log plot of AB/2 on the x-axis and resistivity on the y-axis (Refer to Figure 4). The resistivity-depth table gives information about the different layers' resistivity and thickness, along with the depth from the surface (Refer to Table 1). Similarly, the pseudo-section cross-section shows different resistivity layers and their variation along with the depth (**Figure 3.8**).

Results and Discussion

5.1 VES transect: VES 1

The VES-1 site (Latitude: 23.26556, Longitude: 81.345613, Elevation: 467 m) lie in the North-eastern part of the lease area (**Figure 3.5**). A 4-layer model for the VES-1 site was developed based on the resistivity sounding (**Figure** 3.8). Figure 4a&b shows resistivity variation from

35.04-393.21 Ohm.m, indicating four subsurface layers (**Table 3.2**). Layer-1, the resistivity is 393.21 Ohm.m and extends to a depth of around 2.76 m from the surface. Layer-2, the resistivity is 35.04 Ohm.m, extending up to a depth of 18.56 m and having a thickness of 15.8 m. Layer-3 is found at a depth between 18.56– 38.13 m, with a resistivity of 279.04 Ohm.m and this layer's thickness is 19.57 m. Layer-4, the resistivity is 107.89 Ohm.m and extends up to the maximum depth of investigation. As the top layer has high resistivity than the second layer, the second layer has low resistivity compared to the top and third layers, and the third layer is more resistive than that of 4th and 2nd layers; the above curve indicates an HK - type curve.

Upon comparing the VES section graph with the available lithology in the vicinity of this transect, it is evident that the top layer is mainly composed of Soil. The second layer corresponds to the SST, the third layer is composed of Sandstone with the presence of Coal seam and the last layer comprises Shale and Sandstone Intercalations.

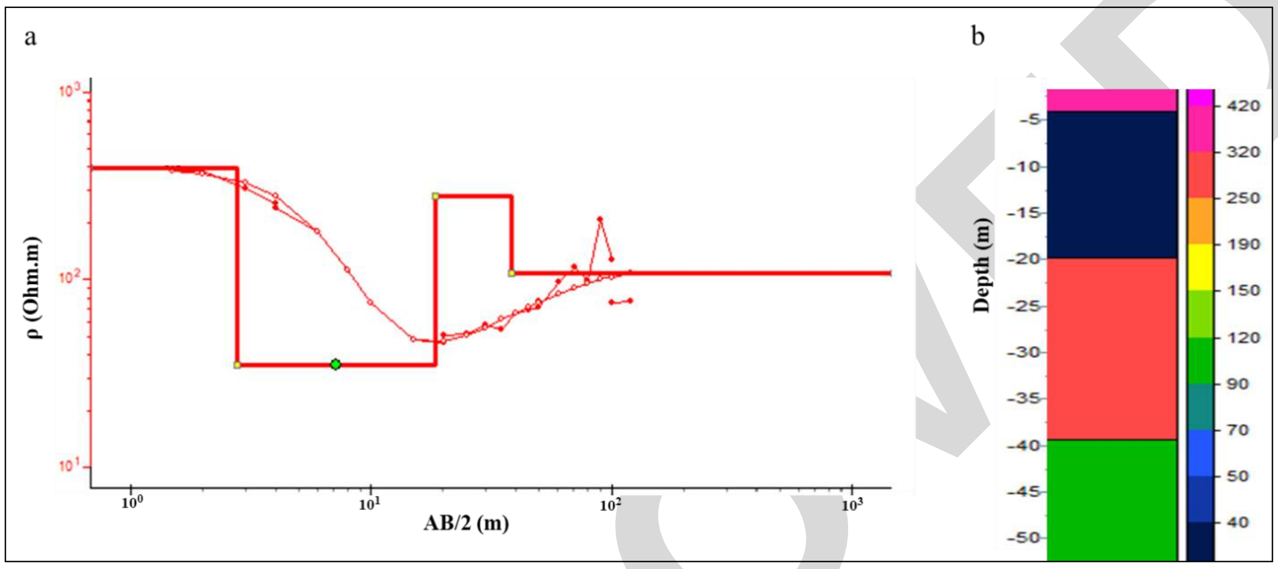

Figure 3.8: (a) Log-log Resistivity graph; (b) Section graph of VES-1.

Table 3.2: A detailed description of VES 1 survey point.

Layer No	Rho (Ohm-m)	Thickness (m)	Depth (m)	Depth (m asl)	Lithology
1	393.21	2.76	0	467	Soil
2	35.04	15.8	2.76	464.24	Sandstone

3	279.04	19.57	18.56	445.68	Sandstone + Coal bands
4	107.89		38.13	407.55	Shale & Sandstone Intercalations

5.2 VES transect: VES 2

The VES-2 site (Latitude: 23.232583, Longitude: 81.319865, Elevation: 511 m) lies in the lease area's southern part (**Figure 3.5**). A 4-layer model for the VES-2 site was developed based on the resistivity sounding (**Figure 3.9**). **Figure 3.9** show resistivity variation from 139 - 717.6 Ohm.m, indicating four subsurface layers (**Table 3.3**). Layer-1, the resistivity is 234.4 Ohm.m and extends to a depth of around 1.31 m from the surface. Layer-2, the resistivity is 717.67 Ohm.m, extending to a depth of 8.53 m and having a thickness of 7.2 m. Layer-3 is found at a depth between 8.53– 30.16 m, with a resistivity of 139.34 Ohm.m, and the thickness of this layer is 21.63 m. Layer-4, the resistivity is 394.32 Ohm.m and extends up to the maximum depth of investigation. As the top layer has low resistivity than the second layer, the second layer has high resistivity compared to the top and third layers, and the third layer is less resistive than that of 4th and 2nd layers; the above curve indicates a KH - type curve.

Upon comparing the VES section graph with the available lithology in the vicinity of this transect, it is evident that the top layer is mainly composed of Soil. The highly resistive second layer is due to Dolerite intrusion; the third layer corresponds to SST, and the last layer is composed of Sandstone with coal bands.

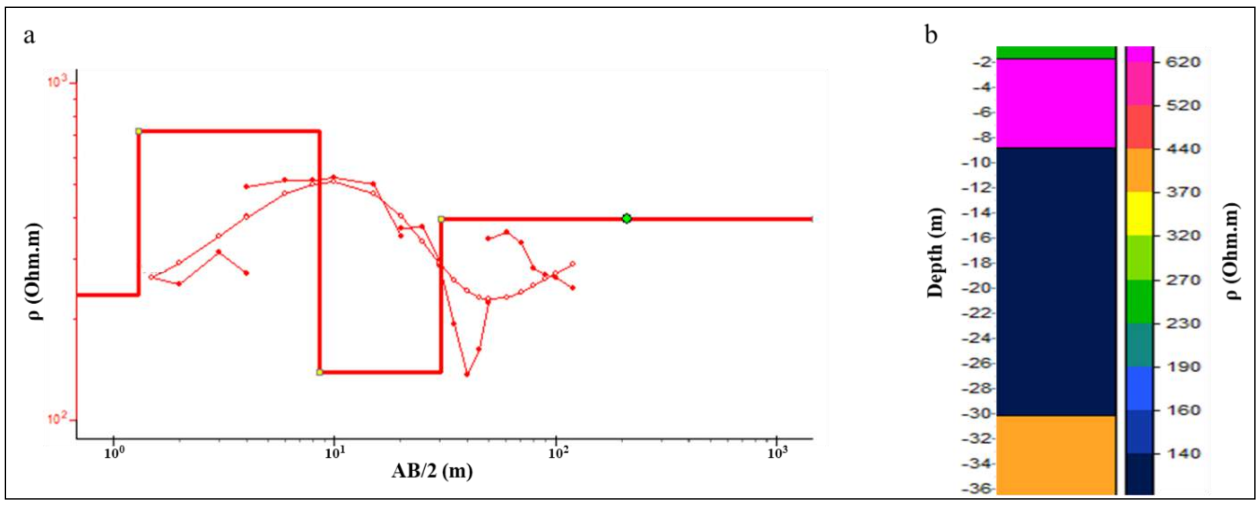

Figure 3.9: (a) Log-log Resistivity graph; (b) Section graph of VES-2

Table 3.3: A detailed description of the VES 2 survey point.

Layer No	Rho (Ohm-m)	Thickness (m)	Depth (m)	Depth (m asl)	Lithology
1	234.4	1.31	0	511	Soil
2	717.67	7.2	1.31	509.69	Dolerite
3	139.34	21.63	8.53	501.16	Sandstone
4	394.32		30.16	471	Sandstone + Coal bands

3.3 HYDROGEOLOGICAL SET UP

The hydrogeological set up of the study area goes hand in hand with the Geological set up of the area. The formations within study areas mainly belong to Gondwanas. The coal seams of the area are of lower Permian in age and occur in Barakar formations. The area is covered by a mantle of soil and alluvium ranging in thickness from 12.56 m to 75.48 m. The coal bearing Barakar formation in the area is totally covered by the younger Supra-Barakar formation. Prominent dykes of dolerite are exposed in the northern part of Amlai Opencast Mine area and maintain a general east- west trend. They usually occur along fault planes/weak zones and more or less vertical in nature. The Barakar formation is chiefly composed of greyish- white coarse and very coarse-grained feldspathic sandstone with subordinate carb-shale and coal seams.

The alluvium formation and weathered Barakar formation comprising mainly of loosely cemented and poorly consolidated sandstone behaves as unconfined aquifer. This unconfined aquifer consists of Supra-Barakar formations also, which is mostly buff coloured, garnetiferous and coarse-grained sandstone and is most potential and prolific aquifer. The lower formations, consisting of compact and medium to coarse grained sandstone with secondary porosity, behave as aquifer of semi-confined to confine in nature. In the confined aquifer, ground water moves laterally through the inter-granular pore spaces in the sandstone.

(Source- District groundwater brochures, 2020).

The permeable sandstone beds intercalated with shale and coal seams behave as an individual hydrogeological unit and form a multi-layered aquifer system. The formation, comprising mainly alluvium, loosely cemented and poorly consolidated sandstone lying above the working seam behaves as unconfined aquifer and contributes the maximum inflow. The lower formations, consisting compact and medium to coarse grained sandstone with secondary porosity, behave as semi-confined to confine in nature. In the confined sandstone aquifer, ground water moves laterally through the inter-granular pore spaces in the sandstone.

In order to better understand the hydrogeological scenario of the study area, an approach has been made to decipher the orientation of the groundwater in the area by virtue of the water table configuration. To undertake the same, a network consisting of 18 monitoring wells covering both core and buffer zones of the study area and beyond them has been established and water levels in the same has been recorded as a part of the study, in the month of April, 2022. The period of water level monitoring however, is set in the pre monsoon season. The details pertaining to the well inventory in and around the study area is presented below as **Table 3.4**. Out of total 18 groundwater samples, 4 samples are collected from 2 km core zone, 10 samples from10 km buffer zone boundary and 4 outside the buffer zone boundary. The location map for the water level monitoring stations is presented as **Figure 3.10**.

Water table elevations around the afore-mentioned monitoring wells has been derived from the well inventory data and also has been presented in the **Table 3.4**. Water table elevation contours generated from the same has been presented along with the ground water flow directions in the Hydrogeology map of the study area shown in **Figure 3.11**.

The map illustrates that the sandstone has an aquifer yield of upto 3% followed by 1.5-2% in basalt and about 1.5% in shale. Based on the map, it may be conferred that the general trend of the groundwater flow in the study area is from south to north which is similar to that of the trends of surficial stream flows in the study area. The contours in the southern region of the buffer area are closely spaced that corresponds to the shallower water levels. It can also be inferred that water level in all the surrounding dug wells (in core & buffer area) varies from 5 to 11 mbgl.

Table 3.4: Details of well inventory in and around the study area.

Sl. No.	Well Id	Latitude	Longitude	Depth to Water Level (m bgl)	Elevation (mamsl)	Water Table Elevation (mamsl)
	CORE ZONE					
1	SHWL1	23.25025	81.33512	8.8	489	480.2
2	SHWL2	23.237	81.32247	7.13	501	493.87
3	SHWL3	23.23699	81.32247	9	501	492
4	SHWL4	23.26327	81.3288	6	481	475
	BUFFER ZONE					
5	SHWL5	23.28159	81.35866	6.8	459	452.2
6	SHWL6	23.28186	81.35869	8.3	458	449.7
7	SHWL7	23.21234	81.35269	8.5	524	515.5
8	SHWL8	23.30703	81.32776	5.6	466	460.4
9	SHWL9	23.29003	81.29003	8	473	465
10	SHWL10	23.26436	81.24031	9.7	513	503.3
11	SHWL11	23.23575	81.41675	7.1	494	486.9
12	SHWL12	23.17412	81.33996	5.22	554	548.78
13	SHWL13	23.33763	81.34907	6.45	446	439.55
14	SHWL14	23.32745	81.27180	6.11	468	461.89
	OUTSIDE BUFFER ZONE					
15	SHWL15	23.28295	81.21093	8.02	537	528.98
16	SHWL16	23.19216	81.45453	10.6	480	469.4
17	SHWL17	23.25982	81.4646	7.5	459	451.5
18	SHWL18	23.38438	81.32848	6.31	440	433.69

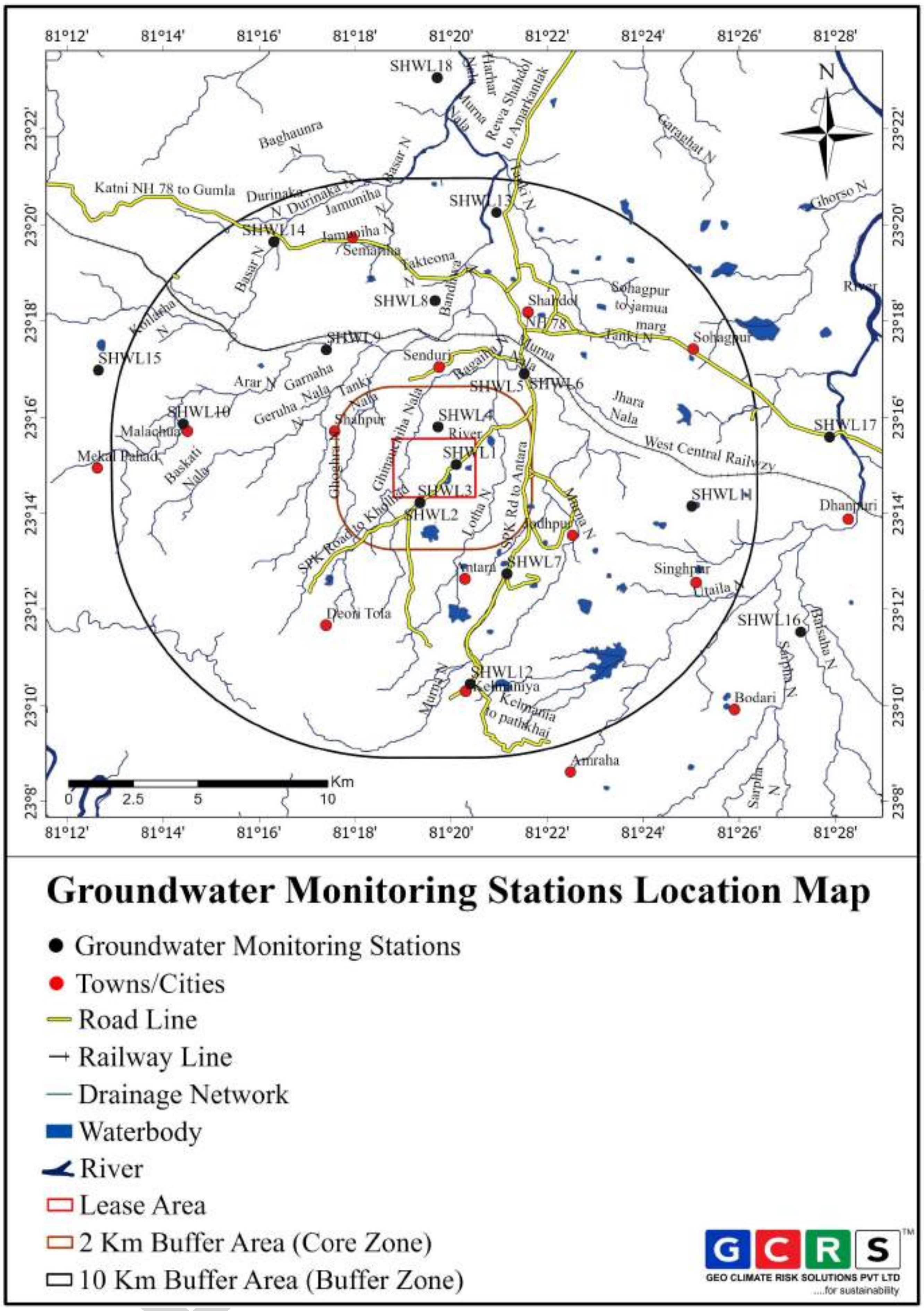

Figure 3.10: Location map of groundwater monitoring stations in and around the study area.

