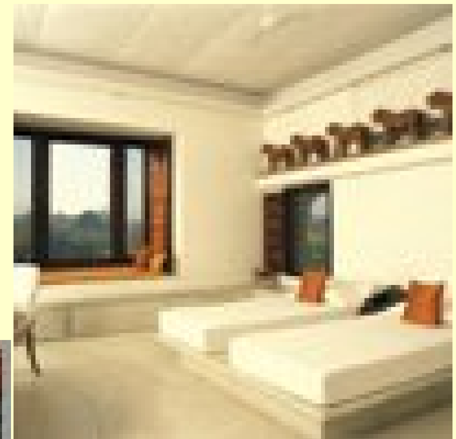
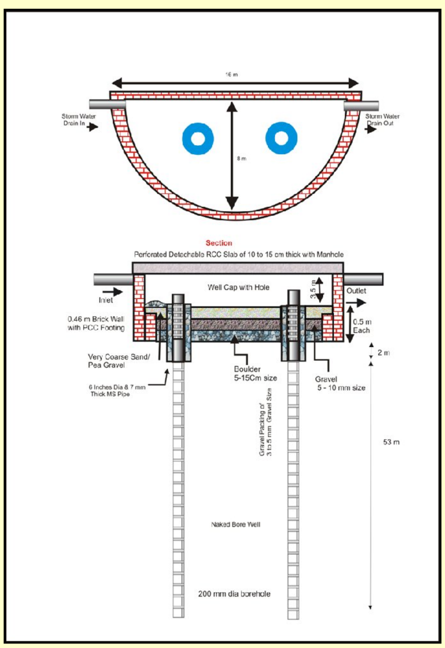
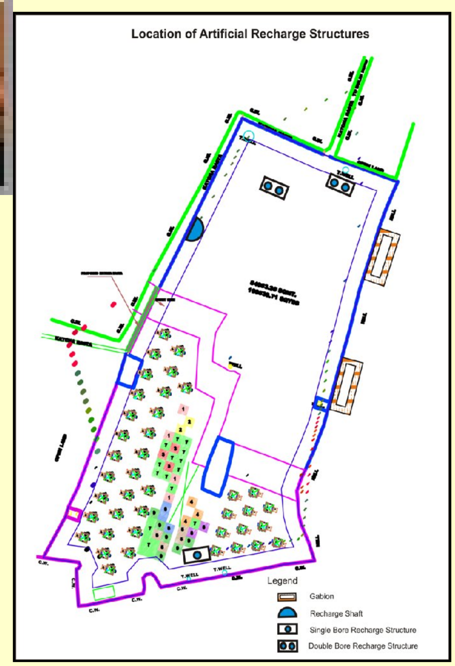
Ground Water & Artificial Recharge Investigations at Devi Rasa Boutique Hotel Site, Amer, Rajasthan







GREEN SYSTEMS

Architects of Sustainable Development

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Ground Water & Artificial Recharge Investigations at Devi Rasa Boutique Hotel Site, Amer, Rajasthan

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CHAPTER 1.0 INTRODUCTION

In the northern part of the country, the National Capital Region (NCR) as well as cities close to NCR such as Jaipur has seen phenomenal growth in population and infrastructure. To accommodate the growing population and industrialization the allied sectors has also expanded tremendously including housing, hotel Industries, Multiplexes etc. The Central and State Govt. have also supported the development process through incentives and various policies. The city of **Jaipur,** popularly known as **"Pink City"** has off late grown as one of the major economic hub and trade center of northern India. The city has the distinction of being one of the most popular historical townships of the country with numerous historical monuments and forts.

The population of Jaipur urban and its agglomerates has increased about 10 times in last six decades. The continuous migration of population from rural to urban areas has led to immense pressure on the natural resources of the urban areas. The city which was earlier confined within walled area has now expanded largely in the outskirt areas. Further, because of historical importance, the city of Jaipur invites number of national as well as international tourists from different parts of the globe. The economy of the town is broadly tourism based, which also provides enhanced opportunities in terms of employment for the local pageants. The growth in floating population and number of tourists in last few decades has enormously increased the requirement of accommodation in terms of Guest houses and Hotels of various kinds. In order to meet the growing requirements Hotel industries are fast picking up in the area and in this context M/s Boutique Hotels (P) Ltd has proposed to build Devi Rasa a multi-facility Hotel complex in Amer block, Jaipur.

The availability of natural resources including water is shrinking against the ever increasing demand. Ground water offers the major source of water supply for the entire city limits. With increasing population and industrialization, there is growing dependability on ground water. Its sustainable development without any adverse environmental impact is one of the major concerns for any development initiatives. In the present project there is a proposal of construction of a multi-facility Resort and in this context the work related to ground water investigation and detailed study of the area has been entrusted to M/s **Green Systems Pvt. Ltd, New Delhi** so as to suggest the most viable and scientifically based plan for ground water development and management for meeting the water demand of the project.

1.1 OBJECTIVE

The broad objectives of the study are:

- Assessment of the ground water availability and its development prospects to meet the water demand of the proposed plant.
- Recommend site specific ground water management plan including recharge to ground water on scientific basis to ensure sustainability of ground water sources.
- Recommend suitable well design for production wells and artificial recharge structures to ameliorate the adverse impact on the ground water regime.

1.2 SCOPE OF WORK

In order to achieve the desired objectives it is 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 using field as well as Remote Sensing data to support the hydrogeological investigations and assess the ground water conditions.
- Geophysical investigations through Vertical Electrical Sounding (VES) in the plot area to decipher subsurface lithology and disposition of the aquifer, locating suitable site for production wells and artificial recharge to ground water.

- 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 project area is situated in the sub urban agglomerate and located at a distance of about 11 km north of Jaipur city. The proposed site of the hotel is located in the east of NH-8 connecting Jaipur with Delhi near village Kunda on way to Nargarh Rescue Center and fall under Amer block of Jaipur district. The Jaipur city is spread over three administrative blocks viz. Sanganer (~ 46%) , Jothwara (42%) and Amer (12%). The hotel site is situated on the valley portion the hill range. 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 40600 sq.m.

The administrative map of Jaipur district showing the location of the proposed project site is given in **Fig.1.1.** The location of the project site on the Google image is 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.**

CHAPTER 2.0 GEO-MORPHOLOGICAL SET UP

The influence of geomorphic parameters on the occurrence and distribution of ground water is important to understand at regional as well as on local scale, in view of this an attempt has been made to study the regional geomorphic set up of Jaipur town with focus and detail pertaining to the study area using various field formation as well as data from remote sensing. The images were visually interpreted to group different landform and geomorphic units existing in the area and to understand the process of their evolution and relation with other parameters which control the occurrence and movement of ground water, such as Lithology / Rock type, Structure Land use/Land-cover, drainage density etc. various geomorphic units have been identified using satellite imagery in conjunction with the existing maps and literature, and different overlays were prepared.

2.1 GEOMORPHOLOGY

The city area is characterized by a wide variety of geomorphic features like sandy plains, hills and Intermountain valleys, pediments etc. Major part of the city area is occupied by the alluvial sandy plains which are dissected at places and dotted with hills. In the northern and eastern parts of the city, the Aravali hills are seen trending NE-SW and occasionally alternating with intermountain valleys. Typical of Aravali, 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. 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 sub urban area close to Amer and lies in the north eastern part of the city and located in the valley portion between 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.** In the study area broadly two distinct geomorphic unit can be seen, the structural hills and alluvium with a transition pediment zone**.** Generally these zone acts as recharge area, hence a little training of the existing drain originating from the area may enhance the entire recharge process and may give positive impact on the ground water conditions of the area.

2.2 PHYSIOGRAPHY AND DRAINAGE

Though the study area represents topographical variations, there is devoid of exclusive drainage system in the area. The prevailing arid conditions added with deficient rain and high evaporation has restricted development of natural river drainage system in the Jaipur city area. There are small seasonal streamlets, nallahs, generally 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 paleo-channels in the area.

2.2 REMOTE SENSING AND GIS STUDIES

The traditional use of remotely sensed image interpretation lies in the qualitative characterization of hydrogeological mapping units and the detection of specific features. Most applications pertain to crystalline basements, quartzites, limestone and Quaternary volcanic terrain. 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.

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.

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 field generated data so as to generate 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 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 the first category includes features which are directly related to ground-water occurrence such as springs, canals, lakes, ponds, and other surface water features. The second category includes hydrogeological parameters that may reflect the ground-water regime, such as drainage characteristics, fracture systems, geological structure, and landform characteristics.

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 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.

The various scenes of IRS satellite images of the study area has been used using different filters to enhance the features as shown in **Fig. 2.2 and 2.3** respectively and finally combined to generate the Digital Elevation Model of the area, which is shown in **Fig. 2.4.** 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. The altitudes have been indicated using the colour codes, the brownish colour with varying shades broadly indicates the hill areas and the yellowish color is alluvial plains, the green color indicates paleo-channels or high 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 desert –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 Observatory (Source : IMD)

Years	Annual Rainfall (mm)
76	622
1977	940.8
978	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
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
	503.25

CHAPTER 4.0 GEOLOGY AND HYDROGEOLOGY

4.1 GEOLOGY

Major part of the city area is covered by a thick mass of Quaternary deposits underlain by sequence of Alwar group (Delhi Super-group) of rocks. Delhi group of rock mostly consists of quartzites. The oldest rocks of the area below the quartzites belong to Bhilwara Super group comprise mainly gneisses and schist's etc. of Achaean age. 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. 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 thin layer of Quaternary alluvium underlain by 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 occupying the major part of the study area and forms the top phreatic aquifer, the potential of these aquifer depends upon the thickness which varies spatially in different parts of the area. The project area is located almost in the valley portion and hence the piedmont type deposits in the form of overburden of scree material are common. The overburden broadly consists of silt, clay with kankar, sand, gravel and pebble beds. The thickness of alluvial overburden ranges from 4 to 8 m bgl in the project 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. However the thickness of alluvium in the project area appears to be very less, may be to the tune of 5 to 15 m, in order to decipher the alluvium thickness as well as depth of basement, the Electrical Resistivity survey has been conducted, the results of which are discussed in subsequent chapters.

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 hills occasionally 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 500 meters. It forms potential aquifer along the foot hills. The thickness of Talus and scree vary from 4 m to 55 m. Groundwater occurs under semi confined to confined conditions.

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 indicated as soft rocks in the map, except in the central and 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 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. The project area lies in the transition zone of alluvium and hilly area, with a thin alluvium layer underlain by hard rock . Weathered quartzites constitute low potential aquifer zones. Tube wells tapping fractured 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. The recommended depth of well in this area is about 150 to 180 m so as to tap sufficient thickness of fractured zone and the expected yield of the well is to the tune of 6 to 7m^3/hr.

4.3 GROUND WATER REGIME

Depth to water table varies from less than 20 m in the eastern p[art of the study area to about 60 m bgl and depth to water level is increases from east to west. Around the project area the depth to water level is 50 m bgl. 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.

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 (m amsl) 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. The depth to water level map of the study area is shown in **Fig. 4.2.**

CHAPTER 5.0 GROUND WATER RESOURCES

Quantitative assessment of ground water resources available in time and space is one of the important aspect of planning and management of ground water. Further, it is an important input for deciding the quantum of ground water withdrawal. Though, the availability of ground water in space is dynamic in nature and depends upon the input and outputs to the system, it provides an overall availability. The entire city of Jaipur including the project area is one of the stressed areas, the population 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 adopt alternative sources to meet the ever increasing demand of water and resorting to suitable augmentation measures including roof top rain water harvesting.

5.1. GROUND WATER AVAILABILITY VIS-A-VIS DEVELOPMENT

Central Ground Water Board jointly with the State agency has 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".

The city area is conglomeration of parts of three administrative blocks viz. Amer, Jhotwara and Sanganer, since the project area is a part of Amer block, the ground water resources and draft for the blocks is given in **Table 5.1.** As such the entire block is overexploited and needs strategic planning for further development. In this context it is opined that the estimates as shown in the table refers to dynamic ground water resources available in the zone of fluctuation in the top unconfined aquifer , mostly made up of quaternary alluvium and or highly weathered quartzite's restricted up to a depth of about 50 mbgl. Due to high withdrawal in the area the water level has gone much deeper and the 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 and this zone is presently being tapped for sustainability. The subsurface exploration carried out in the area indicates two water bearing fractures at deeper zones, at a depth of 60 to 80 m and below 150 m. The fracture zone at both the depths seems to be productive and may be tapped suitably.

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

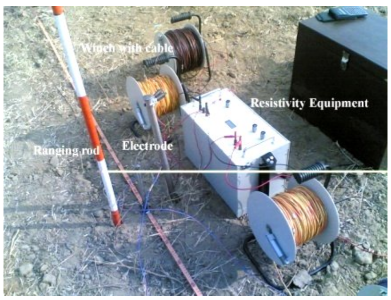
Sl. No.	Assessment Unit of District	Net Annual Ground water Availability (HaM)	Existing Gross Groundwater Draft for All uses (HaM)	Net Groundwater Availability for future irrigation development (HaM)	Stage of Groundwater Development (%)
1	Amer	6293	12028	-7108	191

(Source: CGWB)

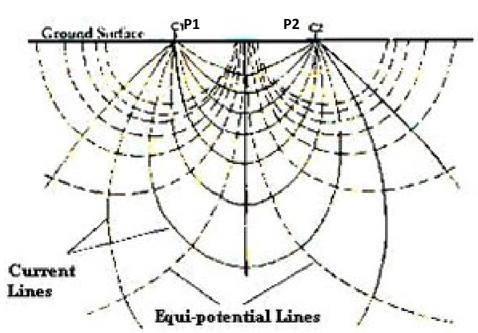
CHAPTER 6.0 GEOPHYSICAL INVESTIGATIONS

6.1 ELECTRICAL RESISTIVITY SOUNDING

UNDERLYING PRINCIPLE IN ELECTRICAL RESISTIVITY MEASUREMENTS



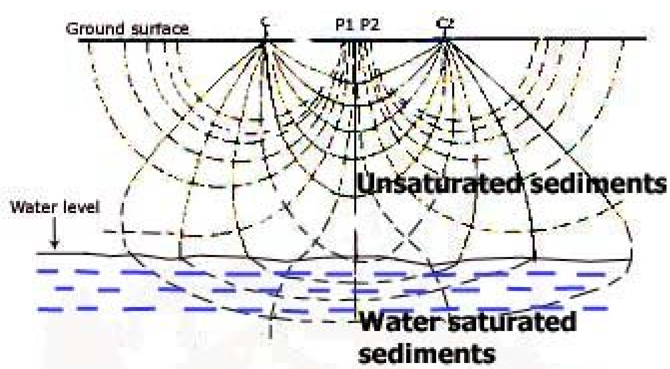
The electrical resistivity equipment used and shown here for the purpose was ANVIC make CRM 500.This instrument has sensitivity to measure potential difference in micro volt accuracy and is equipped with microprocessor based stacking facility (64 stacks) to enhance the signal to noise ratio by averaging 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 $1/5^{th}$ of the current electrode spacing ($MN \leq 1/5AB$).The geometric factor 'K' for Schlumberger configuration is

$$= \quad — + — \quad (— - —)/$$

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 campus, Amer. 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 280 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 3 mbgl to 8mbgl.

Current electrode separation is 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 been encountered from 3 to 8 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 suitable 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.

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

Electrical Resistivity Range in ohm m	Groundwater quality	Inferred litho logy
		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. This is mainly inferred based on the field experience and interpretations with help of computer operated software programmes and manual master curves. 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.

