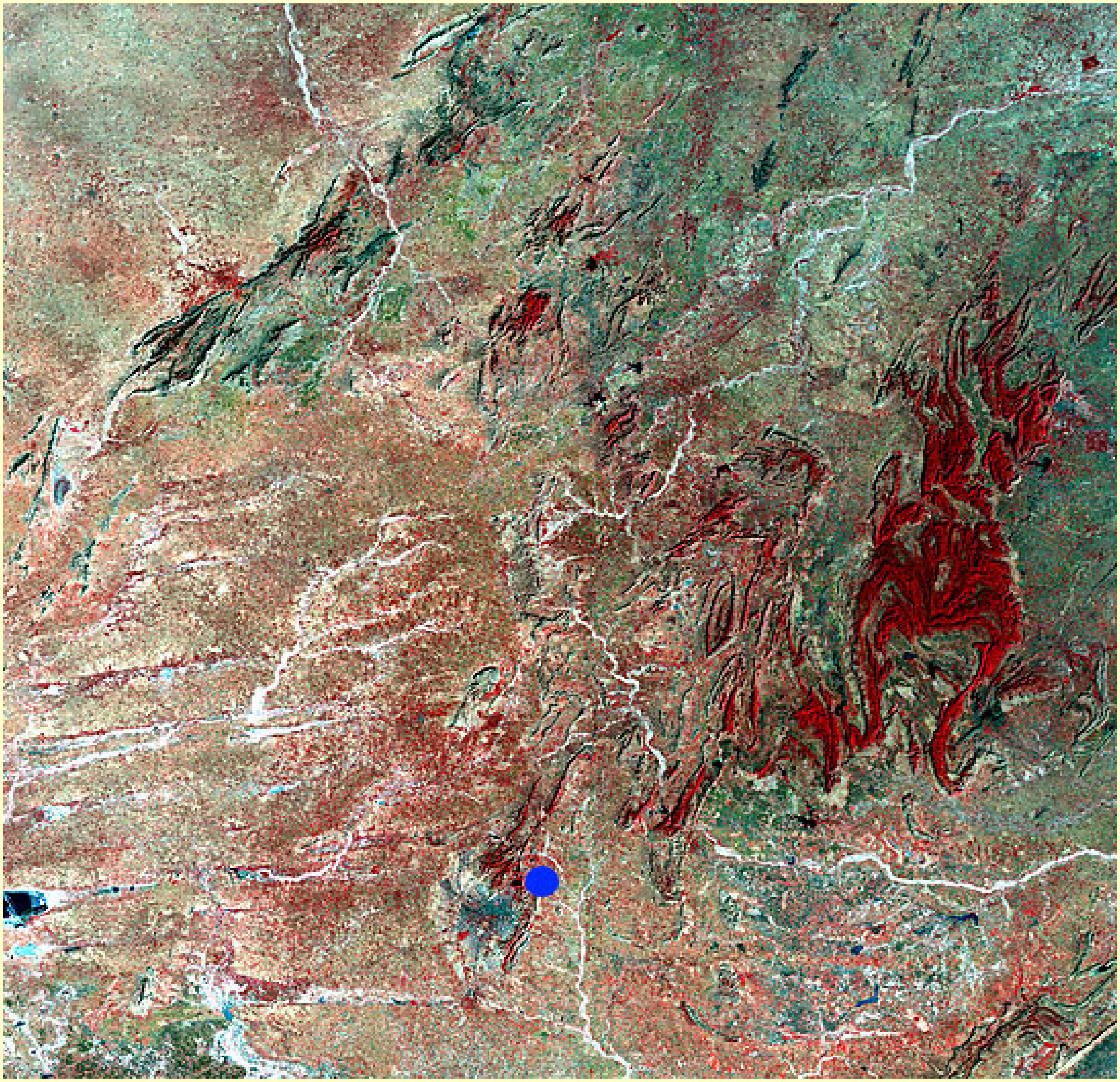
Ground Water & Artificial Recharge Investigations Around Proposed Devi Ratn Hotel Site at Ballupur, Jaipur, Rajasthan



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GROUND WATER & ARTIFICIAL RECHARGE INVESTIGATIONS

AROUND PROPOSED DEVI RATN HOTEL SITE

AT BALLUPUR, JAIPUR, RAJASTHAN

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CHAPTER 1.0 INTRODUCTION

Indian subcontinent has witnessed a phenomenal growth in last few decades especially in terms of infrastructure, industries and allied sectors like estate / residential development, Hotel Industries etc. These developments and liberal Govt. Policies have also opened the door for various leading multinational and corporate companies to invest in the Indian market. Being in close proximity of national capital of Delhi, the city of Jaipur has also seen a spurt in development activities in last one decade. Jaipur, popularly known as "Pink City" is one of the important economic hub and main trade center of the state of Rajasthan. The city has the distinction of being one of the most popular historical townships of the country with several historical monuments and forts. This invites number of foreign tourists from different parts of the globe as well from India every year. The economy of the town is broadly tourism based, which also provides enhanced opportunities in terms of employment for the local pageants. The regular flow of foreigners as well as Indian tourists has increased the requirement of different categories of Hotels in the town. In this row of developing Hotel Industries, M/s Boutique Hotels (P) Ltd has proposed to build a multi-facility Hotel complex at village Ballupur, Jaipur.

In general in the entire Jaipur district including the City area is water stressed because of ever increasing demands of water for growing population as well as agriculture which has over raced the available water resources. Ground water being the major source of water supply, its sustainable development has become the main issue of concern for any development initiatives. The proposed project envisages construction of a multi-facility Hotel complex along with other facilities. For sustenance of any new developing infrastructures basic amenities such as power, water and manpower are essential components. Water being one of the most important commodity in the area, is the main concern before initiating any developmental activity. In view of no prevailing water supply in this area the water dependency of the project will be fully on ground water. In this regard the work related to ground water investigation has entrusted M/s Green Systems Pvt. Ltd, New Delhi to carry out detailed studies and suggest the most viable and scientifically managed plan for development and utilization of water for meeting the water demand of the project.

1.1 Objective

The objectives of the present study are:

- To assess the ground water availability and its development prospects to meet the water demand of the proposed plant.

- Suggest suitable well design for production wells and artificial recharge structures to ameliorate the adverse impact on the ground water regime.
- Provide a scientifically based suitable ground water management plan including recharge to ground water for sustainability of ground water sources.

1.2 Scope of work

- For achieving the desired objectives it has been proposed to undertake following studies and investigations in and around the proposed site.
- Detailed hydrogeological investigation in and around the project site (within a buffer of a radius of 5 km from the site) to assess the ground water potential for development, yield prospects and design of the production wells in the area through application of advanced analytical tools.
- Physiographic and Geomorphological studies along with Remote Sensing analysis to support the hydrogeological investigations and determine the ground water conditions.
- Geophysical investigations by conducting VES in the plot of the project site to decipher subsurface lithology and disposition of the aquifer, locating the best site for production wells and areas suitable for ground water recharge.
- Design of production wells based on the scientific data and aquifer characteristics of the area for sustainable ground water development for utilization.
- Detailed assessment of recharge potential and monsoon runoff availability for "Rain Water harvesting and Artificial Recharge to Ground Water".

1.3 Location & Extent

The proposed site of the hotel is located at about 10 km east of Jaipur town, Sanganer block, Jaipur district of Rajasthan. The district is bounded by Sikar and Alwar districts in the north, Nagaur and Ajmer in the west, Dausa in the east and Tonk in the south. The project area is located at just on the eastern end of city limits of Jaipur, which has typical undulating landscape with hills and plain area. The aerial dimensions of the Jaipur city is between North Latitude 26^{o}47' – 27^{o}02' and East Longitude 75^{o}36' – 75^{o}55', located almost at the center of the district and covers an area of about 470 Sq.km. The Jaipur agglomerate has parts three blocks viz. Sanganer (~ 46%) , Jothwara (42%) and Amer (12%). The hotel site is situated on the eastern flank of the hill range, the township area of Jaipur is broadly occupying the western flank. Major part of the study area is occupied by hard rocks overlain by thin veneer of overburden in the form of top soil and alluvium or aeolian deposits. The total area under the project is about 85,000 sq.m (21 acre).

The administrative map of Jaipur district showing the location of the proposed project site is given in **Fig.1.1.** The location map of the project site as demarcated in the satellite image shown in **Fig. 1.2.** For the purpose of detailed investigation an area of 10 sq km has been studied around the proposed site and being referred as study area as shown in **Fig. 1.3.** The layout plan of the Hotel is given in **Fig. 1.4.**

1.4 About Green Systems

Green Systems (GS) is a formidable mix of environmental experts, engineers, scientists, economists and marketing professionals. We work with the philosophy of providing expertise, quick response and effectiveness to the needs of the corporate, organizations and end users in the field of environmental management. At GS, we provide our clients with a unique portfolio of skills and expertise to add value to their business, uncovering opportunities and providing customized solution to their needs.

CHAPTER 2.0 GEO-MORPHOLOGICAL SET UP

The ground water occurrence and its distribution in space and time are highly influenced by the geo-morphological set up, physiography and drainage network of the area. Hence, any study related to ground water requires a detailed understanding of the geomorphic set up in and around the area, the prevailing physiographic features and local as well as regional drainage network present around the area. Since, the influences of these thematic parameters are on regional scale, an attempt has been made in the present study to present the regional picture of Jaipur town with focus and detail pertaining to the study area.

Geomorphology can be described in terms of several components such as landforms, their nature and characteristics in terms of stability. Geo-morphological set up of the area is surface manifestation of the underlying rock formations and it helps in proper evaluation of the configuration of the bedrock profile when integrated with other hydro geological parameters.

2.1 Geomorphology

The city area is characterized by a wide variety of geomorphic features like sandy plains, hills and Inter-montain valleys, pediments etc. Major part of the city area is occupied by the alluvial sandy plains which are dissected at places and speckled with hills. In the northern and eastern parts of the city, the Aravalli hills can be seen trending NE-SW and occasionally alternating with intermountain valleys. Typical of Aravallis, the hills represented in the form of ridges are generally made up of hard and resistant quartzite rocks. Because of hard and compact nature of quartzites it stands against the erosion and weathering and provides a characteristic physiographic signature. Important among these ridges are Nahargarh, Amer, Puranaghat and Jalana hills. Historically these ridges have been used by our kings as their residential forts for security reasons. The highest peak of these hills is about 650 m amsl. Hills are often marked by escarpments and uplands have slopes of 15-20% and are characterized by sheet and gully erosion. Pediment landscapes are observed in the South Western part of the city. The altitude of the pediplain area ranges from about 350 m in the southern part to 470 m amsl in the northern part of the urban area.

The proposed Hotel site is situated in the eastern extremity of the city and located adjacent to the eastern flank of the hill range trending almost north – south, the same can also be visualized from the Google map as shown in **Fig 1.2.** The Geomorphological map indicating the major geomorphic units of the area is presented in **Fig. 2.1.** Project site being in the close proximity of the ridge and broadly lies in the pediment zone/alluvial plain which also acts as recharge area, it is expected that there may be a positive effect on the ground water conditions of the area. However, a suitable recharge conditions are to be prevalent in the vicinity of the project area to facilitate the recharge to ground water.

2.2 Physiography and Drainage

The prevailing arid conditions added with deficient rain and high evaporation has restricted development of natural river drainage system in the Jaipur city area. One streamlet originating from Nahargarh hills namely Amanishah Nalla flows southerly up to Sanganer area where it takes easterly flow direction due to structural control. The Amanishah nalla and associated streamlets are ephemeral in nature & merge with the Dhund river, a tributary of Morel river (out of urban area). Surface water in extreme western part flow in westerly direction and discharged through Bandi (locally called Mashi) river. In major part, drainage density ranges between 0.30 and 0.5 km/sq.km whereas in extreme western and southern parts it is of the order of 0.20 to 0.30 km./sq.km. Studies reveal the existence of palaeo-channels in the area.

2.2 Remote Sensing and GIS Studies

Remotely sensed satellite images and subsequent digital image processing is very important tools for ground water resource evaluation and management. Satellite images gives an aerial view and helps in detecting and mapping regional structural patterns, including major fracture and fault systems, also assist in understanding the interrelationship of surface and ground water. With advent in high speed computers, Remote Sensing and GIS combined with traditional geologic field mapping has become the most advanced tool to evaluate ground water resources. Various enhancement and manipulation procedures are being applied to the digital satellite images; the results, in digital and hardcopy format, are being used for field mapping and analyzing the regional structures.

The remotely sensed satellite and airborne images spatial coverage helps in mapping and monitoring the earth surface at local and/or regional scales. The Advantages offered by remotely sensed satellite image data include:

- It provide a synoptic/regional view compared to both aerial photographs and ground sampling,
- It is cost effectiveness,
- It is has high spatial resolution and coverage compared to ground sampling, and
- It provides relatively high temporal coverage on a long term basis.

Concept:

Remotely sensed images contain both spectral and spatial information. The spectral information provides various properties and characteristics about the surface cover at a given location or pixel (that is, vegetation and/or soil type). The spatial information gives the distribution, variation, and topographic relief of the cover types from pixel to pixel. Therefore, the main characteristics that determine a pixel's brightness/reflectance and, consequently, the digital number (DN) assigned to the pixel, are the physical properties of the surface and near surface, the cover type, and the topographic slope.

Use of Remote Sensing in Present Study.

The main focus of the remote sensing and digital image processing component under this study is to use both remotely sensed digital satellite images and a Digital Elevation Model (DEM) to extract spatial information related to topographic feature patterns, geological, geomorphological and structural features and fracture density in the area. The digital data on various resolutions available from different sources has been used for studying the different hydrogeological features so as to locate favorable sites for ground water development and recharge.

The image interpretation focuses in fact, on two interrelated aspects i.e. the (hydro) geological subsurface configuration and surface features which influence recharge and show evidence of groundwater outflow. There are two categories of indicators that exist for groundwater with respect to remote sensing data and are listed as below:-

1) First-order indicators

These are directly related to ground-water occurrence such as springs, canals, lakes, ponds, and other surface water features.

2) Second-order indicators

These include hydrogeological parameters that may reflect the ground-water regime, such as drainage characteristics, fracture systems, geological structure, and landform characteristics.

The digital data obtained is subjected to the digital image processing. The data is visually interpreted for features identifications and demarcating their extent in the space. Based on the visual interpretation the sample areas has been selected for picking up the digital signature of the features for computerized supervised classification. In the analysis of image, attempt has been made to locate the following features:

- Evidence of permeable conditions (non-eroded thick soils, colluvial deposits, wind blown sands, etc.) over a dipping rock sequence with good transmissivity? If so, the recharge may be high, particularly when no deep-rooted and dense vegetation is present.
- Appearance of water in rivulets, for example, in ephemeral beds which signifies the emergence of groundwater. If the pattern of the emergence points in an alluvial area is fairly straight, could that be a sign of a buried barrier, such as a fault bringing up rocks of low permeability, or a buried escarpment?
- Observed disappearance of base flow in river beds indicates water loss by infiltration in permeable river bed deposits with the groundwater level below the river bed. The question then are:

What happens to that water?

- Does it appear further downstream (a typical case of a groundwater flow system in an alluvial fan aquifer) or is it not seen again (flowing out through rock formations, large fractures)?
- The drainage pattern, drainage density of the area?
- What are the landforms in the area?
- Demarcation of micro-watersheds

The various scenes of IRS satellite images of the study area is shown in **Fig 2.2 to 2.4 and** FCC image in **Fig 2.5.** Different filters have been used so as to enhance the typical geomorphic features relevant to ground water occurrence and to indentify ground water potential zones as well as high soil moisture areas.

CHAPTER 3.0 CLIMATE AND RAINFALL

The pink city enjoys arid climatic conditions. The national climatic map of India (Fig. 3.1) prepared by IMD indicates that the project site is located on the margin of semi arid to desirt –arid climatic region. The mean annual rainfall recorded at Sanganer, Amer and Jaipur rain gauge stations was 584.0, 676.5 and 639.1 mm respectively (Period 1969-92). The average annual rainfall of the Jaipur city for the last 30 years (1976 - 2007) works out to be 503.25 mm. The yearly variation in rainfall can be observed from the Table 3.1 and graph shown in Fig. 3.2. The normal rainfall of Jaipur region is 550 mm as per the IMD data. Perusal of the graph of annual variation in rainfall indicates an overall decrease in rainfall in last thirty years. The monsoon rainfall , which contributes about 90% of the total annual rainfall extends from June end till September, July & August being the wettest months. It is reported that Based on Chegodev's empirical relation, probability of exceedance of average annual rainfall is about 25% & normal drought 19.4% whereas probability of severe and most severe drought is almost negligible.

Summer season starts in the month of March and continues till mid June. The mean daily maximum temperature is highest (40.6°C) in May, whereas, mean daily minimum temperature is highest (27.3°C) in June. The on-set of monsoon in June end / July brings down the temperature. Winter season starts in November and the temperature continues to fall till January which is the coldest month of the year. The mean daily minimum temperature is lowest in January (8.3°C).

The Isohyetal map of the area is shown in Fig. 3.3. The air is generally dry during the major part of the year. However, during monsoon period (July- September) the relative humidity is generally over 60% and during summer months it is as low as 20%.

Table 3.1 : Annual Rainfall at Jaipur (Source : IMD)

Years	Annual Rainfall (mm)
1976	622
1977	940.8
1978	702.4
1979	434.1
1980	459.6
1981	788.4
1982	530.5
1983	841.4
1984	302.8
1985	590.6
1986	449.3

Years	Annual Rainfall (mm)
1987	310.2
1988	505.2
1989	492.8
1990	716.7
1991	526.9
1992	369.7
1993	560.7
1994	693.3
1995	515.8
1996	148.2
1997	707.8
1998	81.1
1999	296
2000	431.5
2001	609
2002	164.3
2003	475.4
2004	735
2005	358.6
2006	294
2007	450
Average Annual Rainfall (mm)	503.25

CHAPTER 4.0 GEOLOGY AND HYDROGEOLOGY

4.1 Geology

Bhilwara group of rocks is the oldest rocks followed by Delhi Super group rocks. These consolidated rocks are covered by Quaternary deposits in the major part of the city area. The rocks of Bhilwara Super group comprise mainly gneisses and schist's etc. of Achaean age and are overlain by quartzite's with inter-bedded phyllites and schists sequence of Alwar group (Delhi Super-group). These, predominately arenaceous, rocks are exposed as high ridges near Harrnada, Amber, Jhalana etc. Quartzites are generally grey colored and are medium to coarse grained. Major part of the city area is covered by a thick mass of Quaternary deposits. These unconsolidated fluvial as well as aeolian sediments are mainly composed of sand, silt, clay with kankars and gravels at places.

The study area is mainly occupied by Quaternary alluvium and basement is of Delhi quartzites of Alwar super group. The Quaternary deposits are unconsolidated fluvial as well as Aeolian sediments composed of sand, silt, clay with kankars and gravels at places and form the principal aquifer in the area of study. Ground water occurs in unconfined to semi confined condition in alluvium and weathered / jointed / fractured quartzites. In alluvium, sand, silt, kankar and gravel constitute water bearing zones. Occurrence of fractured and weathered Quartzites in basement also suggests some potential of ground water development. The general geological succession is given in the table below

Age	**Formation**	**Rock Type**
Quaternary Proterozoic Quaternary	Unconsolidated	Alluvium and windblown sand, Silt, Clay, Kankar, Gravel etc
-------------------- ------------------Unconformity--		
Proterozoic, Azoic	Delhi Super-Group (Alwar group)	
	Meta Sedimentaries and Basal Crystalline Complex	Quartzites, schist, Phyllites, Pegmatites and Gneisses, Granite and Granite Gneisses.

4.2 Hydrogeology

Unconsolidated sediments such as alluvium and windblown sand occupy major part of the study area. The alluvial deposits consist of silt, clay with kankar, sand, gravel and pebble beds. The alluvium also occurs along the river courses and its tributaries and inter-montane valleys. The alluvium is devoid of cementing materials, except in capillary fringe zone where grains are cemented with secondary calcium carbonate. The thickness of alluvium is variable in the area. The depth of bed rock encountered at various exploratory wells drilled by Central Ground Water Board and other agencies indicates that the thickness of alluvium varies widely in the city area. The sub surface data compiled by different Agencies indicates that thickness of alluvium is maximum up to 80 m in the south western part of the city, in the central and eastern part of the city area including the project area the thickness of alluvium is comparatively less and varies from 50 to 60 m. Below which the bedrock consisting of quartzite are found.

Groundwater occurs under water table condition in the shallow zone of quaternary sediments as well as in the zone of weathering and fracturing of hard rocks. In alluvial areas ground water also occurs under confined to semi confined conditions. In the greater part of the district groundwater occurs in unconsolidated quaternary sediments consisting of fine to medium grained sand, silt, clay and kankar. Talus and scree deposits occurring on the flanks of almost all hills form a potential aquifer consisting of fine to coarse grained sand and angular pieces of rocks with varying amount of loess. The width of the aquifer zone along the foot hills vary from few meters to about 50 meters. It forms potential aquifer along the foot hills. The thickness of Talus and scree vary from 4 m to 55 m. Groundwater occurs semi confined to confined conditions.

Alluvium and blown sand form aquifer in the greater part of the district and the study area. The aquifer material comprises sand, silt with varying amount of Kankar. The coarser material such as gravel and pebbles form aquifer in very limited area of Morel and Banganga basin. Groundwater occurs under unconfined conditions in the shallow zone. The presence of clay and silt at various horizons gives rise to semi confined to confined conditions. The yields of wells tapping alluvium vary widely and the high yield zone are generally related to abandoned river channels. The tube well yield varies from 10 m^3 /hr to 85 m^3/hr. In the western most part of the district covering Sambhar - Ehulera area surface deposit consisting of blown sand attain a maximum thickness of 32 metres. Tube wells yield from 7.8 m^3 /hr to 17.0 m^3 /hr for small drawdown of about 5 metres. In the area near to Jaipur city, wells located on the banks of Amnisha River with depth less than 50 m yield 36 m^3 /hr to 90.8 m^3 /hr.

The hydrogeological map of the study area is shown in **Fig. 4.1**. In the study area major part is underlain by alluvium, except in the north western part occupied by hills. Based on the yield prospect and hydrogeological conditions the alluvial areas have been grouped under two major units. In the western half of the study area, the yield prospects are comparatively more, the wells tapping up to a depth of about 100 m can yield up to 1500 lpm. In the eastern half of the study area the yield is relatively less to the tune of 600 lpm, and even the depth of recommended tube well is about 150 m, the project area lies in this part of alluvium underlained by hard rock.

Based on the topographical features and geomorphology of the area a digital elevation model has been prepared which is also been used for investigations and analysis of ground water occurrence in the study area. **Fig. 4.2** represents Digital Elevation Model for the study area.