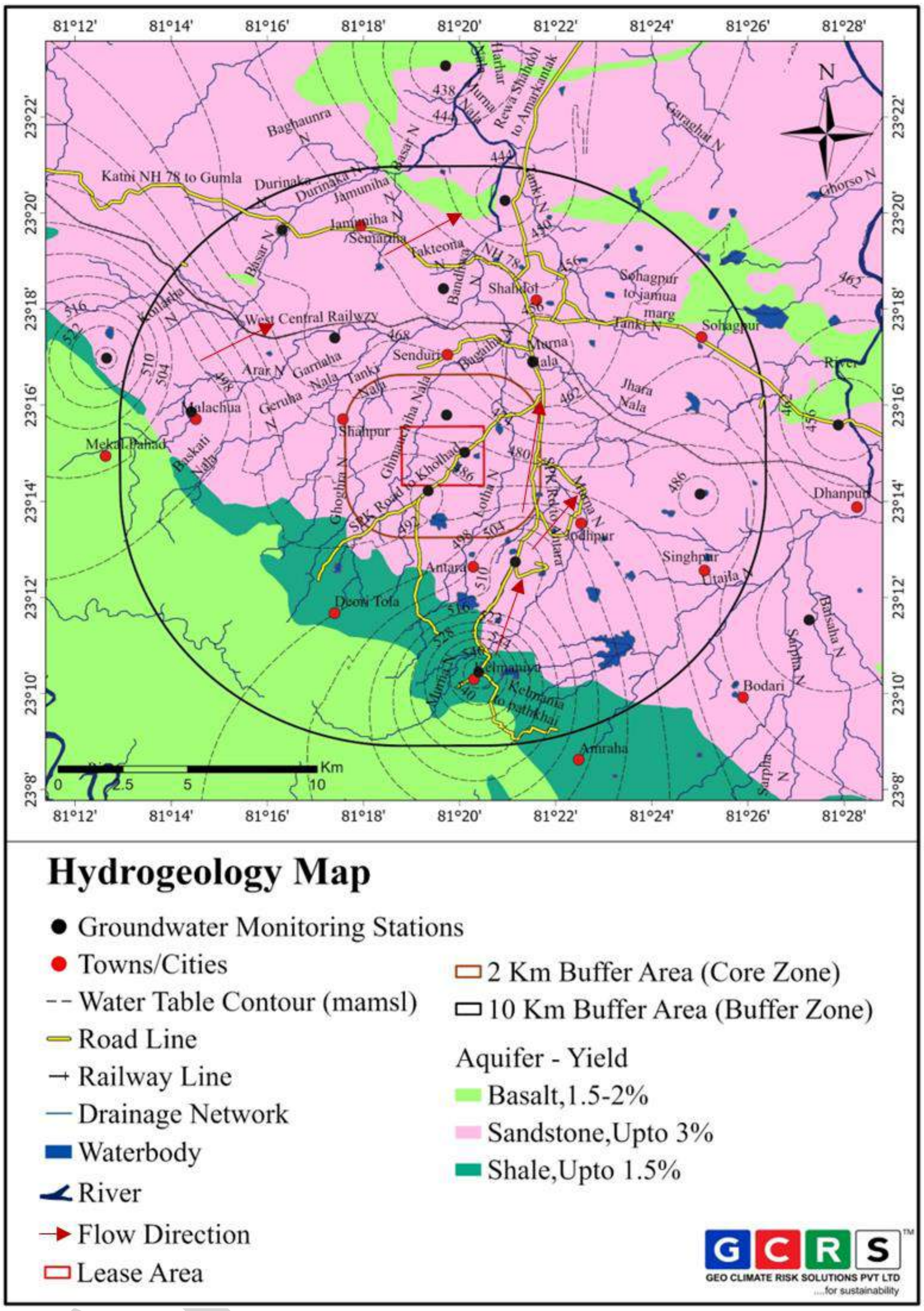

Figure 3.11: Hydrogeology map of the study area.

3.3.1 Aquifer Characteristics

Pumping Test

The principle of a pumping test is to calculate the aquifer's hydraulic characteristics by measuring the well's discharge and the drawdown in the well (**Figure 3.12**; Kruseman and Ridder, 1970). The pumping test is the most reliable method for the estimation of the hydraulic conductivity of an aquifer (Todd, 2004).

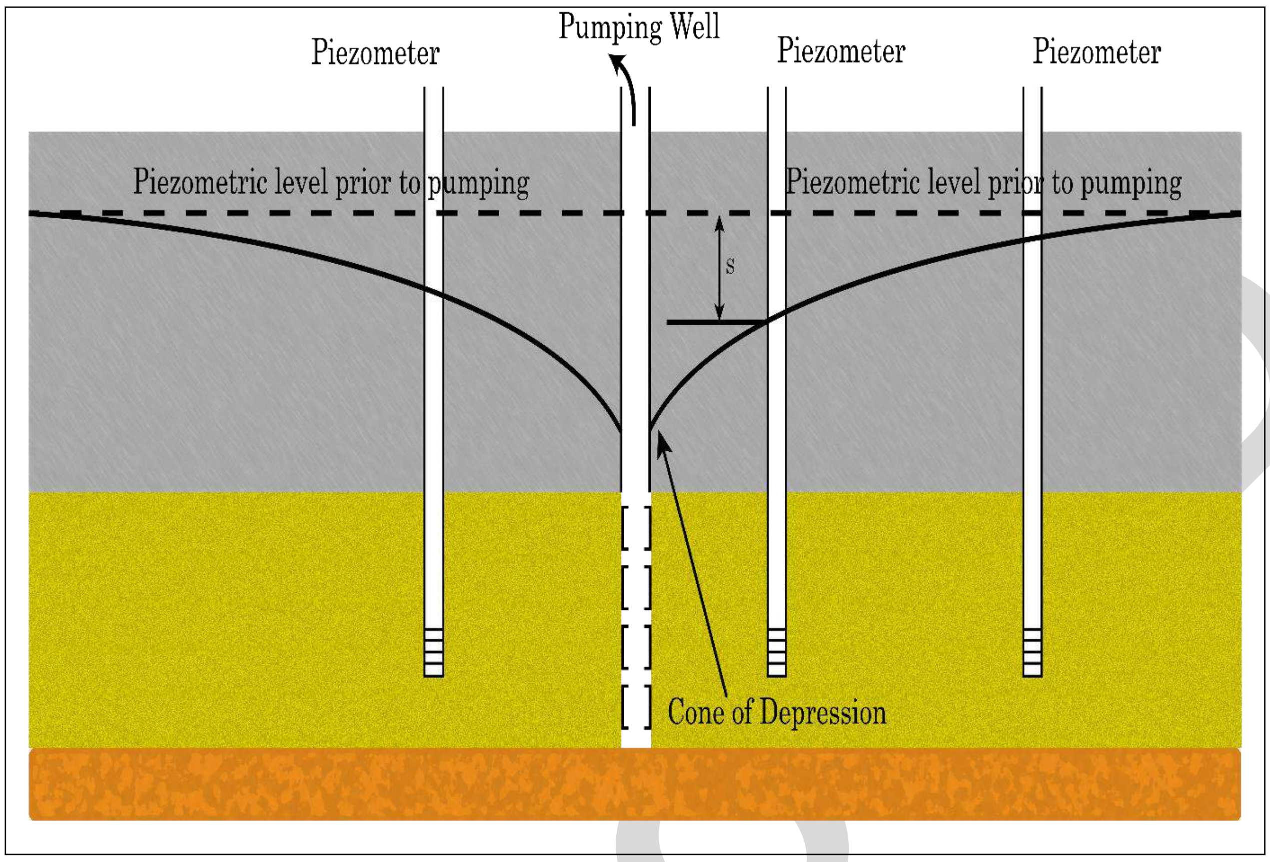

Figure 3.12: Drawdown in a pumping well during groundwater abstraction.

To verify the aquifer parameters of the study area, a pumping test has been carried out in a private bore well at Shahpur. Before the commencement of the pumping test, the water levels in the pumping well were measured with respect to time. The water level measurements were observed by using a water level indicator/sounder **(Table 3.5).** The discharge was measured by volumetric method, using a container of known capacity. The discharge was kept constant during the test period. The results and data interpretation are given in the following sections.

Table 3.5: Drawdown and recovery data of the pumping well.

Location		Height of measuring point (agl)				0.67 m	
Latitude	23.246440 N	Initial Depth to WL (bmp)				6.39 m	
Longitude	81.323929 E						
Diameter of the well				0.21 m			
Casing Upto				24.384 m (80 ft)			
Pump at				36.576 m (120ft)			
Average Discharge rate				77.3 m^3 /day			
Pumping data			Recovery data				
Time (min)	Water level (m)	Drawdown (m)	Time since pumping started in min (t)	Time since pumping stopped in min (t')	t/t'	Water Level (m)	Residual drawdown (m)
0	6.39	0.00	210.5	0.5	421	13.32	6.93
0.5	7.29	0.90	211	1	211	12.09	5.70
1	8.24	1.85	211.5	1.5	141	11.29	4.90
1.5	9.19	2.80	212	2	106	10.49	4.10
2	10.09	3.70	212.5	2.5	85	9.89	3.50
2.5	10.99	4.60	213	3	71	9.44	3.05
3	11.89	5.50	213.5	3.5	61	9.04	2.65

3.5	12.44	6.05	214	4	53.5	8.74	2.35
4	12.89	6.50	214.5	4.5	47.67	8.49	2.10
4.5	13.29	6.90	215	5	43	8.34	1.95
5	13.69	7.30	216	6	36	8.19	1.80
6	14.04	7.65	217	7	31	8.04	1.65
7	14.24	7.85	218	8	27.25	7.94	1.55
8	14.42	8.03	219	9	24.33	7.84	1.45
9	14.47	8.08	220	10	22	7.79	1.40
10	14.50	8.11	221	11	20.09	7.74	1.35
11	14.54	8.15	222	12	18.5	7.69	1.30
12	14.59	8.20	223	13	17.15	7.64	1.25
13	14.61	8.22	224	14	16	7.59	1.20
14	14.64	8.25	225	15	15	7.54	1.15
15	14.66	8.27	226	16	14.13	7.49	1.10

16	14.68	8.29	227	17	13.35	7.44	1.05
17	14.70	8.31	228	18	12.67	7.39	1.00
18	14.72	8.33	229	19	12.05	7.34	0.95
19	14.74	8.35	230	20	11.5	7.29	0.90
20	14.76	8.37	231	21	11	7.27	0.88
21	14.78	8.39	232	22	10.55	7.24	0.85
22	14.79	8.40	233	23	10.13	7.22	0.83
23	14.81	8.42	234	24	9.75	7.19	0.80
24	14.82	8.43	235	25	9.4	7.17	0.78
25	14.84	8.45	236	26	9.077	7.14	0.75
26	14.85	8.46	237	27	8.778	7.13	0.74
27	14.86	8.47	238	28	8.5	7.12	0.73
28	14.87	8.48	239	29	8.241	7.11	0.72
29	14.88	8.49	240	30	8	7.10	0.71

30	14.89	8.50	241	31	7.774	7.09	0.70
31	14.90	8.51	242	32	7.563	7.08	0.69
32	14.91	8.52	243	33	7.364	7.07	0.68
33	14.91	8.52	244	34	7.176	7.07	0.68
34	14.92	8.53	245	35	7	7.06	0.67
35	14.93	8.54	246	36	6.833	7.06	0.67
36	14.93	8.54	247	37	6.676	7.05	0.66
37	14.94	8.55	248	38	6.526	7.05	0.66
38	14.94	8.55	249	39	6.385	7.04	0.65
39	14.95	8.56	250	40	6.25	7.04	0.65
40	14.96	8.57	255	45	5.667	7.02	0.63
41	14.96	8.57	260	50	5.2	6.99	0.60
42	14.97	8.58	265	55	4.818	6.84	0.45

43	14.97	8.58	270	60	4.5	6.79	0.40
44	14.98	8.59	275	65	4.231	6.74	0.35
45	14.98	8.59	280	70	4	6.69	0.30
46	14.99	8.60	285	75	3.8	6.64	0.25
47	14.99	8.60	290	80	3.625	6.59	0.20
48	14.99	8.60	295	85	3.471	6.54	0.15
49	15.00	8.61	300	90	3.333	6.49	0.10
50	15.00	8.61	305	95	3.211	6.47	0.08
51	15.00	8.61	310	100	3.1	6.44	0.05
52	15.01	8.62	315	105	3	6.42	0.03
53	15.01	8.62					
54	15.02	8.63					
55	15.02	8.63					
56	15.03	8.64					
57	15.03	8.64					
58	15.04	8.65					
59	15.04	8.65					

60	15.05	8.66					
65	15.07	8.68					
70	15.09	8.70					
75	15.11	8.72					
80	15.12	8.73					
85	15.14	8.75					
90	15.15	8.76					
95	15.17	8.78					
100	15.18	8.79					
105	15.19	8.80					
110	15.20	8.81					
115	15.21	8.82					
120	15.22	8.83					
130	15.24	8.85					
140	15.26	8.87					
150	15.28	8.89					
160	15.29	8.90					
170	15.31	8.92					
180	15.32	8.93					
195	15.32	8.93					

210	15.32	8.93					

The pumping test data has been analysed by Jacob's straight-line method, using the pumping data of the pumping well. Drawdown data has been analysed using the excel sheet as shown in **Figure 3.13 and** Error! Reference source not found..

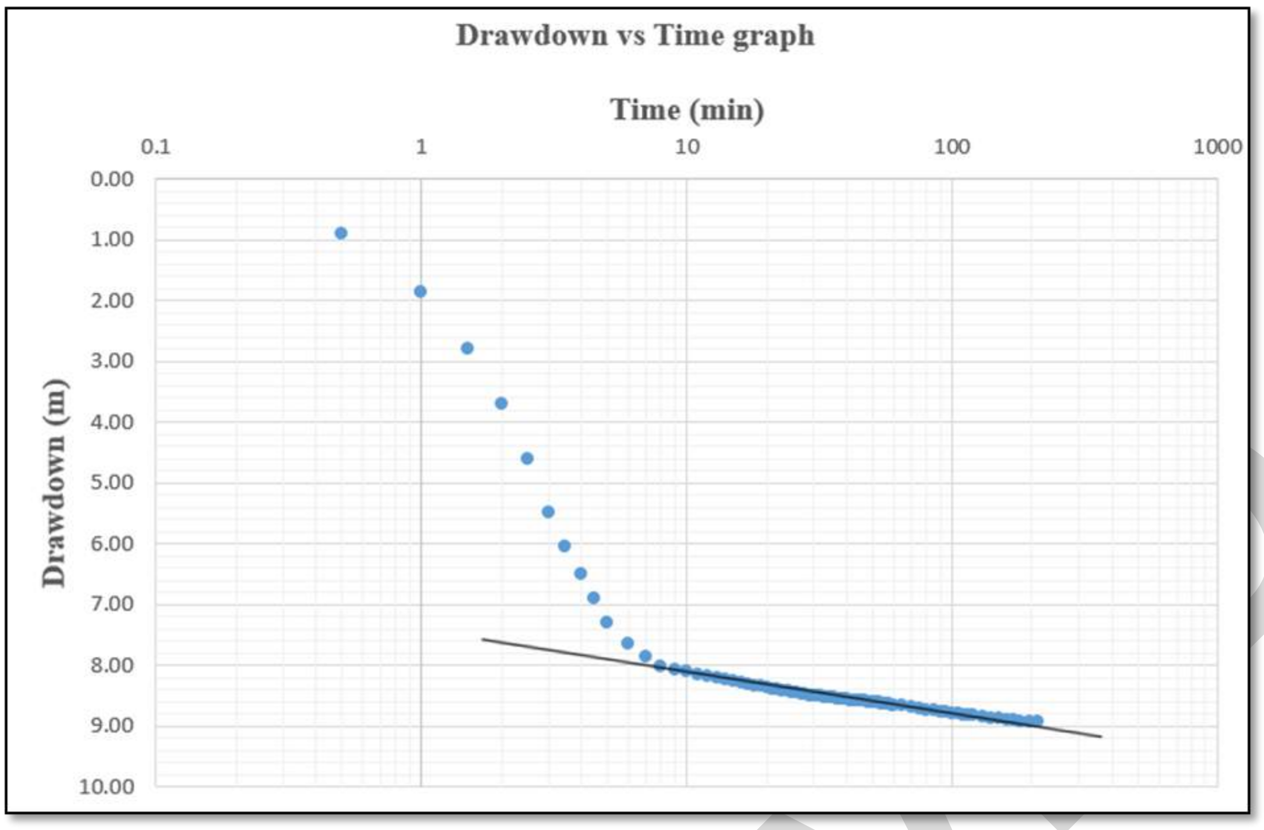

Figure 3.13: Pumping test data analysis by Jacob's straight-line method (based on manual interpretation and calculation using Excel)

The analysis of pumping test data has been prepared by Jacob's straight-line method, based on the following calculations.