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**. 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. 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 RASA Resort at Amer, Jaipur project. 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 90 to 200 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
Amer1 (AB/2=300m)	100	2.70	0.00-2.70	Surface soil with sandy silt	Fresh	15- 20
	38	5.24	2.70-7.94	Moist fine grained sandy silt		50 – 60
	282	4.58	7.94-12.52	Dry weathered quartzite		60 – 80
	V. high	3.00	12.52-15.52	Compact quartzite		150 – 170
	800	5.00	15.52-20.52	Partially saturated fractured quartzite		
	V. high	60.00	20.50-80.52	Compact quartzite		
	800	20.00	80.52-100.52	Partially saturated fractured quartzite		
	V. high	50.00	100.52-150.52	Compact quartzite		
	800	20.00	150.52-170.52	Partially saturated fractured quartzite		
	V. high	Continue*	170.52 - continued	Compact quartzite		
Amer2 (AB/2=175m)	210	1.70	0.00-1.70	Surface soil with sandy silt	Fresh	15- 30
	42	3.24	1.70-4.94	Moist fine grained sandy silt		50 – 60
	203	20.16	4.94-25.10	Dry weathered quartzite		150 – 165
	1800	25.00	25.10-50.10	Compact quartzite		
	800	10.00	50.10-60.10	Partially saturated fractured quartzite		
	1800	90.00	60.10-150.10	Compact quartzite		
	800	15.00	150.10-165.10	Partially saturated fractured quartzite		
	V. high	Continue*	165.10 - continued	Compact quartzite		

VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Ground water quality	Depth Range of Fractures
Amer3 (AB/2=200m)	500 150 550 1200 700 V. high 800 V. high	1.84 4.00 19.24 8.00 30.00 80.00 20.00 Continue*	0.00-1.84 1.84-5.84 5.84-25.08 25.08-33.08 33.08-63.08 63.08-143.08 143.08-163.08 163.08 - continued	Surface dry soil with sandy silt and quartzite fragments Moist fine grained sandy silt with kankar Dry weathered quartzite Compact quartzite Partially saturated fractured quartzite Compact quartzite Partially saturated fractured quartzite Compact quartzite	Fresh	15- 25 50 – 60 150 – 163
Amer4 (AB/2=200m)	120 420 1050 800 V. high 800 V. high	3.00 6.50 21.00 20.00 10.00 30.00 Continue*	0.00-3.00 3.00-9.50 9.50-30.50 30.50-50.50 50.50-60.50 60.50-90.50 90.50 - continued	Surface soil with sandy silt Dry weathered quartzite Compact quartzite Partially saturated fractured quartzite Compact quartzite Partially saturated fractured quartzite Compact quartzite	Fresh	20 – 25 30 – 50 60 – 90

VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Ground water quality	Depth Range of Fractures
Amer5 (AB/2=140m)	48	2.90	0.00-2.90	Surface moist soil with sandy silt	Fresh	40- 50
	168	0.58	2.90-3.48	Dry fine grained sandy silt		80 – 100
	50	1.95	3.48-5.43	Moist fine grained sandy silt		
	290	35.00	5.43-40.53	Dry weathered quartzite		
	150	10.10	40.53-50.63	Partially saturated fractured quartzite		
	1500	30.00	50.63-80.63	Compact quartzite		
	150	20.00	80.63-100.63	Partially saturated fractured quartzite		
	V. high	Continue*	100.63 - continued	Compact quartzite		

* 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
30 to 100	Moist fine grained sandy silt	Alluvium/Overburden
100 to 200	Dry fine grained sandy silt	Alluvium/Overburden
100 to 150	Moist fine grained sandy silt withy kankar	Alluvium/Overburden
200 to 550	Dry sandy silt with kankar and rock fragments	Alluvium/Overburden
200 to 550	Dry weathered quartzite	Basement rock
150 to 800	Partially saturated fractured quartzite	Basement rock
> 800	Compact quartzite	Basement rock

The depth to basement in the area under investigation varies from 3 to 8. The thickness of the alluvium has been estimated between 3m and 8m. Formation comprising of weathered/fractured quartzite predominantly below the depth of 60 to 180 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 50 to 60 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 DTH 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	7.94	4.94	5.84	3	5.43
Groundwater Quality	Fr	Fr	Fr	Fr	Fr
Fractured (**F**)/ Compact (**C**)	F	F	F	F	F
Recommended for drilling	**√**	**√**	**√**	**√**	**√**
Drilling order of preference	1	3	2	4	5
Type of rig needed	**DTH**	**DTH**	**DTH**	**DTH**	**DTH**

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

CHAPTER 7.0 HYDROCHEMISTRY

The data collected from various agencies regarding ground water quality indicates that the quality of ground water being drawn from the medium deep to deep wells tapping quartzite's are 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 mean concentration of cations (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 of the study area as well as in the project area is less than 1250 microsiemens/cm .The maximum limit of EC in drinking water is prescribed as 1400 microsiemens/cm.

Within the limited scope of work detailed water quality sample analysis is not made. However, it is recommended to go for detailed ground water quality analysis for utilization of ground water for drinking purposes.

CHAPTER 8.0 GROUND WATER DEVELOPMENT & WELL DESIGN

8.1 GROUND WATER DEVELOPMENT

The subsurface disposition of aquifers as derived from lithologs further authenticated by geophysical investigations has formed the base for recommending the site specific location for water well drilling and artificial recharge structures. The field investigation aided by advanced tools of remote sensing & GIS and other analytical methods for assessment of ground water potential has confirmed the findings. The geophysical sections prepared based on the sounding data further indicates that the fractures expected at depths from 60 to 90 m bgl and 150 to 180 m bgl are water bearing .

Based on the interpretation of geophysical sounding carried out at five points well distributed in the project area, the probable locations have been recommended for construction of production wells and a tentative design has also been suggested. 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 55 cubic meters per day. As per the findings of the study the expected yield of wells tapping the fractured aquifers in the project area has been estimated to the tune of 5 to 8 m^3/hr. If the pumps are operated for eight hour a day with required staggering in time , and assuming the yield of one well as 5 m^3/hr , single well can yield up to 40 m^3/day. The recommended depth of the wells should be 150 – 180 m bgl. Therefore, to meet the water requirement of 55 m^3/day at least two wells would be required to be constructed which can give water to the tune of 80 m^3/day.

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 is given in **Fig. 8.2** along with the specifications of the material use is described below. It is recommended to deploy a DTH rig for constructions of bore wells as the water bearing formation are hard rock but overburden of alluvial is present. The alluvium thickness to the tune of 5 to 10 m will also be drilled by the DTH bits and once the hard rock is reached the DTH bits will drill the well in quartzite down to the depth of 150 – 180 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 from 0 to 8 m bgl blank casing pipe may be driven 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 150 to 180 m bgl by DTH rig depending upon the occurrence of fractured and weathered water bearing zones 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 Hydrogeologist and geophysicist. 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	1	172	50-80 150-170	6 m^3/hr
2	2	3	163	50-60 150-163 150-160	5 m^3/hr

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.

9.2 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	1500	0.85	0.550	701
2	Road & Paved area	1800	0.75	0.550	743
3	Open & Green land	37300	0.15	0.550	3077
4	Catchment contributing from surrounding hills(slope >20%)	220930	0.30	0.550	36453
	Catchment A	173554	0.30	0.550	28636
	Catchment B	15541	0.30	0.550	2564
	Catchment C	24114	0.30	0.550	3979
	Catchment D	7721	0.30	0.550	1274
	Total (1 to 4)	261530			40974

From the above computation, it is evident that a total quantum of 40974 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.

Rain water as surface runoff generated from the surrounding hills is also coming to the project site area. The calculations for the runoff generated from the surrounding areas has been carried out and it has been calculated that total of 36453 cu.m of water will be coming to the project site area which can be fruitfully harvested and recharged to ground water to provide sustainability to the ground water resources in the project site area. 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	1500	0.85	0.03	38	Recharge from existing Dug well
2	Road & Paved area	1800	0.75	0.03	41	
3	Open area & Green belt	37300	0.15	0.03	168	1 DB recharge structure
4	Catchment contributing from surrounding hills(slope >20%)					
	Catchment A	173554	0.3	0.03	1562	Recharge Shaft with 2 recharge wells
	Catchment B	15541	0.3	0.03	140	Gabion Structure
	Catchment C	24114	0.3	0.03	217	Gabion Structure
	Catchment D	7721	0.3	0.03	69	1 SB recharge structure

DB= Double bore ; SB= Single Bore

9.3 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. 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. As a small part of the land area will be covered with roof top or paved area therefore small amount of runoff will be generated from the roof top and paved area. It is proposed that the runoff of roof top and paved area will be taken to the existing dug well in the centre of the project area and same will be recharged in the dug well recharge structure. The design of dug well recharge structure is given in **Fig. 9.2**

By virtue of location of the project within the valley surrounded by moderate hills with slope more than 20%, significant amount of runoff to the tune of 36453 cu.m will be entering into the area from the catchments surrounding the project site. This runoff can be recharges to ground water aquifers to the extent possible by constructed suitable recharge structures such as recharge shaft and gabion structures.

To accommodate the runoff from catchment 'A' a recharge shaft of 8 m radius (semicircular type)is proposed, driven with two nos. of bore well to the depth of 60 m bgl so as to facilitate the ground water recharge. The design of the recharge shaft is given in **Fig. 9.3.** and de-silting chamber for recharge shaft is given in **Fig. 9.4.**

For catchment area 'B' & 'C' it is proposed to construct Gabion Structures at locations as given in **Fig. 9.1**, by bounding the Nala flowing from the respective hills. The design of gabion structure is given in **Fig.9.5.** As the slope and embankment of the Nala required for gabion structure is falling out of the boundary of project site appropriate permission may be obtain before construction of such water conservation structure in Forest land. At present Forest department is also promoting such water conservation structure and these gabion structures will enhance the soil moisture conditions in and around the location of structures and increase the vegetation.

Three number of double bore recharge trenches are given at suitable location to accommodate the runoff from Catchment D, over flow of recharge Shaft for catchment 'A' and inflow of water coming from the entry gate of the project site. Location of these recharge trenches are given in **Fig.9.1** and design in **Fig. 9.6 & 9.7.**

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 & trenches/shafts 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.

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.

9.4 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.

CHAPTER 10 SUMMARY AND RECOMMENDADTIONS

- The city of **Jaipur,** popularly known as **"Pink City"** has off late grown as one of the major economic hub and trade center of northern India. The growth in floating population and number of tourists in last few decades has enormously increased the requirement of accommodation in terms of Guest houses and Hotels of various kinds.
- In order to meet the growing requirements Hotel industries has enlarged in the area and in this context M/s Boutique Hotels (P) Ltd has proposed to build Devi Rasa a multi-facility Hotel complex in Amer block, Jaipur.
- Water is one of the major inputs to the development process, the sustained supply of water during as well as after the construction of the Hotel need to be ensured. Generally, ground water offers the major source of water supply for the entire city limits. With increasing population and industrialization, there is growing dependability on ground water.
- In this context the work related to ground water investigation and detailed study of the area has been entrusted to M/s **Green Systems Pvt. Ltd, New Delhi** so as to suggest the most viable and scientifically based plan for ground water development and management for meeting the water
- The project area is situated in the sub urban agglomerate and located at a distance of about 11 km north of Jaipur city. The proposed site of the hotel is located in the east of NH-8 connecting Jaipur with Delhi near village Kunda under Amer block of Jaipur district. The total area under the project is about 40600 sq.m.
- In the study area broadly two distinct geomorphic unit is seen, the structural hills and alluvium with a transition pediment zone**.** Project site lies in the valley portion in close proximity of the ridge and represents the transition of the pediment zone and the alluvial plain.

- The prevailing arid conditions added with deficient rain and high evaporation has restricted development of natural river drainage system in the Jaipur city area. There are small seasonal streamlets, nallahs, generally ephemeral in nature & merges with other higher order streams.
- Remote sensing tool has been used in the present so as to generate 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 as well as images of 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 data is visually interpreted for features identifications and demarcating their extent in the space.
- The pink city enjoys arid climatic conditions. 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 study area is occupied by thin layer of Quaternary alluvium underlain by quartzites of Alwar super group. Unconsolidated sediments such as alluvium and windblown sand occupying the major part of the study area and forms the top phreatic aquifer, the potential of these aquifer depends upon the thickness which varies spatially in different parts of the area.
- Weathered quartzites constitute low potential aquifer zones. Tube wells tapping fractured 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. The recommended depth of well in this area is about 150 to 180 m so as to tap sufficient thickness of fractured zone and the expected yield of the well is to the tune of 6 to 7m^3/hr.

- Depth to water table varies from less than 20 m in the eastern p[art of the study area to about 60 m bgl and depth to water level is increases from east to west. Around the project area the depth to water level is 50 m bgl. A steep decline in ground water levels observed in the central part of the city area in last 10 years as a result of fast urbanisation and Industrial development activities and people's dependence and preference for ground water for drinking and industrial water supply.
- The city area is conglomeration of parts of three administrative blocks viz. Amer, Jhotwara and Sanganer, the project area is a part of Amer block, as such the entire block is overexploited and needs strategic planning for further development.
- It is opined that the estimates on which the area has been categorized as over exploited refers to dynamic ground water resources available in the zone of fluctuation in the top unconfined aquifer , mostly made up of quaternary alluvium and or highly weathered quartzite's restricted up to a depth of about 50 mbgl. Due to high withdrawal in the area the water level has gone much deeper and the phreatic aquifer has become more or less unproductive as far as sustainability is concerned.
- 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 and this zone is presently being tapped for sustainability. The subsurface exploration carried out in the area indicates two water bearing fractures at deeper zones, at a depth of 60 to 80 m and below 150 m. The fracture zone at both the depths seems to be productive and may be tapped suitably.
- In order to decipher the sub surface disposition of different litho units as well as their hydrgeological characteristics Vertical Electrical Sounding (VES) has been carried out at five locations evenly distributed in the project area. The findings of the geophysical investigation indicate that the depth to basement in the area under investigation varies

from 3 to 8m. The thickness of the alluvium has been estimated between 3m and 8m. Formation comprising of weathered/fractured quartzite predominantly below the depth of 60 to 180 mbgl is likely to form good aquifers with moderate yield.

- The data collected from various agencies regarding ground water quality indicates that the quality of ground water being drawn from the medium deep to deep wells tapping quartzite's are by and large fresh in the major parts of the city.
- Well design of each well and methodology for construction of the well along with the specifications of the material has been recommended along with deployment of combination rig for constructions of tube wells as the water bearing formation are weathered & fractured hard rock overlain by alluvium.
- It is recommended to deploy a DTH rig for constructions of bore wells as the water bearing formation are hard rock but overburden of alluvial is present. The alluvium thickness to the tune of 5 to 10 m will also be drilled by the DTH bits and once the hard rock is reached the DTH bits will drill the well in quartzite down to the depth of 150 – 180 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 from 0 to 8 m bgl blank casing pipe may be driven into at least 2 to 3 m down within the bed rock. i.e. into the quartzite. Further, a borehole of 8 inches diameter may be drilled in the depth range of 150 to 180 m bgl by DTH rig depending upon the occurrence of fractured and weathered water bearing zones in the well.
- 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.
- In order to manage the runoff and adopting suitable water conservation measures , the runoff generated in the area has been computed based on the normal rainfall, the total quantum of water works out to 40974 cu.m which 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.

- The runoff generated from roof top or paved area is proposed to be diverted to existing dug well in the centre of the project area and same will be recharged in the dug well recharge structure.
- By virtue of location of the project within the valley surrounded by moderate hills with slope more than 20%, significant amount of runoff to the tune of 36453 cu.m will be entering into the area from the catchments surrounding the project site. This runoff can be recharges to ground water aquifers to the extent possible by constructed suitable recharge structures such as recharge shaft and gabion structures.
- To accommodate the runoff from different catchments different structures such as recharge shaft with bore well and Gabion Structures has been suggested so as to facilitate the ground water recharge. The design of the recharge shaft has also been provided.
- 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. 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 & trenches/shafts 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.