4.3 Ground Water Regime

Depth to water table varies from 50m to more than 60 m bgl and depth is increasing from northeast to southwest. Deep water levels are observed in the Jaipur City due to over-exploitable of the ground water resource. The entire district exhibits a declining water table trend. In general, a decline of more than 2 m has been observed in most parts when compared with the 10 years depth to water table average

Fall in water levels are observed in central part in Jhotwara and Govindgarh blocks within the range of 0-2 and more than 2 m resulting into a ground water trough in these area. The general water level fluctuations in the district when compared from the previous years water levels are showing a mixed picture of rise as well as fall within different ranges, in different areas.

Thickness of alluvium varies from negligible in the north near the quartzite outcrops to more than 80 m in south of the city. A number of shallow tube wells of up to 70 m deep in the area of study exist and yield 180 LPM to 250 LPM for moderate drawdowns. Weathered quartzites constitute low potential aquifer zones. Tube wells tapping zones in quartzites down to about 100 m depth yield 50 LPM to 80 LPM for moderate to heavy draw downs.

Limited in-storage ground water resources, depleting ground water resources are the issues of concern. Large scale ground water recharge, ground water conservation and transfer of surface water from other areas is required for sustainable water supply for various uses. The top zones are de-saturated and have potential of accommodating rain water harvesting for recharge to ground water. A steep decline in ground water levels observed in last 10 years is the result of fast urbanisation and Industrial development activities and people's dependence and preference for ground water for drinking and industrial water supply.

The water table contours in the Jaipur city varies from about 430 m above mean sea level (mamsl) in northern part of the area to about 330 m amsl in the southern part . Hydraulic gradient closely follows the physioography and altitude and is in the southerly and south westerly direction. The depth to water level map of the study area is shown in **Fig. 4.3.**

CHAPTER 5.0 GROUND WATER RESOURCES

Ground water is the major source of water supply to meet the drinking and industrial water demand of the Jaipur township area. Being one of the developing areas of the district, the population here has taken a leap jump in last decade leading to more and more withdrawal of ground water to meet the demand. In view of depleting ground water levels, attempts are being made by the civic authorities to arrange alternative water sources to meet the ever increasing demand and resorting to suitable augmentation measures including roof top rain water harvesting.

5.1. Ground Water Availability vis-a-vis Development

Quantitative assessment of ground water availability in space and time is one of the vital component and pre requisite for planning ground water development in an area. As such it requires enormous data on various parameters including water level fluctuation, specific yield, draft etc to assess ground water availability. Central Ground Water Board jointly with the State agency has already made the block wise estimation of ground water availability and draft in different blocks of Rajasthan and the data is available in published reference. As per the latest report published by Central Ground Water Board entitled " Dynamic Ground Water Resources of India".

As per the assessment the Net annual ground water availability in Jaipur district is 60925 Hectare meter (ham). The existing ground water draft for domestic and industrial uses is comparatively high, as per the estimates available the overall stage of ground water development in the district is around 187 % indicating the that the total ground water draft is exceeding the annual dynamic replenishable ground water resources. The city area is conglomeration of parts of three administrative blocks viz. Amer, Jhotwara and Sanganer, the ground water resources and draft for these blocks is given in **Table 5.1.**

The above estimates pertains to dynamic ground water resources available in the zone of fluctuation in the top unconfined aquifer , mostly made up of quaternary alluvium and restricted up to a depth of about 50 mbgl. Due to high withdrawal in the area the water level has gone much deeper and phreatic aquifer has become more or less unproductive as far as sustainability is concerned. However, the quartzite formation underlying the phreatic aquifer wherever jointed and fractured acts as potential aquifer. The ground water resources available below the phreatic zone in the water bearing fractures do not form the part of computation under Dynamic resources.

The subsurface exploration carried out in the area indicates two water bearing fractures at deeper zones, at a depth of 80 to 90 m and 100 to 120 m bgl. The fracture zone at a depth of 100m bgl seems to be productive and may be tapped suitably.

Table 5.1: Dynamic Ground Water Resources in Blocks of Jaipur district

Sl. No.	Assessment Unit of District	Net Annual Ground water Availability	Existing Gross Groundwater Draft for All uses	Net Groundwater Availability for future irrigation development	Stage of Groundwater Development (%)
	2	10	13	15	16
1	Amer	6293	12028	-7108	191
2	Jhotwara	4995	16538	-21263	331
3	Sanganer	4112	9994	-7396	243

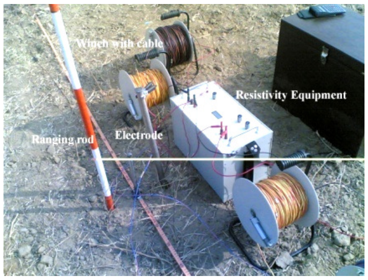
(Source: Central Ground Water Board)

CHAPTER 6.0 GEOPHYSICAL INVESTIGATIONS

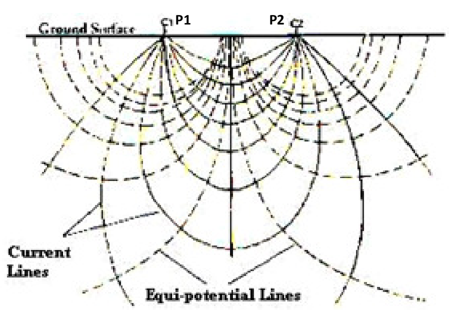
6.1 Electrical Resistivity Sounding

Underlying Principle in Electrical Resistivity Measurements

The electrical resistivity equipment used and shown here for the purpose was ANVIC make CRM 500.This instrument has sensitivity to measure potential difference in micro volt accuracy and is



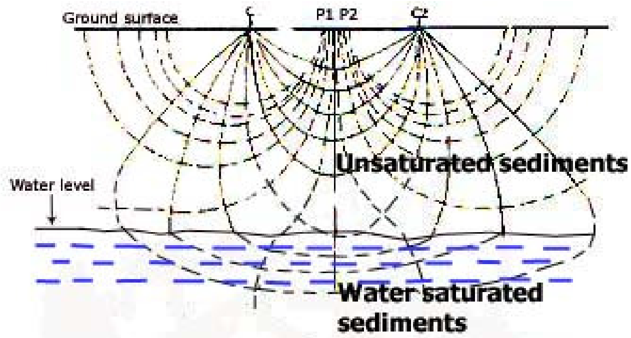
equipped with microprocessor based stacking facility (64 stacks) to enhance the signal to noise ratio by averaging out spurious signals. In the simplest form of resistivity method, a known amount of electrical current is sent into the ground through a pairs of electrodes and potentials developed due to current within the ground are measured across the another pair of electrode on the ground. The ratio of the developed potential difference i.e. electrical resistance values were recorded by gradually increasing current electrode separation from 6 m to 800 m in steps. As the current electrode spacing is increased, the electric current lines focus at deeper level. Therefore, the variation in resistance value with increased current electrode separation indicates how the electrical resistance value changes with depth from the ground surface. The resistance values are ultimately converted to apparent electrical resistivity values, by multiplying with geometric factor (which depends on the electrode configuration being used for the purpose). To make the things further clear, subsurface distribution of electrical current lines and equipotential lines is shown below.



C1, C2: Current electrode pair

P1, P2: Potential electrode pair

The shapes of current and potential lines shown above are expected only when subsurface is homogeneous. But actually, subsurface is not homogeneous and consists of several layers of different thickness and physical properties. As such, the current lines change shape and so are the equipotential lines, as shown below The potential difference observed between P1 and P2 gives the measure of distortion in the shape of equipotential lines and thus indicates the presence of subsurface anomalous substance (here water saturated zones), responsible for creating distortion in the shape of electrical current lines and equipotential lines.



6.2 Geophysical Survey Plan and Field Data Processing

Schlumberger vertical electrical resistivity sounding (VES) technique has been adopted for the purpose. In sounding with Schlumberger configuration the current electrodes are moved outward along a straight line keeping the closely spaced potential electrodes fixed at centre till a measureable, determined by the sensitivity of instrument, potential difference is obtained. In practice, the potential electrode spacing is kept not more than 1/5th of the current electrode spacing ($MN \leq 1/5AB$).The geometric factor 'K' for Schlumberger configuration is

— — — —

AB = Current electrode spacing, MN = Potential electrode spacing

a. VES Data Processing and Software Package used

Tube well sitting, as a source finding measure, will depend on the area where sub surface formations are available carrying appreciable thickness of fresh ground water zone with good water yield prospect. Such zones can be suitably identified by electrical resistivity measurements.

Artificial recharge practices as a water conservation technique are presently considered essential prerequisite especially for big housing complexes and have been introduced in building by laws throughout the country. Artificial recharge measure is to be obviously taken up where recharge to ground water is most effective. It is the top soil cover and formation lying immediately below and extending to few meters depth which mainly controls the effective recharge to ground water. Sand predominant layers are obviously most suitable for this purpose and the requirement is to demarcate and differentiate sand and clay predominant layers. Electrical resistivity measurements can play a very effective role in this regard as the sand predominant sediments show higher electrical resistivity values compared to clay predominant zones, identified by low electrical resistivity values. Silty and loamy formations have a better recharge possibility compared to clay predominant layers. It may further be added that ground water flow through clay predominant formation is sluggish causing salt concentration and quality impairment of ground water. As a result, electrical resistivity values are conspicuously low in such formation.

A total of **Five** (5) Vertical Electrical Sounding (VES) with Schlumberger electrode configuration were carried out in the premise of Boutique Hotel at Ballupura, Jaipur and locations are shown in **Fig 6.1.** A microprocessor based resistivity meter model CRM – 500 make ANAVIC systems was used for data acquisition. This instrument has a facility to stack the measured signal up to 64 stacks (cycles) for minimizing the signal to noise ratio. It is a resistivity meter with constant current selection mode measurements.

The Schlumberger VES were having the maximum current electrode separation (AB) in the range of 300 to 600 m. The values of apparent resistivity ρ_a (product of resistance and geometric factor) in ohm-m were plotted against the related half-current electrode separation *AB/2* on double log paper of 62.5 mm modulus. The curves were carefully smoothened for the interpretation. Preliminary quantitative interpretations of VES curves were attempted by using two-layer master and auxiliary curves of Orellana - Mooney. The data was also processed and interpreted on computer using Schlum Software to verify the manually interpreted results. Any deviation of the computed curves from the related field curves was modified keeping in view of the local geology to arrive at a realistic model. The data was also interpreted by an empirical method known as Resistivity Factor Method to decipher the depth range of the fractures. The inverse slope method was also used wherever required to identify the deeper layers with better resolution. The VES location map is given in **Fig. 6.1** indicating all the locations at which VES has been conducted for different spacing of electrodes to acquire the entire coverage of the area of interest.

b. Limitation

The area is underlain by alluvium formation comprising of silt/clay, sand medium to fine grained with pebbles of quartzite occasionally overlying the basement. The depth to the quartzite basement varies from 18 mbgl to 43 mbgl. Due to presence of thick saturated silty/clayey layers, after certain depth at places the resistivity values were sinked down to very low and restricted the depth of penetration of current. This resulted into limited depth of penetration, even though the current electrode separation was kept to its maximum. Therefore, at many places detailed information of deeper depths where ground water is occurring could not be picked up and some alternative methods are suggested to be used to overcome the limitations. However, the use of such methods is beyond the scope of the present investigations due to the very high cost is involved in these techniques.

Current electrode separation was another limitation at many sites due to either construction work or dumping of material / debris of the construction. This has resulted into limited current electrode separations which has restricted depth of investigation. The Basement rock in the survey area is quartzite and the same has not been encountered from 18 to 43 mbgl with the available current electrode separation in the project area. The survey line was mostly chosen as per the expected sedimentations of alluvium layers mainly in E-W direction. However, the alignment of the sounding lines was also taken in other direction for the want of maximum current electrodes separation and to study the change in the geo-electrical response. High tension power lines, roads, fences, conducting building material lying in project area and under ground power cables and water supply pipes etc. were also the limitations to take noise free observations.

c. Standardization of Electrical Resistivity value

i. Bed Rock-Delhi Quartzite

Within close vicinity of the survey area to a distance of about few kilometers, quartzite exposure exists. However, the joint and fracture patterns in quartzite are highly varying. As a result, the compactness of quartzite varies significantly both laterally and vertically. Based on observations from the present survey and past experience of working in quartzite terrain, the classification, indicating variation in electrical resistivity value with quartzite compactness, has been made and given in Table 6.1.

ii. Alluvial Sediments

Based on available litho-logs and electric-logs of the existing exploratory and deposit wells, located in and around the area, constructed by State and Central Ground Water Departments and private owners, the following gradation of electrical resistivity values has been made. The objective was to standardize electrical resistivity values in terms of subsurface lithology, quality of formation water and degree of water saturation. The main criteria adopted for the gradation of electrical resistivity value is that it reduces with increasing salinity of formation water, also the electrical resistivity value increases with reduction in clay content and increase in sand content of the sediments. Table 6.1 shows the standardization of electrical resistivity value with respect to both alluvial sediments as well as compact/fractured and jointed quartzite

Table 6.1: Standardization of electrical resistivity value in terms of subsurface lithology and groundwater quality

Electrical Resistivity Range in ohm m	Groundwater quality	Inferred litho logy
35-150	Dry zone	Top Soil dry/moist. Sediments, consisting of coarse sands, clay/silt and kankar (rocks fragments) in varying proportion.
15-35	Fresh	Sand and clay mixed sediments, carrying fresh water, suitable for drinking.
10-15	Marginally fresh	Sand and clay mixed sediments, carrying marginally fresh quality of water suitable for domestic, horticulture and even for drinking water use with caution.
5-10	Marginally brackish	Sand and clay mixed sediments, carrying marginal brackish quality of water suitable for domestic and horticulture use. The water can also be used for drinking purpose after initial treatment.
< 5	Brackish/Saline	Sediments consisting mixture of sand and clay, and carrying brackish quality of water suitable only for domestic use.
100-400	Fresh water	Fractured/Jointed quartzite
400-1000	-do-	Partially fractured quartzite
> 1000	Dry	Compact quartzite

6.3 Electrical Resistivity (VES) Interpreted Results

The approximate range of resistivity values are given in the table above. Change in resistivity value in a particular VES and the trend of the curve plays important role for determining the type of formation for any particular study area. This is mainly inferred based on the field experience and interpretations with help of computer operated software programmes and manual master curves.

In order to scan and infer the sub surface lithological description of the sediments and map the bed rock (Quartzite) topography, if available, the entire project area was covered with suitably distributed 05 number of observation points where Schlumberger Vertical Electrical Resistivity Sounding (VES) were carried out. As already mentioned above, the location of VES points is shown in **Fig. 6.1.** Results of interpreted 05 VES measurements along with field measurement data sheets have been shown from **Fig. 6.2 to Fig. 6.6**. The data collected from electrical resistivity method has also been plotted using Rockware software to delineate the interface between detectible layers in space within the premise of Boutique Hotel at Ballupura, and a 3D visualization has been developed for water bearing formations in the project area. The same has been represented in **Fig. 6.7.** The geo electrical parameters (true resistivity and thickness of individual sub surface layer) derived from the VES measurements were ultimately converted to lithological description of the sediments given in Table 6.1. The results of VES measurements in terms of sub surface lithology of sediments have been shown in Table 6.2. This table also indicates inferred ground water quality. The depth of investigations ranged from 120 to 160 mbgl in the project area. At places depth of investigations is restricted as the separation of current electrode could not be kept to the desired distance due to obstructions in surrounding of the project area.

Table 6.2: Results of Schlumberger VES Resistivity Measurements

VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Ground water quality	Depth Range of Fractures
Ballu1 (AB/2=300m)	70	2.70	0.00-2.70	Surface moist soil with sandy silt	Fresh	50– 60
	160	4.86	2.70-7.56	Dry fine grained sandy silt		80 – 90
	30	13.30	7.56-20.86	Moist fine grained sandy silt		105 – 120
	225	20.00	20.86-40.86	Dry weathered quartzite		
	450	80.00	40.86-120.86	Partially saturated fractured quartzite		
	V. high	Continue*	120.86 - continued	Compact quartzite		
Ballu 2 (AB/2=230m)	130	2.50	0.00-2.50	Surface soil with sandy silt	Fresh	30 – 40
	95	15.50	2.50-18.00	Moist fine grained sandy silt		50 – 60
	250	12.00	18.00-30.00	Dry weathered quartzite		90 – 100
	650	85.00	30.00-115.00	Partially saturated fractured quartzite		115 – 125
	V. high	Continue*	115.00 – continued	Compact quartzite		

VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Ground water quality	Depth Range of Fractures
Ballu3 (AB/2=150m)	145 80 550 60 150 350 V. high	2.10 3.67 3.40 33.58 10.00 58.00 Continue*	0.00-2.10 2.10-5.77 5.77-9.17 9.17- 42.75 42.75-52.75 52.75- 110.75 110.75 – continued	Surface soil with sandy silt Fine grained sandy silt Dry sandy silt with kankar Moist fine grained sandy silt Dry weathered quartzite Partially saturated fractured quartzite Compact quartzite	Fresh	55 – 65 80 – 90 110 - 120
Ballu 4 (AB/2=200m)	145 116 195 34 150 350 V. high	2.70 1.89 12.00 5.60 13.00 115.00 Continue*	0.00-2.70 2.70-4.59 4.59-16.59 16.59-22.19 22.19-35.19 35.19-150.19 150.19 – continued	Surface soil with sandy silt Dry fine grained sandy silt Dry sandy silt with kankar Moist fine grained sandy silt Dry weathered quartzite Partially saturated fractured quartzite Compact quartzite	Fresh	40 – 50 60 – 70 100 – 110 150 – 160
Ballu 5 (AB/2=200m)	56 280 52 125 350 V. high	2.60 4.00 44.00 16.00 44.00 Continue*	0.00-2.60 2.60-6.60 6.60-50.60 50.60-66.60 66.60-110.60 110.60 - continued	Surface moist soil with sandy silt Dry fine grained sandy silt Moist fine grained sandy silt Partially saturated weathered quartzite Partially saturated fractured quartzite Compact quartzite	Fresh	50 – 60 80 – 95 110 - 120

* The layer is continued further deeper and the bottom of the layer could not be detected

The electrical resistivity measurements were carried out with the following objectives:

- Identify suitable aquifers within valley fills, fractures/joints in bedrock quartzite and estimate its depth of occurrence and their variation in the survey area.
- Estimate thickness of overburden
- Variation in ground water quality

- Thickness of overburden and existence of fractured quartzite are the parameters of main significance for not only identifying suitable tube well location but also to decide the type of drilling rig needed for well construction.

6.4 Discussion of Results:

The subsurface formations inferred from the ranges of interpreted true resistivity value are given in the table below:

Table 6.3: Inferences of the VES results

Ranges of true resistivity (Ohm-m.)	Inferred subsurface geological formations	Type of formation
< 10	Sandy clay/weathered quartzite with saline water	Alluvium (Overburden)
30 to 100	Moist fine grained sandy silt	Alluvium (Overburden)
100 to 125	Dry fine grained sandy silt	Alluvium (Overburden)
125 to 150	Partially saturated weathered quartzite	Alluvium (Overburden)
190 to 550	Dry sandy silt with kankar	Alluvium (Overburden)
150 to 250	Dry weathered quartzite	Basement rock
250 to 650	Partially saturated fractured quartzite	Basement rock
> 650	Compact quartzite	Basement rock

The depth to basement in the area under investigation varies from 18 to 43. The thickness of the alluvium has been estimated between 18m and 43m. Formation comprising of weathered/fractured quartzite predominantly below the depth of 40 to 50 mbgl is likely to form good aquifers with moderate yield.

The water level in the area under investigation is expected to vary in the range of 40 to 50 mbgl. The feasible sites for ground water development with their priority to be taken up for drilling have been shown in Table 6.4

Drilling recommendation including choice of drilling rig (Rotary or DTH) is based on thickness of overburden and fractures in quartzite. In the project area, sufficient thickness of alluvium is not expected. Hence the combination rig is recommended for drilling of boreholes.

TABLE 6.4: INFERENCES OF THE VES AND RECOMMENDATIONS FOR DRILLING

VES No.	1	2	3	4	5
Depth to Qzt in m	21	18	43	22	43
Groundwater Quality	Fr	Fr	Fr	Fr	Fr
Fractured (**F**)/ Compact (**C**)	F	F	F	F	F
Recommended for drilling	**√**	**√**	**√**	**√**	**√**
Drilling order of preference	4	1	5	2	3
Type of rig needed	**DTH**	**DTH**	**Combination rig**	**DTH**	**Combination rig**

Note: 1. Thickness of overburden, presence of fractured quartzite and water quality are considered for selection of drilling sites and deciding order of preference for drilling. Choice of type of drilling rig has also been suggested based on the fact that interest will be to tap either overburden or fractured quartzite.

2. Five locations are finalized for tube well boring having best water yielding possibility. All are recommended to be drilled by DTH rig with Odex attachment.

Abbreviation: Water Quality: **Fr**=Fresh; **Type of Drilling Rig** to be used: **R**= Rotary;

DTH= Down the Hole Hammer, **VES**: Schlumberger Vertical Electric Sounding

CHAPTER 7.0 HYDROCHEMISTRY

The ground ware quality in Jaipur district is by and large fresh in the major parts of the city. At places it exhibits large variations depending upon the nature of water bearing formations and local hydrogeological conditions. In general the Electrical Conductivity (EC) and TDS are indicative of the overall quality of the ground water.

The analytical results of Groundwater samples shows higher concentration of total dissolved solids, electrical conductivity, total hardness and nitrate, which indicate signs of deterioration but values of pH, calcium, magnesium, sulphate and fluoride are within permissible limit as per WHO standards. From the Hill–Piper trilinear diagram, it is observed that the majority of ground water from sampling stations is calcium–magnesium–chloride–sulphate type water. The values of sodium absorption ratio and electrical conductivity of the ground water were indicates salinity hazard and low sodium hazard. Chemical analysis of groundwater shows that mean concentration of cation (in meq/l) is in order magnesium > sodium > calcium > potassium while for the anion (in meq/l) it is chloride > bicarbonate > sulphate > nitrate > carbonate > fluoride. The water quality map showing the contours of Electrical conductivity for the study area is given in **Fig. 7.1** indicates that in general the EC value in major part is within 1000 microsiemens/cm .The maximum limit of EC in drinking water is prescribed as 1400 microsiemens/cm

CHAPTER 8.0 GROUND WATER DEVELOPMENT & WELL DESIGN

8.1 Ground Water Development

The project area has been investigated through hydrogeological and geophysical investigations suitably aided by advanced tools of remote sensing & GIS and other analytical tools for assessment of ground water potential. The subsurface as derived from lithologs substantiated by geophysical investigations has formed the base for recommending the site specific location for water well drilling and artificial recharge structures. The picture which has emerged after the analysis of the data indicates wide variation in respect of grain size and clay content , the sand content also vary with depth and hence the storage capacity of the underlying aquifers. The geophysical sections prepared based on the sounding data further indicates that ground water availability is from 60 to 80 m bgl and 100 to 135 m bgl in most of the part of the project site. The potential ground water bearing zones are expected to be encountered in the depth range of 100 to 135 m bgl.