$T= 2.303Q/ (4\pi\Delta s)$

Where,

T = Transmissivity

Q = Discharge = 77.3 m^3 /day

Δs = slope of the fitted line (change in drawdown per log cycle time) = 0.9

T = 15.73 m^2 /day

The recovery test data has been analysed by Jacob's straight-line method, using the data of the pumping well. Residual drawdown data has been analysed using two separate excel sheets as shown in Figure **3.14**

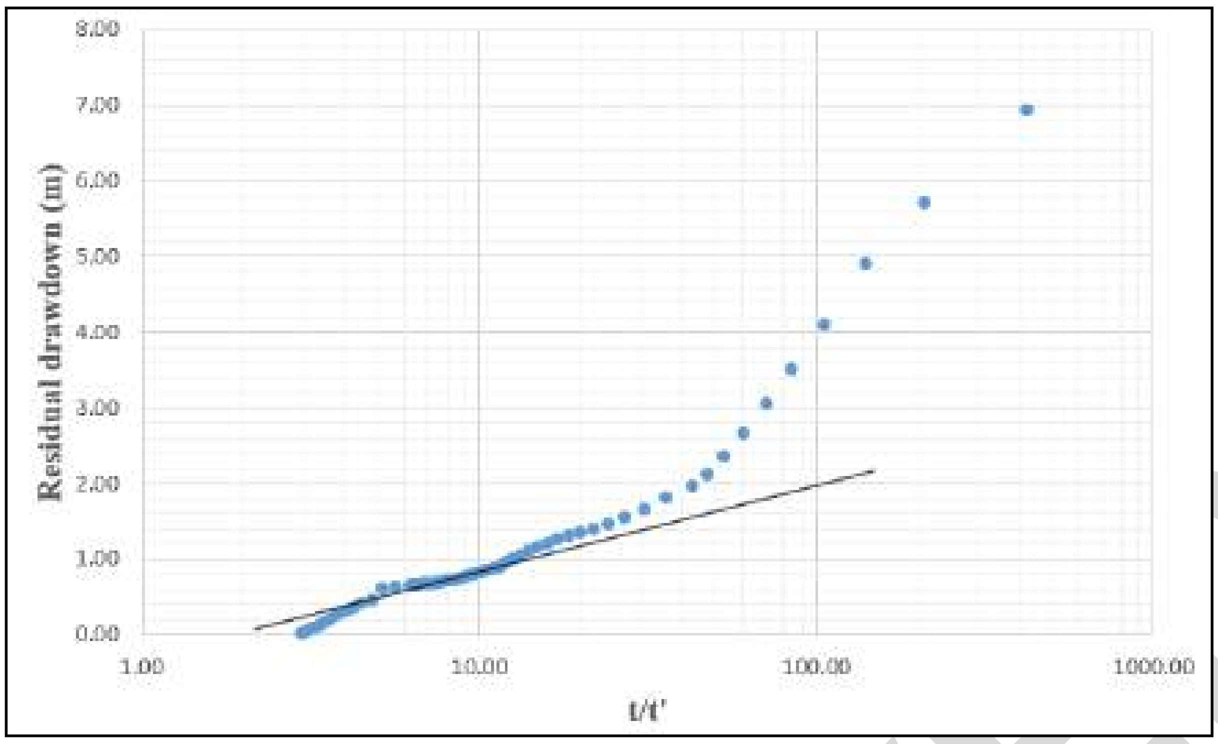

Figure 3.14: Recovery data of the Pumping well at Shahpur (based on manual interpretation and calculation using Excel).

The recovery data of the pumping well has been analysed by Jacob's straight-line method. The calculation is given below.

T= 2.303Q /(4πΔs)

Where,

T = Transmissivity

Q = Discharge = 77.3 m^3 /day

Δs = Slope of the fitted line (change in drawdown per log cycle time) = 1.0

T = 14.16 m^2 /day

Summarised results of the pumping test conducted in the Shahpur village are given in **Table 3.6**

Table 3.6: Summarised results of pumping test.

Village	Type of test	Duration of the test (min)	Q (m^3 /day)	Max drawdown (m)
Chuniya (Shahpur)	Pumping	210	77.3	8.93
	Recovery	105		

Village	Type of test	ΔS	Transmissivity (m^2 /day)	Thickness of the aquifer (m)	Permeability (m/day)	
Chuniya (Shahpur)	Pumping	0.9	15.73	19		0.83
	Recovery	1.0	14.16	19		0.75
					Average	**0.79**

3.3.2 Ground water flow and aquifer interaction with surface water bodies

The groundwater recharge process is mainly governed by surface water and groundwater interaction. Several natural (hydrometeorological and hydrological) and anthropogenic processes play an important role in understanding the groundwater recharge processes and surface water and groundwater interaction (Winter et al., 1998; Mayer et al., 2014). These interaction play an important role in determining water's hydrogeochemical composition, quality, and quantity at regional and local scales (Bhattacharya et al., 1985). Therefore, a proper understanding of surface water and groundwater interaction is essential for calculating water budget and effective water resources management.

Several methods such as water balance, hydrogeochemical approach, water table fluctuation method, rainfall-runoff modelling, and isotopic approach are widely used to identify the surface water and groundwater interaction (Healy and Cook, 2002). The present study uses a water table fluctuation approach to identify surface water and groundwater interaction.

The water table fluctuation approach is widely used for the unconfined aquifers that display a sharp change in groundwater levels (Healy and Cook, 2002; Joshi et al., 2021a & b; Tiwari et al., 2021). The water table fluctuation approach calculates the rise in groundwater level in response to given precipitation. In the water table fluctuation approach, groundwater recharge is estimated from the position of the water table during or after a precipitation event multiplied by the specific yield.

$$R = S_y \frac{\Delta h}{\Delta t}$$

where R is the groundwater recharge, Δh is the water level increase during Δt time, S_y= 0.24 Specific yield of an unconfined aquifer system (CGWB, 2009).

From the water table fluctuation approach, the average recharge rate for Shahpur East coal mine is estimated as 13 mm/year. This indicates low recharge rate conditions in the study area due to the underlaying litholog. The recharge mainly occurs only in the sub-surface strata and contribute to the unconfined or perched aquifers of the region.

On the basis of water table elevation contours presented in the hydrogeology map it is depicted that the general trend of the groundwater flow in the study area is from SW to NE which is similar to that of the trends of surficial stream flows in the study area (**Figure 3.11**). The SW region of the buffer zone is covered with basalt and shale aquifers having low water yield. It increases from SW to NE as the area is occupied with high water yielding sandstone aquifers. The contours in the southern region of the buffer area are closely spaced that corresponds to the shallower water levels. This influences the flow of groundwater as the slope of the area is aligned in same manner as well.

3.3.3 Depth to Water Level

Groundwater always remains under the influence of time-dependent recharging and discharging factors. Due to this continuous influence, water levels of the aquifer system fluctuate, and the range depends on the period of influence. The recharge to the groundwater system is controlled by several factors such as rainfall, seepage from reservoirs, lakes, ponds, rivers, and irrigation. The output from the groundwater system includes groundwater withdrawal, natural seepage to rivers and sea, evaporation from the shallow water table and transpiration through vegetation also influences the water levels prevailing in each area. To get an idea of the orientation of the depths to water level in the study area, a map is prepared to demonstrate the depth to water level data collected during the well inventory.

Based on the water level monitoring conducted in the core and buffer area during the field visit of April 2022 (pre-monsoon depth to water level map was prepared as shown in **Figure 3.15.** It is observed that variation in water level range between 5.6 m bgl to 10.6 m bgl. In the majority of the study area and in mine lease area, water level varies from 7 to 10 m bgl whereas in the southern and northern portions of the study area depth to water levels are shallower, i.e. 5 to 7 m bgl. The post monsoon map prepared for the study area depicts the water level range from 2-7.88 m bgl (**Figure 3.16**). The maximum part of the study area including northern and southern section shows the water level range between 3-5 m bgl. The lowest water level (2-3 m bgl) during the post monsoon season in the buffer zone is observed to the north of the study area. Rest of the study area shows water level range of 5-7.88 m bgl.

The water level fluctuation map is also prepared and depicts that the fluctuation in order of less than 2 to 5.5 m bgl occurs in the study area. The maximum fluctuation of about 3-5.5 m bgl is observed in the west of the 2 km core zone (**Figure 3.17)**.

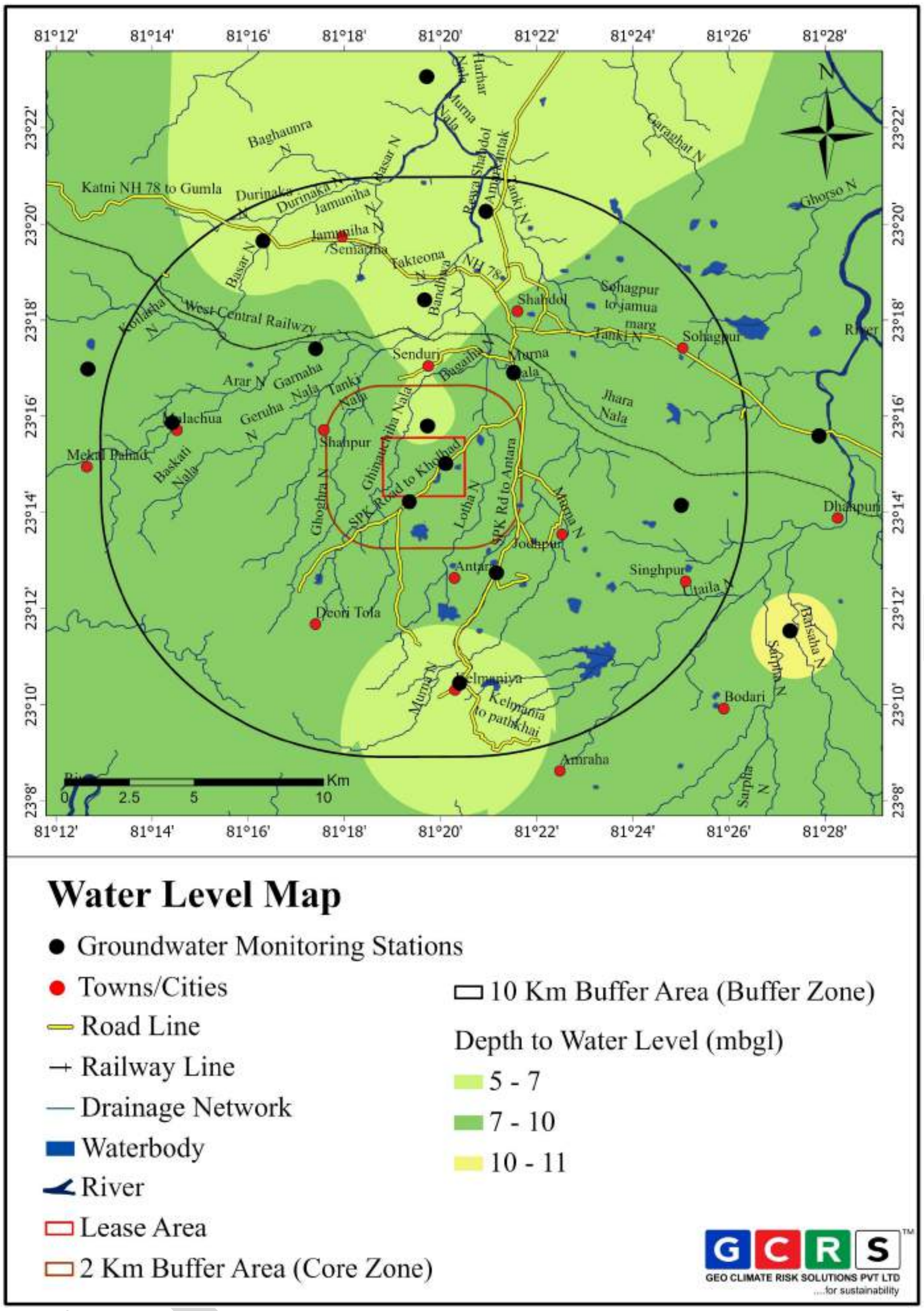

Figure 3.15: Depth to water level map of the study area (Pre-Monsoon, 2022).

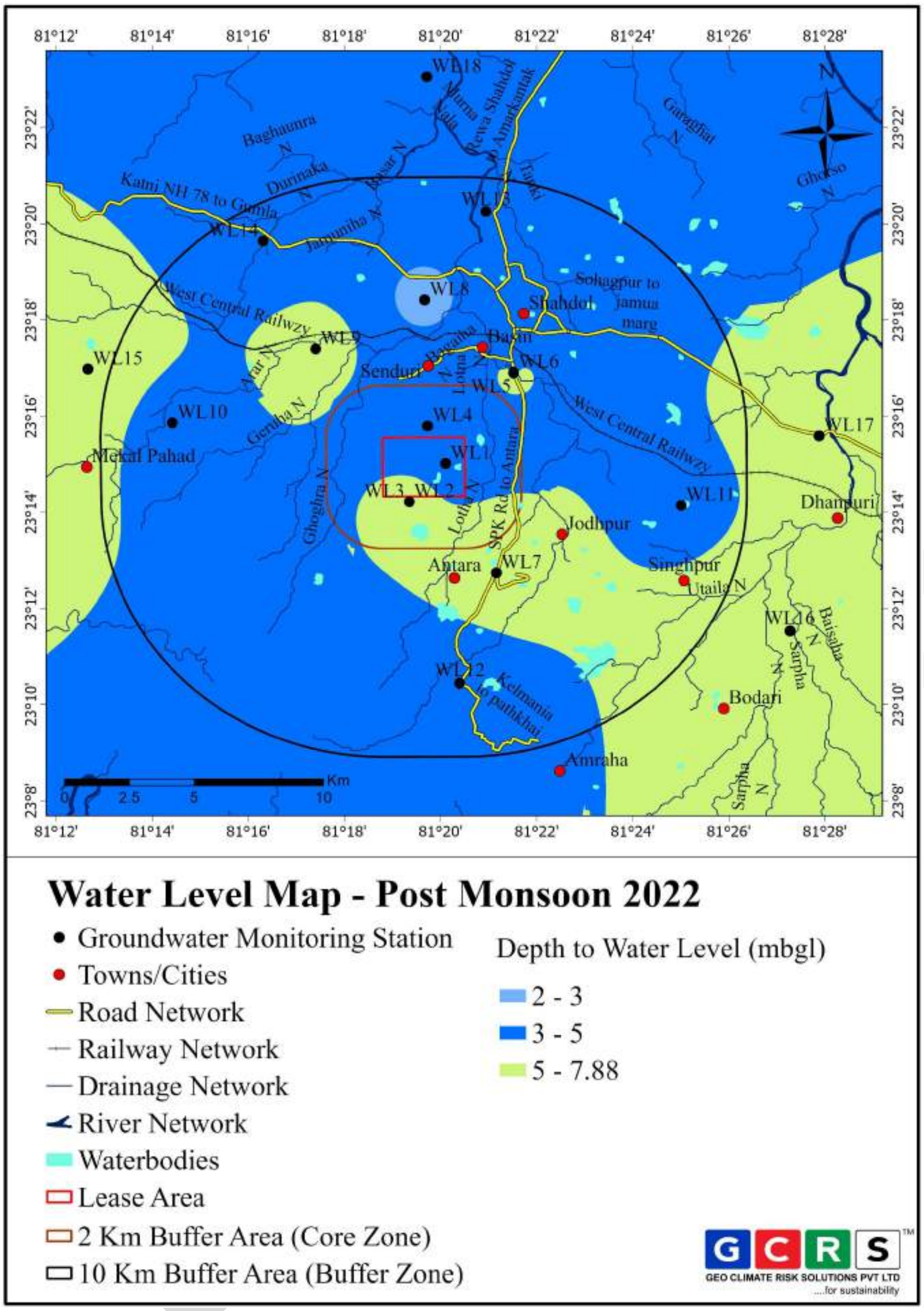

Figure 3.16: Depth to water level map of the study area (Post-monsoon, 2022).