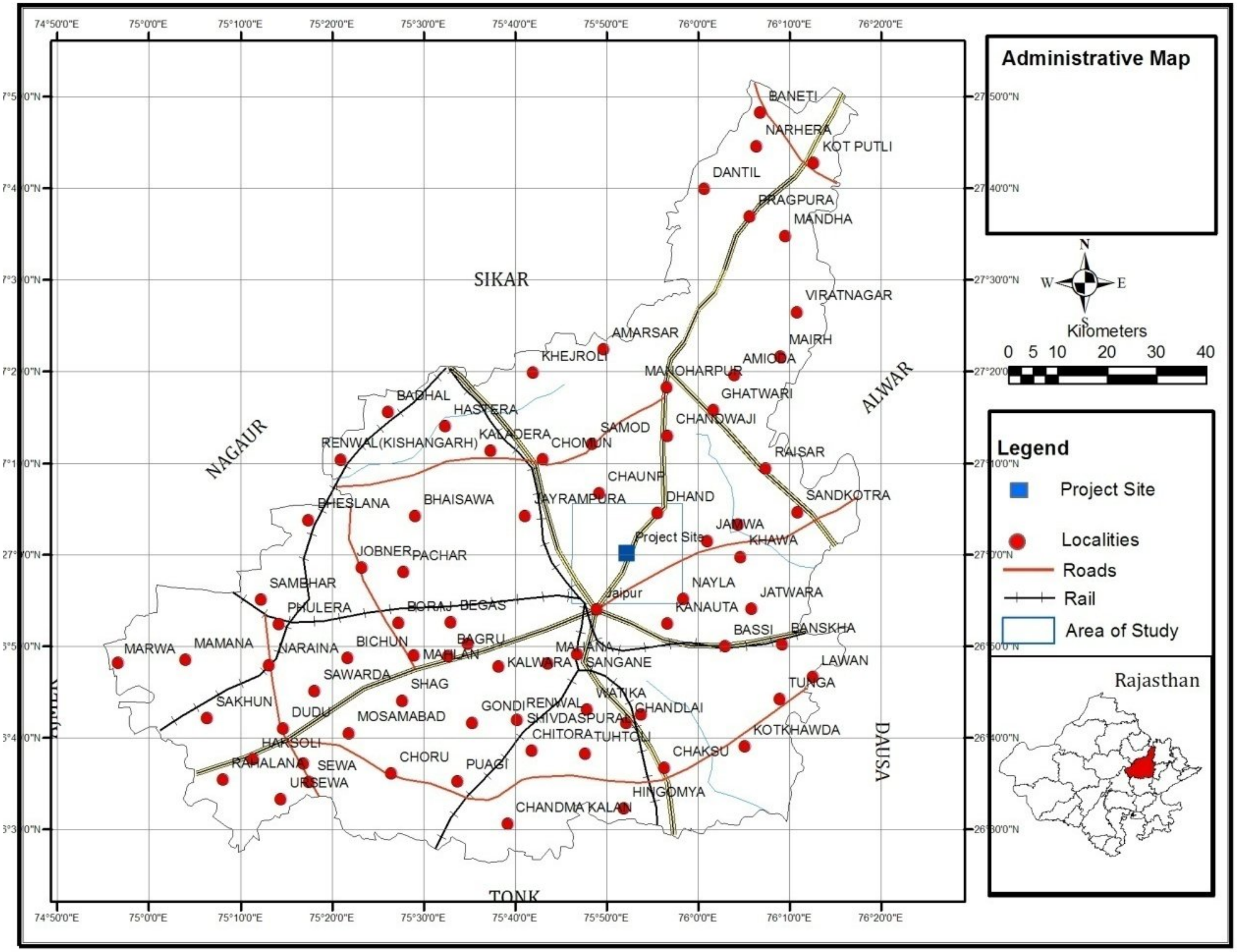


Figure 1.1: Administrative map of Jaipur district with Location of Project Site

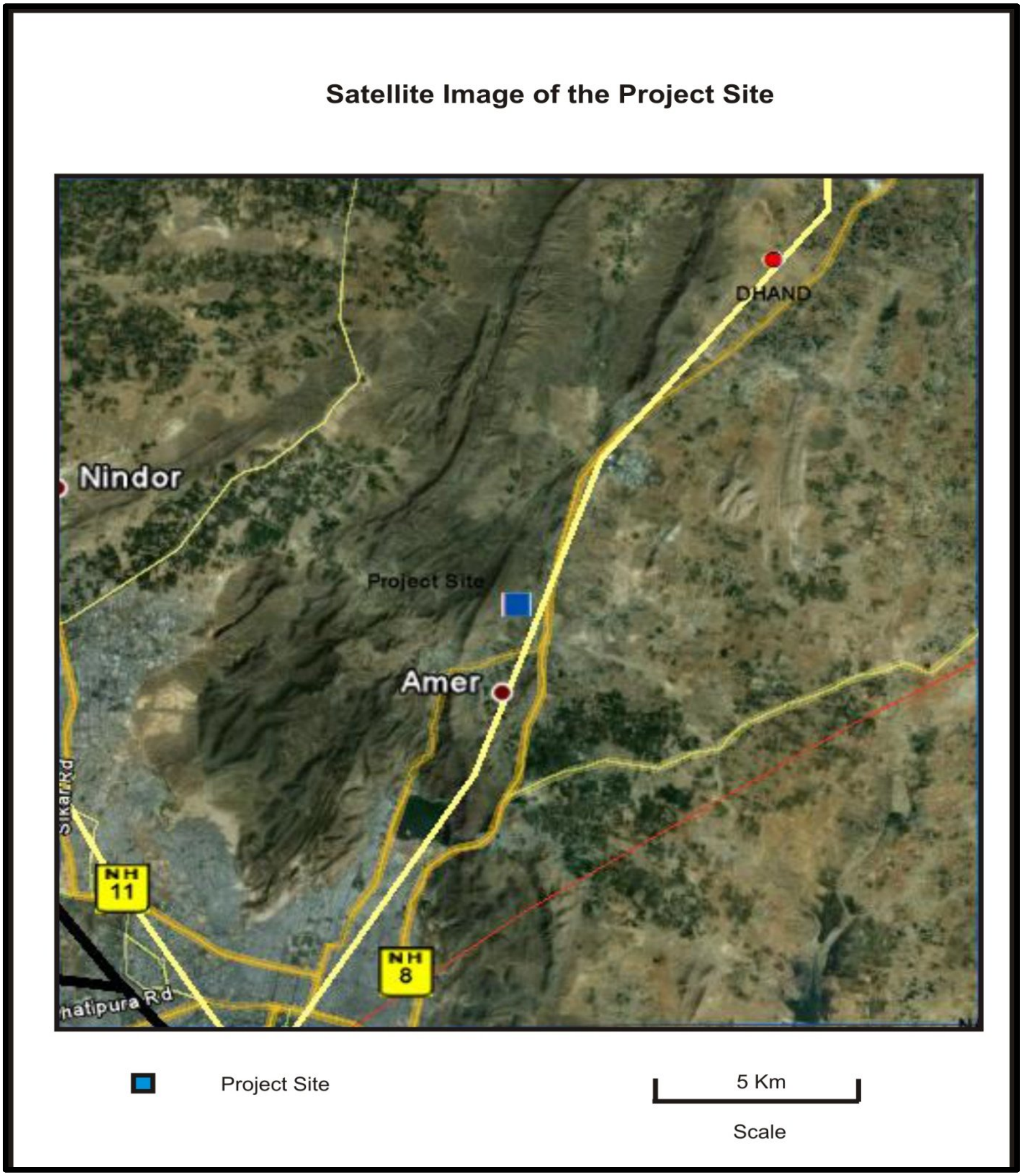


Figure 1.2: Google Image of the Study Area

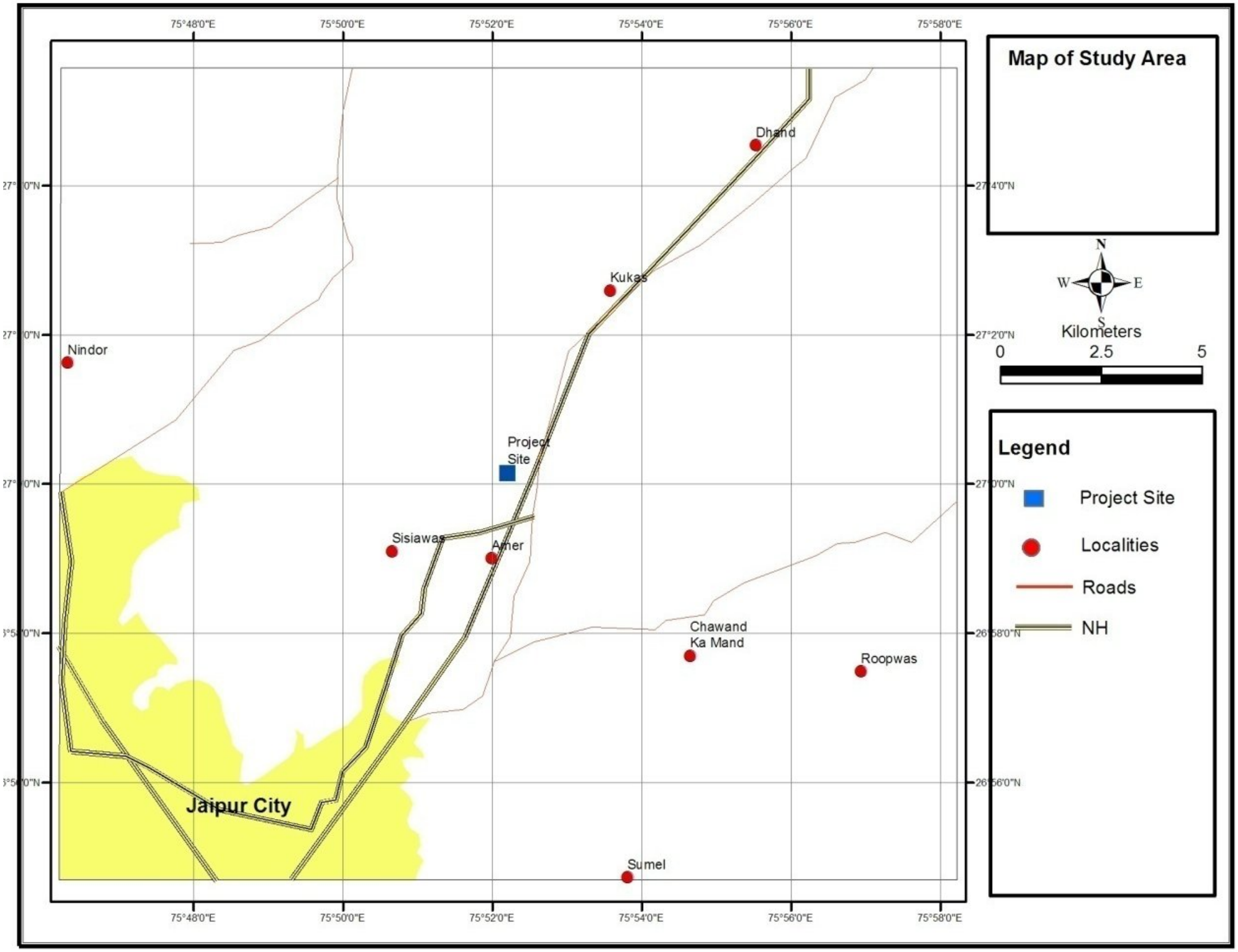


Figure 1.3: Map showing the Study Area

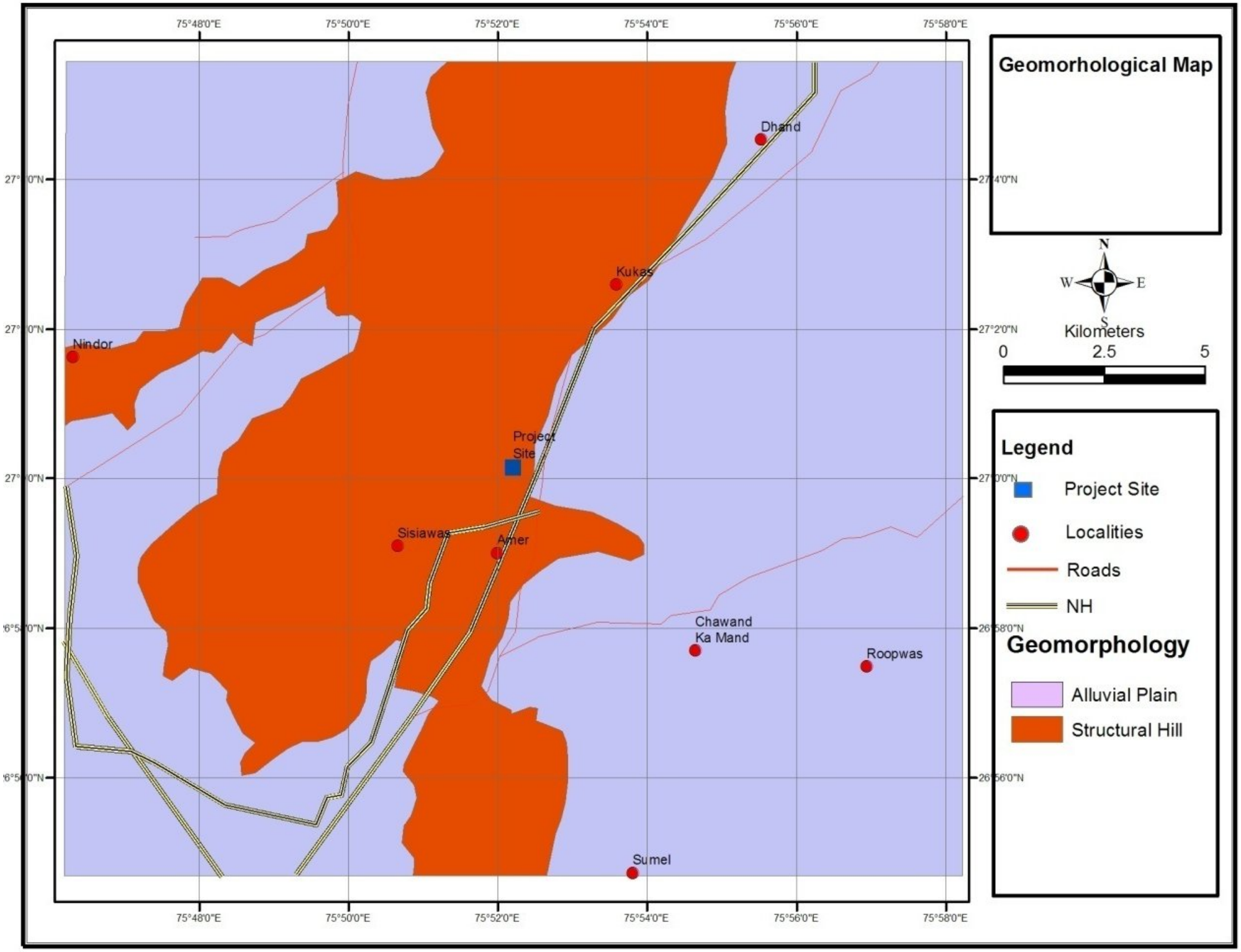


Figure 2.1: Geo-morphological map of Study Area

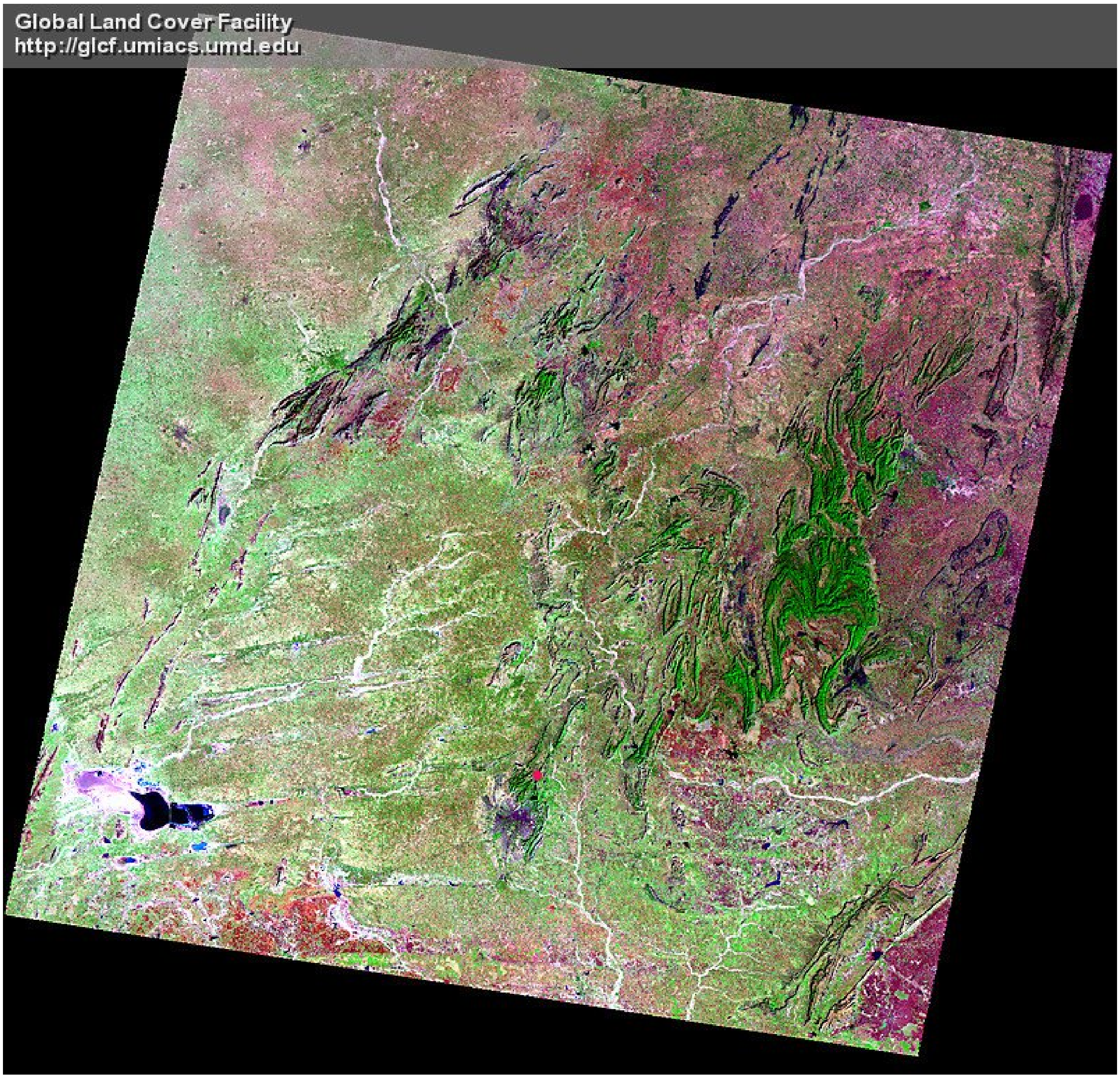