Based on the interpretation of geophysical sounding carried out at four locations well distributed in the project area, locations have been recommended to construct the well as per the design given in following paragraphs. The location of proposed sites for construction of tube wells is given in **Fig. 8.1** in order of preferences. Depending upon the requirement of water in different phases of construction all the number of wells may be decided and constructed.

Based on the analysis of the area around the project site including the locations where the lithologs of Central Ground Water Board and other State Govt. agencies have drilled the exploratory wells, it is recommended that wells may be constructed under strictly under supervision of ground water experts. On completion of the drilling, necessary well tests should be performed in these well for determining the aquifer parameters by ground water experts. And further the subsequent sites should be located for drilling of subsequent wells.

The total water requirement of the project has been estimated to the tune of 160 cubic meter per day. To meet the water demand of the project the expected yield of each well is estimated to be 15 m^3/hr. The depth of the wells drilled will be around 150 – 160 m bgl. Therefore to meet the water requirement of 160 m^3/day at least two wells should be drilled when pumps are estimated to run 8 hour in a day. With this yield 2 well will provide 240 m^3/day of water to meet the demand.

The wells constructed should be properly tested for basic hydrogeological parameters to design the pump and pumping schedule in the project area. Method for conduction of pump tests is elucidated at the end of this chapter. From pump test the drawdown and cone of depression will be determined along with other aquifer parameters.

8.2 Well Design & Construction

Well design of each well and methodology for construction of the well along with the specifications of the material use are described below. It is recommended to deploy a combination rig for constructions of tube wells as the water bearing formation are weathered & fractured hard rock overlain by alluvium.

Well design of water well and methodology for construction of the well along with the specifications of the material use is described below. It is recommended to deploy a Combination rig (Rotary cum DTH rig) for constructions of tube wells as the water bearing formation are hard rock but overburden of alluvial is present. The alluvium thickness to the tune of 20 to 45 m will be drilled by the rotary bits and once the hard rock is reached the DTH bits will drill the well in quartzite down to the depth of 150 – 160 m bgl.

The borehole of 11 inches (280 mm) diameter may be drilled down to 50 m depth to the depth of the bed rock. An assembly of blank casing pipe of 8 inches diameter (203 mm pump housing) from 0 to 50 m bgl, blank casing pipe may be drive into at least 2 to 3 m down within the bed rock. i.e. into the quartzite. The annular space around the tube well assembly is then to be shrouded with appropriate size of pea gravel taking care to avoid bridging in the gravel pack. For this, central guide be provided in the well assembly.

Further, a borehole of 8 inches diameter may be drilled in the depth range of 50 to 150 m bgl by DTH rig depending upon the occurrence of bed rock in the well. The naked borehole should be electrically logged to decipher the potential water bearing zones and water quality under the supervision of ground water exerts consisting of hydro-geologist and geophysicist. Based on the recommendations of the experts on well logging the length of MS slotted pipe and blank casing pipe may be adjusted suitably. The entire well assembly would be of MS Pipes. As a provision of bail plug 2 to 3 m extra drilling may be carried out i.e. from 148 to 150 m bgl depth.

The depth drilling and depth of zones are given for each well in the following table:

Sl.No	Well Location	Reference to VES no	Depth of drilling (m bgl)	Depth of expected zones (m bgl)	Expected yield
1	1	2	130	50-60 90-100 115-125	15 m^3/hr

2	2	4	160	60-70 100-110 150-160	18 m^3/hr
3	3	5	125	80-95 110-120	15 m^3/hr

The designs of the above wells are given in **Fig. 8.2 to 8.4.**

A submersible pump of 4 inches diameter of 5 Horse Power, as recommended by the ground water experts after conducting Primary Yield Test and Aquifer Performance Test, should be lower in the well for sustainable discharge and acceptable drawdown.

Before conducting the well test the tube well may be developed by an air compressor followed by an over capacity pump till the water becomes clear and silt free. After that only the tube well may be tested for its yield characteristics and aquifer parameters using preferably a turbine or otherwise a submersible pump.

Well Development

All the tube wells may initially be developed with an Air Compressor followed by an Over Capacity Pump till the water becomes silt free. Pumping test viz well test and aquifer test are proposed to be conducted for evaluation of well characteristics and aquifer characteristics as specified below:-

Well Test

It comprises a Step Draw Down test of 3 to 4 hrs duration (3 to 4 hrs steps of 1 hr each.) The tube well is pumped at 3 to 4 constant discharge rates in ascending order and lowering of water levels in the well i.e. drawdown is recorded at different time interval. The recorded data is analyzed for evaluation of specific capacity and well efficiency at different discharge rates.

Aquifer Test

It comprises an aquifer performance Test of say 3 to 4 hrs pumping duration (short duration test suffices the need in case of production wells).The tube well is pumped at constant discharge for 3 hrs to 4 hrs and drawdown is recorded at different time intervals. The pumping is stopped after 3 to 4 hrs and recovery of water levels in the tube well is recorded wit time. Time drawdown and time recovery data is analyzed for evaluation of aquifer characteristics viz. Transmissivity and Hydraulic Conductivity. During the above test water sample are collected for chemical quality determination.

CHAPTER 9.0 MANAGEMENT STRATEGIES

9.1 Rain Water Harvesting & Artificial Recharge to Ground Water

9.1.1 General

Artificial recharge systems are engineered systems where surface water is put on or in the ground for infiltration and subsequent movement to aquifers to augment groundwater resources. Other objectives of artificial recharge are to store water, to improve the quality of the water through soil-aquifer treatment or geo-purification, to use aquifers as water conveyance systems, and to make groundwater out of surface water where groundwater is traditionally preferred over surface water for drinking. Artificial recharge is expected to become increasingly necessary in the future as growing populations require more water, and as more storage of water is needed to save water in times of water surplus for use in times of water shortage.

Artificial recharge efforts are basically augmentation of the natural movement of surface water into ground water reservoir through suitable civil construction technique or other similar methods. Availability of source water is one of the important requirements for recharge schemes. It is assessed in terms of non-committed surplus monsoon run-off, which is going unutilized as per the water resource development pattern. The other basic requirement is the availability of sub-surface storage space in different hydrogeological situations of the country. The topography and the soil condition of the area links the above two factors. Topography governs the extent of run-off and its retention where as the soil condition determines the extent of percolation. The artificial recharge technique inter relate and integrate the source water to ground water reservoir which in turn dependent on the hydrogeological situation of the area.

Artificial recharge projects are site specific. The replication of the techniques from similar areas is to be based on the local hydrogeological and hydrological environs. The first step in planning the project is to demarcate the area of recharge. The scheme can be implemented systematically in case a hydrologic unit like watershed is taken for implementation. However, localized schemes also can be taken to augment the ground water reservoir. Schemes are normally taken in the following areas.

- Areas where ground water levels are declining over a period of time.
- Areas where substantial amount of aquifer has already been de-saturated.
- Areas where availability of ground water is in adequate in lean months and there is availability of surface water for recharge during rainy season.
- Areas where salinity ingress is taking place.

- Areas where there is quality problem in ground water

Roof top rain water harvesting can also be adopted to meet domestic water requirements. Roof top rainwater harvesting, which involves the collection of rainwater from the roof of the buildings and its storage in surface tanks or recharge to sub-surface aquifer, can play an important role in conservation of water. In Urban areas dependence on ground water has increased many folds and the natural recharge to ground water has decreased, due to urbanization, construction of buildings and paved area. In these areas water falling on roof tops can be collected and diverted to the open wells/ tube wells/ bore wells by providing a filter bed and can be augmented to ground water for future use. Thus, the need for artificial recharge of groundwater is beyond doubt and it is the most powerful management strategy available to face the challenge of fast depletion in groundwater storages.

9.1.2 Computation of Rainfall Runoff & Approach for Artificial Recharge to Ground Water

It is proposed to implement rain water harvesting structures by diverting the runoff that is generated from the rooftops, paved areas, roads and green belt areas for recharging into the ground water system. Implementation of recharge mechanism shall ensure the balance between the discharge vis-à-vis recharge relationships of the aquifer system and improve in the ground water quality. The normal annual rainfall for the said area has been taken as 550 mm. as per the data of IMD. Based on the site plan and the land use pattern of the plot area, the computation of runoff for each unit has been worked out and the details are tabulated below.

Table 9.1: Computation of Runoff Available for Recharge

Sl. No.	Land use type	Area (m^2)	Co-efficient of runoff	Rainfall (m)	Quantity of Rainwater (m^3)
1	Roof area	11450	0.85	0.550	5253
2	Road & Paved area	4600	0.75	0.550	1898
3	Open & Green land	68950	0.15	0.550	5688
	Total	85000			12839

From the above computation, it is evident that a total quantum of 12839 cu.m of rain water can be fruitfully harvested annually by constructing suitable recharge structures. Beside this 20% of the return seepage from the water being applied to the green area for horticulture and gardening will also contribute to the ground water storages. In order to design the recharge structures, hourly runoff of 30 mm/hr has been taken into account and the details are tabulated below.

Table 9.2 : Recommendations for Recharge Structures Based on Hourly Computation of Runoff – (30 mm/hr)

Sl. No.	Land use type	Area (m^2)	Co-efficient of runoff	Intensity of Rainfall (m)	Quantity of Rainwater (m^3)	Structure
1	Roof area	11450	0.85	0.03	292	4 SB recharge structures
2	Road & Paved area	4600	0.75	0.03	104	2 SB recharge structure
3	Open area & Green belt	68950	0.15	0.03	310	2 DB recharge structure
	Total	85000			706	

DB= Double bore ; SB= Single Bore

9.1.3 Proposed Recharge Structures and Design

It has been worked out that in order to tap effectively the rainfall runoff and subsequently recharging to the aquifer systems, suitable recharge structures with recharge wells of appropriate depths are required. As a major section of the land area will be covered with roof top of RCC therefore significant amount of runoff will be generated. This runoff is proposed to be recharge to ground water at the closest proximity of the area where water is coming down to ground level from roof level. The locations of these sites are indicated in **Fig 9.1,** however, the locations of recharge structures can be slightly modified depending upon the final layout of storm water drains. About 77% of the area in the plot is either open or green belt. Green belts and open areas are most suitable for natural recharge. However, in this case as the ground water levels are very deep and natural recharge to ground water may not take place effectively, therefore, it is suggested that the recharge in the green area should also be done through recharge structures with recharge wells. To make recharge from the green belt more effective it is proposed to do the landscaping of the green area in such a way that all the surface runoff of rainfall should lead to the recharge structures. The design and number of recharge structures proposed for green belt has been worked out on considering the optimum space required to accommodate the runoff even during heavy rainfalls. Necessary precautions shall be taken to avoid any contaminated water entering into recharge structures envisaged for recharge. Provision for de-silting mechanism adjacent to the recharge structures would be taken up so as to ensure that the runoff diverted to the recharge structure is silt free. Frequent maintenance of the de-silting chambers would be taken up to overcome the problem of clogging of the recharge wells. The recharge structures are so designed that these are operational only during the monsoon seasons.

Recharging the water from the landscaping, garden and open and unpaved land is proposed to be done through recharge structures of single bore constructed all along the lawn, garden or boundary wall near the open area and landscaping is done in such a way that the slope of the landscaping is towards the recharge structures. Recharge structures should be filled with inverted filter of boulder, gravel and sand. Intake and recharging capacity of recharge structure without recharge well is limited and slow as compared to the recharge trenches with recharge wells. More over in this area due to deeper ground water levels recharge structures with recharge wells are most suitable for an effective recharge to ground water. The proposed designs for recharge structures are given in **Fig. 9.2 & 9.3.**

9.1.4 Additional recharge from surrounding area

Surveying the topography, analyzing the geomorphology and remote sensing data it has been inferred that a drainage flowing behind the Hotel site, adjacent to the foothills of Aravali in this area could be most suitable location for water conservation and recharging of ground water. Although, the drainage under consideration is relatively small but it carries the runoff of the hill range behind the hotel site and if this rainfall runoff can be checked in to percolation pond or check dam, the water stored during the rainy season will recharge the ground water aquifers beneath the hotel site. The Physiography of the area is such that the type of structures (percolation tank or check dam) will involve huge amount of investment. Therefore, such type of recharge projects can be taken up in association with any government department through several active schemes of recharge to ground water.

Besides the above , there are several erosional gullies which are the result of rainfall runoff. These gullies can be well used for water harvesting sites by construction of gabion structures at suitable sites preferably closer to the boundary of Hotel site.

9.1.5 Points to be considered For Implementation of Artificial Recharge Structures

- All the storm water drains would be kept clean. Connection of down spouts will be provided wherever required so as diverting the runoff to the structures.
- No contaminated water would be diverted into the storm water drains. Necessary peripheral drains will be constructed to divert the runoff to the recharge structures.
- Before the onset of the monsoon all the catchment area considered for recharge would be cleaned. The recharge structures would be in operation during the monsoon season only so as to avoid any contamination.
- Oil traps and oil separators to be placed at all the vulnerable locations from where there is slightest possibility of mixing of oil in to the storm water (rain water).
- A mesh would be provided on the mouth of the inlet to discard the debris entering into the recharge pit. A sluice/ shutter would be provided to ensure that no water other than rainwater is diverted to the recharge structure.
- Depth and location of the recharge wells may vary slightly as per the prevailing site conditions.
- After the first rain the de-silting pit would be cleaned and subsequently on the onset of next monsoon. A hygienic condition in the area would be maintained after implementation of artificial recharge structures, as the recharged water would augment the water level in the proposed tubewells.
- Depth of the retaining capacity of the recharge shafts/ trenches (as per the enclosed designs) is below the proposed inlet pipes. All the dimensions indicated in the designs are the inner dimension.
- The work of rain water harvesting would be undertaken by the specialized agencies so that the objective of rainwater harvesting is implemented in true sprit and due benefits are accrued. The drilling agency engaged in construction of the recharge structures would be a registered one with the Central Ground Water Authority.

9.2 Water Recycle and Reuse

Water recycling is an essential component of managing our water resources efficiently and making the most of a resource that is often wasted. Water recycling adopts the concept of using water that is 'fit for purpose'. In practice this means using high quality water for drinking and other personal uses, but not necessarily for purposes where alternative water sources can be safely used, such as toilet flushing, garden watering and crop irrigation.

The world's 5th will come an increased need for water to meet various needs, as well as an increased production of wastewater. Moreover, there has been significant decline in runoff in the surface water catchments and recharge to groundwater resources, in general. This has increased pressure on the water resources in the area.

Many areas throughout the world are approaching, or have already reached, the limits of their available water supplies. This subsection details out the recycle or reuse of wastewater with the sole objective to minimize the water demand during the operation phase of the project.

9.2.1 RECYCLING AND REUSE BENEFITS

The benefits of water reuse and recycling are:

- Lower use of drinking water resources
- Less fresh water extracted from rivers/groundwater for irrigation
- Less wastewater discharged into our rivers and stream channels
- Potential to release recycled water (instead of drinking water) to mimic natural environmental river/stream flow

9.2.2 REUSE APPLICATION

Quantity and quality requirements are considered for each reuse application, as well as any special considerations necessary when reclaimed water is substituted for more traditional sources of water. The common key elements of water reuse are supply and demand, treatment requirements, storage, and distribution. There are a number of practical options for using recycled water which is as listed below.

Urban Reuse

Urban reuse systems provide reclaimed water for various non-potable purposes including:

- Irrigation of parks and recreation centers, athletic fields, school yards and playing fields, highway medians and shoulders, and landscaped areas surrounding buildings and facilities
- Irrigation of landscaped areas surrounding residences, general wash down, and other maintenance activities.
- Irrigation of landscaped areas surrounding commercial, office, and industrial developments

- Ornamental landscape uses and decorative water features, such as fountains, reflecting pools, and waterfalls
- Dust control and concrete production for construction projects
- Fire protection through reclaimed water fire hydrants
- Toilet and urinal flushing in commercial and industrial buildings

Water reclamation facilities must provide the required treatment to meet appropriate water quality standards for the intended use. In addition to secondary treatment, filtration, and disinfection are generally required for reuse in an urban setting. Because urban reuse usually involves irrigation of properties with unrestricted public access or other types of reuse where human exposure to the reclaimed water is likely, reclaimed water must be of a higher quality than may be necessary for other reuse applications.

CHAPTER 10 SUMMARY AND RECOMMENDADTIONS

- The city of Jaipur is one of the tourist hubs of the country; regular flow of international and national tourists has necessitated the requirement of different categories of Hotels in the town. In the row of developing Hotel Industries, M/s Boutique Hotels (P) Ltd has proposed to build a multi-facility Hotel complex at village Ballupur, Jaipur.
- Water being one of the essential prerequisite for any such developmental activities, especially in the city like Jaipur, it has become the main issue of concern for any such initiatives. Ground water is the major source of water supply in the city, its sustainable development needs efficient planning based on scientific understanding. In view of this , M/s Boutique Hotels (P) Ltd has entrusted the work related to ground water investigation to M/s Green Systems Pvt. Ltd, New Delhi to carry out detailed studies and suggest the most viable and scientifically managed plan for development and utilization of water for meeting the water demand of the project.
- The broad objective of the present study is to assess the ground water availability and its development prospects in time and space to meet the water demand of the proposed plant. To suggest suitable well design for production wells and artificial recharge structures to ameliorate the adverse impact on the ground water regime.
- In this context a detailed hydrogeological investigation aided by advanced tools of geophysical investigations, remote sensing etc. has been undertaken in and around the project site (within a buffer of a radius of 5 km from the site).
- The proposed site of the hotel is located at about 10 km east of Jaipur town in the Sanganer block, Jaipur district of Rajasthan. The total area under the project is about 85,000 sq.m (21 acre).
- Project site is in the close proximity of the ridge and broadly lies in the pediment zone/alluvial plain which also acts as recharge area. The hotel site is situated on the eastern flank of the hill range whereas the township area of Jaipur broadly occupies the western flank. Major part of the study area is occupied by hard rock's overlain by thin veneer of overburden in the form of top soil and alluvium of aeolian origin.
- The prevailing arid conditions added with deficient rain and high evaporation has restricted development of natural river drainage system in the area, there is devoid of any perennial surface water source in the project area.

- In the present study the advanced tools like remote sensing and digital images processing of satellite data has been attempted to study the hydro-geomorphic set up of the area and a Digital Elevation Model (DEM) has been prepared by extracting spatial information related to topographic, geological, geomorphological and structural features in the area.
- The digital data on various resolutions available from different sources has been used for studying the hydrogeological features in order to locate favorable sites for ground water development and recharge. The image interpretation focuses on two interrelated aspects i.e. the (hydro) geological subsurface configuration and surface features which influence recharge and show evidence of groundwater outflow.
- The pink city enjoys arid climatic conditions. The mean annual rainfall recorded at Sanganer, Amer and Jaipur raingauge stations was 584.0, 676.5 and 639.1 mm respectively (Period 1969-92). The average annual rainfall of the Jaipur city for the last 30 years (1976 - 2007) works out to be 503.25 mm.
- The study area is mainly occupied by moderately thick alluvium of Quaternary age and underlain by quartzites of Alwar super group as basement. The Quaternary deposits are unconsolidated fluvial as well as Aeolian sediments composed of sand, silt, clay with kankars and gravels at places and form the principal phreatic aquifer in the area of study.
- The depth of bed rock encountered at various exploratory wells constructed by different Agencies varies widely in the city area. The thickness of alluvium varies accordingly, the maximum thickness up to 80 m has been deciphered in the south western part of the city, in the central and eastern part of the city area including the project area the thickness of alluvium is comparatively less and extends up to 50m. Below which the bedrock consisting of quartzite are found.
- Ground water occurs in unconfined to semi confined condition in alluvium and weathered / jointed / fractured quartzites. In alluvium, sand, silt, kankar and gravel constitute water bearing zones. Occurrence of fractured and weathered Quartzites in basement also suggests some potential of ground water development.
- Talus and scree deposits occurring on the flanks of almost all hills also form a potential aquifer consisting of fine to coarse grained sand and angular pieces of rocks with varying amount of loess. The width of the aquifer zone along the foot hills vary from few meters to about 50 meters. It forms potential aquifer along the foot hills. The thickness of Talus and

scree vary from 4 m to 55 m and the groundwater in such formations occurs under semi confined to confined conditions.

- The yields of wells tapping alluvium vary widely and the high yield zone is generally related to abandoned river channels. The tube well yield varies from 10 m^3 /hr to 85 m^3/hr. In the western most part of the district covering Sambhar - Ehulera area surface deposit consisting of blown sand attain a maximum thickness of 32 meters. Tube wells yield from 7.8 m^3 /hr to 17.0 m^3 /hr for small drawdown of about 5 meters. In the area near to Jaipur city, wells located on the banks of Amnisha River with depth less than 50 m yield 36 m^3 /hr to 90.8 m^3/hr.
- A number of shallow tube wells of up to 70 m deep in the area of study exist and yield 10 m^3 /hr to 15 m^3 /hr for moderate draw downs. Weathered quartzites constitute low potential aquifer zones. Shallow tube wells tapping zones in quartzites down to about 100 m depth yield 3 m^3 /hr to 5 m^3 /hr for moderate to heavy draw downs.
- In the western half of the study area, the yield prospects are comparatively more; the wells tapping up to a depth of about 100 m can yield up to 90 m^3 /hr. In the eastern half of the study area the yield is relatively less to the tune of 36 m^3 /hr, and even the depth of recommended tube well is about 150 m, the project area lies in this part of alluvium underlained by hard rock.
- Depth to water table varies from 50m to more than 60 m bgl and depth is increasing from northeast to southwest. Deep water levels are observed in the Jaipur City due to over-exploitable of the ground water resource. The entire city exhibits a declining water table trend. In general, a decline of more than 2 m has been observed in most parts when compared with the 10 years depth to water table average
- The water table contours in the Jaipur city varies from about 430 m above mean sea level (mamsl) in northern part of the area to about 330 m amsl in the southern part . Hydraulic gradient closely follows the physiography and altitude and is in the southerly and south westerly direction.
- As per the assessment the Net annual ground water availability in Jaipur district is 60925 Hectare meter (ham). The existing ground water draft for domestic and industrial uses is comparatively high, as per the estimates available the overall stage of ground water development in the district is around 187 % indicating the that the total ground water draft is exceeding the annual dynamic replenishable ground water resources.