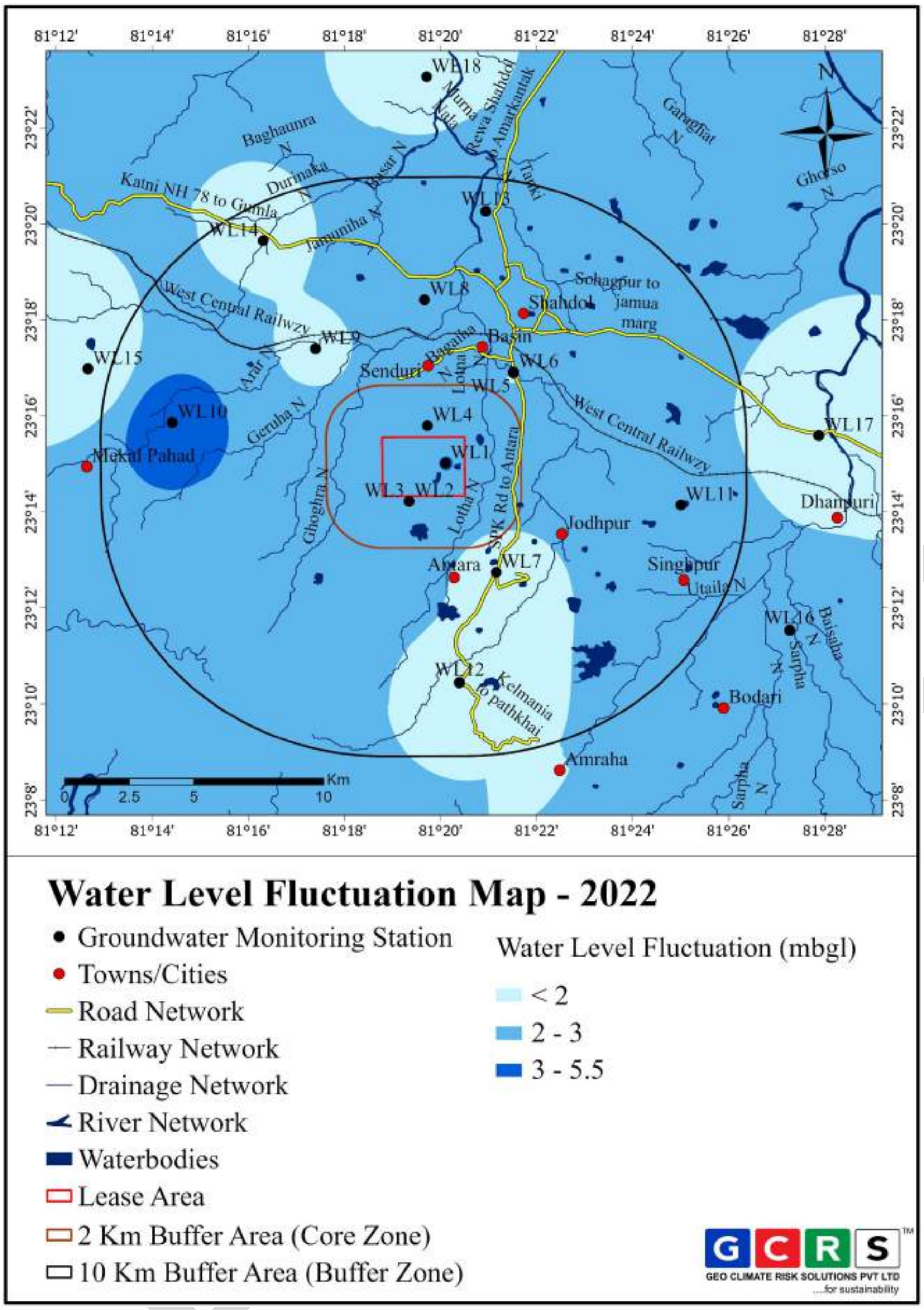

Figure 3.17: Water level fluctuation in the study area, 2022.

3.3.4 Long term water level data analysis

The long term water level data for four (4) season of the study area is analysed based on CGWB water level monitoring wells available in the study area as well as long term water level data of permanent observation wells cum hydrographs stations located around the study area. Water levels for the CGWB observation wells are available from 2014 to 2020. The details pertaining to the CGWB monitoring wells in the study area along with their location coordinates are furnished in Table **3.7**.

To identify the trends in the ground water level of the study area, linear hydrographs of the long-term data are plotted based on the water level data of the hydrograph stations and selected CGWB observation wells covering different directions in and around the study area. Shahdol, Shahdol D, Amliya, and Singpur 1 are identified as CGWA continuous monitoring stations. The hydrographs pertaining to the pre and post monsoon seasons of the aforesaid data for the CGWB observation wells is presented as **Figure 3.18**.

The CGWB observation wells shows a linear water level trend with seasonal fluctuation due to continuous abstraction and recharge in the area. The water level trend is constant and no deviation is observed in the water level of the area from January 2014 to January 2020.

Table 3.7: Long term water level data of the Permanent Observation Wells around the study area.

Hydrograph Station	Shahdol	Shahdol-D	Singhpur1	Amiliya
Laitude	23.28806	23.28806	23.2	23.32194444
Longitude	81.35972	81.35972	81.42	81.29777778
Distance from the site	7.8 km NE	7.8 km NE	11.54 km SE	9.1 km NW

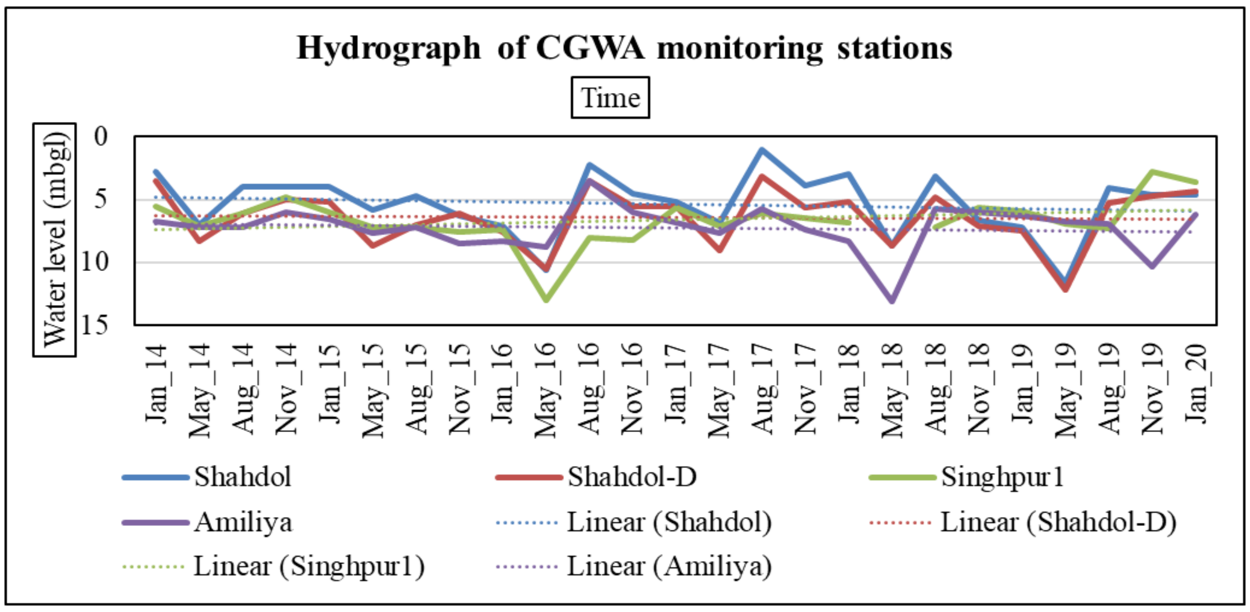

Figure 3.18: Long term water level hydrograph of the CGWB monitoring stations.

3.3.5 Ground water quality

To analyse the water quality of the study area, 17 no of groundwater samples from various locations in and around the buffer zone were collected. These are analysed by adopting standard method of chemical analysis. A map depicting the locations of the water sample collection points is presented as **Figure 3.20**.

The TDS concentration of the collected water samples (groundwater and surface water) varies from 176 to 1221 mg/l which lies within the range of maximum permissible limit (2000 mg/l). The variation is presented in **Figure 3.19**.

The Electrical conductivity and Chloride contour maps are prepared to analyse the groundwater quality in the buffer zone. The chloride content in the groundwater of the buffer area ranges from 7 to 180.9 mg/l and it lies within the permissible limit (250 mg/l) (**Figure 3.21**). On perusal of the iso-conductivity, it is observed that the electrical conductivity for shallow and deep Aquifer in the buffer zone (248-1738 µS/cm) is within the range of maximum permissible limit (2500 µS/cm) (**Figure 3.22**).

In addition, Fluoride and Nitrate concentration map of the study area are prepared based on the analysis results of the water samples collected and presented as **Figure 3.20**. These are plotted as point data in terms of their magnitude of concentration proportional to the size of the point and their distribution (**Figure 3.23 and Figure 3.24**). The fluoride ion concentration ranges from 0.22 to 0.39 mg/l and it is within the range of maximum permissible limit (1.5 mg/l). The nitrate ion concentration varies from 2-136.8 mg/l which is higher than the maximum permissible limit (45 mg/l). The high concentration of the nitrate may be due to the anthropogenic activities that includes agriculture fertilizers, release from industrial sewage systems and wastewater treatment plants etc. This can be mitigated by some in situ and ex-situ processes. Several wetlands and drainage system can be constructed to control nitrate contamination in the groundwater.

Consumption of water containing higher content of nitrate can also lead to Methemoglobinemia also known as 'blue baby' syndrome in infants under 6 months of age. To avoid health issues excess of nitrates can be effectively treated by ion exchange, reverse osmosis and electrodialysis method (Singh, 2016).

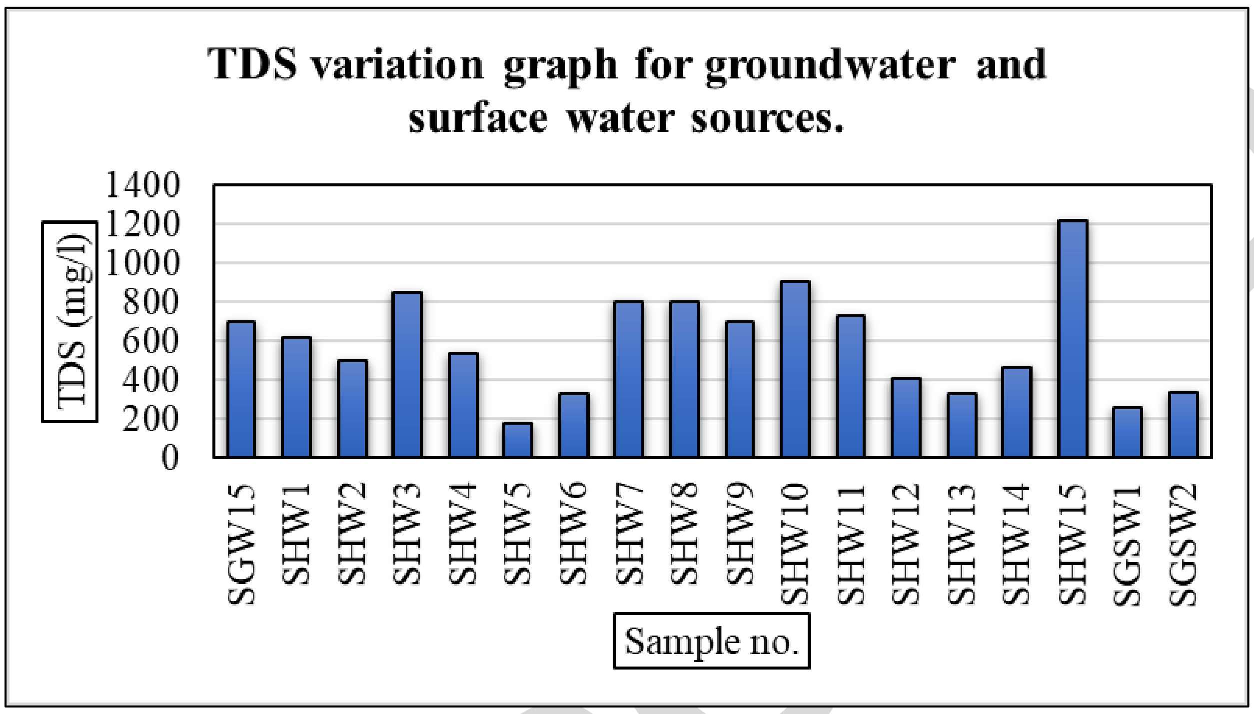

Figure 3.19: TDS variation graph in groundwater and surface water (SGSW1 & SGSW2).

The water quality test results are given in **Annexure 2**.

Table 3.8: Water quality results of groundwater samples.

S.No.	Latitude	Longitude	pH Value @ 250C	Electrical Conductivity (EC)	Total Dissolved Solids (TDS)	Total Alkalinity (as CaCO3)	Chloride (as Cl)	Calcium Hardness (as CaCO3)	Magnesium Hardness (as CaCO3)	Iron (as Fe)	Sulphate (as SO4)	Nitrate (as NO3)	Fluoride (as F)	Sodium (as Na)	Potassium (as K)	Zinc (as Zn)	Mercury (as Hg)	Arsenic (as As)
Unit			-	µmhos/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Standard as per IS: 10500(2012)			6.5 - 8.5(NR)	-	500(2000)	200(600)	250(1000)	75(200)	30(100)	0.3(NR)	200(400)	45(NR)	1.0(1.5)	-	-	5(15)	0.001(NR)	0.01(0.05)
SGW15	23.16895	81.38448	7	1085	702	344	58	67.3	61.3	0.16	14.2	58.92	0.32	38.8	2.8	0.44	<0.001	<0.005
SHW1	23.38438	81.32848	7.82	1149	618	221	126	60.9	23.3	0.13	27.05	52.04	0.28	82.6	3.1	0.39	<0.001	<0.005
SHW2	23.24679	81.34747	6.99	775	496	294	54	78.6	22.4	0.18	14.5	6.2	0.36	36.1	2.1	0.42	<0.001	<0.005
SHW3	23.25025	81.33512	6.37	1242	848	324	180.9	115.4	18.5	0.14	15.7	73.88	0.38	119.6	3.8	0.52	<0.001	<0.005
SHW4	23.26327	81.3288	7.09	760	542	288	71	57.7	38.9	0.22	17.1	16.92	0.36	45.5	2.2	0.42	<0.001	<0.005
SHW5	23.25366	81.3088	6.47	248	176	86	7	19.2	12.6	0.17	1	25.99	0.22	4.3	0.2	0.28	<0.001	<0.005
SHW6	23.32745	81.2718	6.87	437	327	112	28	32.1	18.5	0.15	5.6	51.92	0.34	16.6	1.2	0.29	<0.001	<0.005
SHW7	23.30703	81.32776	7.42	1381	800	368	138	66.5	57.9	0.14	49.3	16.5	0.22	92.1	3.7	0.28	<0.001	<0.005
SHW8	23.32248	81.35559	6.48	1221	802	372	157	73.8	48.6	0.17	42.6	8.47	0.34	104.5	3.8	0.47	<0.001	<0.005
SHW9	23.290032	81.41817	7.64	1079	701	341	109	56.5	53.2	0.12	41.7	3.51	0.35	68.2	2.9	0.41	<0.001	<0.005
SHW10	23.212344	81.352686	6.27	1163	909	268	160	109.8	24.8	0.21	28	136.84	0.39	106.4	3.9	0.54	<0.001	<0.005
SHW11	23.17412	81.33996	7.32	1356	728	498	26	97.8	69	0.22	36.6	29.91	0.32	17.2	1.2	0.54	<0.001	<0.005
SHW12	23.26436	81.24031	6.7	663	408	178	20	54.1	22.6	0.14	12.1	68.28	0.28	13.4	1	0.34	<0.001	<0.005
SHW13	23.23575	81.41675	7.09	486	332	138	33	46.5	12.6	0.14	8.3	34.55	0.22	21.8	1.5	0.24	<0.001	<0.005
SHW14	23.19216	81.45453	6.92	893	468	342	7	113.8	16.5	0.21	14.4	7.68	0.34	4.2	0.2	0.45	<0.001	<0.005
SHW15	23.25982	81.4646	6.92	1738	1221	548	114	193.2	52	0.21	101.2	111.48	0.36	76.7	2.8	0.54	<0.001	<0.005
SGW15	23.16895	81.38448	7	1085	702	344	58	67.3	61.3	0.16	14.2	58.92	0.32	38.8	2.8	0.44	<0.001	<0.005

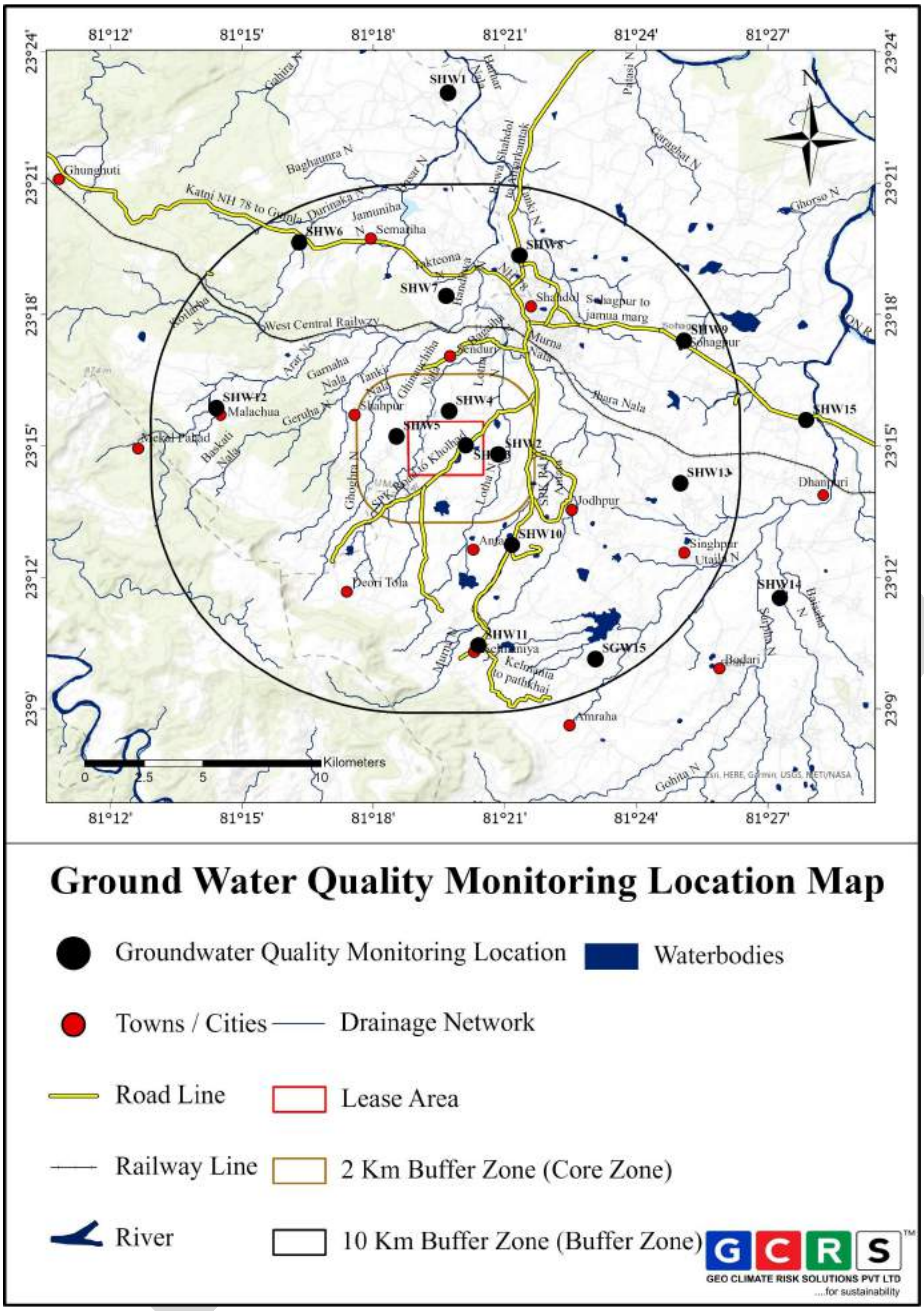

Figure 3.20: Groundwater sample location map for quality analysis.