Figure 2.2: Different Scenes of Satellite Image

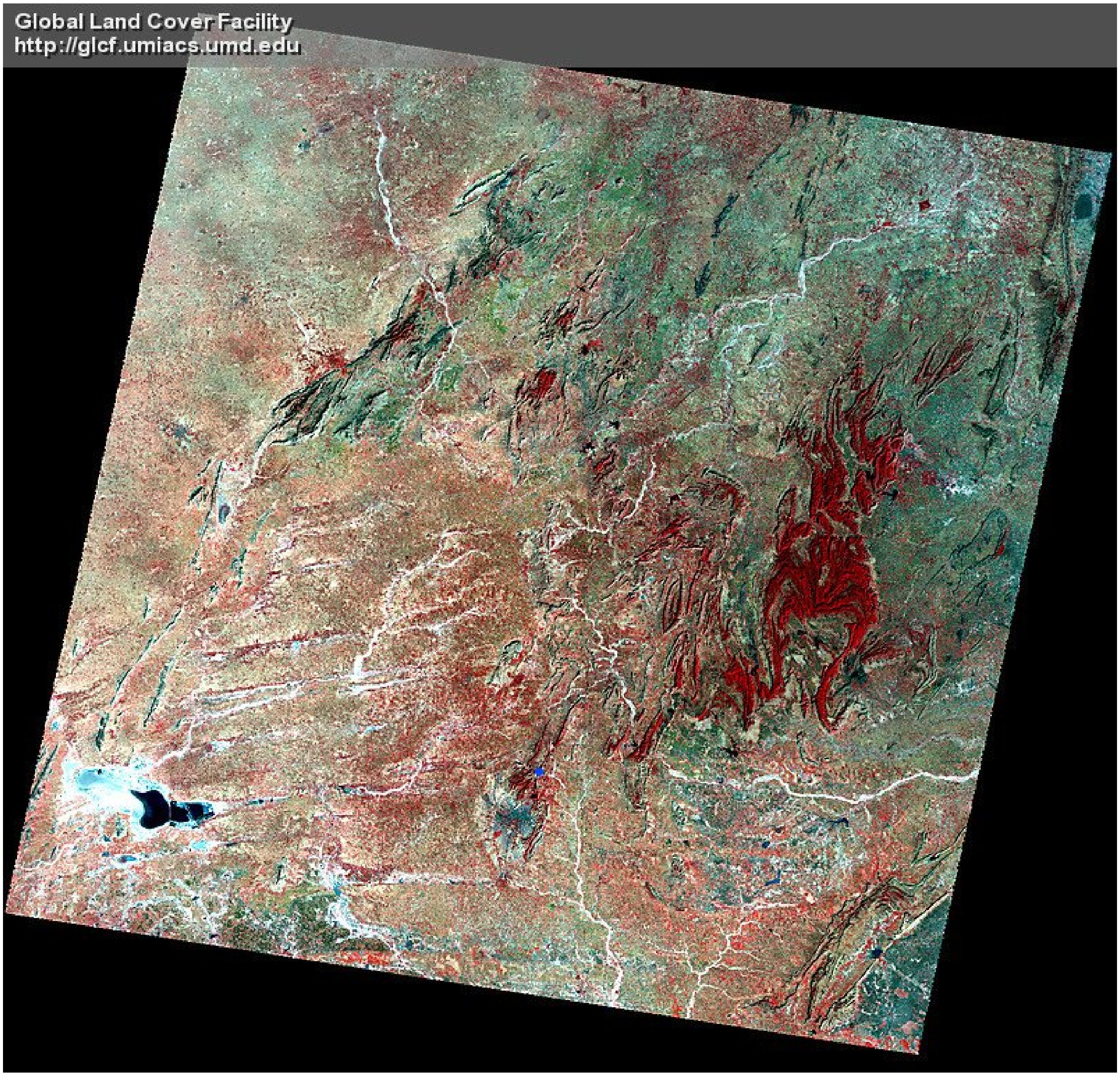


Figure 2.3: Different Scenes of Satellite Image

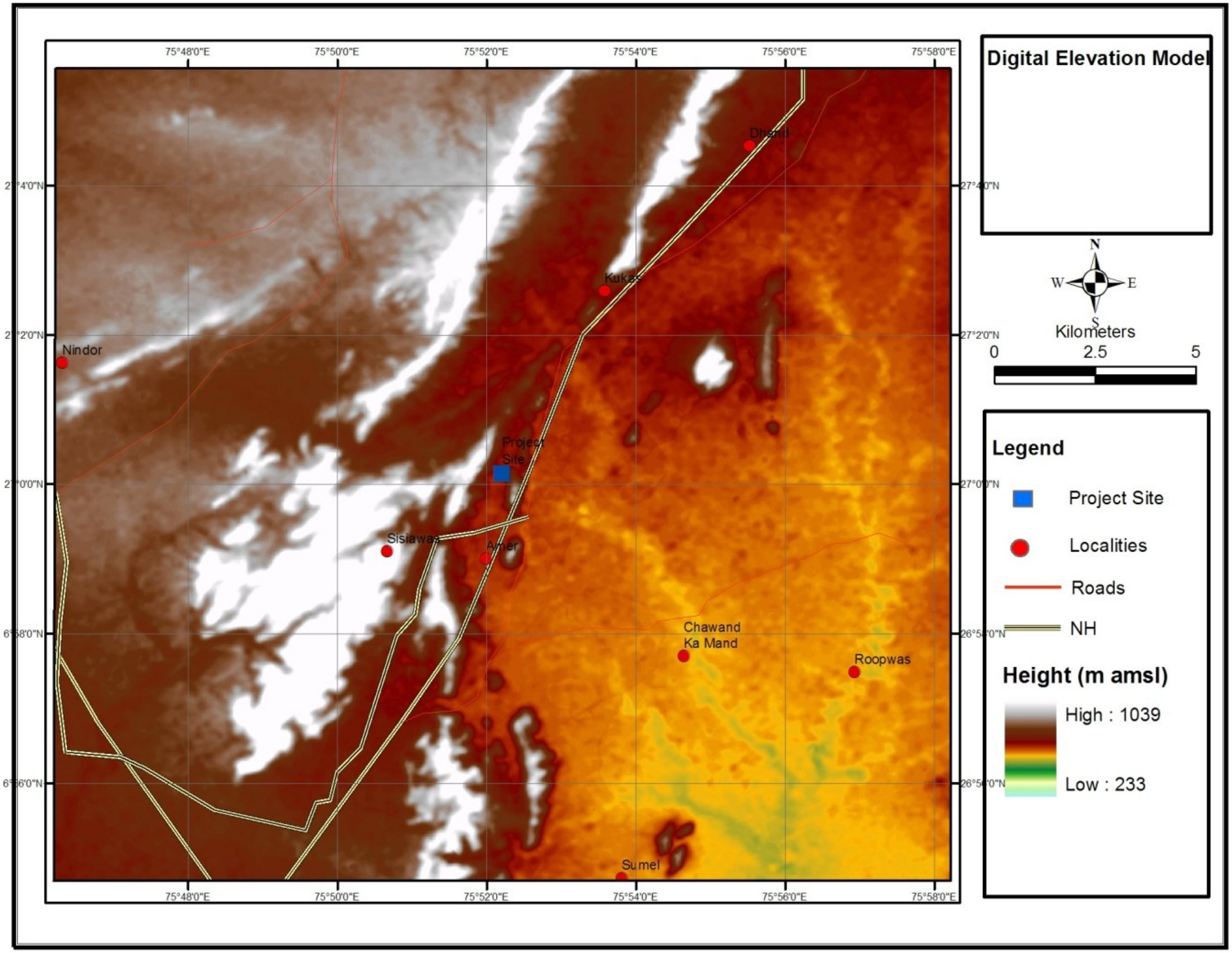


Figure 2.4: Digital Elevation of the Study Area

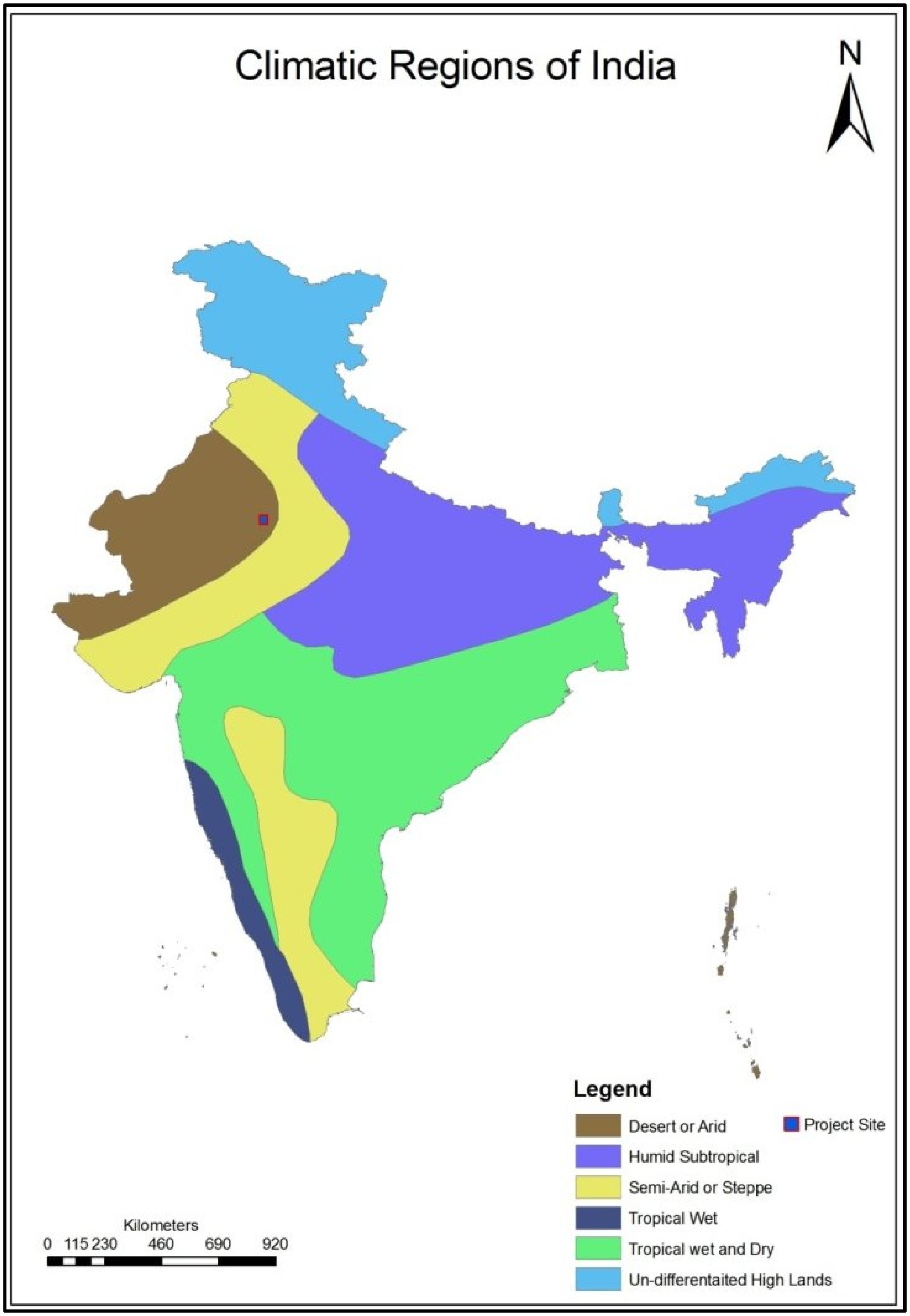


Fig: 3.1: Climatic Regions of India

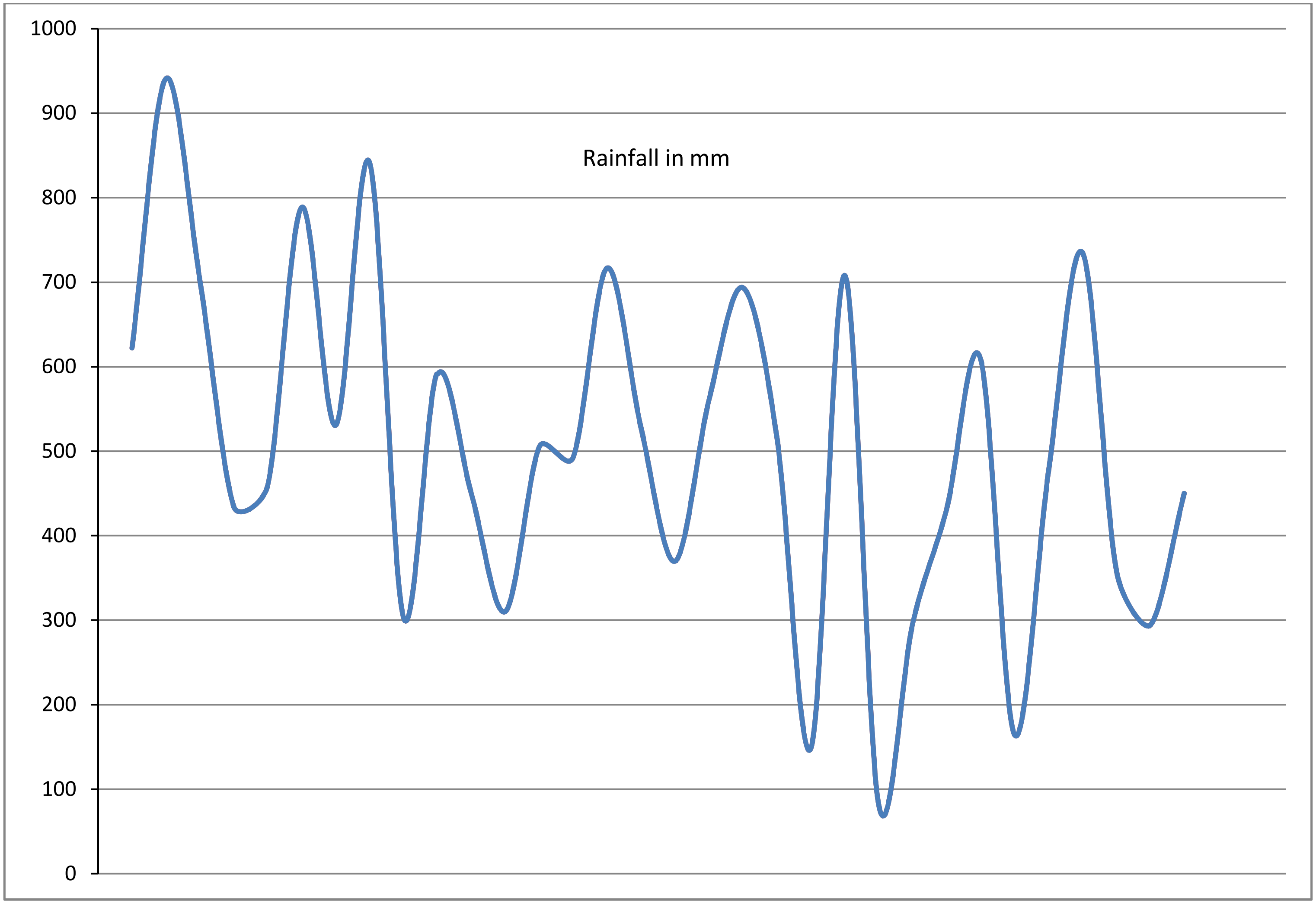


Figure 3.2: Annual Rainfall variations of Years (1976 – 2007)