- The above estimates pertains to dynamic ground water resources available in the zone of fluctuation in the top unconfined aquifer , mostly made up of quaternary alluvium and restricted up to a depth of about 50 mbgl. Due to high withdrawal in the area the water level has gone much deeper and phreatic aquifer has become more or less unproductive as far as sustainability is concerned.
- However, the underlying quartzite formation acts as potential aquifer wherever jointed and fractured. The ground water resources available below the phreatic zone in the water bearing fractures do not form the part of computation under Dynamic resources.
- The subsurface exploration up to 200 m depth carried out in the area indicates in general two major water bearing fractures at moderately deeper zones, at a depth of 80 to 90 m and 100 to 120 m bgl respectively. The fracture zone at a depth of 100m bgl seems to be productive and may be tapped suitably.
- In order to scan and infer the sub surface lithological disposition of the sediments and map the bed rock (Quartzite) topography the entire project area has been covered with suitably distributed 05 number of Schlumberger Vertical Electrical Resistivity Sounding (VES). The VES has been conducted for different spacing of electrodes varying in the range of 300 to 600 m, to acquire the entire coverage of the area of interest..
- The data collected from electrical resistivity survey has also been plotted using Rockware software to delineate the interface between detectible layers in space within the premise of Boutique Hotel at Ballupur, and a 3D visualization has been developed for water bearing formations in the project area.
- The geophysical investigations in the project area has indicated that the depth to basement in the area varies from 18 to 43 and accordingly the thickness of the alluvium also varies between 18m and 43m. Formation comprising of weathered/fractured quartzite predominantly below the depth of 40 to 50 mbgl is likely to form good aquifers with moderate yield.
- The ground ware quality in Jaipur district is by and large fresh in the major parts of the city. At places it exhibits large variations depending upon the nature of water bearing formations and local hydrogeological conditions.
- In general the Electrical Conductivity (EC) and TDS are indicative of the overall quality of the ground water. The Electrical conductivity value of ground water in the study area is within

1000 microsiemens/cm .The maximum limit of EC in drinking water is prescribed as 1400 microsiemens/cm

- The picture which has emerged after the analysis of all relevant data indicates that the upper alluvial aquifer generally behaving as water table aquifer is no more sustainable, the hard formation with good fractures and joints in the depth range of m 60 to 80 m bgl and 100 to 135 m bgl in major part of the project site forms a good aquifer. The potential ground water bearing zones are expected to be encountered in the depth range of 100 to 135 m bgl.
- The total water requirement of the project has been estimated to the tune of 160 cubic meter per day. Based on the existing data, the expected yield of well in the area is estimated to the tune of 15 m^3/hr. If the wells are operated for 6-8 hours a day with a suitable capacity of pump , each well can yield 90 – 120 cubic meter of water per day. Hence, to meet the present day water requirement of 160 m^3/day at least two wells should be drilled. The recommended depth of the wells is 150 – 160 m bgl.
- Since the wells are tapping the fractured formation, the yield of the well would depend upon the lateral and vertical continuity of the fractures; it is recommended that as far as possible continuous pumping for a longer time may be avoided, by staggering the pump operation in time.
- Based on various factors and tools , the locations of wells have been recommended for construction of the well, the tentative design is also given. However, the exact specification of well design need to be finalized after the frilling in the presence of qualified hydrogeologist. Depending upon the requirement of water in different phases of construction all the number of wells may be decided and constructed.
- It is recommended that wells may be constructed under strictly under supervision of ground water experts. On completion of the drilling, necessary well tests should be performed in these well for determining the aquifer parameters by ground water experts. Depending upon the results subsequent sites should be located for drilling.
- It is recommended to deploy a Combination rig (Rotary cum DTH rig) for constructions of wells. The alluvium thickness to the tune of 20 to 45 m will be drilled by the rotary bits and once the hard rock is encountered the DTH bits will drill the well in quartzite down to the depth of 150 – 160 m bgl.

- A submersible pump of 4 inches diameter of 5 Horse Power, as recommended by the ground water experts after conducting Primary Yield Test and Aquifer Performance Test, should be lower in the well for sustainable discharge and acceptable drawdown.
- It is proposed to implement rain water harvesting structures by diverting the runoff which is generated from the rooftops, paved areas, roads and green belt areas for recharging into the ground water system. Implementation of recharge mechanism shall ensure the balance between the discharge vis-à-vis recharge relationships of the aquifer system and improve in the ground water quality.
- In order to assess the volume of rain water available for recharge, the normal annual rainfall for the study area has been taken as 550 mm. as per the data of IMD. Based on the site plan and the land use pattern of the plot area, the computation of runoff for each unit has been worked out.
- A total quantum of 12839 Cu.m of rain water can be fruitfully harvested annually by constructing suitable recharge structures. Beside, 20% of the return seepage from the water being applied to the green area for horticulture and gardening will also contribute to the ground water storages. In order to design the recharge structures, hourly runoff of 30 mm/hr has been taken into account.
- Significant amount of runoff is being generated from roof top area and green belt which can be recharged to ground water by recharge structures as suggested. Green belts and open areas are most suitable for natural rechargebut due to deeper ground water levels natural recharge to ground water is not taking place. Therefore, it is suggested that the recharge in the green area should also be done through recharge structures with recharge wells.
- The landscaping of the green area should be done in such a way that all the surface runoff of rainfall should lead to the recharge structures. Necessary precautions shall be taken to avoid any contaminated water entering into recharge structures envisaged for recharge. Provision for de-silting mechanism adjacent to the recharge structures would be taken up so as to ensure that the runoff diverted to the recharge structure is silt free and are operational only during the monsoon seasons. Recharge structures should be filled with inverted filter of boulder, gravel and sand.
- Surveying the topography, analyzing the geomorphology and remote sensing data it has been inferred that a drainage flowing behind the Hotel site is most suitable location for

water conservation and recharging of ground water. The runoff of these drainage can be checked in to percolation pond or check dam, the water stored during the rainy season will recharge the ground water aquifers beneath the hotel site.

- Considering the huge involvement of investment in such structures such recharge projects can be taken up in association with any government department under several active schemes of recharge to ground water.
- Erosional gullies which are the result of rainfall runoff can be well used for water harvesting sites by construction of gabion structures at suitable sites preferably closer to the boundary of Hotel site.
- The exact locations of recharge structures will finally be decided as per the layout of storm water drains, rainfall catch basins that are proposed to be constructed and any other modification if comes up during construction of proposed plant.
- Water recycling is an essential component of managing the water resources efficiently and making the most of a resource that is often wasted. Water recycling adopts the concept of using water that is 'fit for purpose'. In practice this means using high quality water for drinking and other personal uses, but not necessarily for purposes where alternative water sources can be safely used, such as toilet flushing, garden watering and crop irrigation.
- Quantity and quality requirements are considered for each reuse application, as well as any special considerations necessary when reclaimed water is substituted for more traditional sources of water. The common key elements of water reuse are supply and demand, treatment requirements, storage, and distribution. There are a number of practical options for using recycled water which is as listed below.