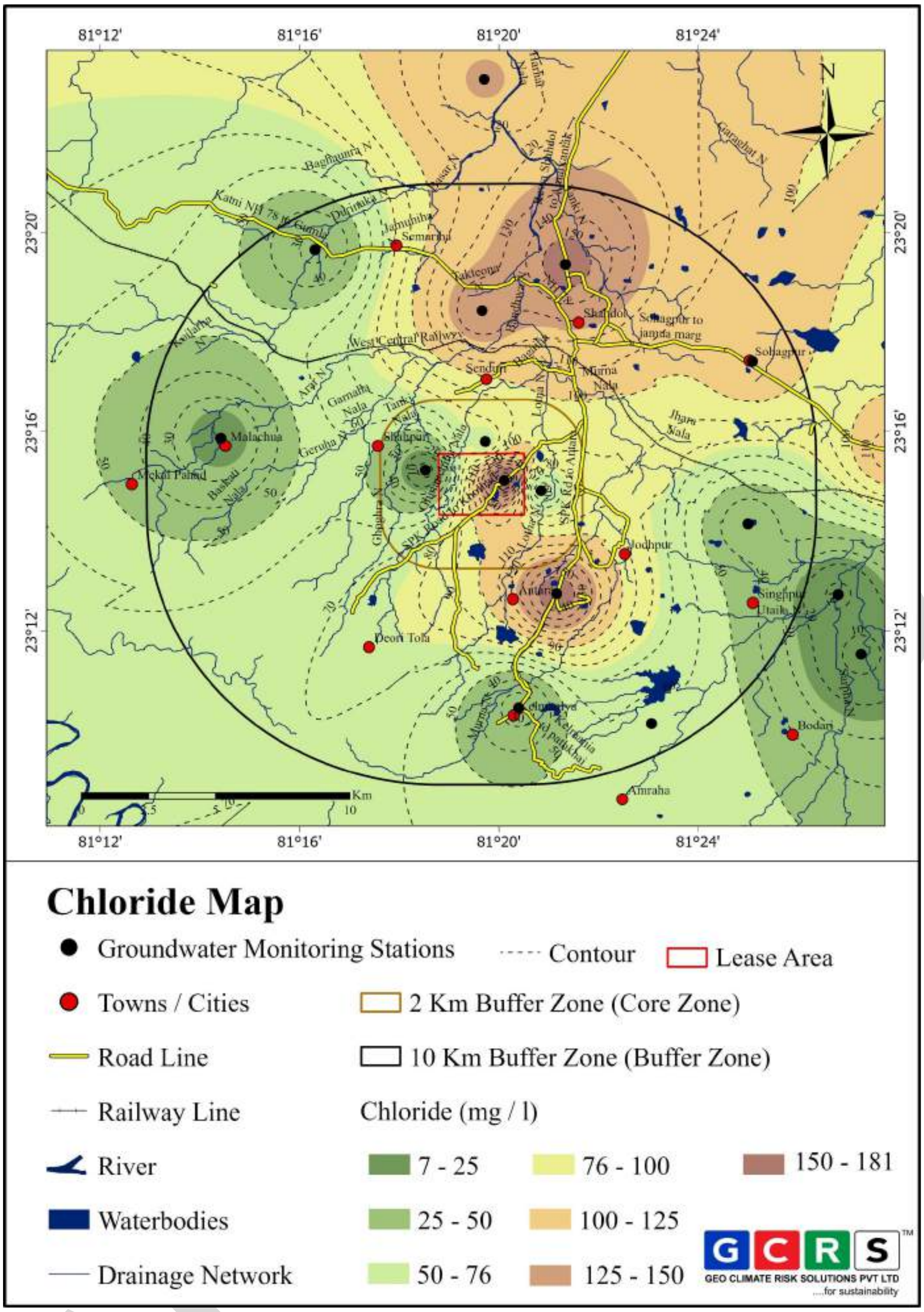

Figure 3.21: Chloride Contour Map of the study area.

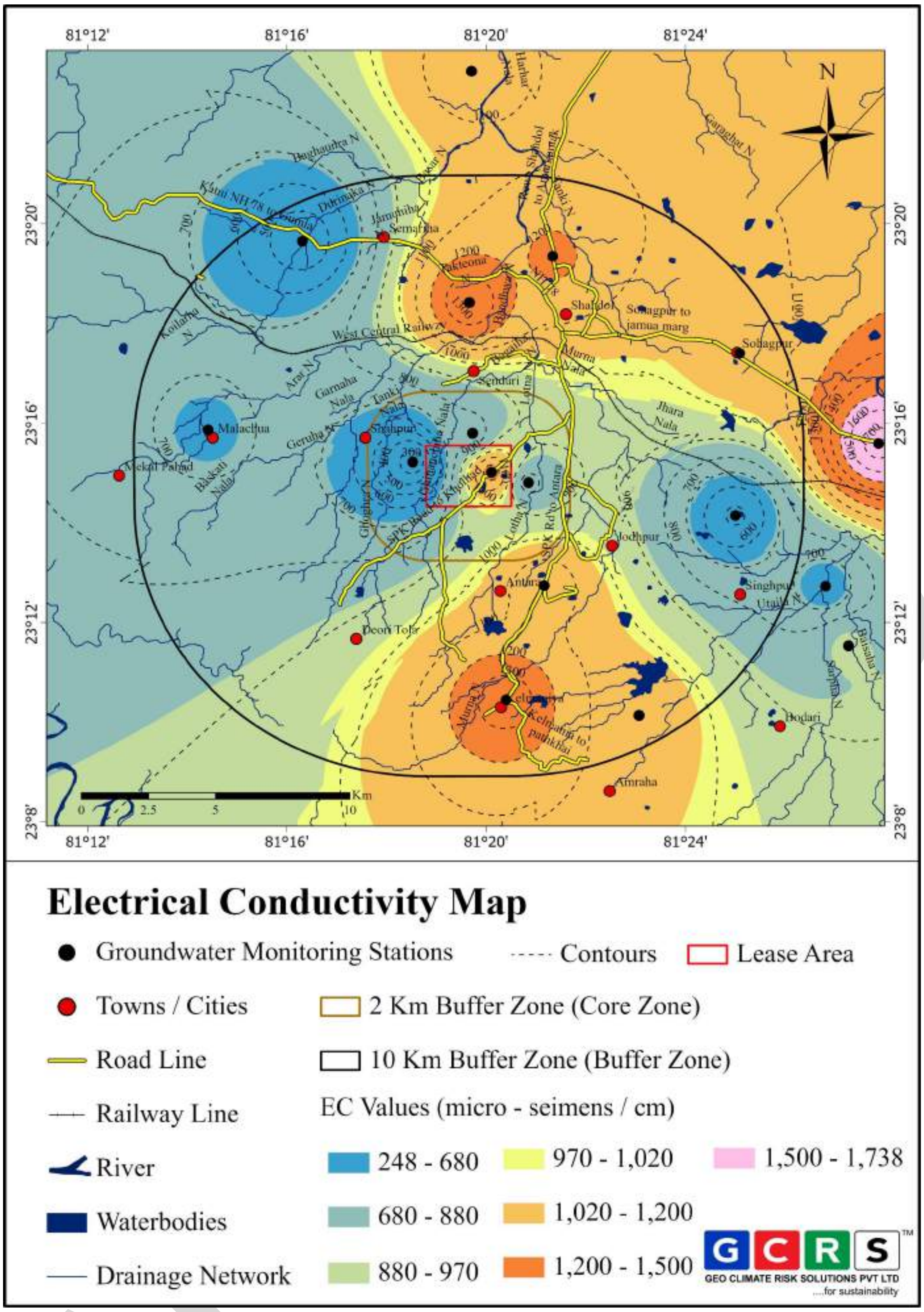

Figure 3.22: Electrical Conductivity Contour map of the study area.

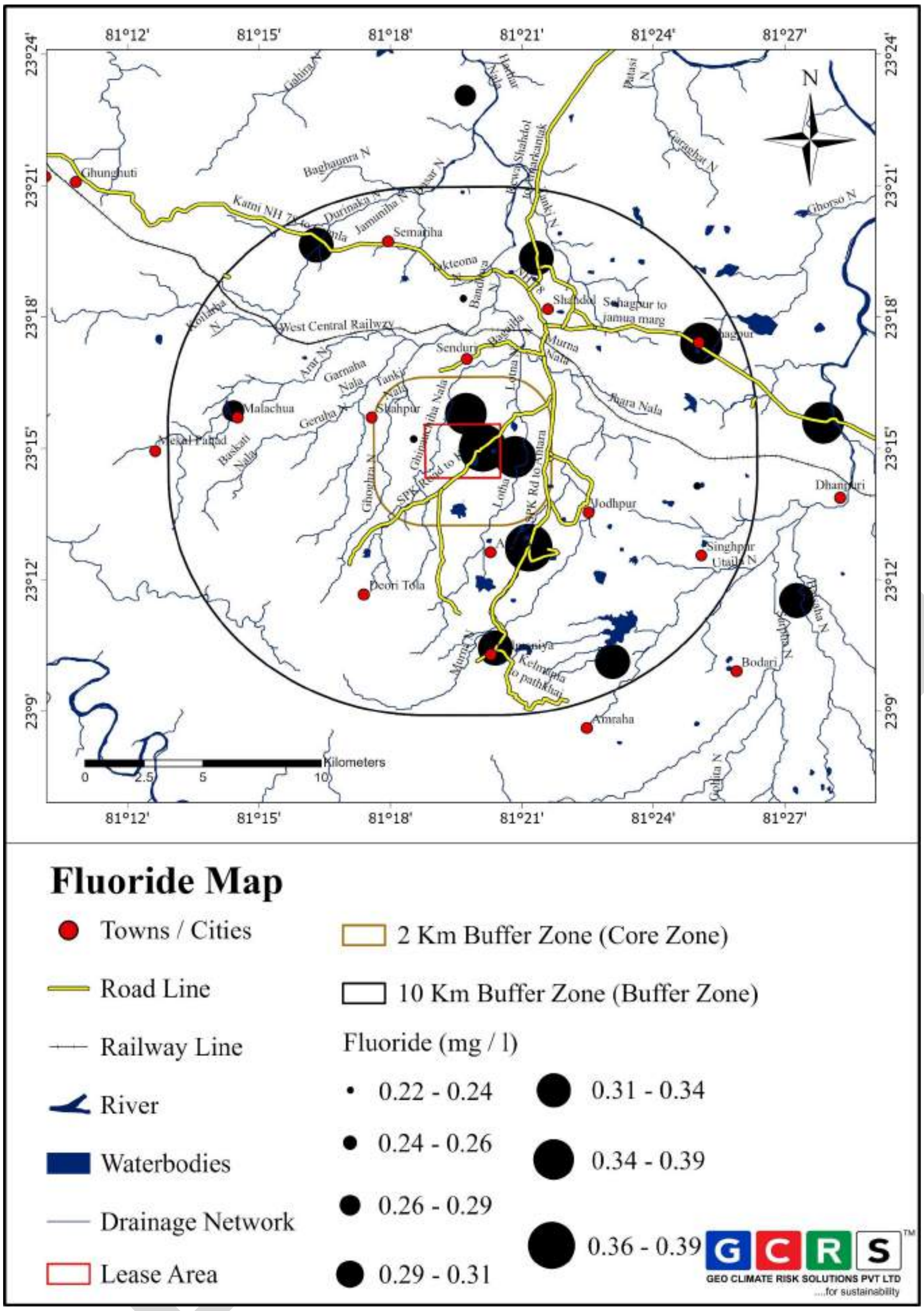

Figure 3.23: Fluoride Concentration map of the study area.

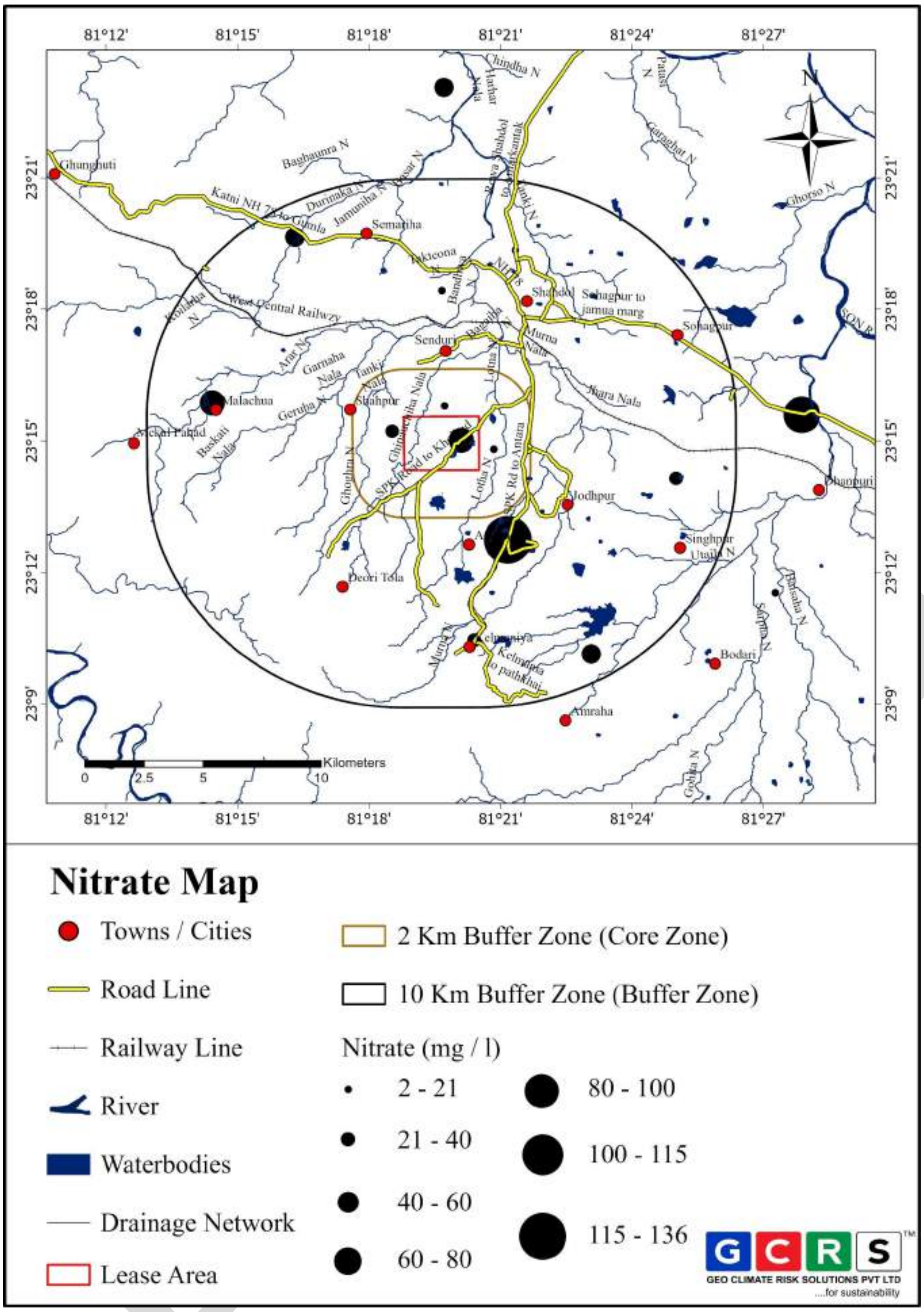

Figure 3.24: Nitrate Concentration map of the study area

3.3.6 Water quality of nearby water bodies

SGSW1 and SGSW2 are two monitoring stations from where the data for estimation of surface water quality has been taken and the results for the same are analysed. The sample no. SGSW1 is collected from Chachai Dam and sample no. SGSW2 from Sarpha Nala. The location of SGSW1 and SGSW2 is 14.14 km and 35 km SW of study area respectively. Both locations do not fall within 10km buffer zone. The Surface water quality analysis result of the study area and the concerned parameters are found to be within the range of maximum permissible limits (**Table 3.9**).