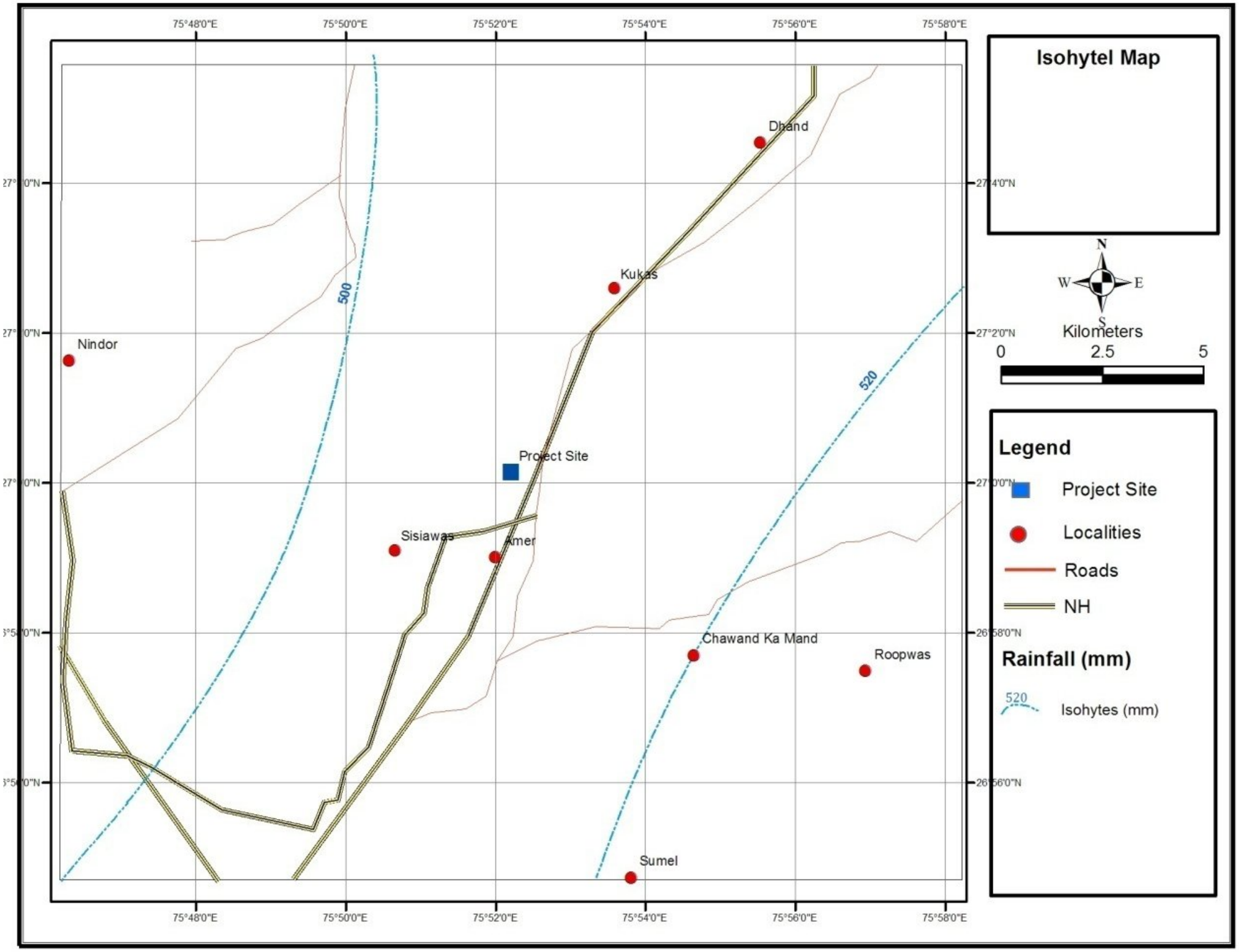


Figure3.3: Isohyetal map of the study area

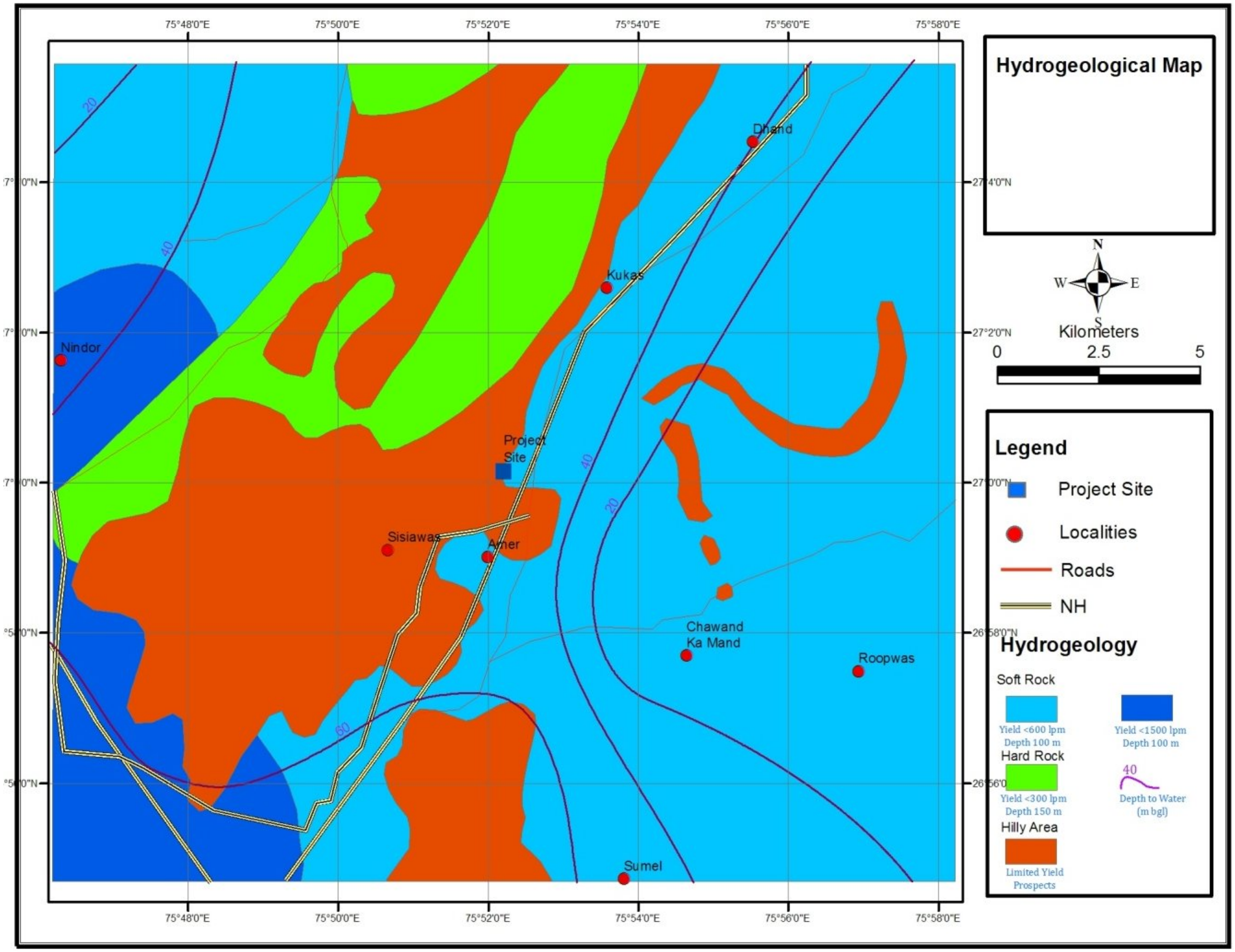


Figure 4.1: Hydrogeological map of the Study Area

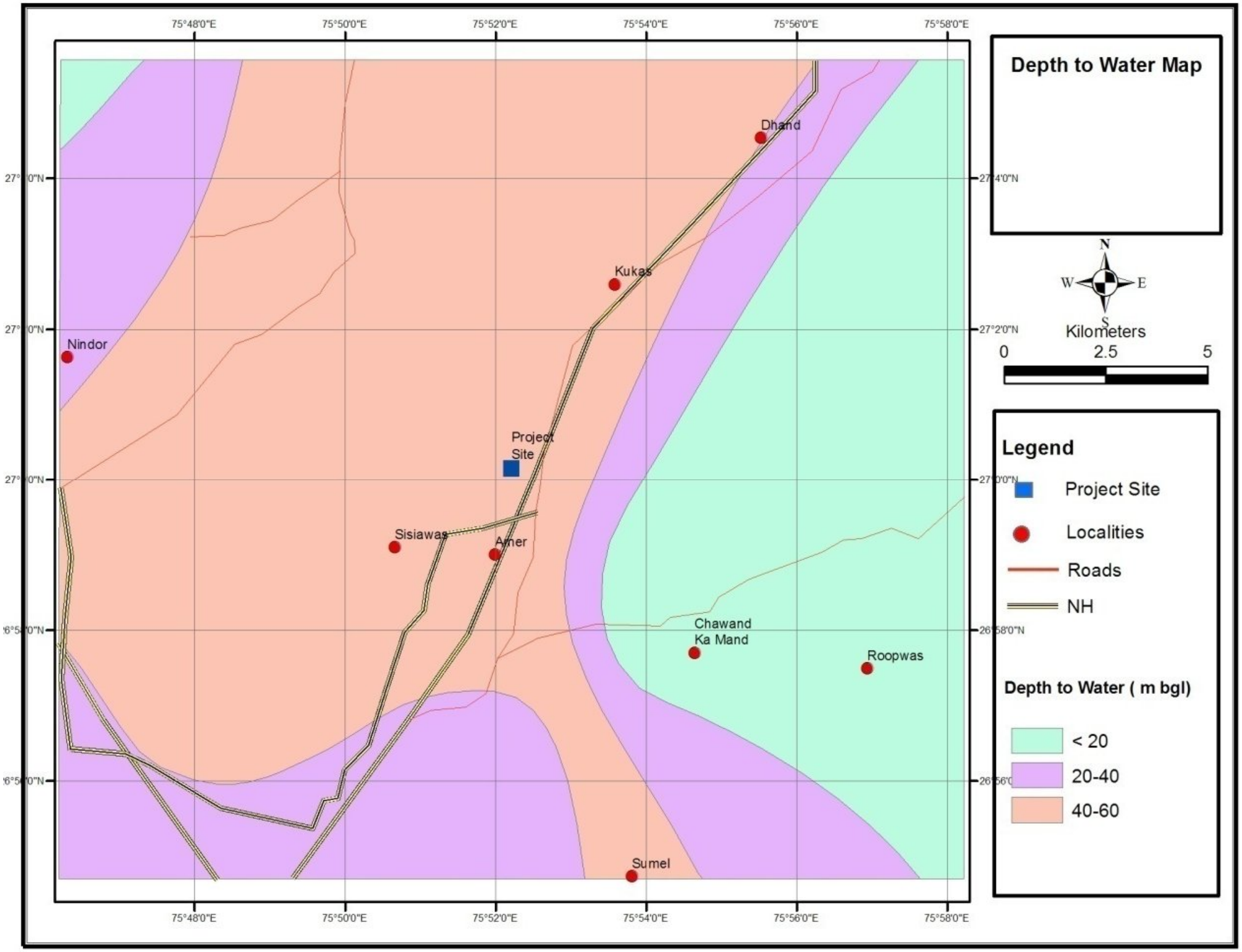


Fig.4.2 Depth to Water level map of the study area

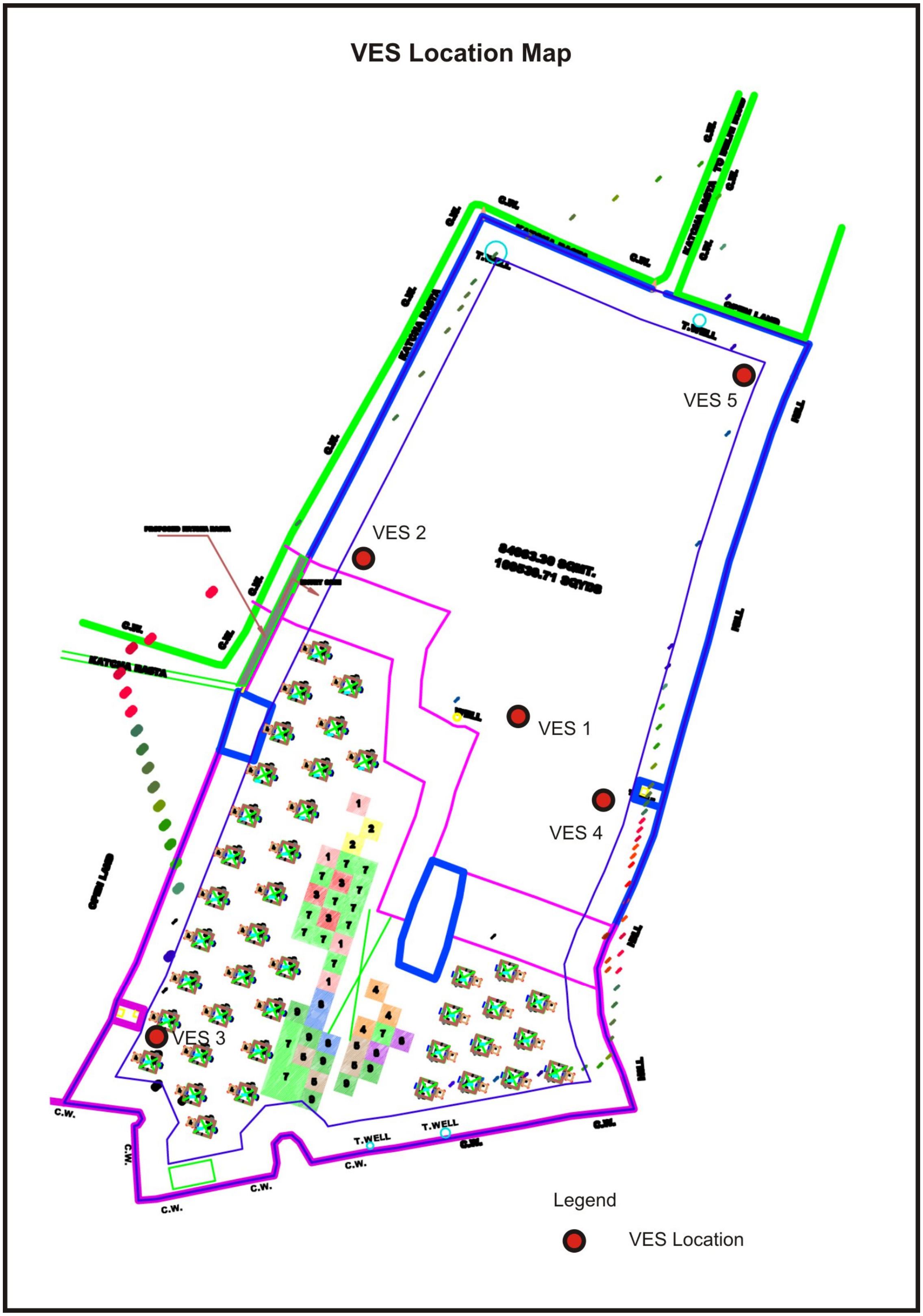
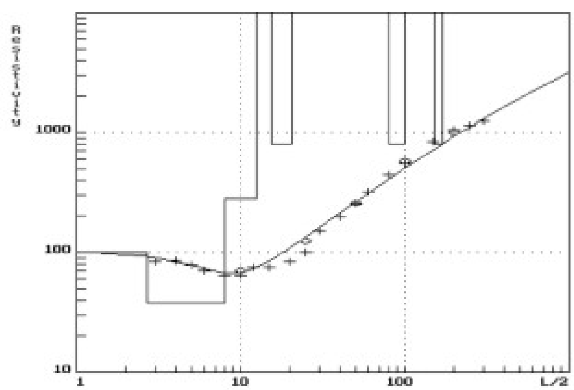
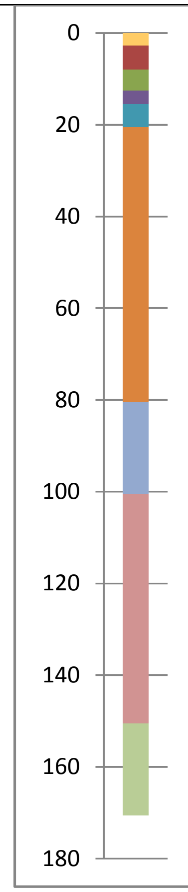