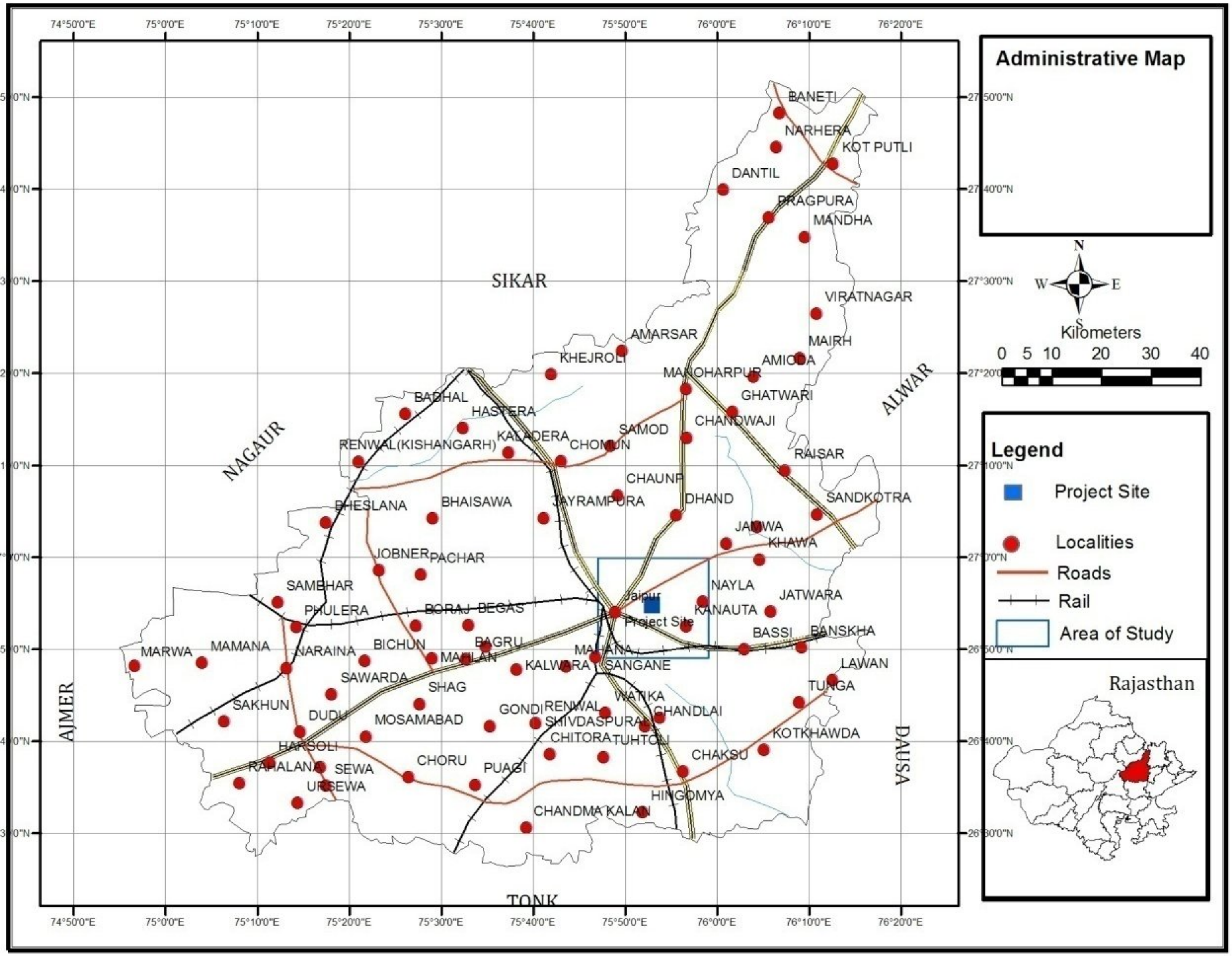


Fig. 1.1: Administrative map of Jaipur district with Location of Project Site

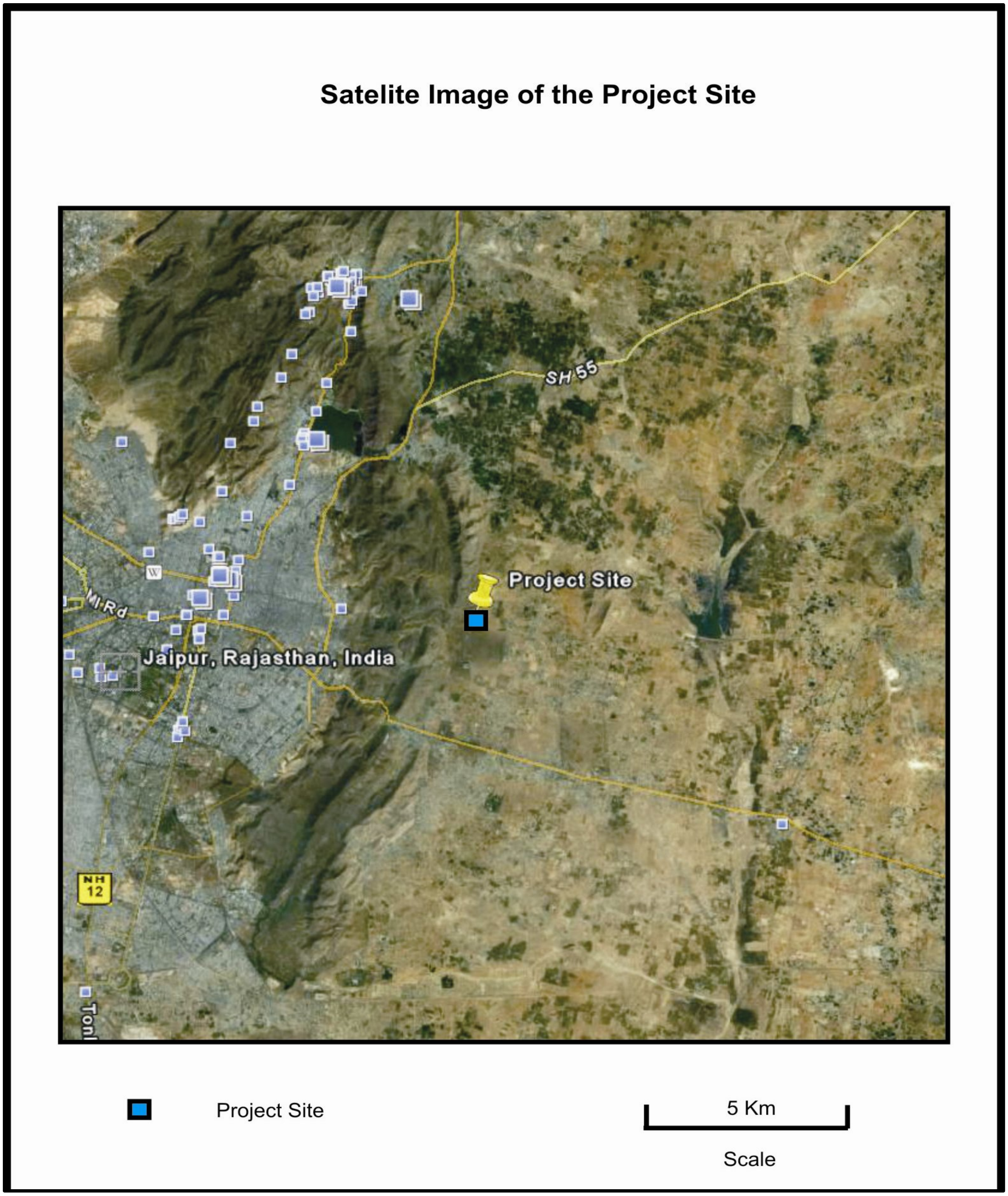


Fig. 1.2: **Google Image of the Study Area**

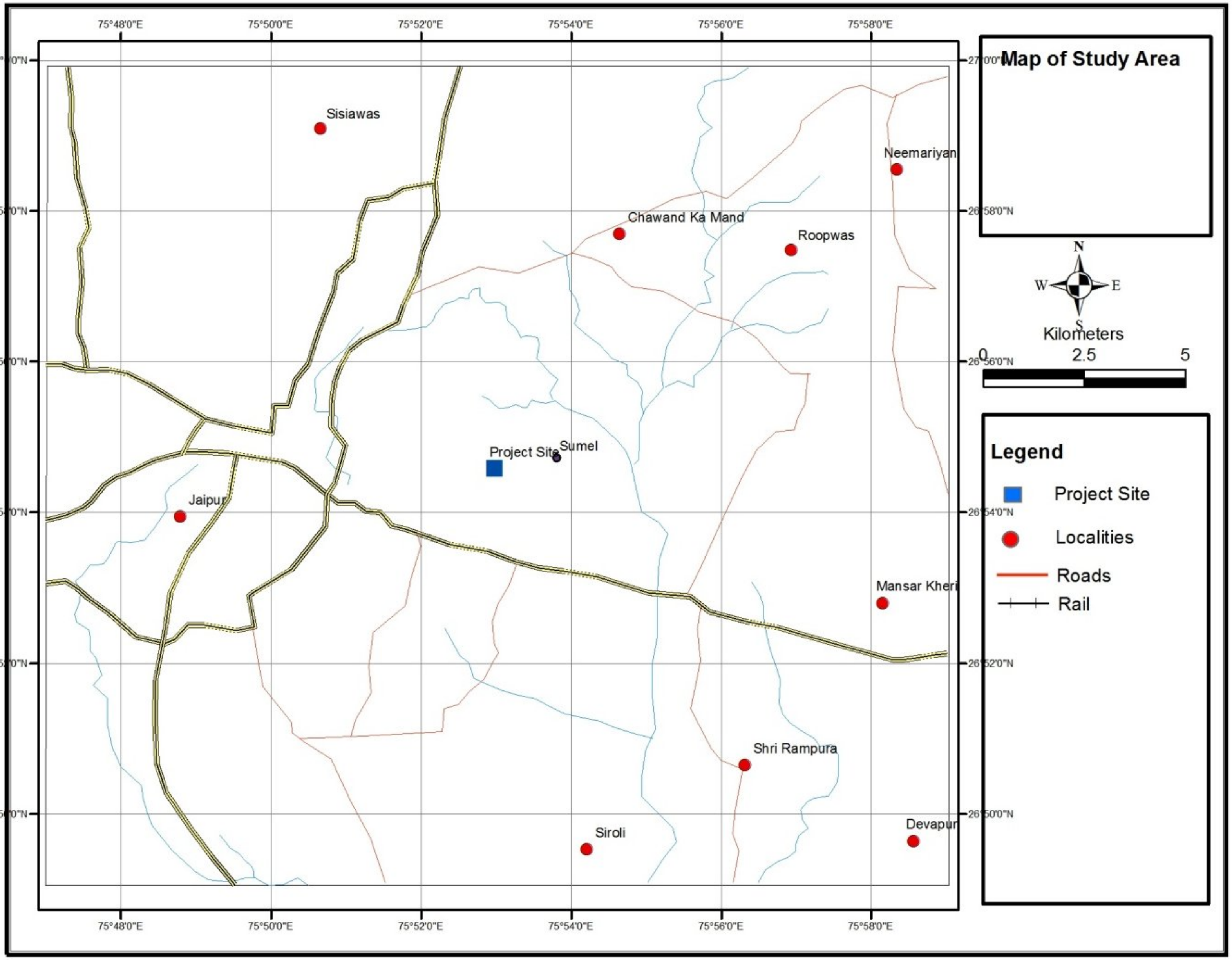


Fig. 1.3: **Map showing the Study Area**

Layout Plan of the Project Site

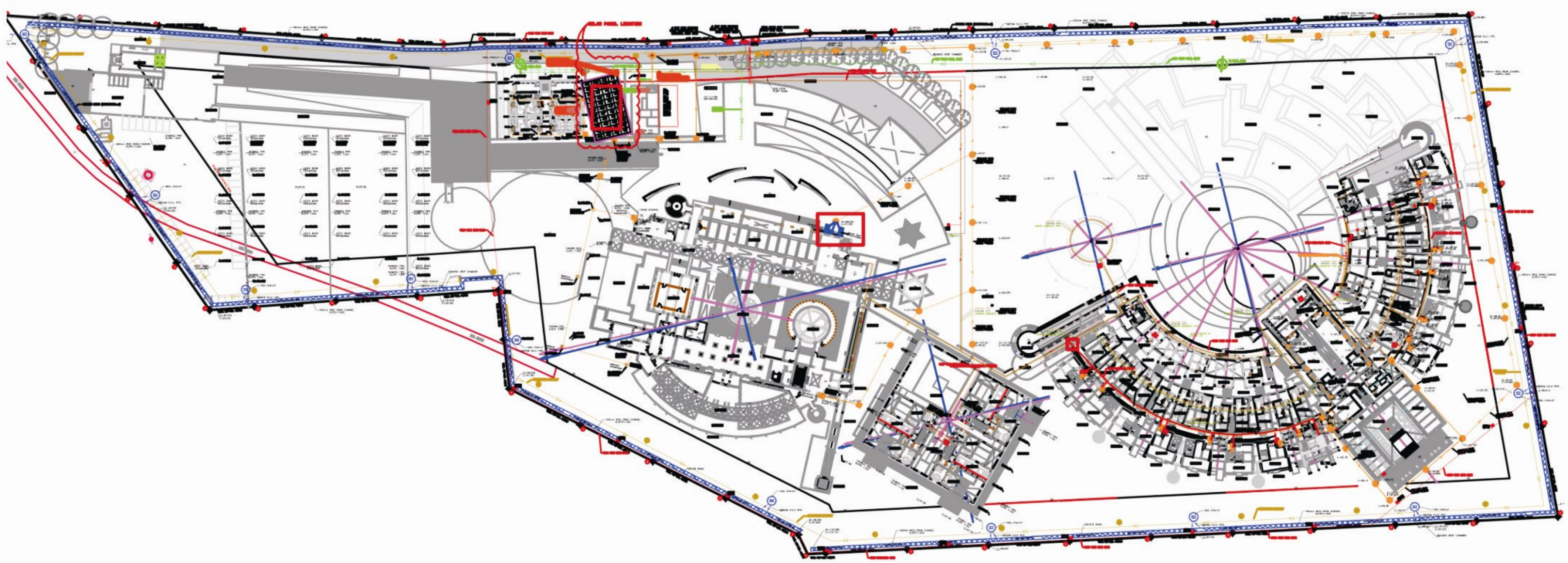


Fig. 1.4 : Layout of the Project Site

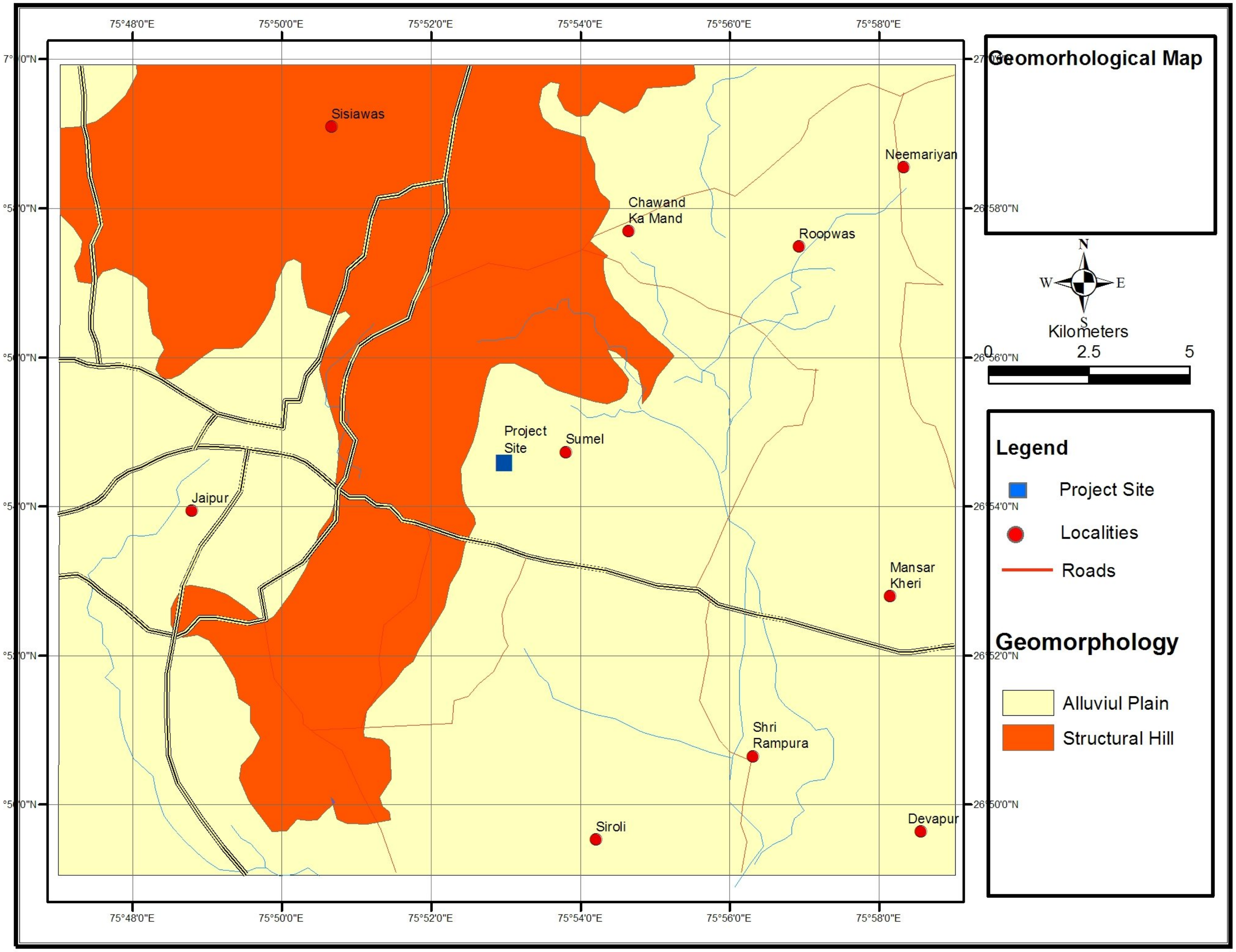


Fig. 2.1 : Geomorphological map of Study area

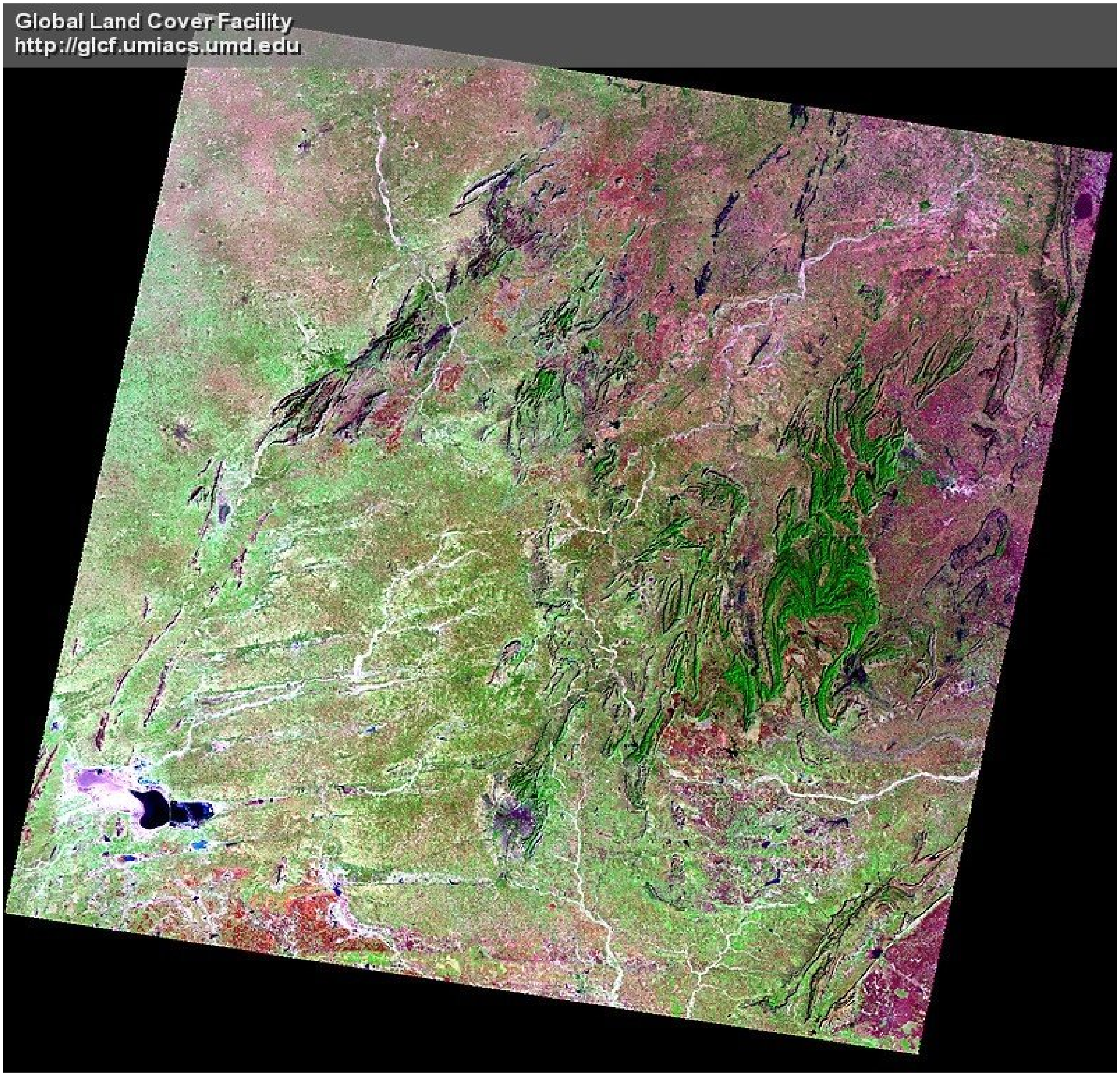


Fig. 2.2: Satellite Imagery of the area

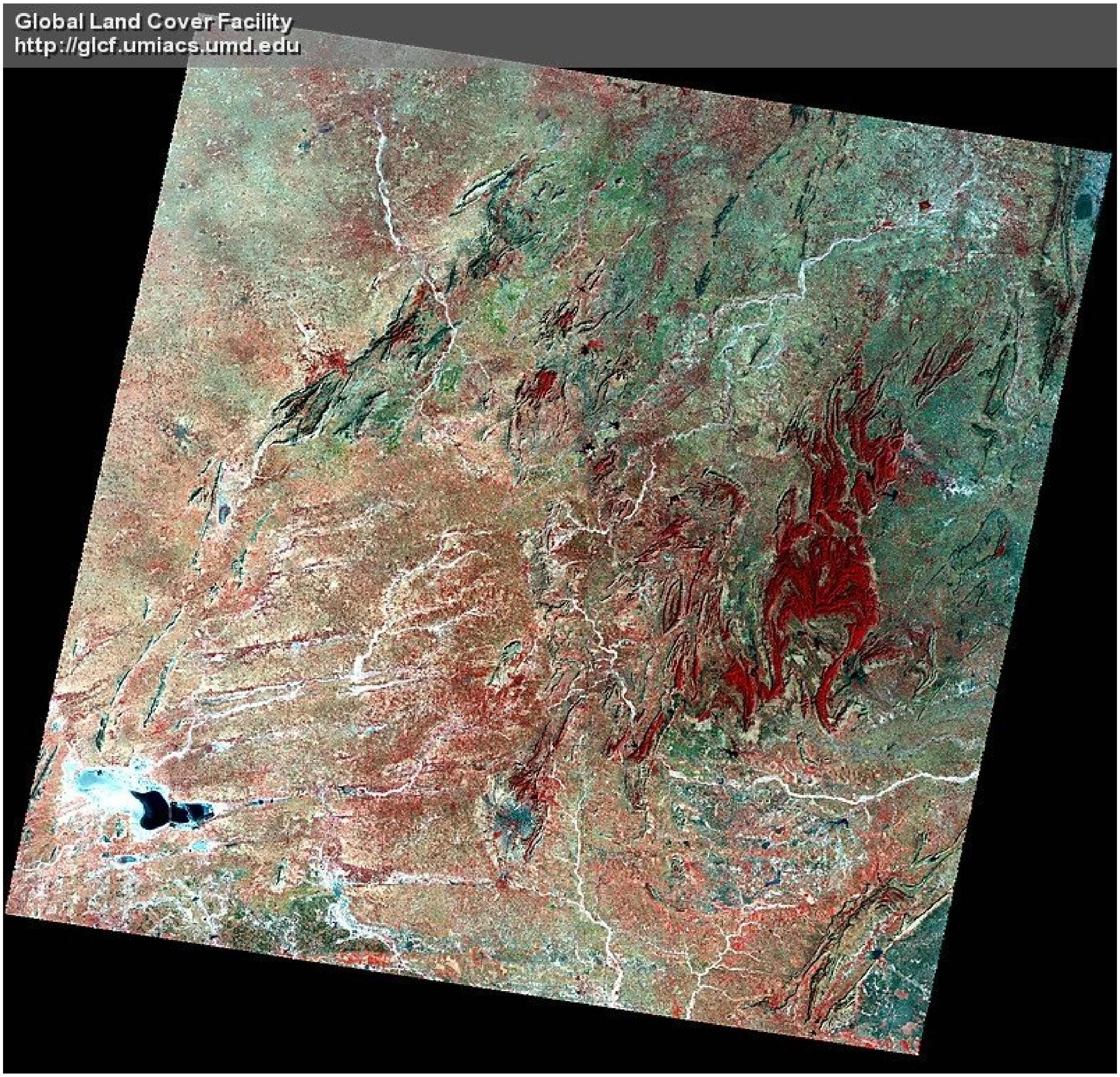


Fig. 2.3: Satellite Imagery of the area

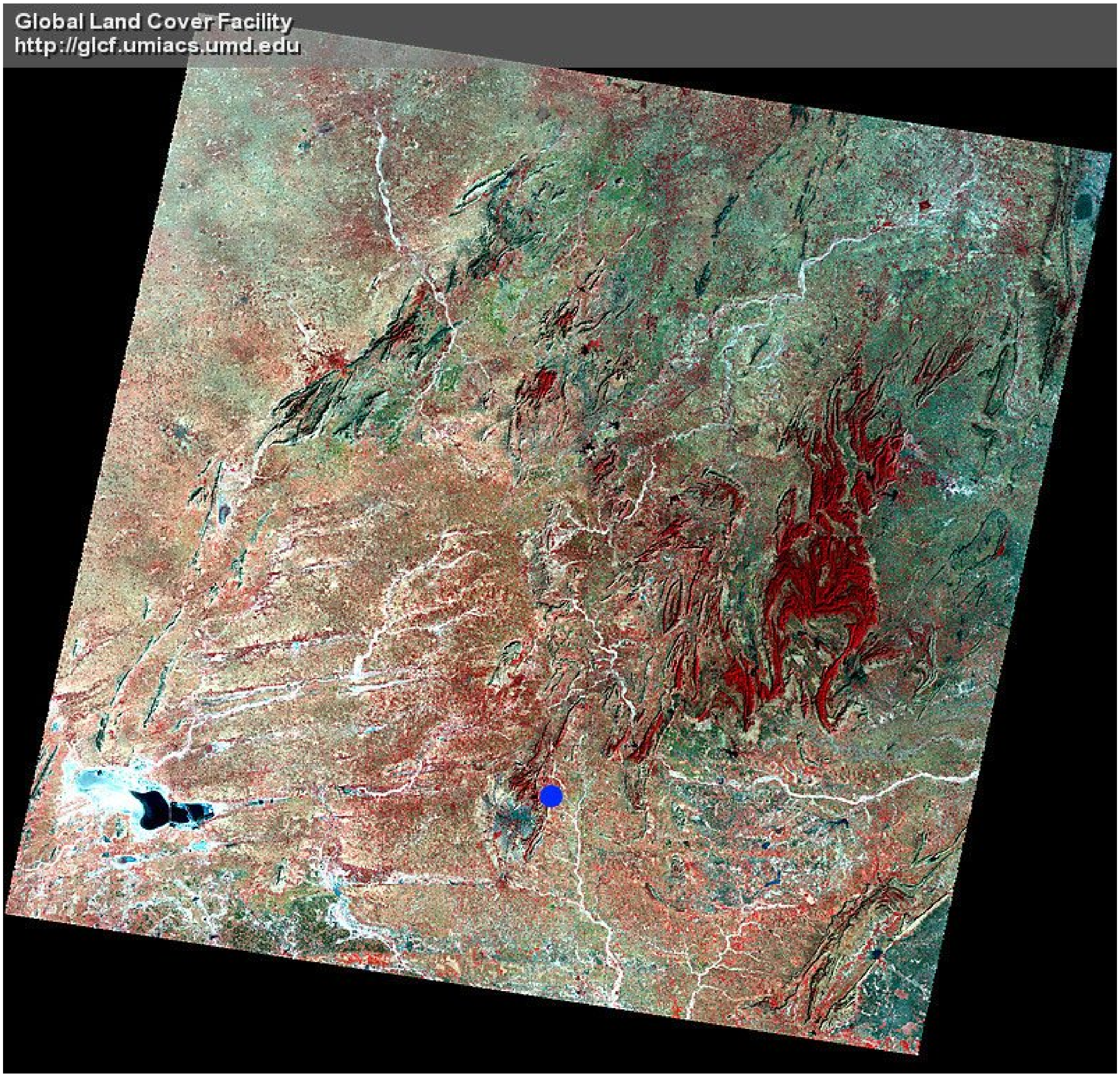


Fig. 2.4: Satellite Imagery of the area

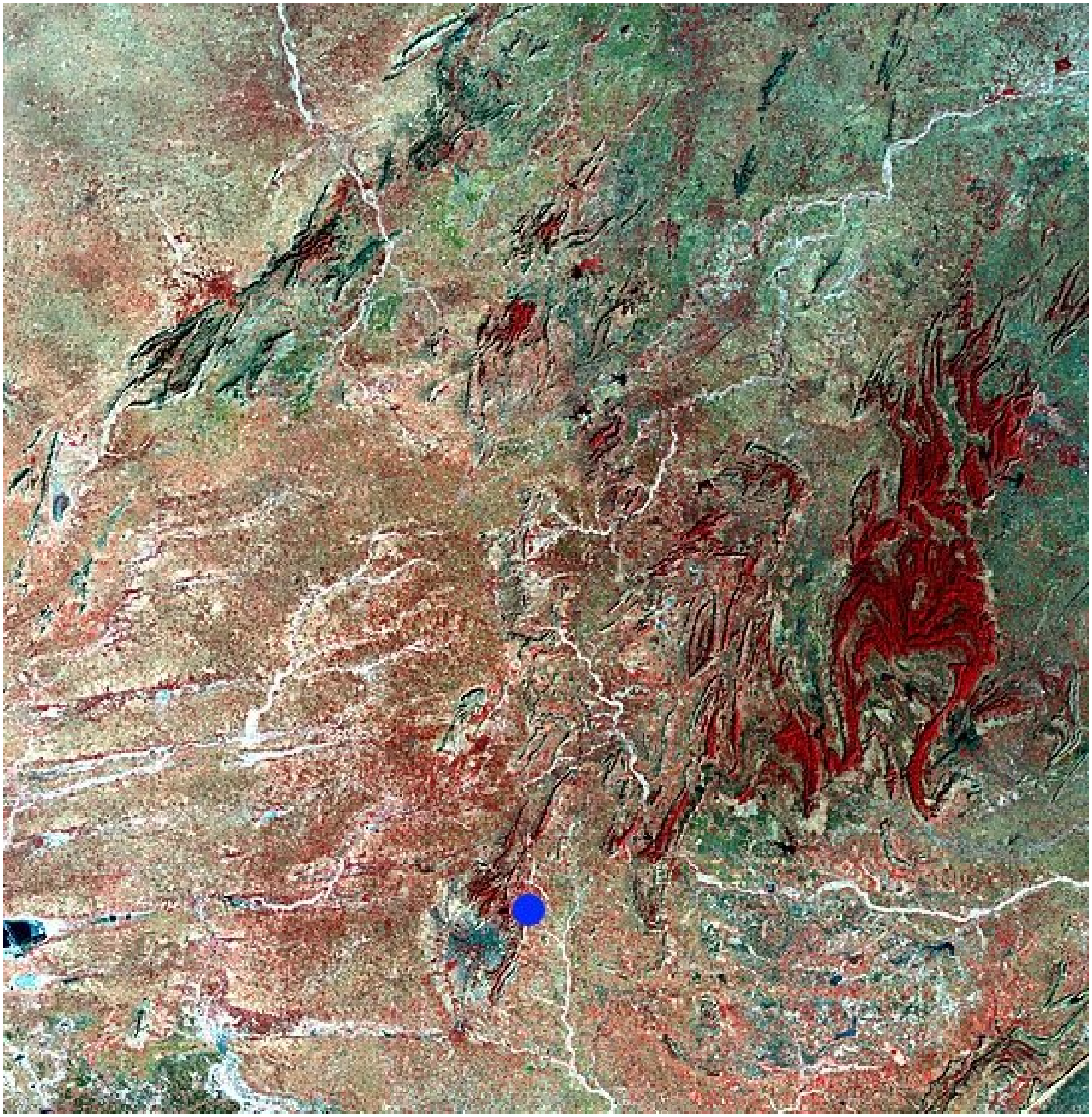


Fig. 2.5: FCC Image of the Jaipur area

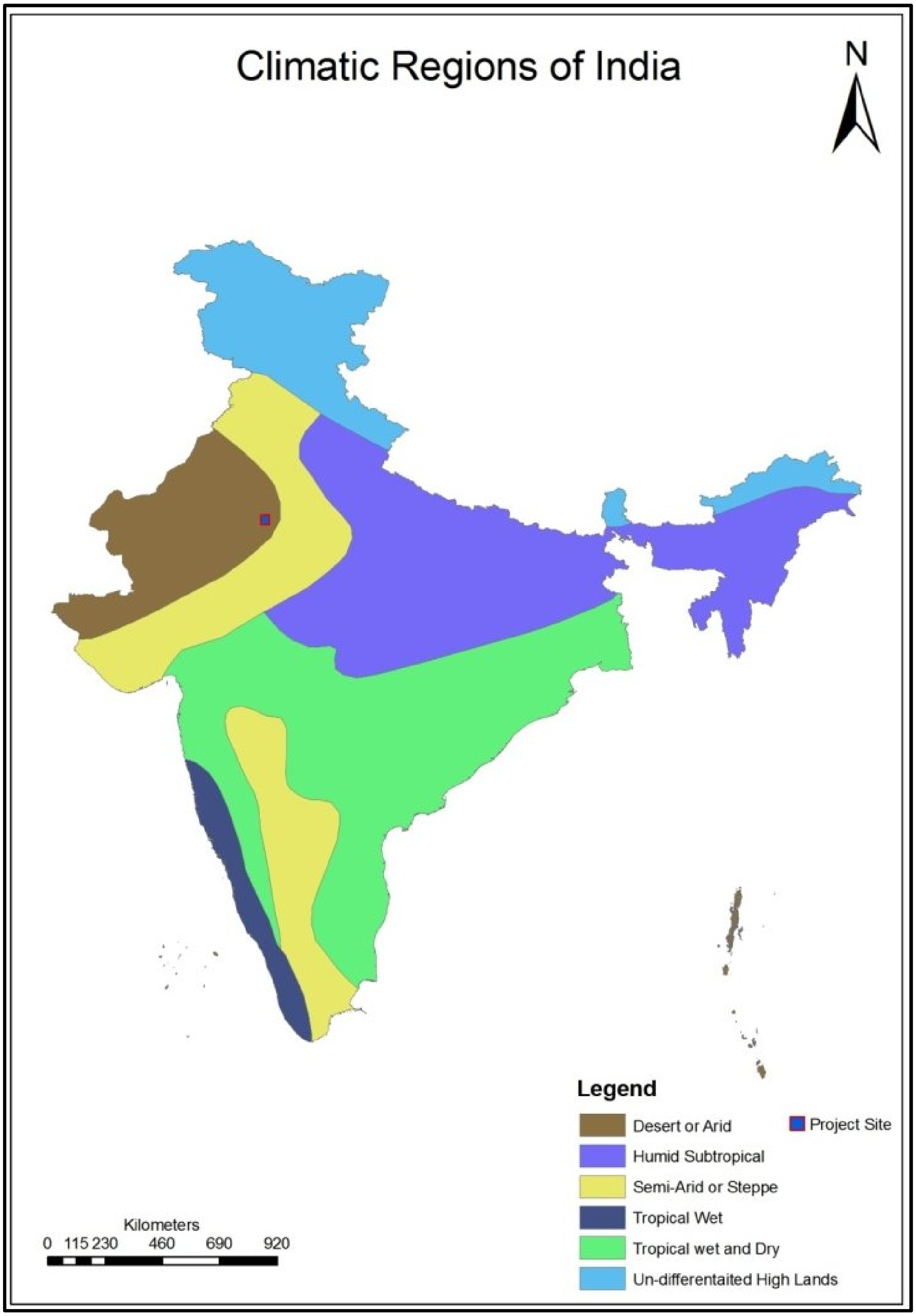


Fig: 3.1: Climatic Regions of India

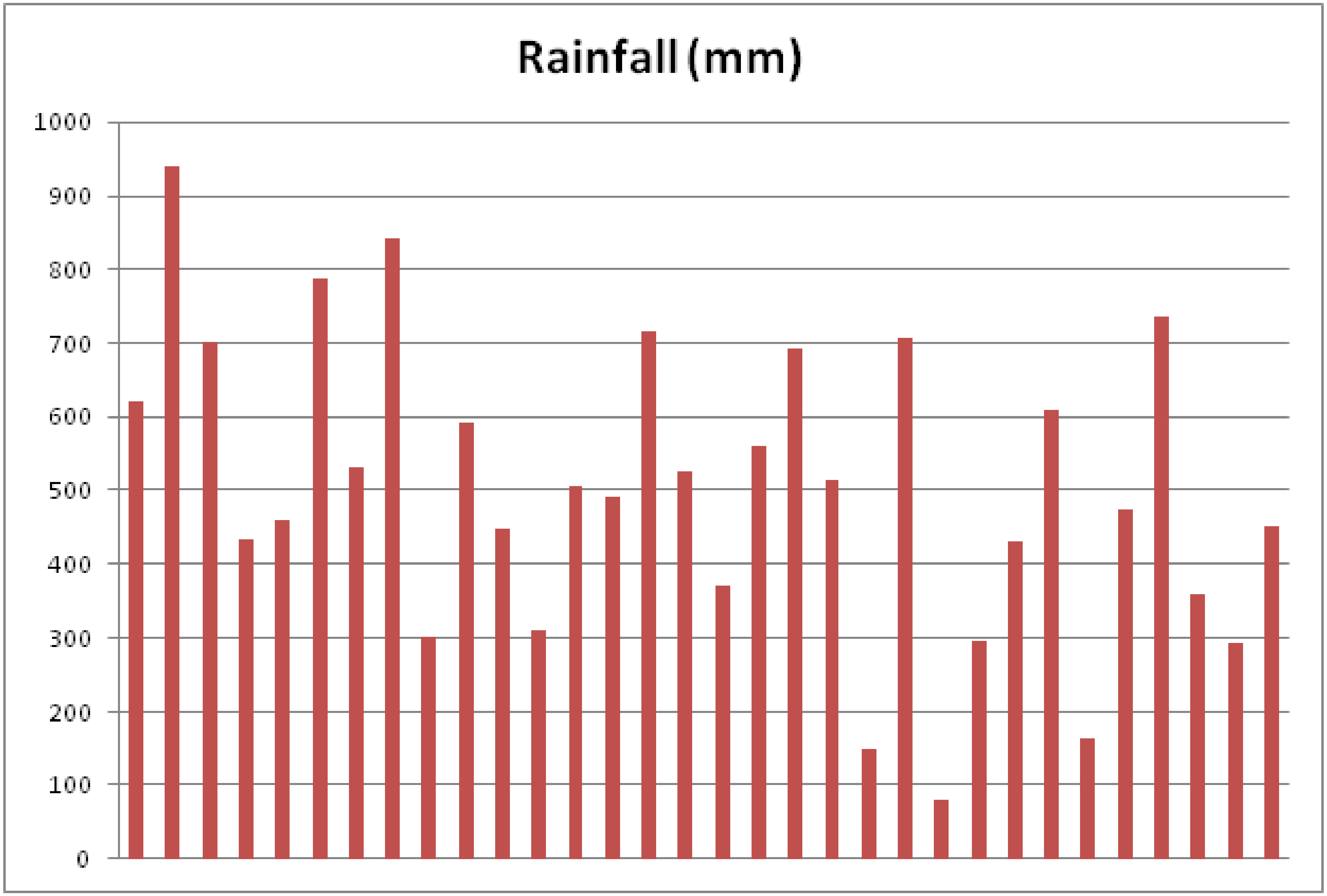


Fig. 3.2 Annual Rainfall variations of Years (1976 – 2007)