Table 3.9: Surface water quality results.

Well ID	**Unit**	**Standard as per IS: 10500(2012)**	SGSW1	SGSW2
Latitude			23.17066	23.2121
Longitude			81.65767	81.44687
pH Value @ 250C	**-**	6.5 - 8.5(NR)	8.4	7.89
Electrical Conductivity (EC)	µmhos/cm	-	344	624
Total Dissolved Solids (TDS)	mg/l	500(2000)	256	342
Total Alkalinity (asCaCO3)	mg/l	200(600)	122	222
Chloride (as Cl)	mg/l	250(1000)	6	8
Calcium Hardness (as CaCO3)	mg/l	75(200)	30.5	51.3
Magnesium Hardness (as CaCO3)	mg/l	30(100)	16.5	23.3
Iron (as Fe)	mg/l	0.3(NR)	0.18	0.17
Sulphate (as SO4)	mg/l	200(400)	25.1	9.53
Nitrate (as NO3)	mg/l	45(NR)	2.78	2.37
Fluoride (as F)	mg/l	1.0(1.5)	0.29	0.28
Sodium (as Na)	mg/l	-	3.8	5.1
Potassium (as K)	mg/l	-	0.2	0.2
Zinc (as Zn)	mg/l	5(15)	0.34	0.25
Mercury (as Hg)	mg/l	0.001(NR)	<0.001	<0.001

Arsenic (as As)	mg/l	0.01(0.05)	<0.005	<0.005

4 APPROVED MINE PLAN

A total of 5 coal seams of variable thickness are viable for working. To protect the surficial features, board and pillar mining method is considered to be the most appropriate. Given that the seam gradient is almost flat, underground mining with continuous miner and shuttle car combination for mechanized method and LHDs with solid blasting method in semi-mechanized method of mining is a suitable option. As most of the coal is good grade, therefore, the mining plan is prepared for thickness range of more than 1.20m having a total net reserve of 51.49 Mt. Out of this total net reserve, 22.187 Mt is extractable.

The life of the mine is 34 years and operations shall be done in three stages which are given below in **Table 4.1**.

The production from continuous miner will be 0.4 MTPA or 1333 TPD. The three LDH deployed panels with 5 headings will give production of 400 TPD. Additional 100 TPD will be obtained from development of one dip drive with one LHD in for each panel.

The total production per day of the mine will be as follows:

1) Output from two semi-mechanized LHD panels = 800 te /day
2) Development of two dip drives with one LHD = 200 te/day
3) Output from continuous miner panel = 1333 te/day

Thus, total production per day will be over 2333 TPD or 0.70 MTPA and mining plan is adopted as such.

The calendar program of mine production is given in Table **4.1**. The plate of master surface plan is given in **Annexure 3**.

Table 4.1: Calendar program of production.

YEAR	SEAM IV			SEAM L2			SEAM III A & III B			SEAM II			TOTAL
	DEV	DEP	TOTAL	DEV	DEP	TOTAL	DEV	DEP	TOTAL	DEV	DEP	TOTAL	DEV
1	0.045	0.000	0.045	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.045
2	0.150	0.000	0.150	0.133	0.000	0.133	0.208	0.000	0.208	0.000	0.000	0.000	0.491
3	0.150	0.000	0.150	0.150	0.000	0.150	0.400	0.000	0.400	0.000	0.000	0.000	0.7
4	0.150	0.000	0.150	0.150	0.000	0.150	0.255	0.000	0.255	0.255	0.000	0.255	0.696
5	0.150	0.000	0.150	0.150	0.000	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.7
Total (A)	**0.645**	**0.000**	**0.645**	**0.583**	**0.000**	**0.583**	**0.863**	**0.000**	**0.863**	**0.541**	0.000	**0.541**	**2.632**
6	0.150	0.000	0.000	0.150	0.000	0.000	0.000	0.000	0.000	0.400	0.000	0.400	0.700
7	0.150	0.000	0.150	0.150	0.000	0.150	0.000	0.000	0.000	0.400	0.000	0.400	0.700
8	0.150	0.000	0.150	0.100	0.050	0.150	0.000	0.000	0.000	0.400	0.000	0.400	0.650
9	0.110	0.139	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.400	0.000	0.400	0.411

10	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.204	0.196	0.400	0.204
11	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
12	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
13	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
14	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
15	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
Total (B)	**0.461**	**1.039**	**1.350**	**0.400**	**1.100**	**1.350**	**0.000**	**0.000**	**0.000**	**1.804**	**2.196**	**4.000**	**2.665**
16	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
17	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
18	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
19	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
20	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
21	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000

22	0.000	0.150	0.150	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.400	0.400	0.000
23	0.000	0.150	0.150	0.000	0.144	0.144	0.000	0.000	0.000	0.000	0.400	0.400	0.000
24	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.150	0.150	0.000	0.400	0.400	0.000
25	0.000	0.150	0.150	0.000	0.000	0.000	0.000	0.150	0.150	0.000	0.400	0.400	0.000
Total (C)	**0.000**	**1.500**	**1.500**	**0.000**	**1.194**	**1.194**	**0.000**	**0.300**	**0.300**	**0.000**	**4.000**	**4.000**	**0.000**
26	0.000	0.041	0.041	0.000	0.000	0.000	0.000	0.240	0.240	0.000	0.400	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.300	0.000	0.400	0.400	0.000
28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.300	0.000	0.400	0.400	0.000
29	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.300	0.000	0.400	0.400	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.300	0.000	0.400	0.400	0.000
31	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.300	0.000	0.400	0.400	0.000
32	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.300	0.000	0.400	0.400	0.000
33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.296	0.296	0.000	0.383	0.383	0.000

Total (D)	**0.000**	**0.041**	**0.041**	**0.000**	**0.000**	**0.000**	**0.000**	**2.336**	**2.336**	**0.000**	**3.183**	**2.783**	**0.000**
Grand Total (A+B+C+D)	**1.106**	**2.580**	**3.536**	**0.983**	**2.294**	**3.127**	**0.863**	**2.636**	**3.499**	**2.345**	**9.379**	**11.324**	**5.297**

5 ESTIMATION OF MINE SEEPAGE AND ADVANCED DEWATERING PLAN

5.1 ESTIMATION OF MINE SEEPAGE

Water in the mining operations is expected either from the accumulation of the surface run off and direct downpour in the concerned site or from the seepage from the ground water. The proposed project in this case being an underground mining project, the surface run-off accumulation in the working sites is negligible. Hence, the ground water seepage is anticipated on the intersection of the mine development with the local ground water table. In this case, the make of water in the underground may be from the following sources:

- Seepage from the overlying sandstone of Barren Measure/Barakar formation.
- Inflow of water from Barakar Sandstone roof during the underground mining.

The average thickness of the overlying sandstone of the Barren measure range between 3 and 100m. The coal bearing Barakar formation range in between 121 to 243m. Based on the general experience of the area, assuming the depth to water level of the area to be 8 to 10 meters below ground level and deducing the aquifer thickness to be 110 to 250 meters, the make of water from the seepage available to be dewatered is considered to be 1000 GPM, i.e. ~ 91KLD. Pumping set up to dewater a similar quantum is suggested for the project.

During Coal mining seepage (water-inrush) is mostly considered. Fractures are developed and expanded in the surrounding rock and connected with the fractured geological structure, then water flow channels are formed, and finally, water-inrush happens indirectly. Numerical modelling helps a lot in evaluating this seepage by a result of numerical modelling to predict the quantity of inflow & provides valuable information for an appropriate dewatering system. The water inflow to the pit is mainly from a confined aquifer, mainly by horizontal flow in the upper layers and vertical flow at the pit bottom.

The groundwater seepages start in the mining as the water table of the area is encountered. The quantum of water that accumulates in the mine sump is quite large and varies with time and season. Any mining activity would require pumping of this water to allow mining activity.

The mine seepage has been estimated using Darcy's equation which states that flow is directly proportional to the surface area of the aquifer exposed in the mine pit face and the gradient of the water table.

Q α K I A

Where,
Q = rate of flow

I = water table gradient

A= cross section area of aquifer exposed in mine pit

The above relationship may be written as Q = KIA or Q = (Kb)IA where k is permeability, b is aquifer thickness.

Note: K for the area of about 0.79 m/day (from pumping test results).

Aquifer thickness is taken as 2 m by considering average the height of the working face/galley (Source mining Plan) and the underground working area is below the water table. So, the total height is taken as aquifer thickness.

The mine seepage is calculated for the 5-year plan period for pre-monsoon and post-monsoon seasons as per the availability of mine development plan **(Table 5.1**). The estimated quantity of mine seepage during 5year period varies from 46 to 4520 m3/day. The estimated mine seepage is given in **Table 5.2** and **Table 5.3**.

Seepage calculation is based on constant parameters. So, the actual seepage quantity may vary from the estimated seepage quantity.

Table 5.1: Details of working seams.

Year	**Season**	**Working Coal Seam**	**Perimeter of the working seam**
1st Year	Pre-monsoon	Seam-IV	121787
		Seam-L2	0
		Seam-3A	0
		Seam-II	0
	Post-Monsoon	Seam-IV	1334
		Seam-L2	0
		Seam-3A	0
		Seam-II	0
2nd Year	Pre-monsoon	Seam-IV	19,50,924.37
		Seam-L2	2680
		Seam-3A	5480
		Seam-II	0

	Post-Monsoon	Seam-IV	4700
		Seam-L2	2680
		Seam-3A	5480
		Seam-II	0
3rd Year	Pre-monsoon	Seam-IV	19,50,924
		Seam-L2	5760
		Seam-3A	7580
		Seam-II	0
	Post-Monsoon	Seam-IV	5891
		Seam-L2	5760
		Seam-3A	7580
		Seam-II	0
4th Year	Pre-monsoon	Seam-IV	8313
		Seam-L2	7016
		Seam-3A	9077
		Seam-II	2120
	Post-Monsoon	Seam-IV	8313
		Seam-L2	7016
		Seam-3A	9077
		Seam-II	2120
5th Year	Pre-monsoon	Seam-IV	10413
		Seam-L2	9400
		Seam-3A	9077
		Seam-II	4940
	Post-Monsoon	Seam-IV	10413
		Seam-L2	9400
		Seam-3A	9077
		Seam-II	4940

Table 5.2: Estimated seepage details.

Year	Season	Working Coal Seam	Tunnel length of the working seams	Water Table (mamsl)	Aquifer thickness (b,m)	Permeability (K,m/day)	Hydraulic Gradient (I)	Seepage(Q, m3/day)	Average seepage (m3/day)
1st Year (2023-2024)	**Pre-monsoon**	**Seam-IV**	6102	480.2	2	0.79	0.0048	46	46
		Seam-L2	0	480.2	2	0.79	0.0048	0	
		Seam-3A	0	480.2	2	0.79	0.0048	0	
		Seam-II	0	480.2	2	0.79	0.0048	0	
	Post-Monsoon	**Seam-IV**	6102	482	2	0.79	0.0048	46	
		Seam-L2	0	482	2	0.79	0.0048	0	
		Seam-3A	0	482	2	0.79	0.0048	0	
		Seam-II	0	482	2	0.79	0.0048	0	
2nd Year (2024-2025)	**Pre-monsoon**	**Seam-IV**	43,602	480.2	2	0.79	0.0051	351	763
		Seam-L2	13058	480.2	2	0.79	0.0051	105	
		Seam-3A	38068	480.2	2	0.79	0.0051	307	
		Seam-II	0	480.2	2	0.79	0.0051	0	

	Post-Monsoon	**Seam-IV**	43,602	482	2	0.79	0.0051	351	
		Seam-L2	13058	482	2	0.79	0.0051	105	
		Seam-3A	38068	482	2	0.79	0.0051	307	
		Seam-II	0	482	2	0.79	0.0051	0	
3rd Year (2025-2026)	**Pre-monsoon**	**Seam-IV**	61136	480.2	2	0.79	0.0054	522	1702
		Seam-L2	44182	480.2	2	0.79	0.0054	377	
		Seam-3A	94211	480.2	2	0.79	0.0054	804	
		Seam-II	0	480.2	2	0.79	0.0054	0	
	Post-Monsoon	**Seam-IV**	61136	482	2	0.79	0.0054	522	
		Seam-L2	44182	482	2	0.79	0.0054	377	
		Seam-3A	94211	482	2	0.79	0.0054	804	
		Seam-II	0	482	2	0.79	0.0054	0	
4th Year (2026-2027)	**Pre-monsoon**	**Seam-IV**	117421	480.2	2	0.79	0.0057	1057	3546
		Seam-L2	96586	480.2	2	0.79	0.0057	870	
		Seam-3A	164776	480.2	2	0.79	0.0057	1484	
		Seam-II	14960	480.2	2	0.79	0.0057	135	

	Post-Monsoon	**Seam-IV**	117421	482	2	0.79	0.0057	1057	
		Seam-L2	96586	482	2	0.79	0.0057	870	
		Seam-3A	164776	482	2	0.79	0.0057	1484	
		Seam-II	14960	482	2	0.79	0.0057	135	
5th Year (2027-2028)	**Pre-monsoon**	**Seam-IV**	243447	480.2	2	0.79	0.006	2308	4520
		Seam-L2	181632	480.2	2	0.79	0.006	1722	
		Seam-3A	0	480.2	2	0.79	0.006	0	
		Seam-II	51701	480.2	2	0.79	0.006	490	
	Post-Monsoon	**Seam-IV**	243447	482	2	0.79	0.006	2308	
		Seam-L2	181632	482	2	0.79	0.006	1722	
		Seam-3A	0	482	2	0.79	0.006	0	
		Seam-II	51701	482	2	0.79	0.006	490	

Table 5.3: Year wise estimated mine seepage

Year	Seepage (m3/year)
1st Year	46
2nd Year	763
3rd Year	1702
4th Year	3546
5th Year	4520

Note: K for that area about 0.79 m/day based on the pumping test results.

Water table gradient varies from 0.0048 to 0.006 for the study period from 2023 to 2027 from hydrogeological map.

Aquifer thickness is taken as 2 m by considering average height of the working face/galley (Source mining Plan) and the underground working area is below the water table. So, the total height is taken as aquifer thickness.

Seepage calculation is based on constant parameters. So, the actual seepage quantity may vary from the estimated seepage quantity.

5.2 ADVANCED DEWATERING PLAN

Underground

When mining activity reaches the water table of that area, water seepage starts. Large sumps are built to stock up to control the run-off. Rainfall plays as an important role to create mine seepage. So protective measures should be adopted to control this infiltration of rainfall to the ground in and around the lease area. Rainwater harvesting ponds are one of the suitable options where rainwater in diverted by creating drainage system to these settling ponds. Further this water can be used for various mining and supporting activities by pumping.

Opencast

In mines as soon as the water table is encountered, the ground water seepages start and the flow rate depends on the aquifer properties, hydraulic gradient etc. The quantum of water that accumulates in the mine sump is quite large and varies with time and season. Any mining activity would require pumping of this water to allow mining activity. There are two sources of water accumulation in mine sump

- Monsoon rainfall
- Mine seepage

Both the components need to be estimated separately. The rainwater accumulation due to monsoon rainfall over the mine lease area can be worked out based on the actual size of mine pit taken from the working mine plan and long-term mean monsoon rainfall data for the area. As per the standard practice, it is assumed that out of total rainfall accumulation of rainwater 30% evaporates and 20% is probable recharge to groundwater storage. The balance is available for other use. The appropriate measures, such as the construction of diversion channels, walls along the pit boundary etc., are constructed to prevent the surface runoff inflow in the mine pits. It is also proposed to reduce the rainwater infiltration into the ground by conducting an appropriate scientific study in the nearby pit area. This water will be diverted to rainwater harvesting ponds.

5.3 GROUND WATER MODELLING

The Groundwater modelling report is attached as a separate report which assess the impact of withdrawal on groundwater system on long term basis.

6 MINE WATER MANAGEMENT

Total requirement of water for mining and allied services are estimated as 394 KL/day. The requirement of potable water will be 33 KL/day for the allied services i.e., canteen, rest shelters, offices colony etc (Source: Mine plan).

The projected water demand can be met from the mine seepage water after adequate development of the mine. However, in the initial few years of the mining, the water demand will be met from the ground water abstraction structures (Bore Wells). Out of the 394 KL, 80% shall be generated as wastewater, treated in STP, and used for plantation, dust suppression and sprinkling. The details of the water demand and supply for the project is briefed below as **Table 6.1**. To meet the initial groundwater requirement, the proponent has proposed 3 borewell structures with 200 m depth and 200 mm diameter (**Table 6.2**). In the later years of mine development this fresh water requirement from borewells will be reduced and the mine seepage water will be used for the dust suppression, vehicle washing and other allied mining activities.