Figure 6.1: VES location map in the project area

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

AB/2(m)	Ra (Ohm-m)
3	83.57
4	86.09
5	78.84
6	70.42
8	63.88
10	64.87
10	71.03
12	74.44
15	75.65
20	83.66
25	99.49
25	125.16
30	151.74
40	196.93
50	258.92
50	258.62
60	321.07
80	440.37
100	553.61
100	582.02
150	843.56
200	1045.02
200	997.02
250	1151.46
300	1245.62



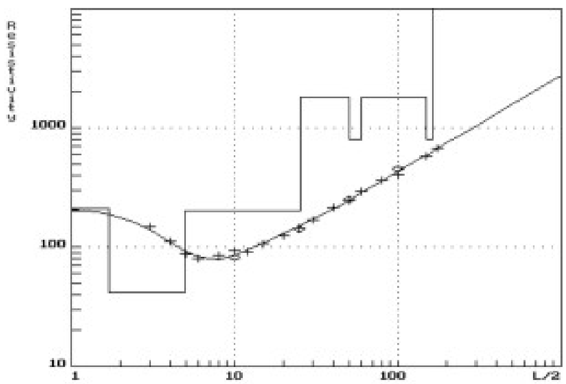


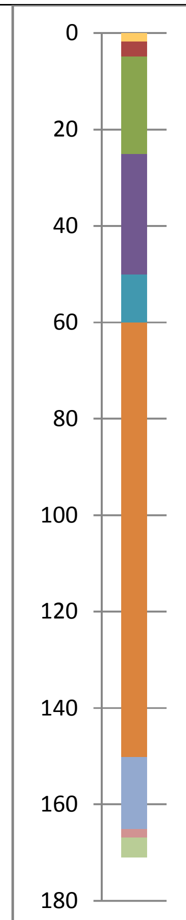
VES No.	**True Resistivity (Ohm-m)**	**Thicknes s(m)**	**Depth Range (m)**	**Inferences**	**Groundwater quality**	**Depth Range of Fractures**
Amer1	100	2.7	0.00-2.70	Surface soil with sandy silt	Fresh	15- 20
(AB/2=300m)	38	5.24	2.70-7.94	Moist fine grained sandy silt		50 – 60
	282	4.58	7.94-12.52	Dry weathered quartzite		60 – 80
	V. high	3	12.52-15.52	Compact quartzite		150 – 170
	800	5	15.52-20.52	Partially saturated fractured quartzite		
	V. high	60	20.50-80.52	Compact quartzite		
	800	20	80.52-100.52	Partially saturated fractured quartzite		
	V. high	50	100.52-150.52	Compact quartzite		
	800	20	150.52-170.52	Partially saturated fractured quartzite		
	V. high	Continue*	170.52 - continued	Compact quartzite		

Figure 6.2: VES 1 data, Graphs and Interpreted logs

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

AB/2(m)	Ra (Ohm-m)
3	147.34
4	112.81
5	87.78
6	80.52
8	85.71
10	94.32
10	82.11
12	91.59
15	107.96
20	125.41
25	144.86
25	140.99
30	170.71
40	213.26
50	245.7
50	253.72
60	290.83
80	361.2
100	405.87
100	453.14
150	576.24
175	671.8



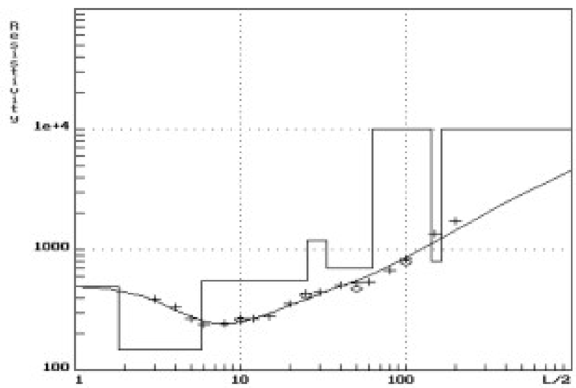


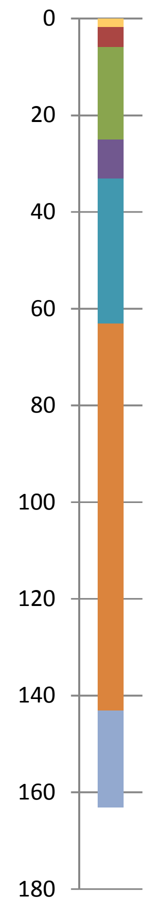
VES No.	True Resistivity (Ohm-m)	Thickness(m)	Depth Range (m)	Inferences	Groundwater quality	Depth Range of Fractures
Amer2	210	1.7	0.00-1.70	Surface soil with sandy silt	Fresh	15- 30
(AB/2=175m)	42	3.24	1.70-4.94	Moist fine grained sandy silt		50 – 60
	203	20.16	4.94-25.10	Dry weathered quartzite		150 – 165
	1800	25	25.10-50.10	Compact quartzite		
	800	10	50.10-60.10	Partially saturated fractured quartzite		
	1800	90	60.10-150.10	Compact quartzite		
	800	15	150.10-165.10	Partially saturated fractured quartzite		
	V. high	Continue*	165.10 - continued	Compact quartzite		

Figure 6.3: VES 2 data, Graphs and Interpreted logs

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

AB/2(m)	Ra (Ohm-m)
3	390.89
4	333.49
5	269.03
6	239.22
8	247.54
10	268.24
10	260.88
12	270.49
15	280.49
20	358.91
25	436.03
25	412.43
30	446.97
40	504.69
50	533.39
50	478.78
60	536.58
80	670.94
100	839.75
100	788.67
150	1371.22
200	1723.04



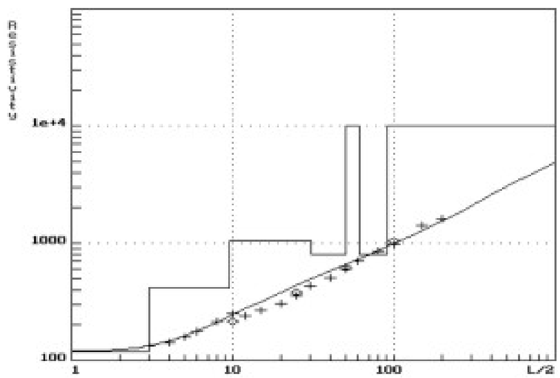


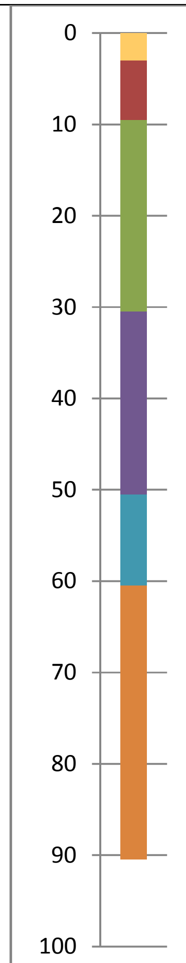
VES No.	**True Resistivity (Ohm-m)**	**Thickness (m)**	**Depth Range (m)**	**Inferences**	**Groundwater quality**	**Depth Range of Fractures**
Amer3	500	1.84	0.00-1.84	Surface dry soil with sandy silt and quartzite fragments	Fresh	15- 25
(AB/2=200m)	150	4	1.84-5.84	Moist fine grained sandy silt with kankar		50 – 60
	550	19.24	5.84-25.08	Dry weathered quartzite		150 – 163
	1200	8	25.08-33.08	Compact quartzite		
	700	30	33.08-63.08	Partially saturated fractured quartzite		
	V. high	80	63.08-143.08	Compact quartzite		
	800	20	143.08-163.08	Partially saturated fractured quartzite		
	V. high	Continue *	163.08 - continued	Compact quartzite		

Figure 6.4: VES 3 data, Graphs and Interpreted logs

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

AB/2(m)	Ra (Ohm-m)
3	131.95
4	142.5
5	159.39
6	176.32
8	215.29
10	248.5
10	216.39
12	243
15	265.57
20	306.04
25	357.51
25	382.65
30	434.33
40	511.13
50	601.04
50	610.73
60	698.22
80	858.97
100	975.04
100	1048.04
150	1423.29
200	1604.85





VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Groundwater quality	Depth Range of Fractures
Amer4	120	3	0.00-3.00	Surface soil with sandy silt	Fresh	20 – 25
(AB/2=200m)	420	6.5	3.00-9.50	Dry weathered quartzite		30 – 50
	1050	21	9.50-30.50	Compact quartzite		60 – 90
	800	20	30.50-50.50	Partially saturated fractured quartzite		
	V. high	10	50.50-60.50	Compact quartzite		
	800	30	60.50-90.50	Partially saturated fractured quartzite		
	V. high	Continue *	90.50 - continued	Compact quartzite		

Figure 6.5: VES 4 data, Graphs and Interpreted logs

Field Data : Electrical Resistivity Sounding Measurements

Project Name : Ground Water Investigation

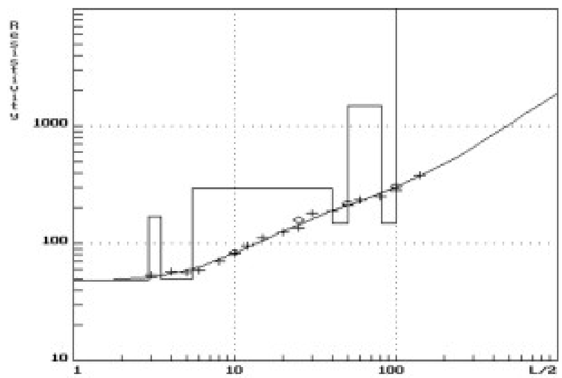
Location : Amer, Jaipur

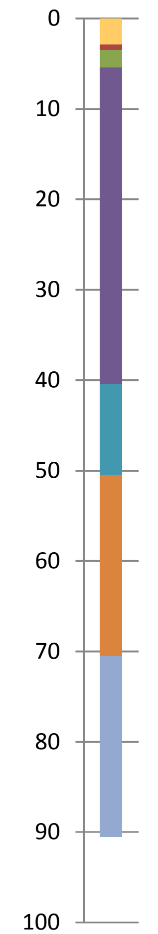
Type of data : Schlumberger

VES Name : VES5

Investigator : Water Solutions, Delhi

AB/2(m)	Ra (Ohm-m)
3	54.04
4	57.89
5	57.07
6	58.62
8	70.09
10	81.47
10	83.54
12	96.54
15	111.43
20	124.41
25	136.56
25	159.09
30	179.77
40	189.01
50	209.93
50	219.41
60	236.41
80	249.37
100	279.92
100	303.1
140	380





VES No.	True Resistivity (Ohm-m)	Thickness (m)	Depth Range (m)	Inferences	Groundwater quality	Depth Range of Fractures
Amer5	48	2.9	0.00-2.90	Surface moist soil with sandy silt	Fresh	40- 50
(AB/2=140m)	168	0.58	2.90-3.48	Dry fine grained sandy silt		80 – 100
	50	1.95	3.48-5.43	Moist fine grained sandy silt		
	290	35	5.43-40.53	Dry weathered quartzite		
	150	10.1	40.53-50.63	Partially saturated fractured quartzite		
	1500	30	50.63-80.63	Compact quartzite		
	150	20	80.63 - 100.63	Partially saturated fractured quartzite		
	V. high	Continue*	100.63 - continued	Compact quartzite		