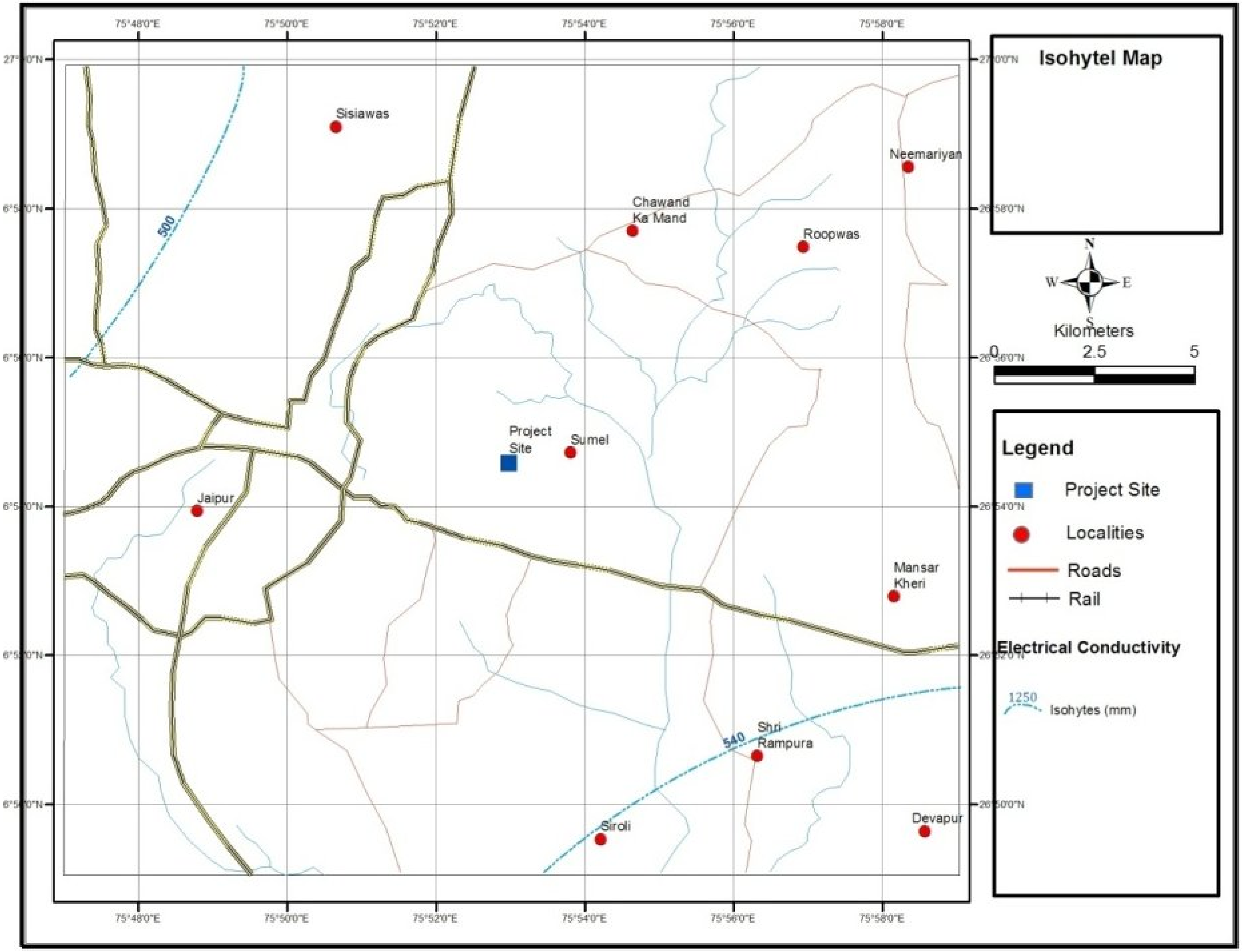


Fig.3.2. Isohyetal map of the study area

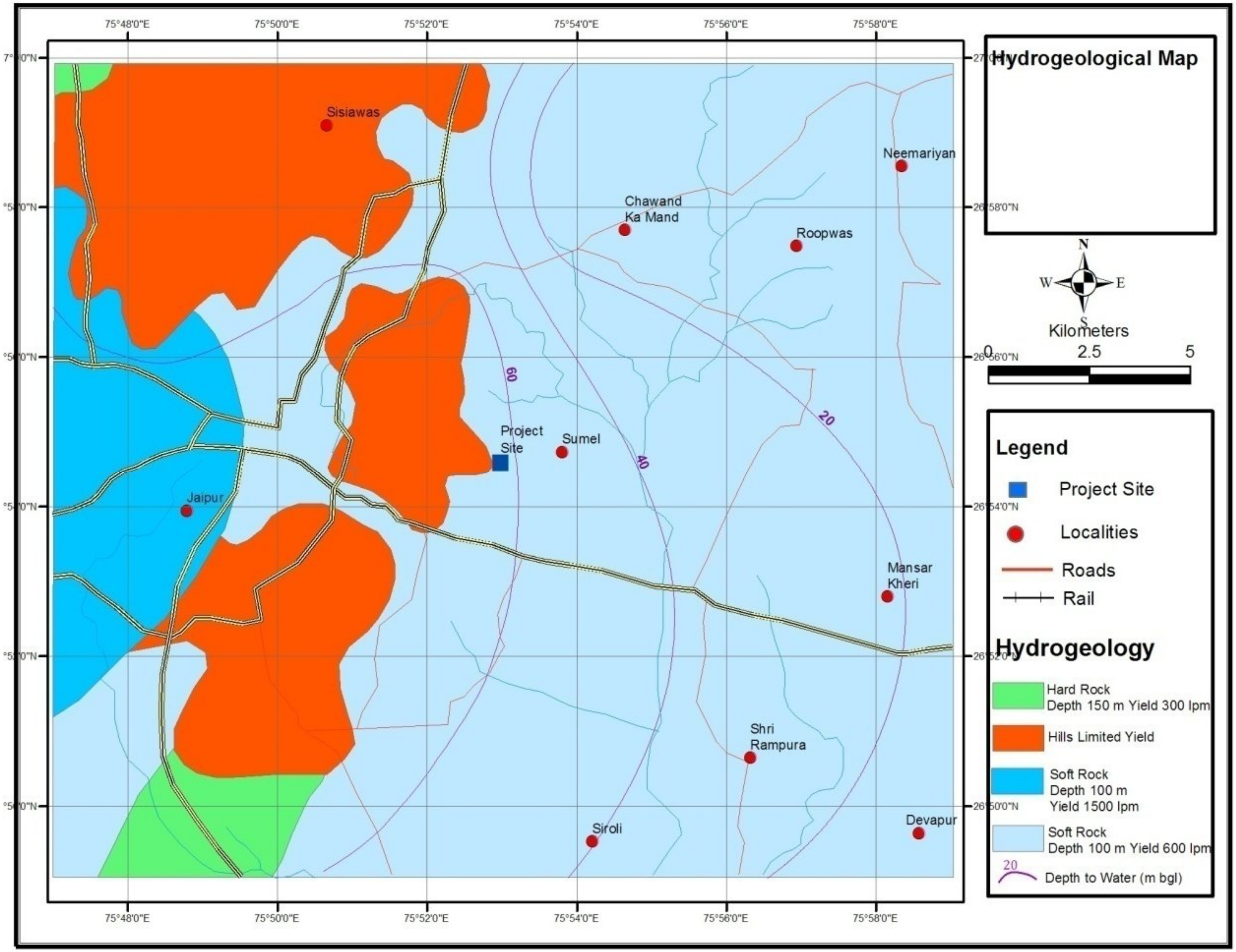


Fig. 4.1 : Hydrogeological map of the Study Area.

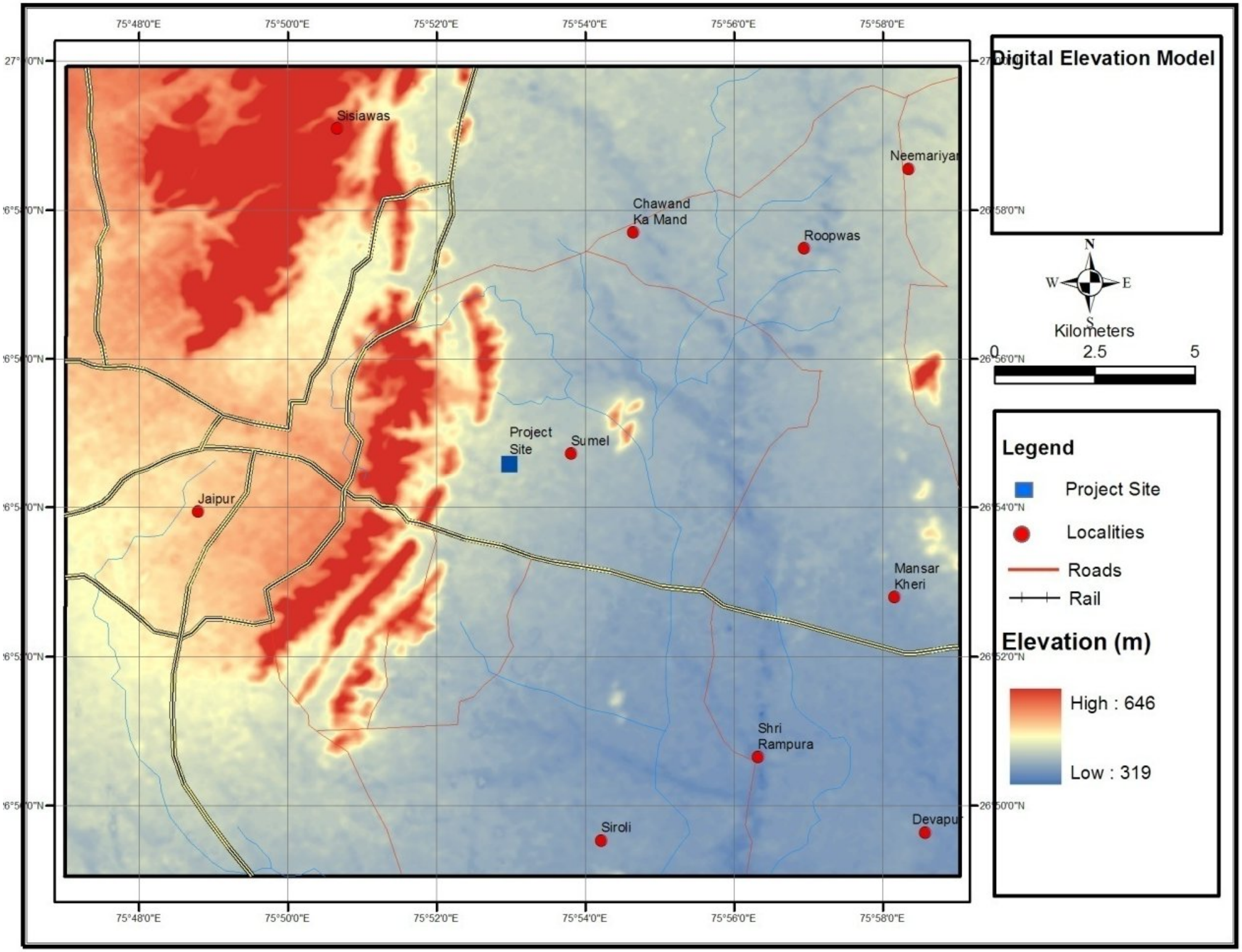


Fig. 4.2: Digital Elevation Model for the study area.

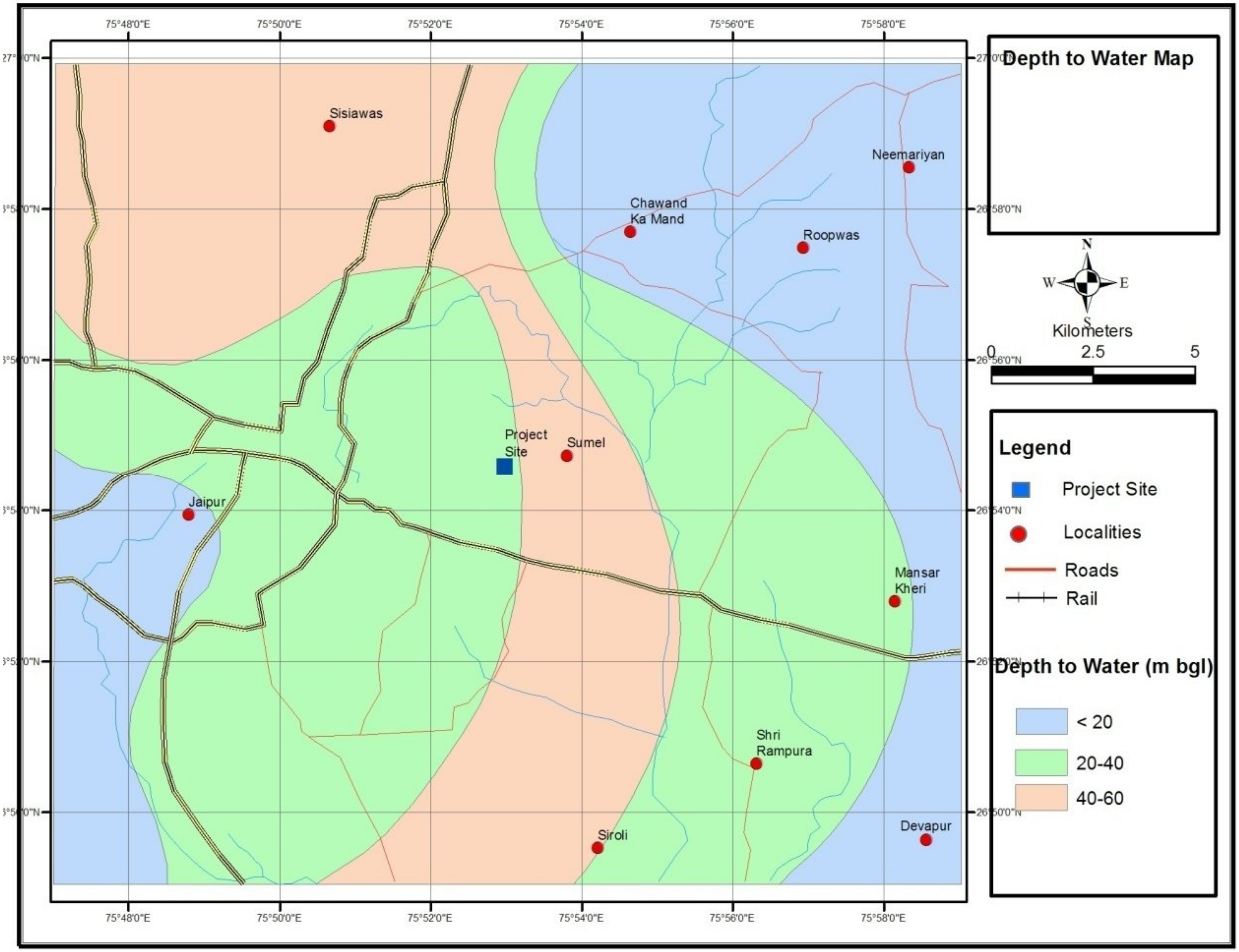


Fig.4.3 Depth to Water level map of the study area

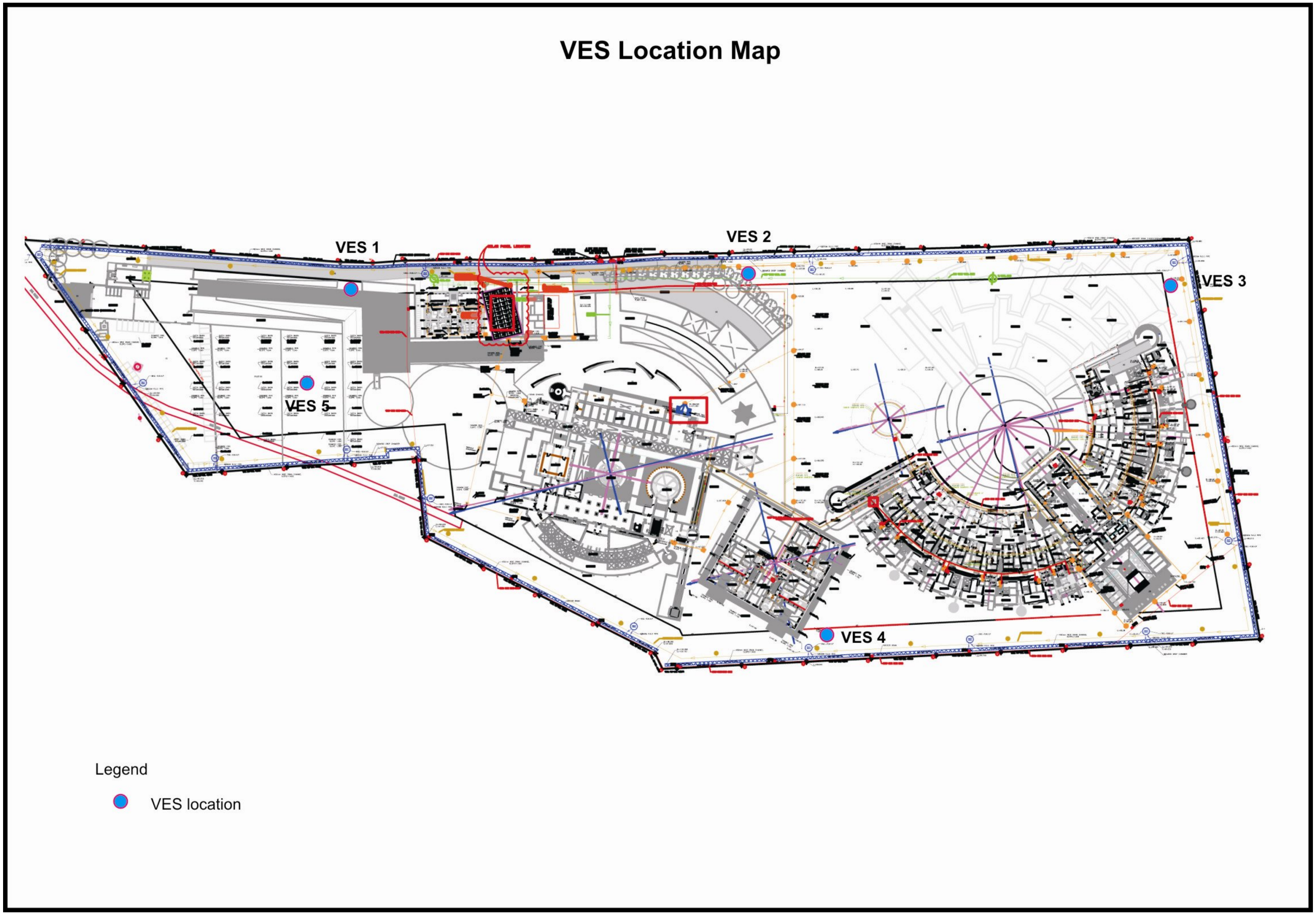
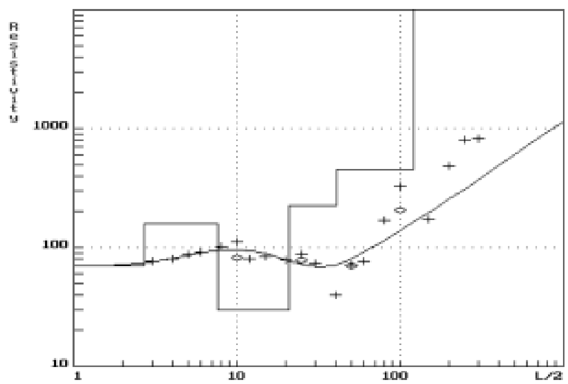
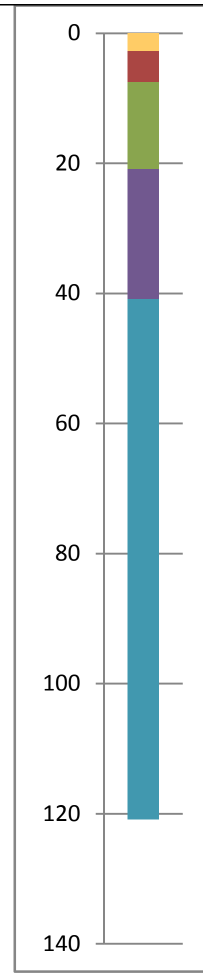