Table 6.1: Water Requirement of the Project.

Purpose	**Water requirement (KLD)**	**Source**
Dust suppression	120	Borewell water
Plantation	150	
Vehicles washings	91	
Domestic Purpose	33	
Total	**394**	

Table 6.2: Details of proposed tentative abstraction borewells.

S. No.	**Number of structures**	**Depth (m)**	**Diameter (mm)**	**Depth to Water Level (mbgl)**	**Discharge Rate (m3/hour)**	**Operational hours/day, days/year**	**Mode of Lift (H.P)**
1.	Borewell 1	200	200 mm	8	10	13 hrs	5
2	Borewell 2	200	200 mm	8	10	13 hrs	5
3	Borewell 3	200	200 mm	8	10	13 hrs	5

7 IMPACT OF MINE DEWATERING / ABSTRACTION AND MITIGATION MEASURES

7.1 IMPACT ON THE GROUND WATER REGIME

The impact of mining on local ground water regime depends on various parameters like method of mining, depth and rate of expansion, ground water recharge and hydraulic parameters of the aquifers system of the area. In underground mining, the aquifer lying in the immediate roof of the working coal seam contributes major inflow and gets affected. Due to the presence of several impermeable strata overlying the working seams (such as clay, shale, and coal beds), the impact on the phreatic aquifer at shallow depth will be negligible. In order to prevent the impact on groundwater regimes several mitigation measures will be adopted by the proponent as per the issued guidelines like construction of rainwater harvesting structures and water conservation structures and, desilting of irrigation tanks of nearby villages.

7.2 IMPACT ON SURFACE WATER SOURCES

The study area is a flat terrain except in the North-West part of the block. Due to the abundance of the soil cover, there is no effective drainage developed within the block area. Seasonal Nallas are flowing towards south and north-east within the mining lease area. Since the depth of the mine workings (of top seam) in this area is about 300 m below ground level to facilitate safe working conditions so there will be no impact of the mine on Hydrology of the area or the existing users in surrounding villages.

7.3 IMPACT ON WATER QUALITY

The overall impact on water environment due to proposed mine is likely to be short term and insignificant. There are no harmful ingredients contained in coal or stone waste to leach down to the water table and pollute it. So, it has no adverse effect on the groundwater quality.

7.4 MITIGATION MEASURES

To mitigate the possible impacts imposed on the ground water environment due to the mining activities, adequate measures are being taken in accordance with the mandates stipulated by concerned statutory bodies. As a part of environmental protection, the project has been adopting all possible measures to increase the groundwater recharge potential in the influenced and nearby areas. Moreover, the wastewater recycling after due treatment will enable conservation of water. Storage of conserved water in mine sumps will be given due emphasis to provide water round the year and quality of water will be maintained thereof.

Garland drains will be made around the periphery of the quarry. These garland drains will be connected to the local nallah which is not likely to be disturbed by mining operation. In the workings, heavy duty pumps will be deployed in rainy season which will throw the accumulated water from the working face into these garland drains. As the extraction of the quarry advances, the position of garland drain will also advance. Thus, these garland drains will drain off the rainwater away from the workings. The rainwater harvesting structures will be constructed in and around the project area as per type design provided by Central Ground Water Board. In addition to this, desilting of irrigation tanks of nearby villages will be taken up for augmentation of ground water recharge.

Rainwater can be harvested either storing in tanks for ready use or charged into soil for withdrawal later i.e., ground water recharging. M/s Chowgule & Company Private Limited has proposed to install Rainwater Harvesting system to prevent runoff and to help reduce freshwater consumption. Storm water network will be designed throughout the site for collection of roof top as well as internal runoff during the monsoon season. Pipeline and storm water drainage will be connected/diverted to water harvesting tank after due treatment to free it from any possible contamination. The water harvested in the tank will be utilized for the dust suppression, green belt development and workshops etc.

Internal storm water drain with natural slope around the project site has been proposed by the Project proponent. Efficient working of the drainage under the rainwater harvesting program to collect the adequate rain water shall be ensured by refraining the drainage network from any potential clogging or blockage prior and during the monsoon. Garland drains along the plant boundary shall also be constructed in order to contribute towards the run off material.

Apart from the above-mentioned recharge measures proposed to be adopted to mitigate the impacts of the withdrawal corresponding to the concerned project, below are a few suggested methods that may be induced in and around the project area in order to augment the recharge quantum even further. These are as follows *(Guide on Artificial Recharge to Groundwater, 2000)*.

• Roof-top catchment:

The roof-top water collected can be made drinkable after suitable treatment. The excess water that flows can be stored in underground storage tanks. The water collected from this source is mostly used for storage purposes to be used later for dust suppression on roads, constructional activities, washing of dumpers, dozers, cranes, coal haulers, etc., fire-fighting, floor washing, road watering etc. Besides these activities, the water collected can be efficiently used for ground water recharging through various structures like percolation well, bore-well or open well method where water is diverted towards existing well or bore wells to recharge ground.

Since water collected from the above source would not be suitable for consumption, it can be used for storage and later used for many purposes as discussed above. However, the water collected from pavements can be diverted through gutters to underground masonry tanks, reinforced cement concrete tanks, ferro-cement tanks, etc. for storage and to be used later.

Besides, based on the size /area of the building and the underlying lithological nature of the formation rain water available in the open spaces around the building may be recharged into the ground through the following simple effective methods either individually or in combinations.

The mine lease area has 47420 m^2 of roof top area (buil-up area) which includes facilities like Office, Work shop, store, VTC, Canteen, Diesel Bunk & area between the buildings but excluding Magazine and ventilation shaft. The total estimated quantum available for RWH from this is **49,577.61 m3/year (Table 7.1).**

Table 7.1: Estimation of Quantum of runoff available through Rain water harvesting (within premises).

S.No.	Particulars	Area (Sqm)	Rain fall (m)	Runoff Coefficient*	Quantum of Run off available (Cum/Year)
1	Roof Top of building/Shed/	47420	1.23	0.85	49577.61
2	Road/Paved area	0	1.23	0.65	0
3	Open Land	0	1.23	0.20	0
4	Green Belt	0	1.23	0.15	0

5	Total (sqm)	47420		Total Quantum of available runoff	**4,9577.61**

• Recharge through abandoned wells:

Utilisation of the open well if any, within the lease area or nearby villages to divert the rainwater from open area into the abandoned wells. Otherwise, construction of a well for this purpose is preferable. The rainwater falling on the open space around the complex can be collected at a point by providing a gutter with perforated lid. The collected water can be led through necessary piping arrangements into a recharge well of 1 metre dia and 5 metre deep.

• Percolation pit with bore method:

A percolation / absorption pit is a hand bore, made in the soil with the help of an augur and filled up with pebbles and river sand on top. The depth of these pits may be anywhere between 4 and 8 meters depending on the nature of the soil. If the soil is clayey, the pit has to be dug to a depth till a reasonably sandy stratum is reached. The diameter of these pits will be 25 cm (10 inches). A square / circular collection chamber with silt arrester is provided at the top. A borehole is to be drilled at the bottom of the percolation pit. Borehole size: 150 - 300 mm dia with 10 -15 ft depth (approx.) filled with broken bricks.

• Open well method/ Bore well method:

Roof top rainwater may also be diverted to a bore well. Settlement/filter tank of required size need to be provided for the purpose. Overflow water may be diverted to a percolation pit nearby. The rate of recharge through bore well in this case is, however, less effective than open wells. Defunct bore wells may also be used.

Mitigation measures

Several control measures will be taken up at the mine to control the pollution created by mine activities. The overall drainage planning will be done in such a manner that the existing pre mining drainage conditions are recreated and run off distribution is not affected.

- Garland drains will be constructed. All the garland drains will be routed through adequately sized settling ponds to remove suspended solids from flowing into storm water. The design of settling ponds will be based on silt load, slope and detention time required. Settling pits and drains will be periodically desilted.

- Retaining walls with weep holes will be built all-round the surface dumps. The storm water will pass through weep holes to the garland drains.
- The surplus treated mine water will be discharged into local nearest natural drain, agricultural fields (if farmers are willing to use) or for other purposes for its gainfully utilization.
- Suitable networking for pumping mine drainage water to the settling pond would be ensured.
- Shallow and deeper piezometers will be constructed close to mine area for monitoring the water levels in the aquifer. The locations of piezometers would be selected in consultation with Central Ground Water Board (CGWB).
- Stone barriers across the drain will be constructed to check the water current and arrest solids and stone pitching will be made at suitable location to regulate water flow and prevent soil erosion.

7.5 SALINE WATER DISPOSAL STRATEGIES

The proposed project does not involve utilization of saline water by any means or purpose for the concerned project and hence, disposal strategies for the same is not applicable for this project.

8 OTHER DETAILS PERTAINING TO THE PROJECT

In order to understand the impact of Ghinachunia Nala (stream) diversion inside the mine lease area, an additional study is conducted using surface run-off modelling (HEC-HMS) and flood risk flooding (HEC-RAS) softwares. To estimate the stream flow and generation of flood inundation maps for the mine lease area HEC-RAS modelling software was used to analyse the impact of Nala on the underground mining work and accordingly its mitigation measures were also suggested. A separate report is prepared to estimate the peak discharges and the Highest Flood Level in the nala in the peak rainfall season.

9 SUMMARY AND CONCLUSION

The Shahpur East Underground Coal mine is a Greenfield project holding an area of about 659Ha in the western part of the Sohagpur Coalfields and located at villages Chunia, Senduri, Kathotia, Khamaria Kala, Kholhar Villages of Sohagpur Tehsil of Shahdol District and Khamariya Khurd Village of Pali Tehsil of District Umaria, Madhya Pradesh. It is bounded between latitudes 23°14'19" and 23°15'33" N and longitudes 81°18'48" and 81°20'30" E. The area is covered in Survey of India toposheet No. 64 E/7 and 64 E/8 (R.F. 1:50,000).

The area is approachable by both rail and road. The Shahdol and Sohagpur towns are both close to the project area and are connected through metalled road. The nearest railway station to the project area is at Shahdol lying 3.7 km Northeast of the Project area.

The predominant land use in the study area for pre-monsoon 2022 is agriculture land with 69.15% followed by 27.92% forest area (green area), 1.51%, built up, 0.77% water body and 0.63% barren land. The project area lies at a height of about 500m amsl and shows higher elevations of the order of 600 to 1000m amsl. The study area is characterized by pediment pediplain complex with moderately dissected plateaus and minor dissected hills and valleys.

The Sohagpur Coalfield forms one of the main coal bearing areas of the Rewa-Gondwana basin within the Shahdol district of Madhya Pradesh The area is covered by a thick mantle of soil & alluvium, and the coal bearing strata by the younger Supra Barakar Formation; chiefly composed of grayish white coarse & very coarse grained sandstone, a few of coal seams and carb shales.The formations within study areas mainly belong to Gondwanas. The coal seams of the area are of lower Permian in age and occur in Barakar formations.

The study area is encompassed with deep confined, semi-confined, and unconfined aquifer system. The permeable sandstone beds intercalated with shale and coal seams behave as an individual hydrogeological unit and form a multi-layered aquifer system. The unconfined aquifer contributes to the maximum inflow and lie above the working seam. It comprises mainly of the alluvium, loosely cemented and poorly consolidated sandstone. The lower formations, consisting compact and medium to coarse grained sandstone with secondary porosity, behave as semi-confined to confined in nature.

To decipher the water table configuration, a network consisting of 18 monitoring wells covering both core and buffer zones of the study area and beyond them has been established and water levels in the same has been recorded as a part of the study, in the month of April, 2022. Depth to water level in and around the study area in the month of April 2022 (pre-monsoon) varies between 5.6 metres below ground level (WL12) to 10.6 metres below ground level (WL16). Based on the map, it may be conferred that, the general trend of the groundwater flow in the study area is from south to north which is similar to that of the trends of surficial stream flows in the study area.

In addition, the concentration maps of Electrical conductivity, chloride, fluoride, and nitrate are prepared based on the analysis results of the water samples collected. The concentrations of the same are found to be within the permissible limits stipulated by the statutory authorities. Further, it is envisaged that the project site is not influencing the water quality of the area by any means.

Total requirement of water for mining and allied services are estimated as 394 KL/day. The requirement of potable water will be 33 KL/day for the allied services i.e., canteen, rest shelters, offices colony etc. To fulfil the water requirement, 3 borewell structure are proposed by the proponent.

The comprehensive hydrogeological study reveals that Shahpur East Coal mine will not pose any significant impact in the core and buffer zone of the study area. The proponent should adopt the following measures after obtaining the NOC permission from CGWA as per the statutory regulations:

- The proponent shall ensure that water available from de-watering operations is properly treated and should be gainfully utilized for supply for irrigation, dust suppression, mining process, recharge in downstream and for maintaining e-flows in the river system.
- Construction of observation well(s) (piezometers with DWLR & manual) as per the compliance conditions mention on the obtained NOC for monthly ground water level monitoring
- The proponent shall monitor ground water levels by establishing observation wells (piezometers) in the core and buffer zones as specified in the No Objection Certificate
- In order to avoid contamination (like acid mine drainage, etc) of surface water advanced dewatering technology should be adopted by the proponent.
- The proponent shall check the water quality of mine seepage and mine discharge

through NABL accredited/ Govt. approved laboratories and the same shall be submitted at the time of self-compliance.

- The proponent shall pay advance annual groundwater abstraction charges as per the CGWA guidelines issued on 24.09.2020 through NOCAP portal.
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References:

1. Agnihotri, D., Pillai, S, Aggarwal N., Tewari, R., Jasper, A., & Uhl, D. I. E. T. E. R. (2018). Palynomorphs from the Barakar Formation of Dhanpuri Open Cast Mine, Sohagpur Coalfield, Madhya Pradesh, India. *The Palaeobotanist*, *67*, 171-184.
2. Bhattacharya, S., Gupta, S. and Krishnamurthy, R. (1985). Oxygen and hydrogen isotopic ratios in groundwaters and river waters from India. Proceedings of the Indian Academy of Sciences - Earth and Planetary Sciences 94(3), 283-295.
3. CGWB (2009). Methodology for assessment of development potential of deeper aquifers, Central Ground Water Board, Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India, Faridabad.
4. Dhanam K, Kumar PS, Mysaiah D, Prasad PP & Seshunarayana T 2013. High resolution seismic imaging of the Sohagpur Gondwana Basin, central India: Evidence for syn sedimentary subsidence and faulting. Journal of Earth System Science 112: 1495–1505.
5. Gautam S, Ram–Awatar, Tewari R & Goswami S 2016. Permian–Triassic palynofloral transition in Sohagpur Coalfield, South Rewa Gondwana Basin, Madhya Pradesh, India. Palaeobotanist 65: 109−130.
6. Healy, R.W. and Cook, P.G. (2002). Using groundwater levels to estimate recharge. Hydrogeology Journal, 10(1), pp.91-109.
7. https://bhukosh.gsi.gov.in/Bhukosh/MapViewer.aspx
8. http://cgwb.gov.in/Regions/NCR/Reports/Ground%20Water%20Year%20Book%20(Year%202020-21)_Madhya%20Pradesh.pdf
9. https://indiawris.gov.in/wris/#/rainfall
10. https://www.indiawris.gov.in/wris/#/
11. https://www.surveyofindia.gov.in/
12. Jhariya, D., Khan, R., & Thakur, G. S. (2016). Impact of mining activity on water resource: an overview study. Proceedings of the Recent Practices and Innovations in Mining Industry, Raipur, India, 19-20.

13. Joshi, S. K., Gupta, S., Sinha, R., Densmore, A. L., Rai, S. P., Shekhar, S., Mason, P. J. and Dijk W. M. (2021b). Strongly heterogeneous patterns of groundwater depletion in northwestern India. Journal of Hydrology. https://doi.org/10.1016/j.jhydrol.2021.126492.

14. Joshi, S.K., Tiwari, A., Kumar, S., Saxena, R., Khobragade, S.D. and Tripathi, S.K. (2021a). Groundwater recharge quantification using multiproxy approaches in the agrarian region of Bundelkhand, central India. Groundwater for Sustainable Development, 13, p.100564.

15. Kruseman, G.P., De Ridder, N.A. and Verweij, J.M., 1970. Analysis and evaluation of pumping test data (Vol. 11, p. 200). Wageningen, The Netherlands: International Institute for land reclamation and improvement.

16. Mayer, A., Sültenfuß, J., Travi, Y., Rebeix, R., Purtschert, R., Claude, C., La Salle, C.L.G., Miche, H. and Conchetto, E. (2014). A multi-tracer study of groundwater origin and transit-time in the aquifers of the Venice region (Italy). Applied Geochemistry, 50, pp.177-198.

17. Pareek HS 1987. Petrographic, chemical and trace–elemental composition of the coal of Sohagpur Coalfield, Madhya Pradesh, India. International Journal of Coal Geology 9: 187–207.

18. Praticò, S., Solano, F., Di Fazio, S. and Modica, G., 2021. Machine learning classification of mediterranean forest habitats in google earth engine based on seasonal sentinel-2 time-series and input image composition optimisation. Remote Sensing, 13(4), p.586.

