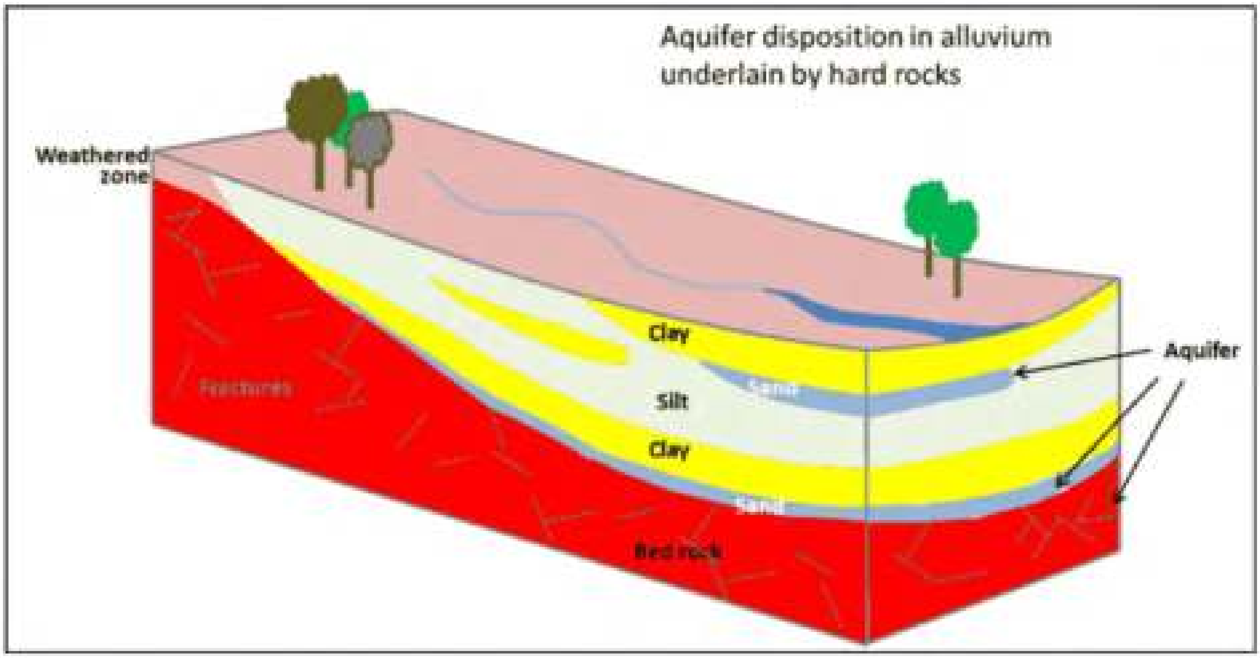
भारत सरकार
जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय
केंद्रीय भूमि जल बोर्ड

GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVINATION

CENTRAL GROUND WATER BOARD



प्रायोगिक जलभृत मानचित्रण परियोजना का प्रतिवेदन
बासवा-बांदीकुई क्षेत्र, दौसा जिला, राजस्थान

REPORT ON PILOT PROJECT ON AQUIFER MAPPING IN BASWA-BANDIKUI AREA, DAUSA DISTRICT, RAJASTHAN

पश्चिमी क्षेत्र, जयपुर WESTERN REGION, JAIPUR
दिसम्बर -2015 December-2015

K. B. Biswas
Chairman

केन्द्रीय भूमि जल बोर्ड
जल संसाधन, नदी विकास
एवं गंगा संरक्षण मंत्रालय
भारत सरकार
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Central Ground Water Board
Ministry of Water Resources,
River Development and Ganga Rejuvenation
Government of India
New Delhi

FOREWORD

Increasing development of ground water to meet the requirements of various segments has resulted in the over-exploitation of this vital natural resource in parts of the country and consequent adverse environmental impacts include, deepening water levels and drying up of shallow wells, reduction in sustainability of wells and seawater ingress in coastal freshwater aquifers. Contamination of ground water due to natural and anthropogenic causes has also increased substantially in the recent decades. The anticipated impact of global warming and climate change are also considered to add to further complicate the issues plaguing the water resources sector in India in the not so distant future. Sustainable development of ground water through judicious management interventions becomes very important to ensure the water security of the future generations.

It is in this context that the Central Ground Water Board, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India decided to take up the National Aquifer Mapping and Management (NAQUIM) Programme, aimed at detailed and systematic study of the major aquifer systems in the country and formulation of management plans for sustainable development of their ground water resources. The Programme envisaged various activities such as compilation of all available data, analysis of data gaps and generation of additional data to fill them, preparation of detailed aquifer maps and formulation of management plans. Various conventional and modern techniques of field data generation, data processing and analysis including integration of data on a GIS platform and numerical groundwater modelling were expected to be used for the programme.