Fig. 6.1 : VES location map in the project area

Field Data	: Electrical Resistivity Sounding Measurements
Project Name	: Ground Water Investigation
Location	: Boutique Hotel Ballupura Jaipur
Type of data	: Schlumberger
VES Name	: VES1
Investigator	: Water Solutions, Delhi

AB/2(m)	ra(Ohm-m)
3	76.14
4	79.66
5	87.47
6	92.54
8	102.94
10	112.81
10	81.73
12	80.16
15	84.53
20	77.75
25	87.79
25	78.03
30	72.84
40	40.07
50	72.31
50	70.49
60	76.41
80	168.23
100	326.56
100	205.08
150	171.84
200	488.29
250	809.64
300	821.08



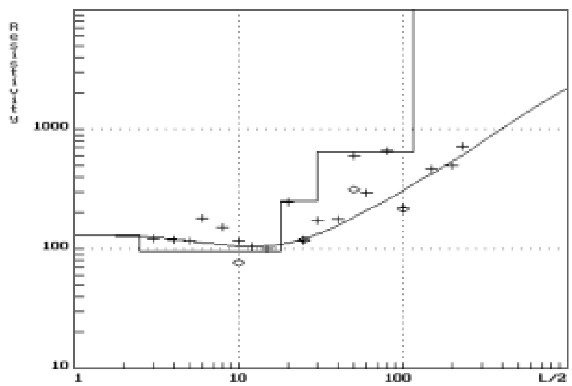


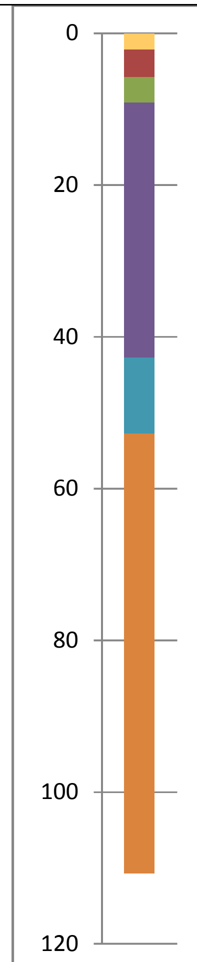
VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Ground water quality	Depth Range of Fractures
Ballu1	70	2.7	0.00-2.70	Surface moist soil with sandy silt	Fresh	50– 60
(AB/2=300m)	160	4.86	2.70-7.56	Dry fine grained sandy silt		80 – 90
	30	13.3	7.56-20.86	Moist fine grained sandy silt		105 – 120
	225	20	20.86-40.86	Dry weathered quartzite		
	450	80	40.86-120.86	Partially saturated fractured quartzite Compact quartzite		
	V. high	Continue *	120.86 - continued			

Fig 6.2: VES1 data, Graphs and Interpreted logs

Field Data : Electrical Resistivity Sounding Measurements
Project Name : Ground Water Investigation
Location : Boutique Hotel Ballupura Jaipur
Type of data : Schlumberger
VES Name : VES2
Investigator : Water Solutions, Delhi

AB/2(m)	ra(Ohm-m)
3	123.15
4	118.75
5	117.41
6	179.69
8	151.02
10	117.83
10	76.75
12	103.79
15	101.02
20	244.78
25	116.08
25	119.88
30	174.28
40	176.15
50	608.04
50	312.52
60	289.73
80	666
100	219.27
100	216.39
150	468.64
200	497.62
230	725.71



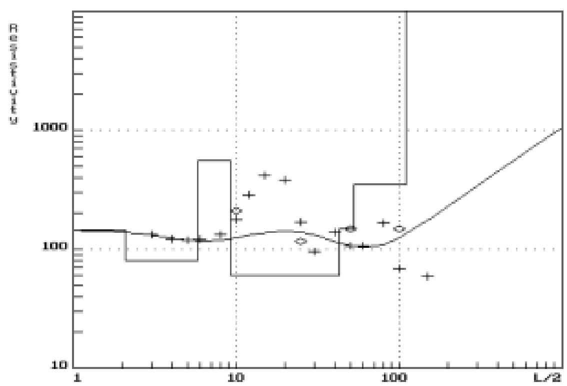


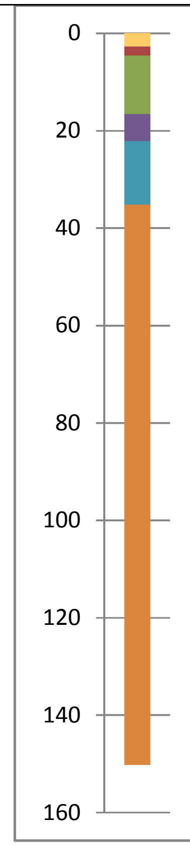
VES No.	True Resistivity	Thickness	Depth Range	Inferences	Ground water quality	Depth Range of Fractures
	(Ohm-m)	(m)	(m)			
Ballu 2	130	2.5	0.00-2.50	Surface soil with sandy silt	Fresh	30 – 40
(AB/2=230m)	95	15.5	2.50-18.00	Moist fine grained sandy silt		50 – 60
	250	12	18.00-30.00	Dry weathered quartzite		90 – 100
	650	85	30.00-115.00	Partially saturated fractured quartzite Compact quartzite		115 – 125
	V. high	Continue*	115.00 – continued			

Fig 6.3 : VES2 data, Graphs and Interpreted logs

Field Data	: Electrical Resistivity Sounding Measurements
Project Name	: Ground Water Investigation
Location	: Boutique Hotel Ballupura Jaipur
Type of data	: Schlumberger
VES Name	: VES3
Investigator	: Water Solutions, Delhi

AB/2(m)	ra(Ohm-m)
3	134.15
4	122.71
5	118.34
6	120.84
8	132.58
10	176.74
10	212.62
12	283.68
15	420.07
20	376.95
25	170.71
25	117.62
30	95.11
40	138.54
50	105.74
50	149.28
60	106.65
80	164.27
100	68.42
100	147.78
150	59.02



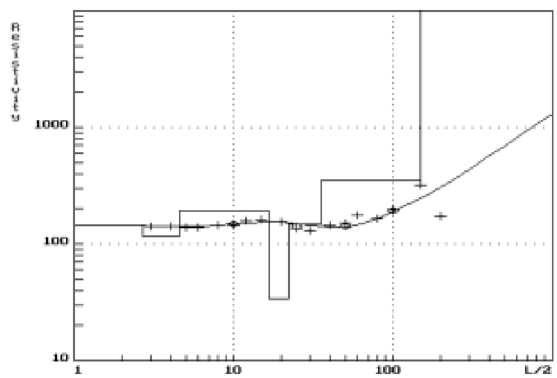


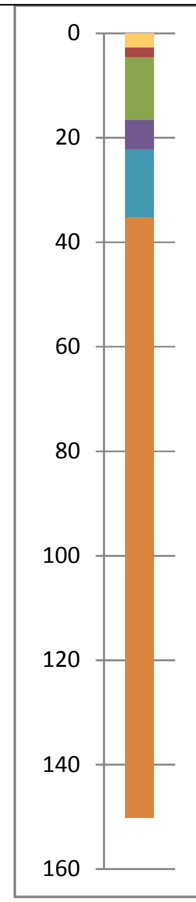
VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Ground water quality	Depth Range of Fractures
Ballu3	145	2.1	0.00-2.10	Surface soil with sandy silt	Fresh	55 – 65
(AB/2=150m)	80	3.67	2.10-5.77	Fine grained sandy silt		80 – 90
	550	3.4	5.77-9.17	Dry sandy silt with kankar		110 - 120
	60	33.58	9.17- 42.75	Moist fine grained sandy silt		
	150	10	42.75-52.75	Dry weathered quartzite		
	350	58	52.75- 110.75	Partially saturated fractured quartzite Compact quartzite		
	V. high	Continue*	110.75 – continued			

Fig 6.4: VES3 data, Graphs and Interpreted logs

Field Data	: Electrical Resistivity Sounding Measurements
Project Name	: Ground Water Investigation
Location	: Boutique Hotel Ballupura Jaipur
Type of data	: Schlumberger
VES Name	: VES4
Investigator	: Water Solutions, Delhi

AB/2(m)	ra(Ohm-m)
3	141.84
4	142.01
5	137.62
6	138.14
8	146.6
10	146.03
10	148.53
12	159.43
15	162.98
20	153.95
25	135.1
25	143.07
30	128.92
40	145.47
50	153.18
50	141.74
60	177.57
80	166.25
100	197.49
100	193.02
150	319.37
200	174.17



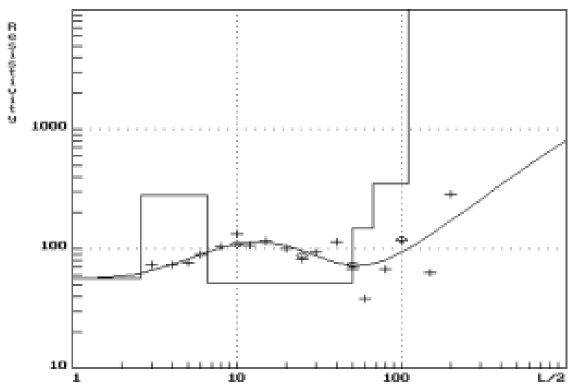


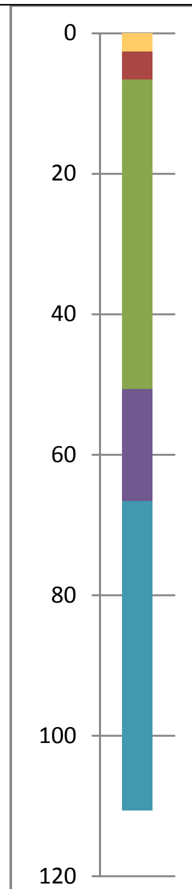
VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Groundwater quality	Depth Range of Fractures
Ballu 4	145	2.7	0.00-2.70	Surface soil with sandy silt	Fresh	40 – 50
(AB/2=200m)	116	1.89	2.70-4.59	Dry fine grained sandy silt		60 – 70
	195	12	4.59-16.59	Dry sandy silt with kankar		100 – 110
	34	5.6	16.59-22.19	Moist fine grained sandy silt		150 – 160
	150	13	22.19-35.19	Dry weathered quartzite		
	350	115	35.19-150.19	Partially saturated fractured quartzite Compact quartzite		
	V. high	Continue*	150.19 – continued			

Fig 6.5: VES4 data, Graphs and Interpreted logs

Field Data	: Electrical Resistivity Sounding Measurements
Project Name	: Ground Water Investigation
Location	: Boutique Hotel Ballupura Jaipur
Type of data	: Schlumberger
VES Name	: VES5
Investigator	: Water Solutions, Delhi

AB/2(m)	ra(Ohm-m)
3	73.67
4	73.27
5	77.53
6	89.96
8	105.35
10	132.87
10	110.08
12	107.98
15	117.68
20	99.52
25	81.94
25	87.08
30	92.63
40	113.8
50	67.64
50	74.27
60	37.93
80	67.29
100	116.63
100	119.13
150	62.48
200	289.24





VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Ground water quality	Depth Range of Fractures
Ballu 5	56	2.6	0.00-2.60	Surface moist soil with sandy silt	Fresh	50 – 60
(AB/2=200m)	280	4	2.60-6.60	Dry fine grained sandy silt		80 – 95
	52	44	6.60-50.60	Moist fine grained sandy silt		110 - 120
	125	16	50.60-66.60	Partially saturated weathered quartzite		
	350	44	66.60- 110.60	Partially saturated fractured quartzite Compact quartzite		
	V. high	Continue*	110.60 - continued			