19. Qian, X., & Zhang, L. (2022). An integration method to improve the quality of global land cover. Advances in Space Research, 69(3), 1427-1438.

20. Raja Rao CS 1983. Coalfields of India Vol. III Coal Resources of Madhya Pradesh and Jammu and Kashmir. Bulletin of Geological Survey of India (Series A) 45: 1–204.

21. Schulz, D., Yin, H., Tischbein, B., Verleysdonk, S., Adamou, R., & Kumar, N. (2021). Land use mapping using Sentinel-1 and Sentinel-2 time series in a

heterogeneous landscape in Niger, Sahel. ISPRS Journal of Photogrammetry and Remote Sensing, 178, 97-111.

22. Singh, Asha. (2013). Nitrate and phosphate contamination in water and possible remedial measures.
23. Singh, R., Syed, T. H., Kumar, S., Kumar, M., & Venkatesh, A. S. (2017). Hydrogeochemical assessment of surface and groundwater resources of Korba coalfield, Central India: environmental implications. Arabian Journal of Geosciences, 10(14), 1-16.
24. Tiwari, A., Joshi, S.K., Tripathi, S.K. and Saxena, R. (2021). Spatial pattern of groundwater recharge in Jhansi district in the Bundelkhand region, central India. Environment, Development and Sustainability, pp.1-13.
25. Tiwary, R. K. (2001). Environmental impact of coal mining on water regime and its management. Water, Air, and Soil Pollution, 132(1), 185-199.
26. Todd, D.K. and Mays, L.W., 2004. Groundwater hydrology. John Wiley & Sons.
27. Viana, C. M., Girão, I., & Rocha, J. (2019). Long-term satellite image time-series for land use/land cover change detection using refined open-source data in a rural region. Remote Sensing, 11(9), 1104
28. Winter, T. C., Harvey, J. W., Franke, O. L., and Alley, W. M. (1998). Groundwater and surface water, in: A single resource, edited by: Survey, U. G., US Government Printing Office, Denver, Colorado.

10 ACCREDITATION CERTIFICATE

Accreditation Board of CGWA

Certificate of Accreditation

M/s. Geoclimate Risk Solutions
Vishakhapatnam, A.P.

Has been accredited as a Ground Water Professionals to prepare reports in the Functional Areas of

- *Impact Assessment of Existing / Proposed GW Extraction*
- *GW Modelling*
- *Hydrogeological conditions in mining projects.*

Valid from : 15.02.2021 — *Certificate No. : CGWA/RGI/005*

Valid thru : 14.02.2026 — *Dated : 07.07.2021*

क्षेत्रीय निदेशक
Regional Director
आरजीएनजीडब्ल्यूटीआरआई
RGNGWT&RI

सदस्य
Member
आरजीएनजीडब्ल्यूटीआरआई
RGNGWT&RI

Annexure 1

CHOWGULE GROUP SINCE 1916

Ref. CCPL/SE/2204/24

Date : 20th April 2022

To,
M/s Geo Climate Risk Solutions Pvt Ltd. (GRCS)
APIS, Sunrise Incubation Tower,
Hill No. 3 , IT SEZ, Madhura Wada,
Visakhapatnam – 530048 (AP)

Sub: Contract for Preparation of Comprehensive Hydrogeological Report along with Ground Water Modelling Study as per Central Ground Water Authority (CGWA) Guidelines for Sahapur (East) Coal Block, located in Shahdol district, Madhya Pradesh & issuance of Final permission/NOC from CGWA.

Ref: Your Revised Quotation dated 05.04.2022

Kind Attention: Mr. Prasad Babu (+91-98107-08901)

Dear Sir,
With reference to your above quotation and subsequent negotiation you had with us, we are pleased to issue Work Order/Service Order for the Preparation of Comprehensive Hydrogeological Report along with Ground Water Modelling Study as per CGWA Guidelines for Sahapur (East) Coal Block, located in the districts of Shahdol and Umaria, Madhya Pradesh & issuance of Final permission/NOC for Chowgule & Company Pvt. Limited (hereinafter as CCPL) from CGWA.

A. Scope of Work:
Preparation of Comprehensive Hydrogeological Report along with Ground Water Modelling Study.

1) Generation of baseline data, establishing a network of observation wells, conducting aquifer performance test.
2) To carry out Hydrogeological studies viz. general topography, drainage analysis, Geology, Meteorology & rainfall analysis, aquifer geometry; surface and ground water potentiality, Aquifer characteristics, Quality of water; Ground water resources estimation and categorization, seepage of ground water in mine workings; Mining impact on surface and ground water environment and remedial measures.
3) Preparation of Hydrogeological report. The report shall constitute the following mandatory components:
   a) Mapping of Surface and subsurface water bodies.
   b) Deriving a watershed and stream network layout from digital elevation data.
   c) Sub-surface hydro geologic description of aquifers.
   d) Computing stream flow and ground water flow rates.
   e) Impact of water utilization: locating reservoirs, water withdrawals, discharges, and aquifer pumping. Their effects on water flow and constituent transport.
   f) Detailed mathematical modelling of computed data.
   g) Characterization and quantification of impact due to mining.
   h) Suggested mitigation measures on impact of mining.
   i) Impact of Ghinachunia Nala on the underground mining work and its mitigation measures.

CHOWGULE AND COMPANY PRIVATE LIMITED

Chowgule House, Mormugao Harbour, Goa 403 803 India
T: +91 (832)2525001 F: +91 (832)2521011 E: ccl@chowgule.co.in W: chowgule.co.in
CIN: U63031GA1965PTC000041 GSTIN: 30AAACC5479J1ZP

Annexure 2

Water quality test results

M/s BIOMES

ENVIRONMENTAL CONSULTANT & NABL (ISO/IEC 17025:2017) ACCREDITED LABORATORY

[ISO 14001:2015, ISO 9001:2015 & ISO 45001:2018 Certified Organization]

Report No –BMS/22/GCRS /25 Issued Date-24.05.2022

WATER QUALITY TEST REPORT

Name & Address of the Client	Geo Climate Risk Solution Pvt. Ltd. At-Hill-3, IT-SEZ, Madhurwada, Visakhapatnam, AP-530048
Work Order No./ Date	GCRS-04-05-2022 / 09-05-2022
Location with Coordinates	SHWQ1 Lat 23.38438 Long 81.32848 SHWQ2 Lat 23.24679 Long 81.34747 SHWQ3 Lat 23.25025 Long 81.33512 SHWQ4 Lat 23.26327 Long 81.3288
Sample Description	Ground Water
Sampling by	BIOME's Representative
Date of Sampling	06.05.2022
Date of Sample Received	07.05.2022
Date of Analysis	10.05.2022-22.05.2022

ANALYSIS RESULT

Sl. No.	Parameter	Unit	Standard as per IS: 10500(2012)	SHWQ1	SHWQ2	SHWQ3	SHWQ4
1.	pH Value @ 25°C	–	6.5-8.5(NR)	7.82	6.99	6.37	7.09
2.	Electrical Conductivity (EC)	µmhos/cm	—	1149	775	1242	760
3.	Total Dissolve Solid (TDS)	mg/l	500(2000)	618	496	848	542
4.	Total Alkalinity (as $CaCO_3$)	mg/l	200(600)	221	294	324	288
5.	Chloride (as Cl)	mg/l	250(1000)	126.0	54.0	180.9	71.0
6.	Calcium Hardness (as $CaCO_3$)	mg/l	75(200)	60.9	78.6	115.4	57.7
7.	Magnesium Hardness (as $CaCO_3$)	mg/l	30(100)	23.3	22.4	18.5	38.9
8.	Iron (as Fe)	mg/l	0.3(NR)	0.13	0.18	0.14	0.22
9.	Sulphate (as SO_4)	mg/l	200(400)	27.05	14.5	15.7	17.1
10.	Nitrate (as NO_3)	mg/l	45(NR)	52.04	6.2	73.88	16.92

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Email – biomes.bbsr@gmail.com,biomes.enviro@gmail.com
Contact: 0674-2747444 / 797808808

M/s BIOMES

ENVIRONMENTAL CONSULTANT & NABL (ISO/IEC 17025:2017) ACCREDITED LABORATORY

[ISO 14001:2015, ISO 9001:2015 & ISO 45001:2018 Certified Organization]

11.	Fluoride (as F)	mg/l	1.0(1.5)	0.28	0.36	0.38	0.36
12.	Sodium as Na	mg/l	–	82.6	36.1	119.6	45.5
13.	Potassium as K	mg/l	–	3.1	2.1	3.8	2.2
14.	Zinc as Zn	mg/l	5(15)	0.39	0.42	0.52	0.42
15.	Mercury as Hg	mg/l	0.001(NR)	<0.001	<0.001	<0.001	<0.001
16.	Arsenic as As	mg/l	0.01(0.05)	<0.005	<0.005	<0.005	<0.005

M/S BIOMES * BHUBANESWAR

Seal of Laboratory

End of test report

Authorized Signatory
(Technical Manager)

Note:

1. The results listed refer only to tested samples and applicable parameters Endorsement of products is neither inferred nor implied.
2. Total liability of our lab is limited to the invoiced amount.
3. Samples will be destroyed after 30 days from the date of test report unless otherwise specified.
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[ISO 14001:2015, ISO 9001:2015 & ISO 45001:2018 Certified Organization]

Report No –BMS/22/GCRS /26 Issued Date-24.05.2022

WATER QUALITY TEST REPORT

Name & Address of the Client	Geo Climate Risk Solution Pvt. Ltd. At-Hill-3, IT-SEZ, Madhurwada, Visakhapatnam, AP-530048
Work Order No./ Date	GCRS-04-05-2022 / 09-05-2022
Location with Coordinates	SHWQ5 Lat 23.25366 Long 81.3088 SHWQ6 Lat 23.32745 Long 81.2718 SHWQ7 Lat 23.30703 Long 81.32776 SHWQ8 Lat 23.32248 Long 81.35559
Sample Description	Ground Water
Sampling by	BIOME's Representative
Date of Sampling	06.05.2022
Date of Sample Received	07.05.2022
Date of Analysis	10.05.2022-22.05.2022

ANALYSIS RESULT

Sl. No.	Parameter	Unit	Standard as per IS: 10500(2012)	SHWQ5	SHWQ6	SHWQ7	SHWQ8
1.	pH Value @ 25°C	–	6.5-8.5(NR)	6.47	6.87	7.42	6.48
2.	Electrical Conductivity (EC)	µmhos/cm	—	248	437	1381	1221
3.	Total Dissolve Solid (TDS)	mg/l	500(2000)	176	327	800	802
4.	Total Alkalinity (as $CaCO_3$)	mg/l	200(600)	86	112	368	372
5.	Chloride (as Cl)	mg/l	250(1000)	7.0	28.0	138.0	157.0
6.	Calcium Hardness (as $CaCO_3$)	mg/l	75(200)	19.2	32.1	66.5	73.8
7.	Magnesium Hardness (as $CaCO_3$)	mg/l	30(100)	12.6	18.5	57.9	48.6
8.	Iron (as Fe)	mg/l	0.3(NR)	0.17	0.15	0.14	0.17
9.	Sulphate (as SO_4)	mg/l	200(400)	1	5.6	49.3	42.6
10.	Nitrate (as NO_3)	mg/l	45(NR)	25.99	51.92	16.5	8.47

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11.	Fluoride (as F)	mg/l	1.0(1.5)	0.22	0.34	0.22	0.34
12.	Sodium as Na	mg/l	–	4.3	16.6	92.1	104.5
13.	Potassium as K	mg/l	–	0.2	1.2	3.7	3.8
14.	Zinc as Zn	mg/l	5(15)	0.28	0.29	0.28	0.47
15.	Mercury as Hg	mg/l	0.001(NR)	<0.001	<0.001	<0.001	<0.001
16.	Arsenic as As	mg/l	0.01(0.05)	<0.005	<0.005	<0.005	<0.005

M/S BIOMES BHUBANESWAR-751016

End of test report

Seal of Laboratory

Authorized Signatory
(Technical Manager)

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[ISO 14001:2015, ISO 9001:2015 & ISO 45001:2018 Certified Organization]

Report No –BMS/22/GCRS /27 Issued Date-24.05.2022

WATER QUALITY TEST REPORT

Name & Address of the Client	Geo Climate Risk Solution Pvt. Ltd. At-Hill-3, IT-SEZ, Madhurwada, Visakhapatnam, AP-530048
Work Order No./ Date	GCRS-04-05-2022 / 09-05-2022
Location with Coordinates	SHWQ9 Lat 23.290032Long 81.41817 SHWQ10 Lat 23.212344Long 81.352686 SHWQ11 Lat 23.17412 Long 81.33996 SHWQ12 Lat 23.26436 Long 81.24031
Sample Description	Ground Water
Sampling by	BIOME's Representative
Date of Sampling	06.05.2022
Date of Sample Received	07.05.2022
Date of Analysis	10.05.2022-22.05.2022

ANALYSIS RESULT

Sl. No.	Parameter	Unit	Standard as per IS: 10500(2012)	SHWQ9	SHWQ10	SHWQ11	SHWQ12
1.	pH Value @ 25°C	–	6.5-8.5(NR)	7.64	6.27	7.32	6.70
2.	Electrical Conductivity (EC)	µmhos/cm	—	1079	1163	1356	663
3.	Total Dissolve Solid (TDS)	mg/l	500(2000)	701	909	728	408
4.	Total Alkalinity (as $CaCO_3$)	mg/l	200(600)	341	268	498	178
5.	Chloride (as Cl)	mg/l	250(1000)	109.0	160.0	26.0	20.0
6.	Calcium Hardness (as $CaCO_3$)	mg/l	75(200)	56.5	109.8	97.8	54.1
7.	Magnesium Hardness (as $CaCO_3$)	mg/l	30(100)	53.2	24.8	69	22.6
8.	Iron (as Fe)	mg/l	0.3(NR)	0.12	0.21	0.22	0.14
9.	Sulphate (as SO_4)	mg/l	200(400)	41.7	28	36.6	12.1
10.	Nitrate (as NO_3)	mg/l	45(NR)	3.51	136.84	29.91	68.28

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11.	Fluoride (as F)	mg/l	1.0(1.5)	0.35	0.39	0.32	0.28
12.	Sodium as Na	mg/l	–	68.2	106.4	17.2	13.4
13.	Potassium as K	mg/l	–	2.9	3.9	1.2	1
14.	Zinc as Zn	mg/l	5(15)	0.41	0.54	0.54	0.34
15.	Mercury as Hg	mg/l	0.001(NR)	<0.001	<0.001	<0.001	<0.001
16.	Arsenic as As	mg/l	0.01(0.05)	<0.005	<0.005	<0.005	<0.005

End of test report

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Report No –BMS/22/GCRS /28 Issued Date-24.05.2022

WATER QUALITY TEST REPORT

Name & Address of the Client	Geo Climate Risk Solution Pvt. Ltd. At-Hill-3, IT-SEZ, Madhurwada, Visakhapatnam, AP-530048
Work Order No./ Date	GCRS-04-05-2022 / 09-05-2022
Location with Coordinates	SHWQ13 Lat 23.23575 Long 81.41675 SHWQ14 Lat 23.19216 Long 81.45453 SHWQ15 Lat 23.25982 Long 81.4646
Sample Description	Ground Water
Sampling by	BIOME's Representative
Date of Sampling	06.05.2022
Date of Sample Received	07.05.2022
Date of Analysis	10.05.2022-22.05.2022

ANALYSIS RESULT

Sl. No.	Parameter	Unit	Standard as per IS: 10500(2012)	SHWQ13	SHWQ14	SHWQ15
1.	pH Value @ 25°C	–	6.5-8.5(NR)	7.09	6.92	6.92
2.	Electrical Conductivity (EC)	µmhos/cm	—	486	893	1738
3.	Total Dissolve Solid (TDS)	mg/l	500(2000)	332	468	1221
4.	Total Alkalinity (as $CaCO_3$)	mg/l	200(600)	138	342	548
5.	Chloride (as Cl)	mg/l	250(1000)	33.0	7.0	114.0
6.	Calcium Hardness (as $CaCO_3$)	mg/l	75(200)	46.5	113.8	193.2
7.	Magnesium Hardness (as $CaCO_3$)	mg/l	30(100)	12.6	16.5	52
8.	Iron (as Fe)	mg/l	0.3(NR)	0.14	0.21	0.21
9.	Sulphate (as SO_4)	mg/l	200(400)	8.3	14.4	101.2
10.	Nitrate (as NO_3)	mg/l	45(NR)	34.55	7.68	111.48
11.	Fluoride (as F)	mg/l	1.0(1.5)	0.22	0.34	0.36

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12.	Sodium as Na	mg/l	–	21.8	4.2	76.7
13.	Potassium as K	mg/l	–	1.5	0.2	2.8
14.	Zinc as Zn	mg/l	5(15)	0.24	0.45	0.54
15.	Mercury as Hg	mg/l	0.001(NR)	<0.001	<0.001	<0.001
16.	Arsenic as As	mg/l	0.01(0.05)	<0.005	<0.005	<0.005

M/S BIOMES * 751016 BHUBANESWAR

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End of test report

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Annexure 3

Plate III master surface plan.