With a view to understand the applicability and efficacy of the above-mentioned techniques in different hydrogeological settings, pilot projects on aquifer mapping were taken up in Six different Hydrogeological terrains in the states of Bihar, Rajasthan, Maharashtra, Karnataka and Tamil Nadu.CSIR-NGRI was engaged as a consultant by CGWB to facilitate use of advanced geophysical techniques in the programme. During the course of the study, groundwater issues have been identified by CGWB specific to the area. With inputs from aquifer mapping studies, aquifer response models have been formulated and various strategies have been tested to arrive at optimal aquifer management plan for sustainable management of precious resources.

This is one among the six reports being brought out based on the studies taken up in the pilot projects. The findings are brought out in the report very coherently and I would like to place on record my appreciation for the excellent work done by the team. I fondly hope that this report will serve as a valuable guide for sustainable development of ground water in the area.

K.B.Biswas
Chairman

Preface

The Central Ground Water Board carried out the Pilot Project on Aquifer Mapping in 6 different hydrogeological environs of the country during 2011-12 to 2014-15 with active support and funding from the World Bank. The Baswa-Bandikui watershed in Rajasthan was selected as the type area for study of aquifers in "*Semi-Arid and Over-Exploited area where alluvium is underlain by hard-rock formations*".

During the project period, available data was compiled, data gap analysis was carried out and data generated to fill these gaps. Extensive hydrogeological surveys were carried out including village wise well inventory, water level and water quality monitoring, collecting hydrogeological information through well drilling, pumping tests, slug test, infiltration tests, etc. Geophysical studies were done both by CGWB and CSIR-NGRI. The geophysical studies included, Vertical Electrical Soundings, ERT, Ground TEM and SkyTem. Advance geophysical techniques of heli-borne sky-TEM surveys were carried out by CSRI-NGRI, Hyderabad in association with Aarhus University, Denmark and SkyTEM (STS), Denmark.

All the data collected using various techniques was studied and synthesized in the form of 3 dimensional aquifer maps incorporating the various attributes of the aquifer system. The data collected and generated was also used to develop a 3D ground water flow model using USGS–MODFLOW software. Various scenarios were generated using this model. Based on the 3D aquifer maps and the results of ground water flow model. Aquifer Management Plans were prepared.

Apart from the efforts made by the officers and staff members of CGWB, there was significant contribution from the scientists of CSIR-NGRI and Ground Water Department, Rajasthan. Sincere efforts of Shri Rana Chatterjee, Scientist D and nodal officer of the project and the entire project team in bringing this project to a fruitful end and compilation of this report are thankfully acknowledge.

I am sure that this report would form a good basis for any aquifer management studies, including the National Aquifer Mapping and Management Programme (NAQUIM), in similar terrains.

(P.K. Parchure)
Regional Director

ACKNOWLEDGEMENT

The entire team of Pilot Aquifer Mapping Studies in Baswa-Bandikui Watershed, Dauas district, Rajasthan extends sincere thanks to Er. K. B. Biswas, Chairman, Central Ground Water Board, Faridabad for leading this flagship project of MoWR, RD & GR, Govt. of India from the front. His continued guidance and support has led to the successful completion of this study.

Sincere thanks is also expressed to Dr. S. C. Dhiman, Sh. Sushil Gupta and Dr. R. C. Jain former Chairmans, Central Ground Water Board, Faridabad under whose tenure the project was conceptualized and initiated.

The guidance and overall supervision of Sh. K. C. Naik, Member (SAM), and of former Members of Central Ground Water Board, Dr. S. Kunar, Dr. Varadaraj, Dr. R. C. Jain and Asish Chakrabarty, is gratefully acknowledged.

The time to time support and scientific guidance during the project work extended by the officers from Central Ground Water Board, CHQ, Faridabad especially Dr. Sunil Kumar, Regional Director & then Director (admin), Sh. Sanjay Marwah, Regional Director, Dr. S. Suresh, Scientist 'D' , Sh. S. K. Sinha, Scientist 'D', Er. K.R. Biswas, S.E., Er. Nidhish Verma, Ex.En. , Sh. K. V. Kumar, Superintending Geophysicist (Retd.), Sh. Madhukar, Superintending geophysicist, Sh. Rajesh Chandra, Sc 'C', Sh. Pankaj Kumar, Assistant Hydrogeologist, are thankfully acknowledged. The report of the Pilot Aquifer Mapping Project Studies of Baswa-Bandikui watershed took the present shape because of the meticulous scrutiny of the project report by the expert team from Central Ground Water Board, Central Head Quarters. The reviewers of the project report at Central Ground Water Board, CHQ, Faridabad are gratefully acknowledged. Thanks are also due to the team of officers Dr. Subhash Chandra, Dr. Saurabh K. Verma, Dr. Murlidharan, N.C.Mondal, from NGRI, Hyderabad under the competent leadership of Dr. Sakeel Ahmad, Chief Scientist, NGRI for providing useful geophysical input for finalization of Aquifer map.