Fig 6.6: VES5 data, Graphs and Interpreted logs

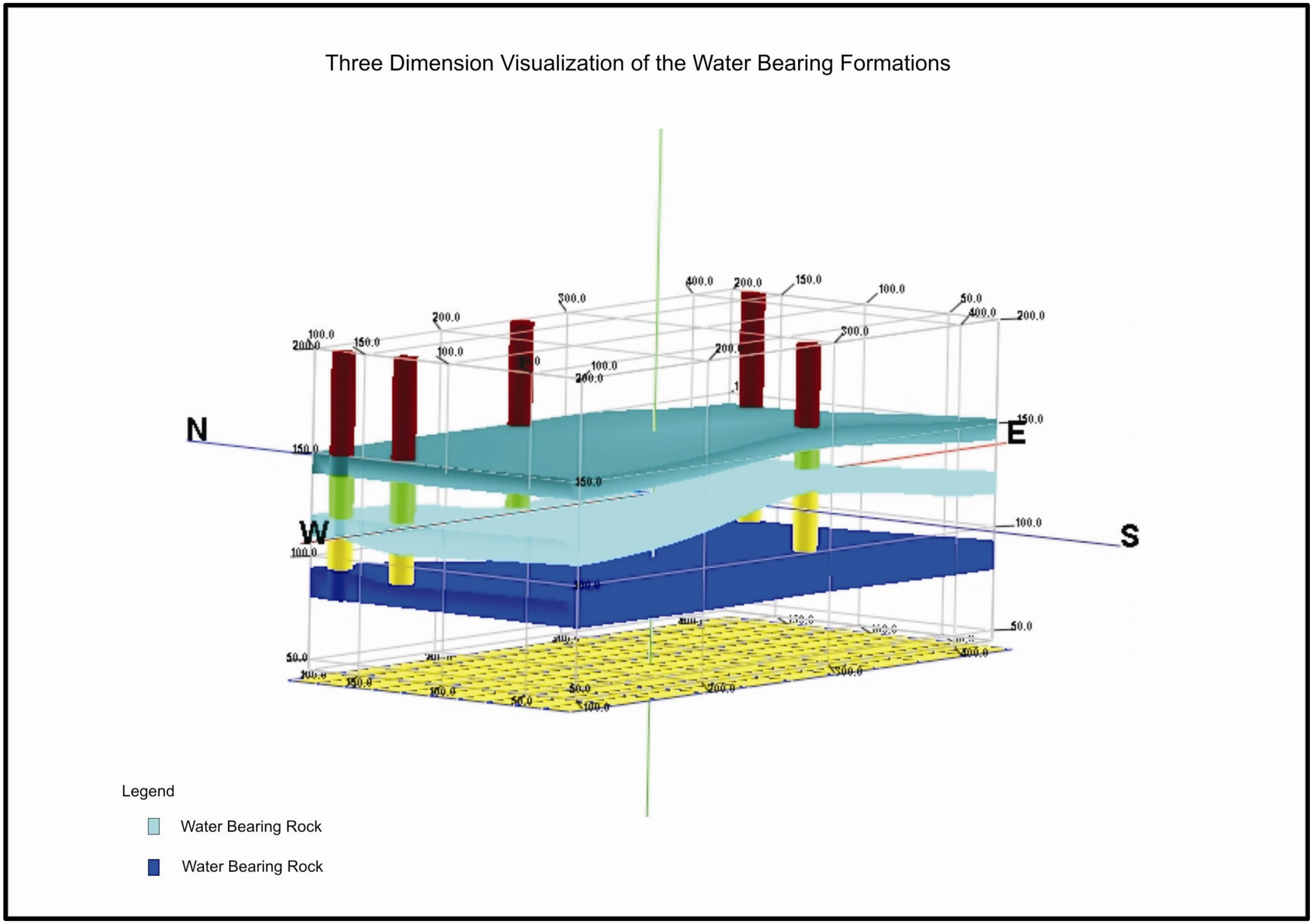


Fig. 6.7: 3D visualization of the VES data in the project area

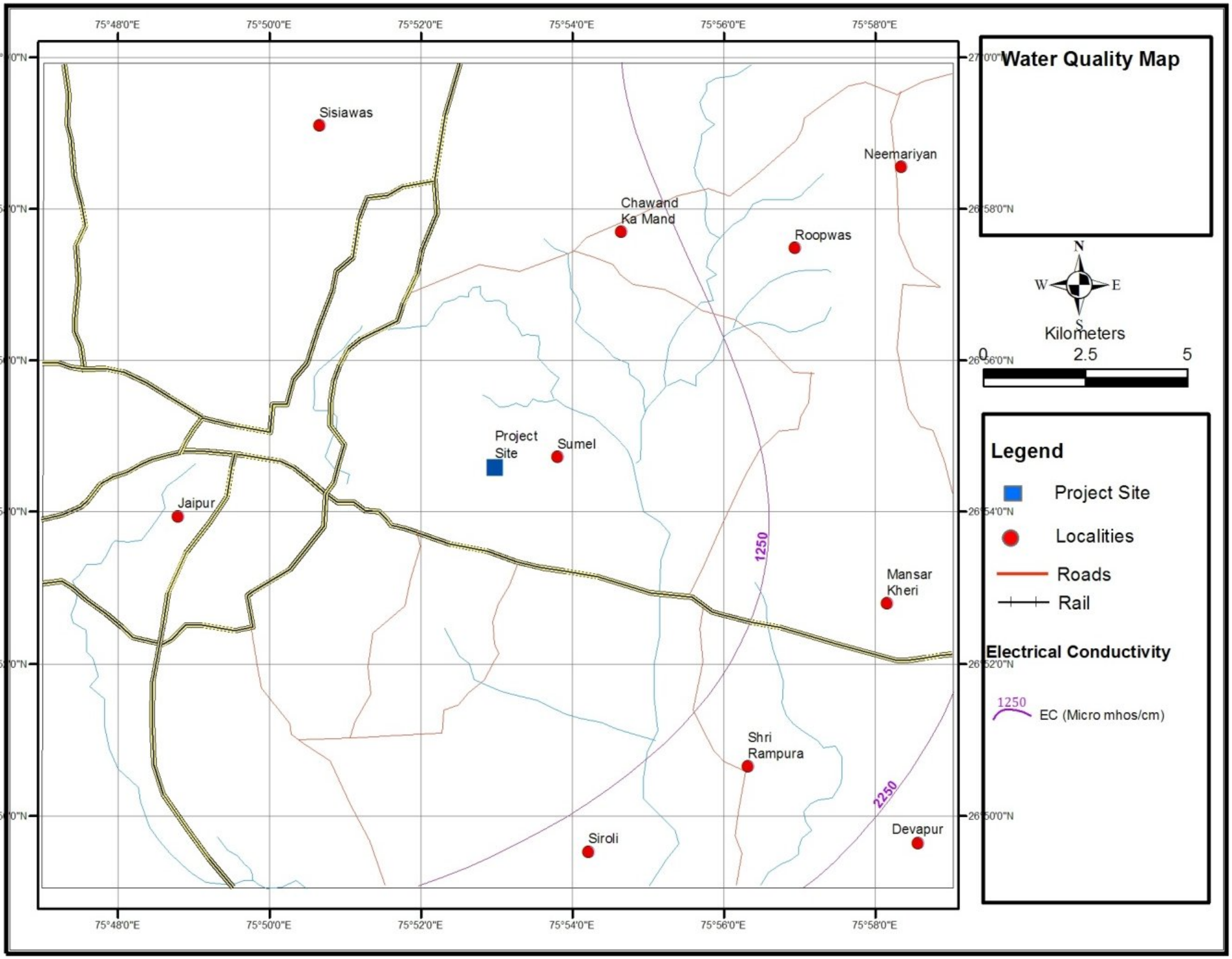


Fig. 7.1: Electrical Conductivity Map of the study area

Location of Proposed Tube Wells

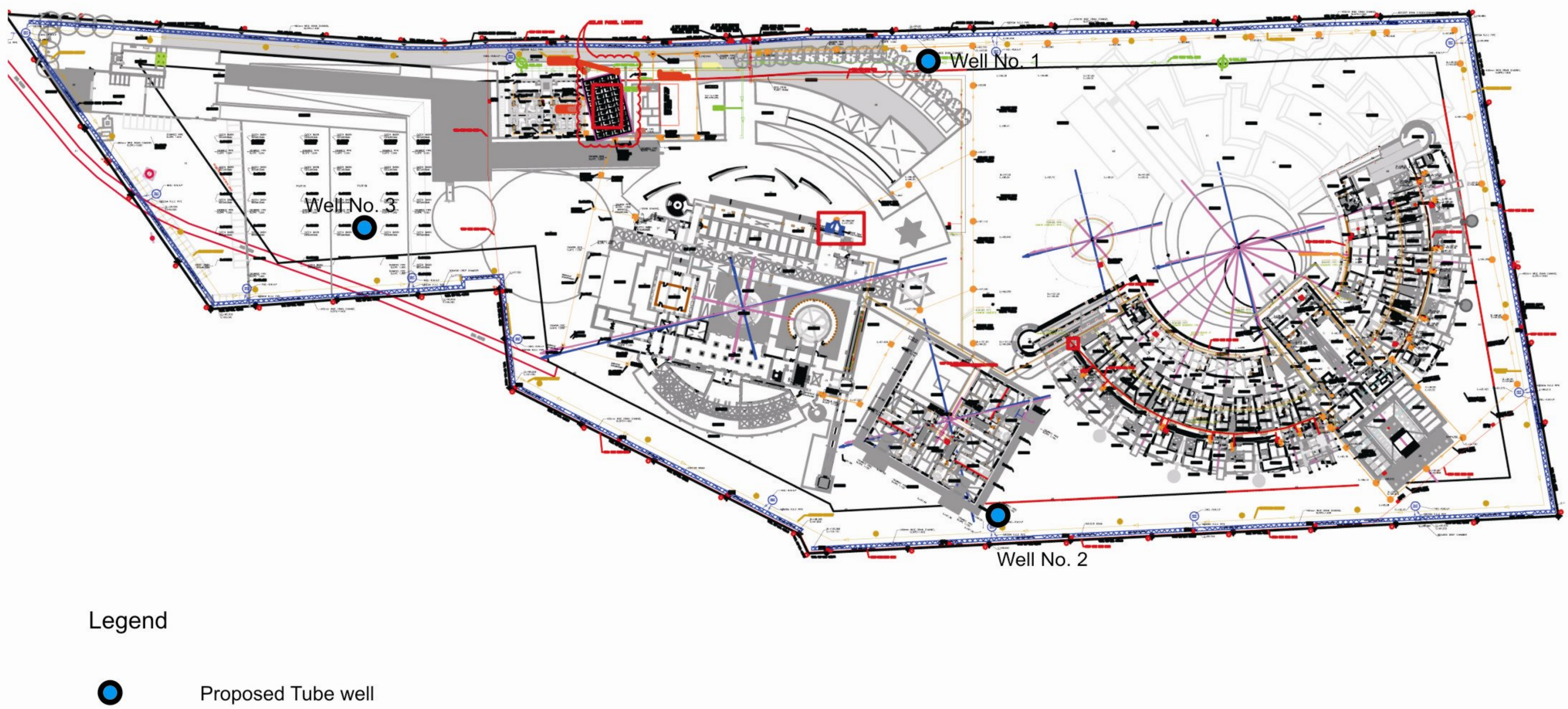


Fig. 8.1: **Location of Recommended Tube Well Sites**

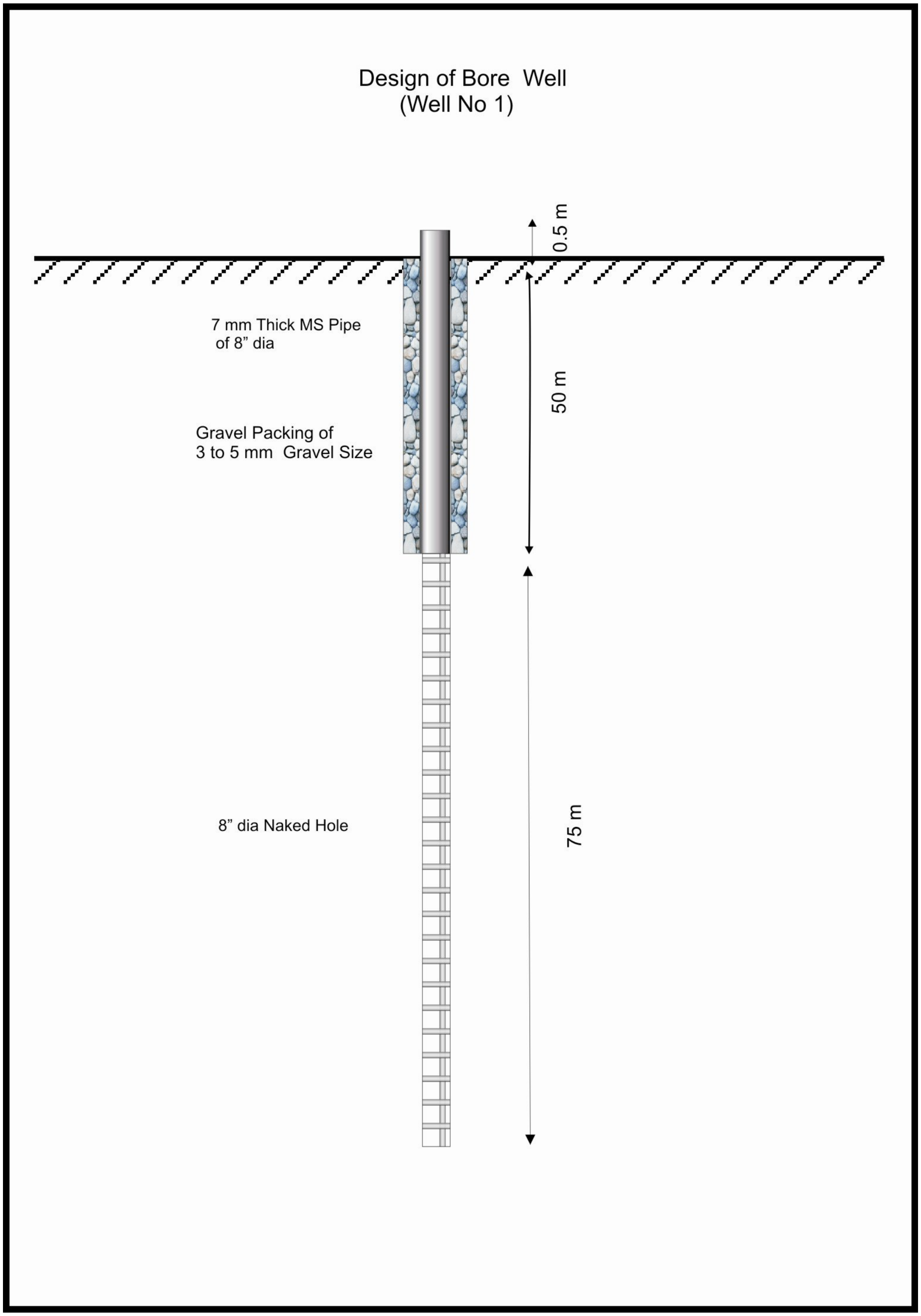


Fig. 8.2: Recommended Well Design for well no 1

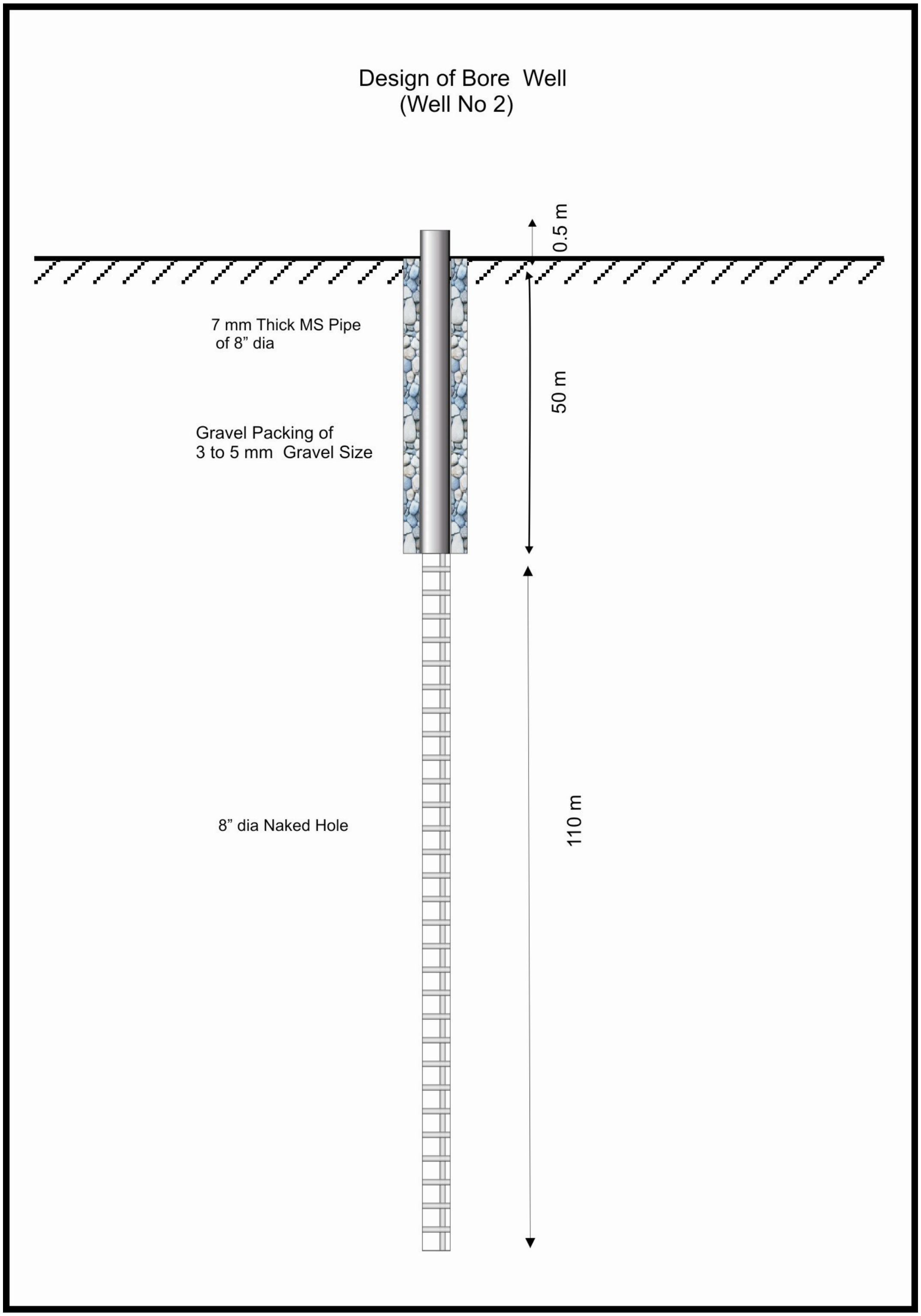


Fig. 8.3: Recommended Well Design for well no 2

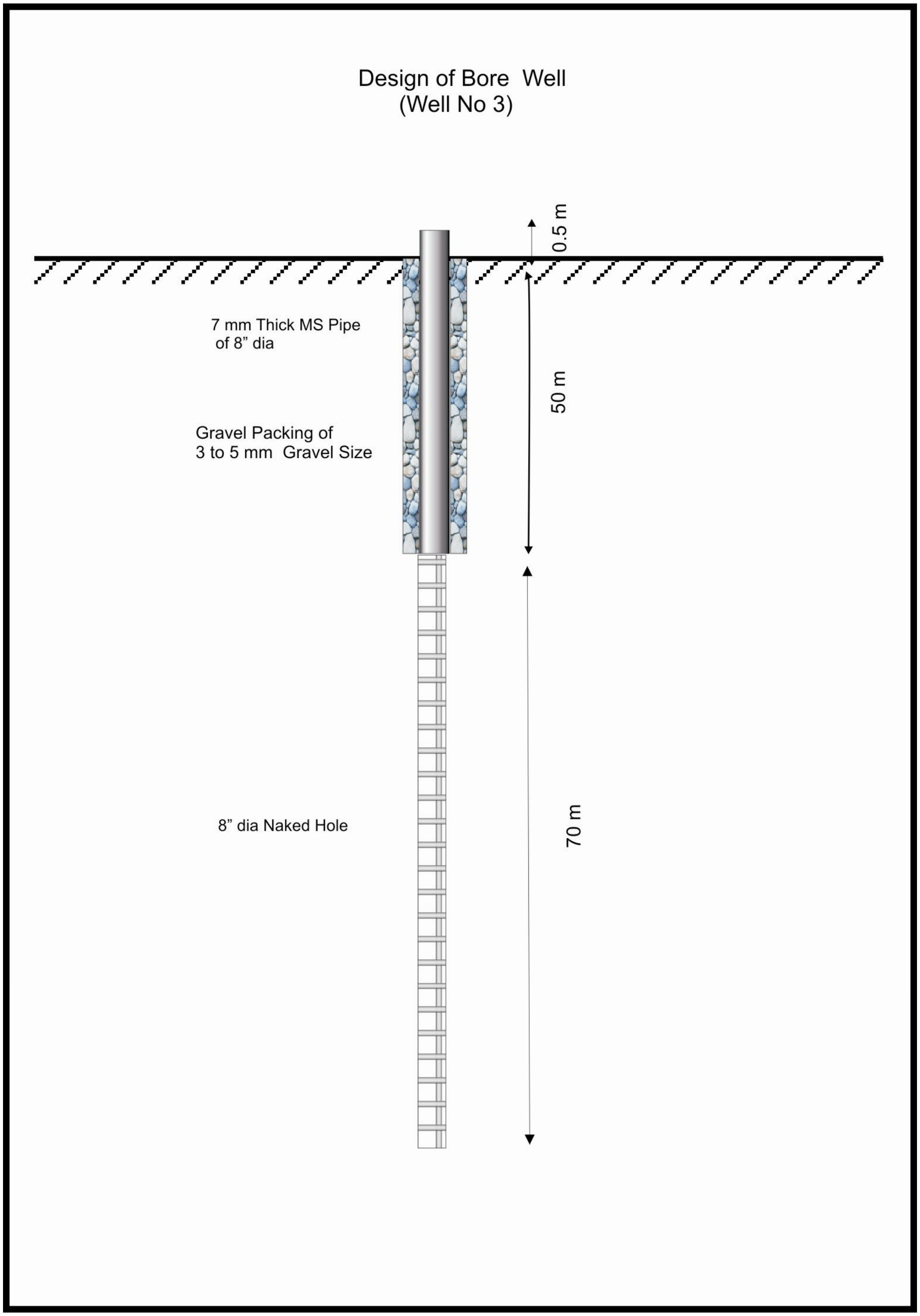
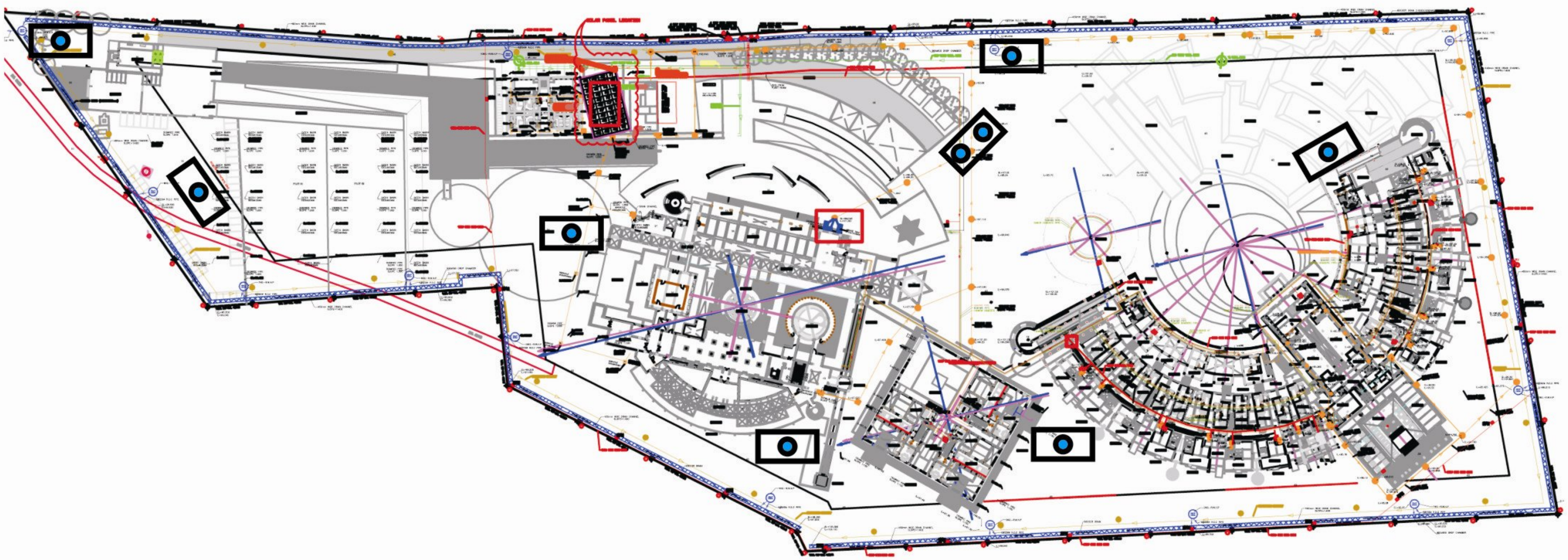


Fig. 8.4: Recommended Well Design for well no 3

Location of Artificial Recharge Structures



Legend

Single Bore Recharge Structure

Double Bore Recharge Structure

Fig. 9.1: Location of Proposed Recharge Structure

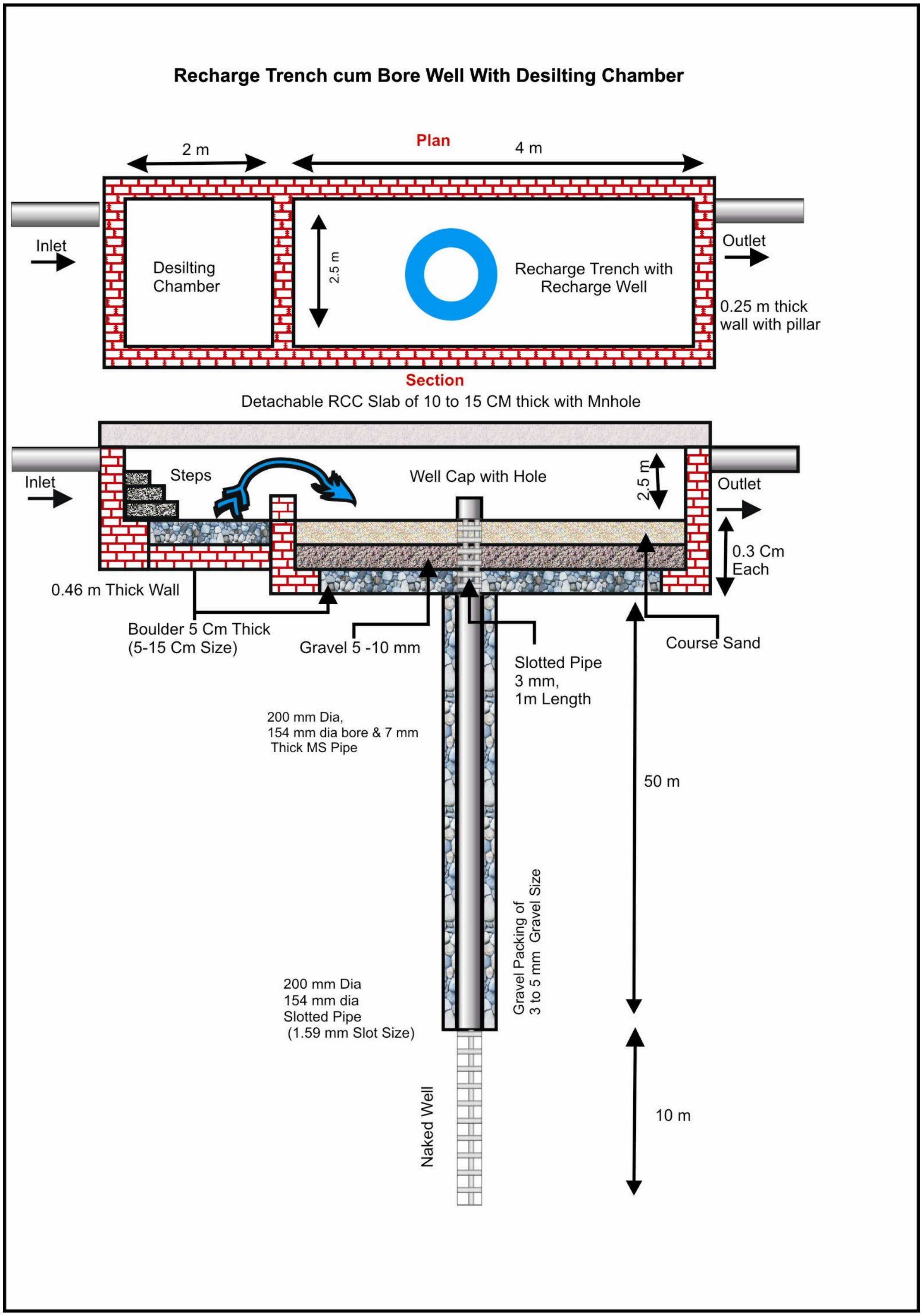


Fig. 9.2: Proposed Design of Artificial Recharge Structure (Single Bore)

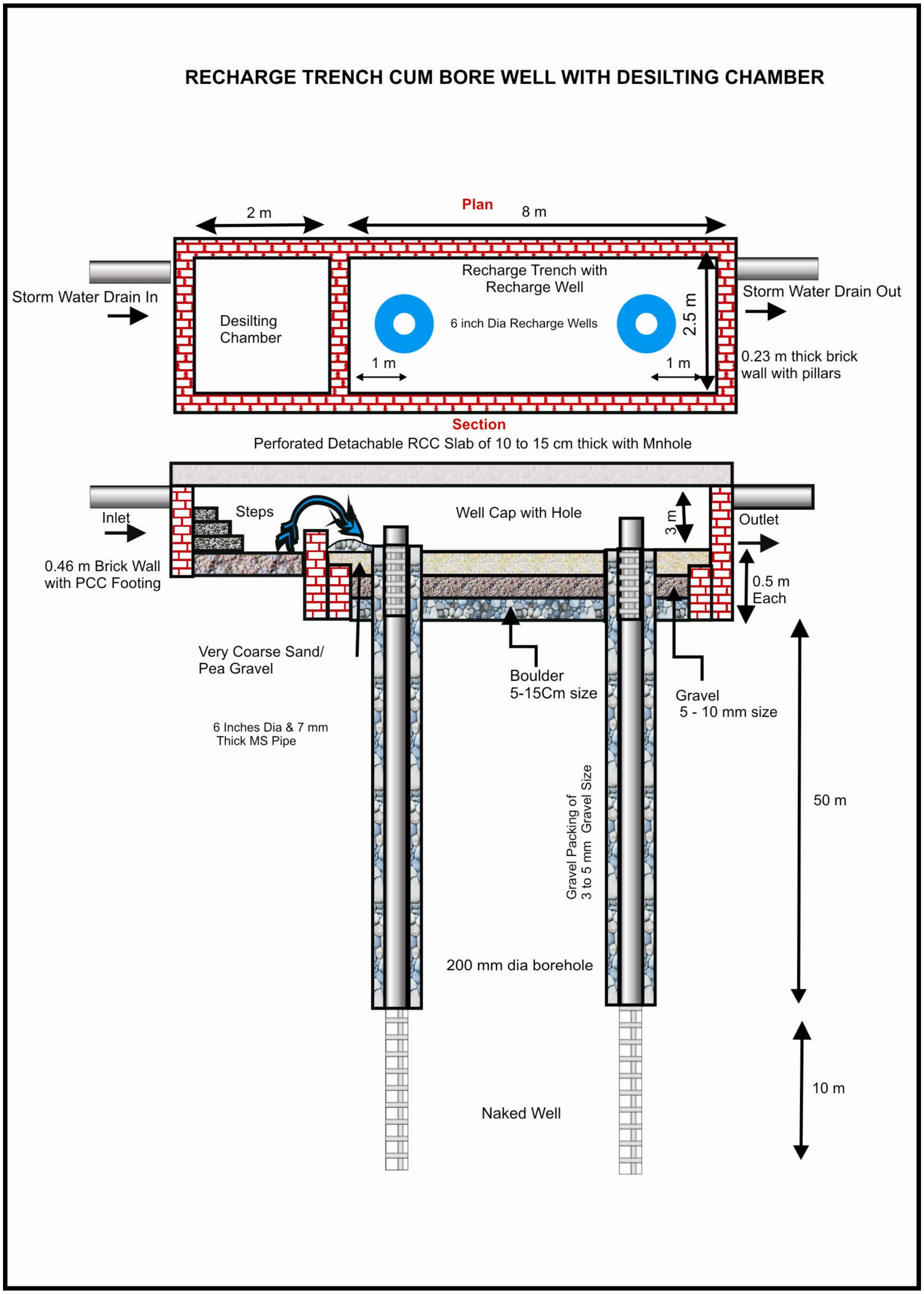


Fig. 9.3: Proposed Design of Artificial Recharge Structure (Double Bore)