Figure 6.6: VES 5 data, Graphs and Interpreted logs

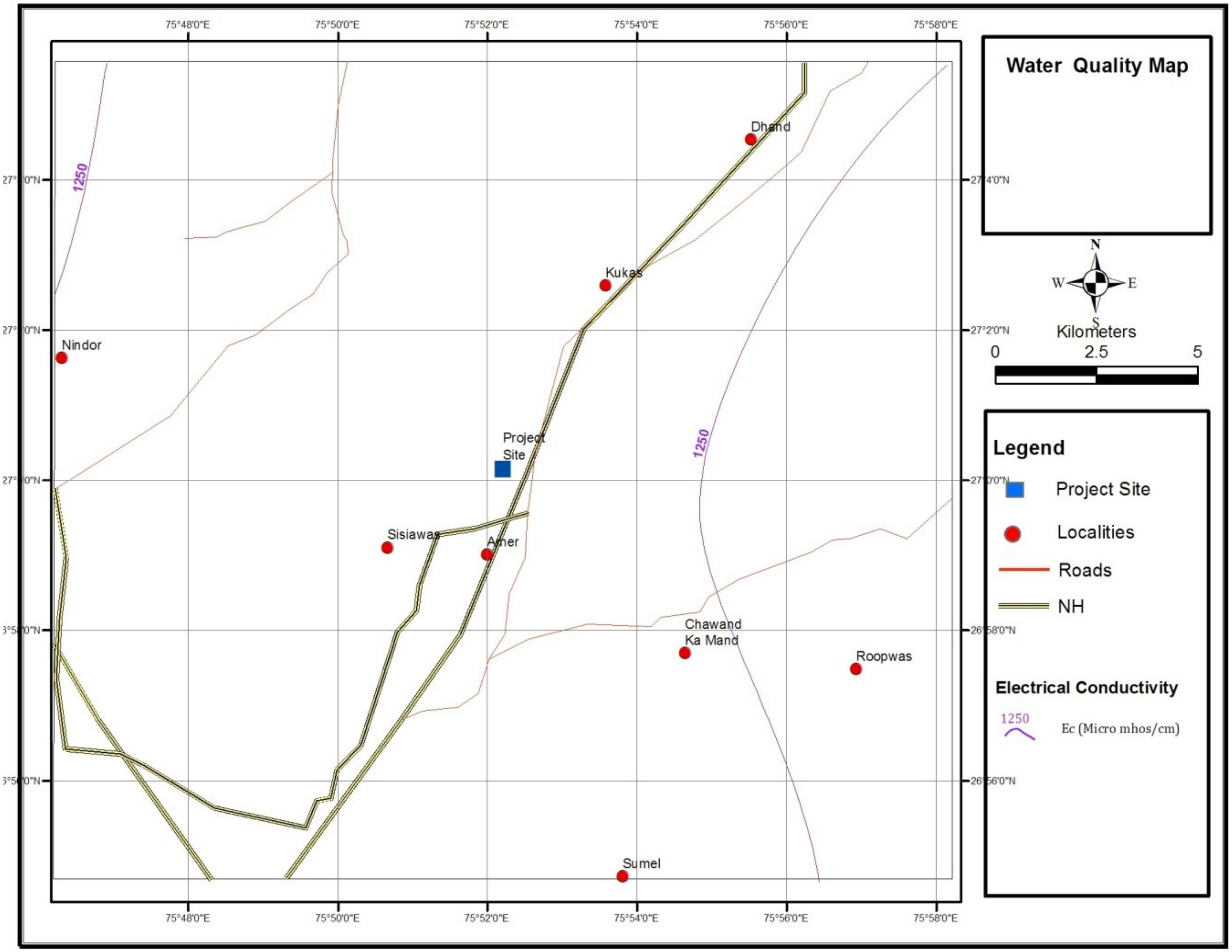


Figure 7.1: Electrical Conductivity Map of the study area

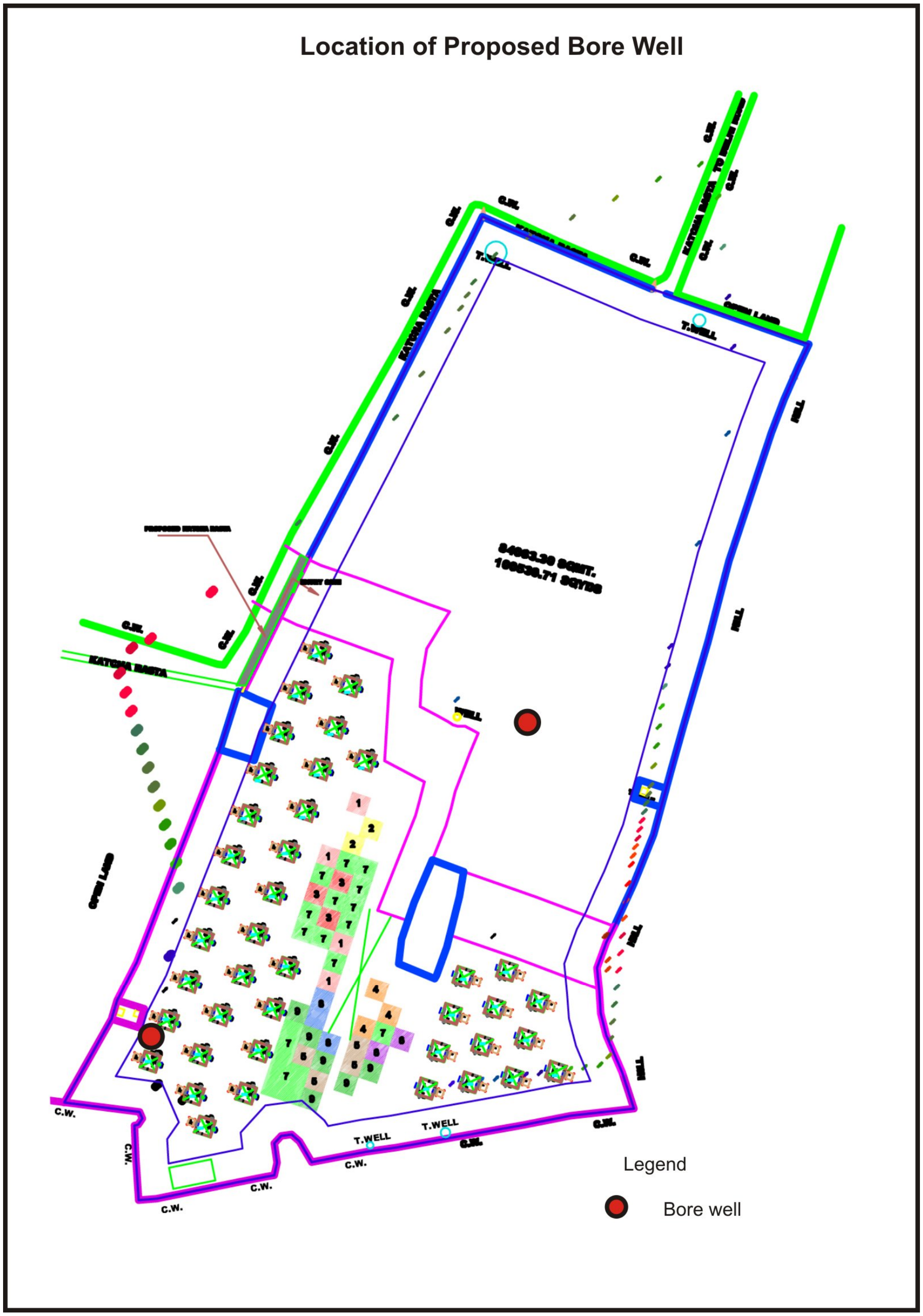


Figure 8.1: Location of Recommended Tube Well Sites

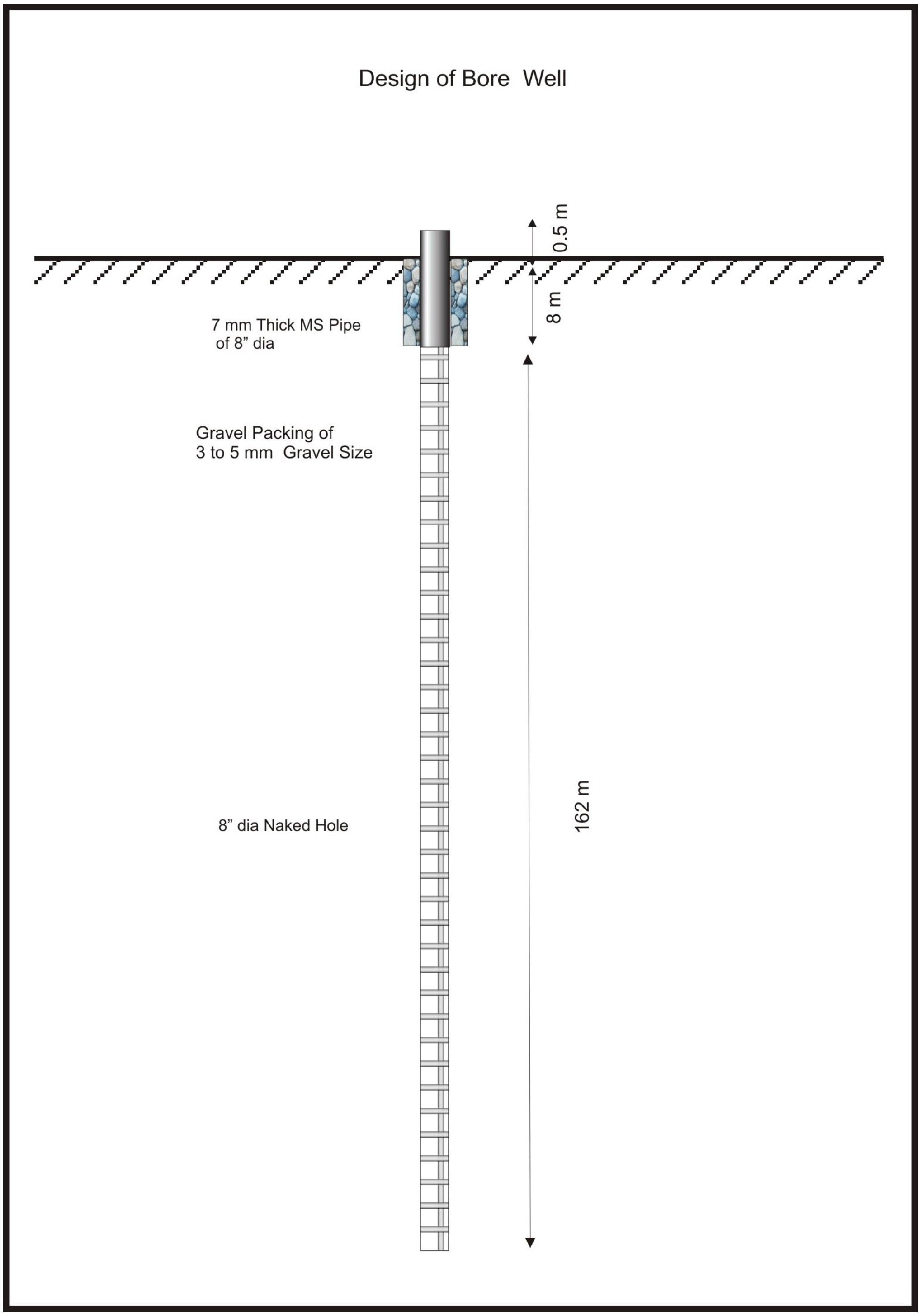


Figure 8.2: Recommended Well Design for Bore wells in project area

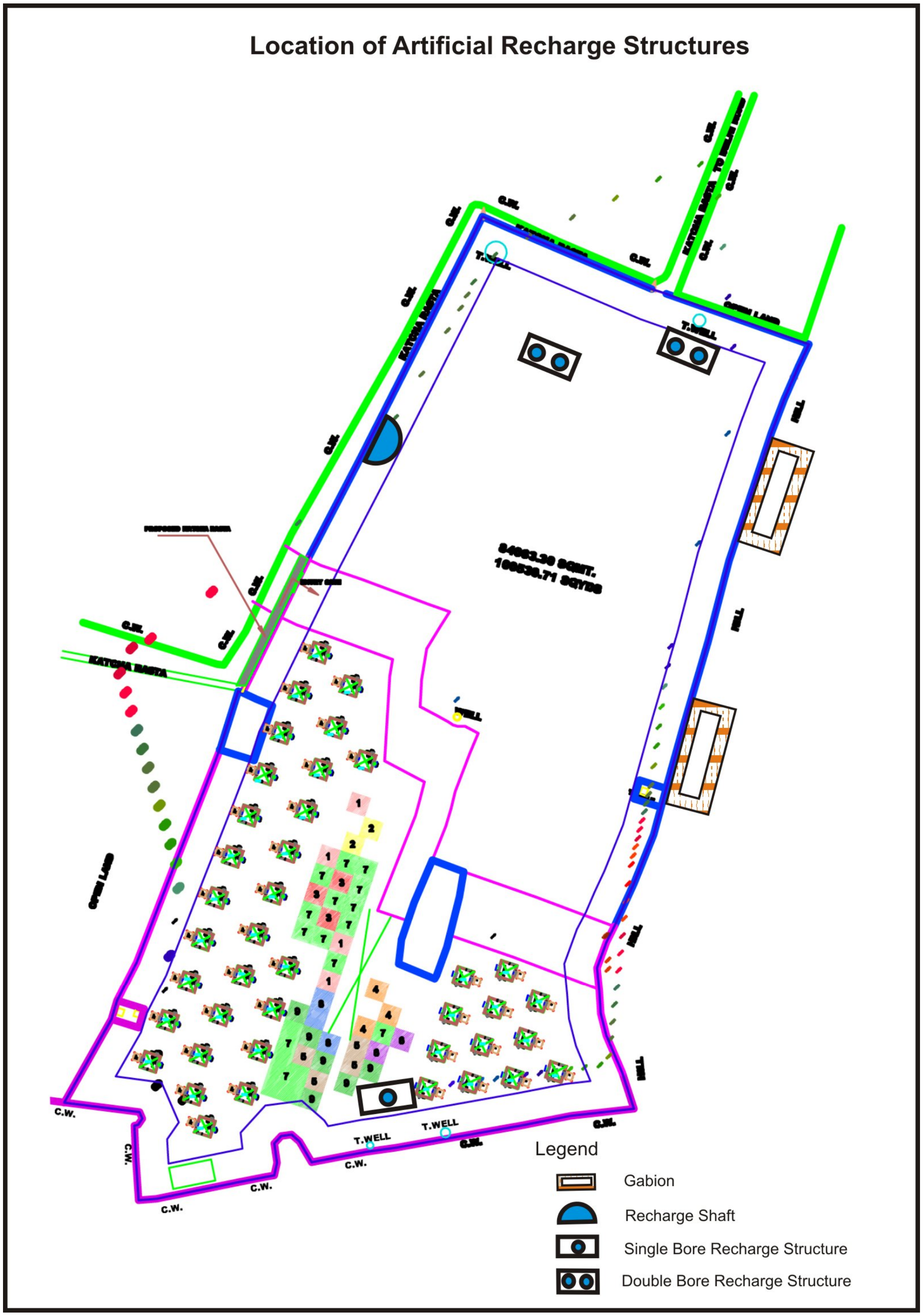


Figure 9.1: Location of Proposed Recharge Structure

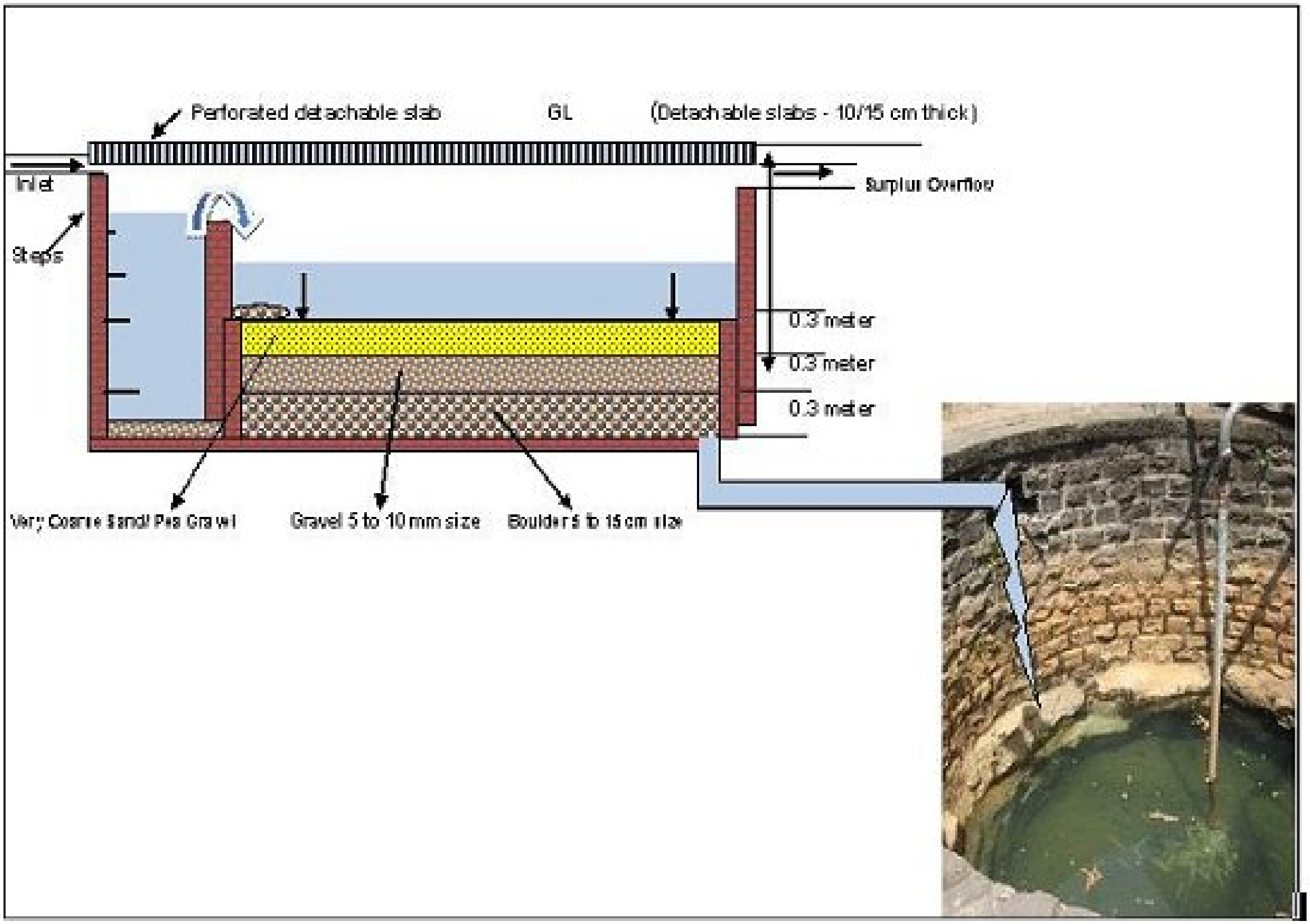


Figure 9.2: Dug well Recharge Design of Artificial Recharge Structure

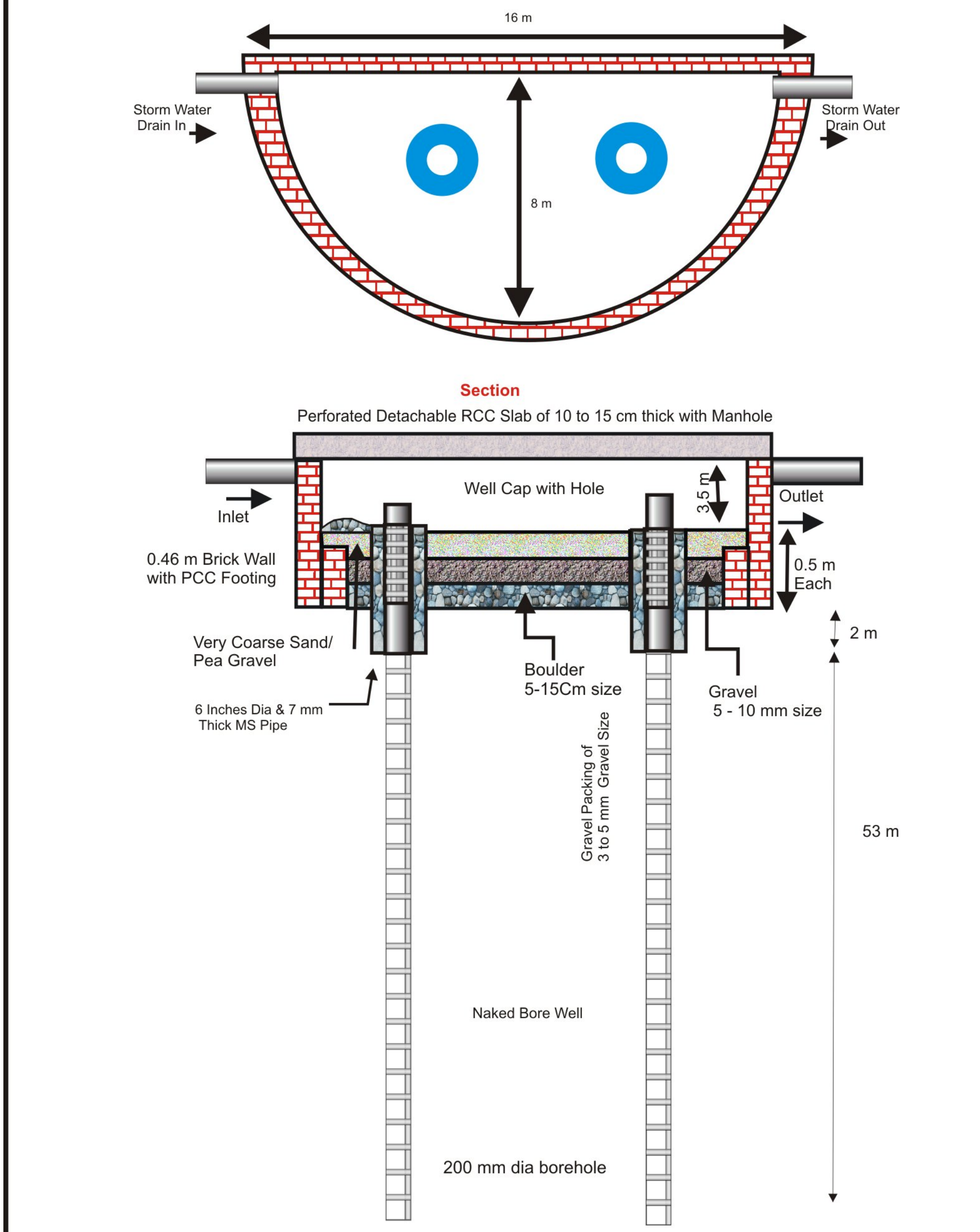


Figure 9.3: Design of Recharge Shaft with 2 recharge wells

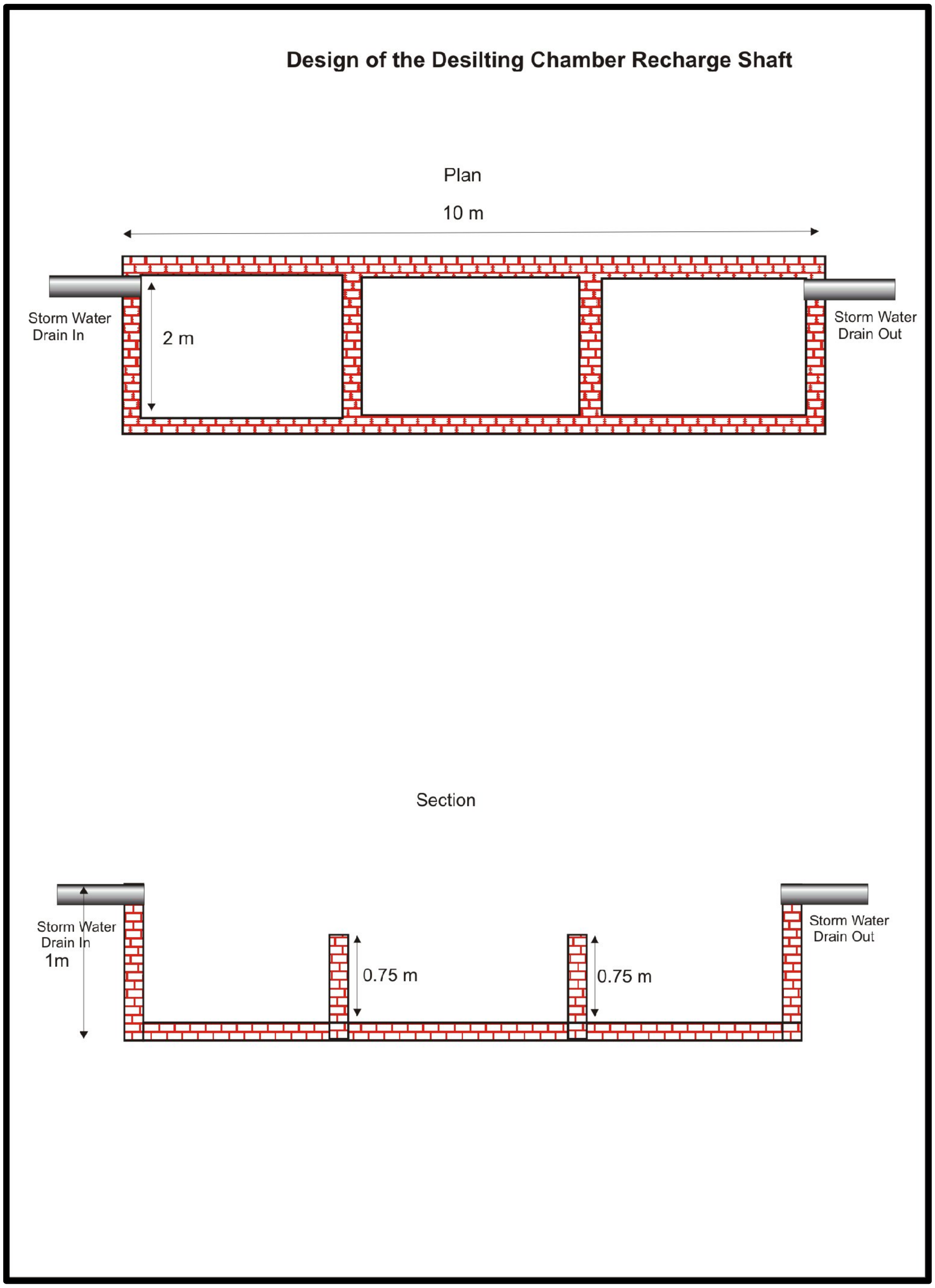


Figure 9.4: Design of de-silting Chamber for Recharge Shaft

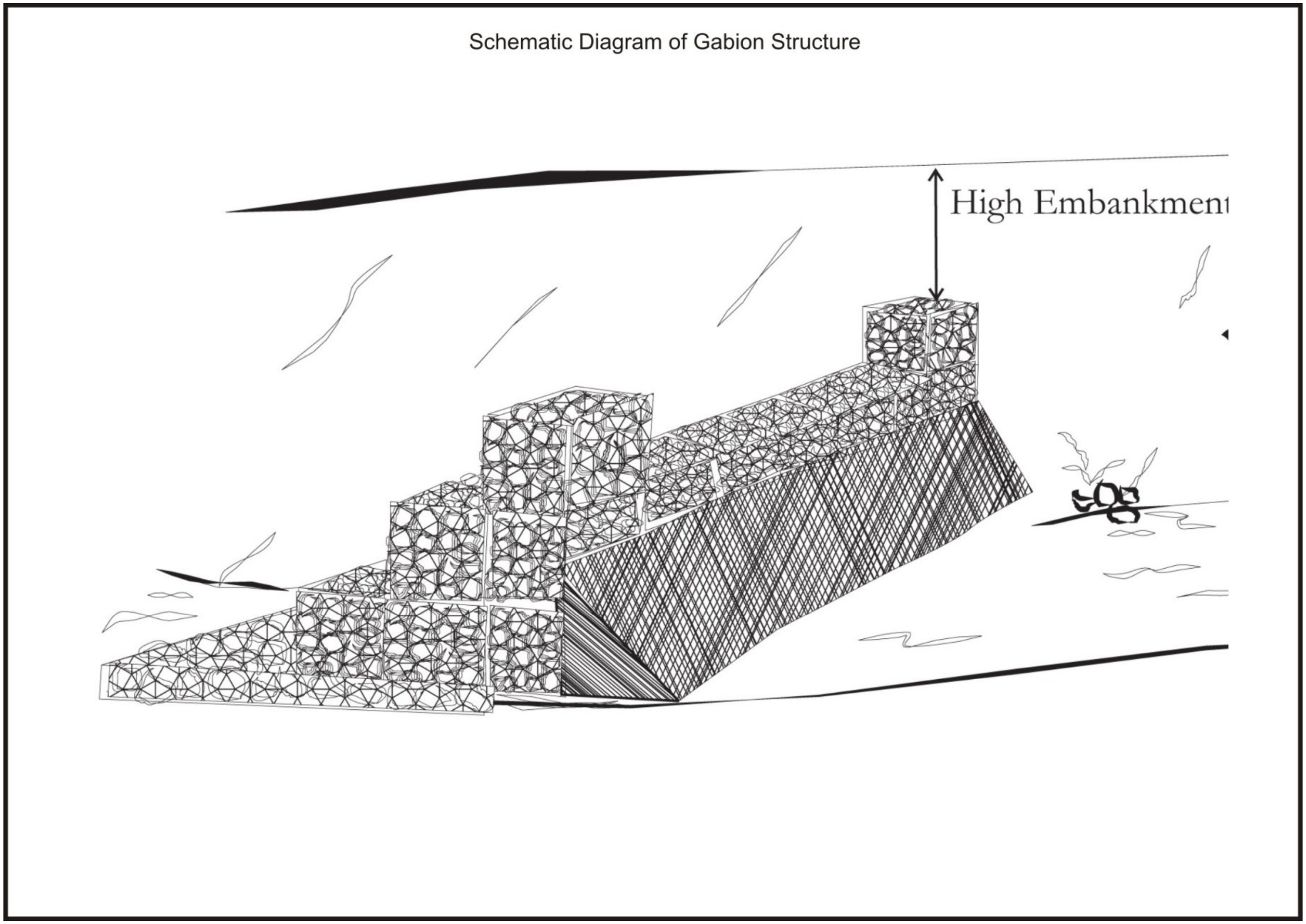


Figure 9.5: Design of Gabion Structure

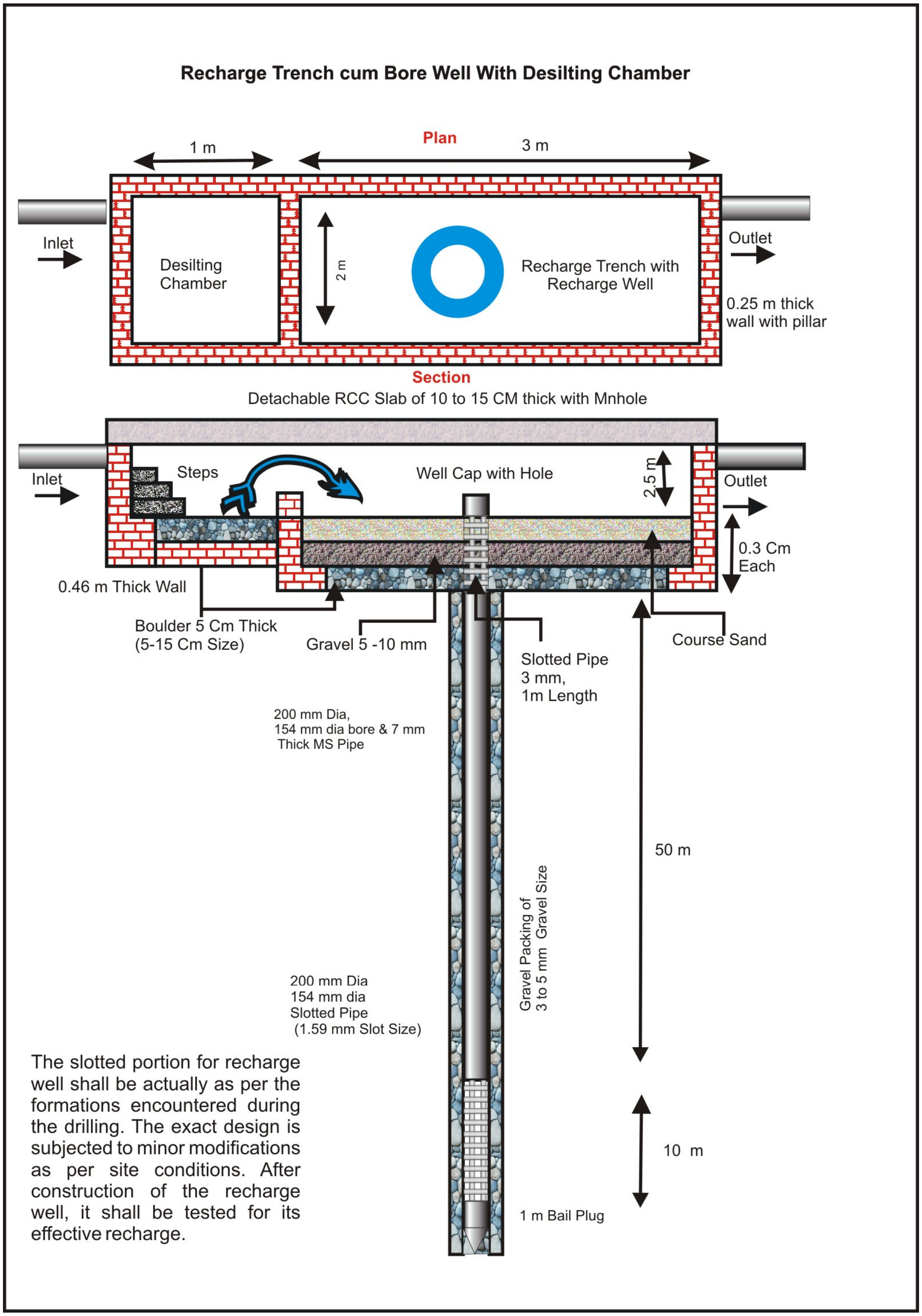


Figure 9.6: Proposed Design of Artificial Recharge Structure (Single Bore)

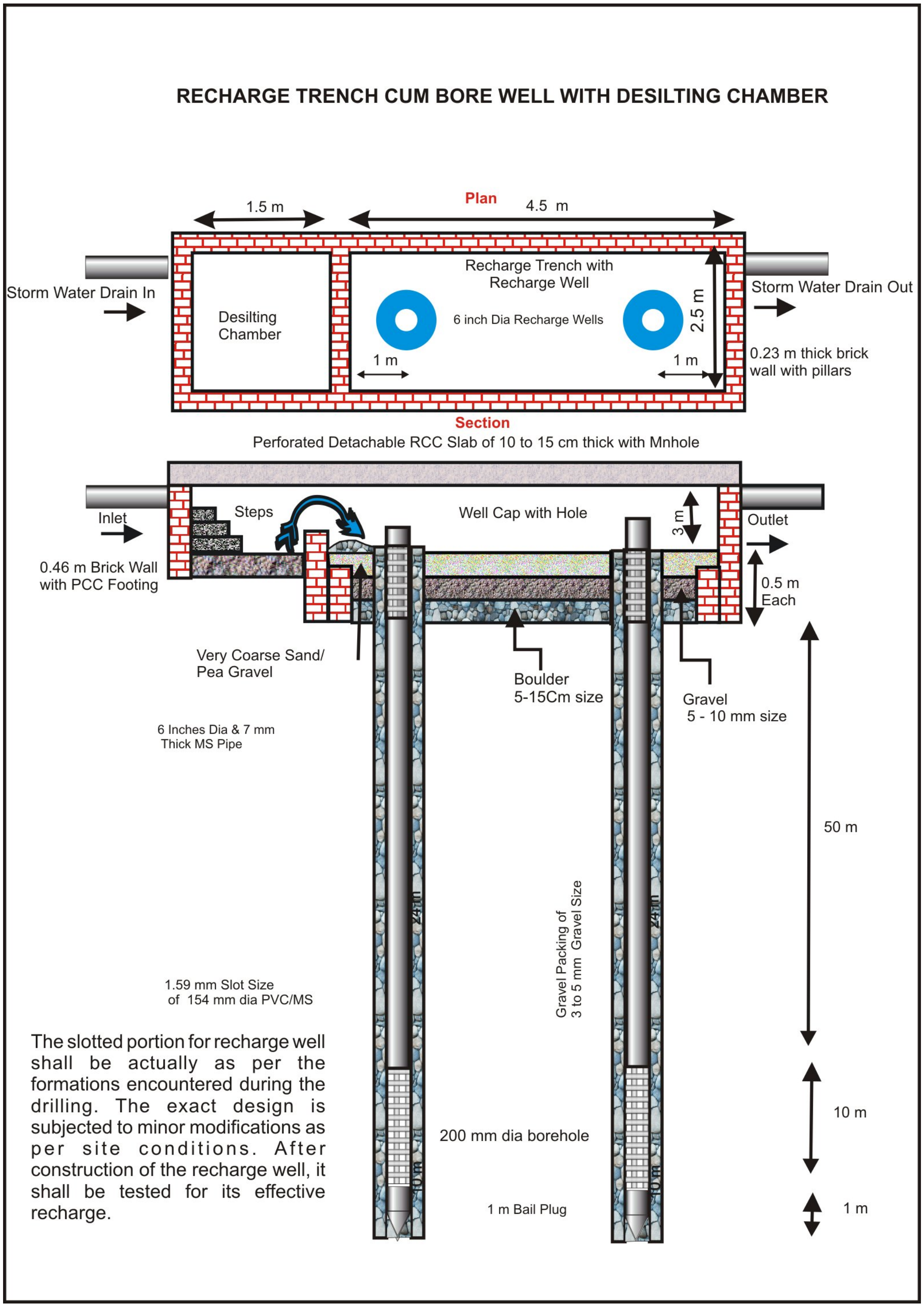


Figure 9.7: Proposed Design of Artificial Recharge Structure (Double Bore)