The pilot project team of Baswa-Bandikui Project, Rajasthan gratefully thanks Sh. Avnish Kant, Scientist 'C' and other senior officers in the Hydrology Project cell of MoWR, RD & GR, Govt. of India co-coordinating the project in flawless manner. The authors express sincere thanks to World Bank and its representatives, especially Dr. Anju Gaur and Dr. P.C. Chandra and Sh. B. Jayakumar, the Consultants, World Bank for valuable guidance.

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The support and technical input from the colleagues of Central Ground Water Board, Western Region, Jaipur is gratefully acknowledgement.

The authors sincerely thanks to all nodal officers of the other four pilot projects and officers concerned for the technical discussions and inputs during the meetings.

Thanks are also due to various State and Central Govt. agencies viz., Rajasthan State Ground Water Department, Jodhpur, Water Resources Department of Rajasthan, Jaipur, Geological Survey of India, Jaipur, Irrigation Department, Jaipur, Agriculture Department, Jaipur and

SRSAC, Jodhpur for providing valuable data and suggestions. Special thanks are due to S/Sh. Yogesh Sharma, ex. Superintending Hydrogeologist and Dr. Vinay Bhardwaj and M.M. Kant, Senior Hydrogeologists of GWD, Jaipur district for extending full cooperation during the entire tenure of the project. Sh. K.K. Sharma, Director of Education in the State Education Department and founder of a NGO named 'Sujalam' has been instrumental in demonstrating low cost Roof Top Harvesting constructed in the school buildings in Baswa-Bandikui watershed. The input from Sh. K.K. Sharma is gratefully acknowledged. The valuable input from Dr. Hitendra Gera, Agriculture Research Officer, Govt. of Rajasthan on micro-irrigation systems in Rajasthan is gratefully acknowledged.

Last but not the least, sincere thanks is expressed to every person involved in this project and the villagers from project area.

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ABBREVIATIONS

CGWB	Central Ground Water Board
cm	Centimetre
DES	Department of Economics & Statistics
Ham	Hectare metre
Heli-TEM	Heliborne Transient Electro Magnetic Method
IMD	India Meteorological Department
LCI	Laterally constrained inversion
Lps	Litres per second
M	Meter
m bgl	Meter below ground level
m ham	Million hectare metre
M.I.	Minor Irrigation
mcm	Million cubic metre
mm	Millimetre
MOWR	Ministry of Water Resources, Govt. of India
NGRI	National Geophysical Research Institute
SCI	Spatially constrained inversion
sq.m.	Square meter

EXECUTIVE SUMMARY

The aquifer mapping project in Baswa-Bandikui watershed, Dausa district, Rajasthan, India is taken up with the objective to evolve an aquifer management plan in a semi-arid terrain in the western India which is suffering from continuous depletion of ground water level and is categorized as 'Over-exploited'. The project study involves establishing the aquifer disposition and its characterization at 1:50,000 scale using latest state of art technology in the field of hydrogeology and geophysics. Based on the aquifer mapping findings, suitable aquifer management plans are recommended.

The study area covers around 600 sq.km. forming a part of the Banganga river basin. Banganga river has two tributaries - Sanwan Nadi and Palasan Nadi. The area receives about 660 mm rainfall annually. Soil cover is predominantly loamy and alluvial soil.

The Aquifer disposition of the study area was constructed based on results of the ground water exploratory drilling investigations and advanced geophysical studies using various techniques including VES, ground TEM, ERT 2-D imaging and Heliborne studies viz. SkyTEm. Broadly two Aquifer systems are identified – upper Aquifer I is alluvium and underlying, Aquifer II is hard rock. Alluvium aquifer consists of alternate horizons of coarser sediments comprising fine to medium grained sand, silt and kankar and finer grained sediments comprising silty clay, clay intercalated with kankar. Hard rock aquifer comprise of upper weathered and lower fractured/ crystalline hard rock including quartzites, gneisses, schists and phyllites. The thickness of alluvium increases towards east where it is more than 60m thick.

Water level in the aquifers in the major part of the area varies from 40 m to 60 metre below ground level. Ground water flow direction is from west to east. Ground water quality is good in major part of the area. However at certain localized pockets, salinity, fluoride, nitrate content in ground water are found to be higher than the permissible limit. Various aquifer parameters are determined based on field studies, like infiltration rate through infiltration studies, draft parameter using unit draft sample survey, aquifer parameters using APT and Slug tests.

Ground water flow modeling was carried out to assess the ground water availability, its flow pattern and predict future scenario based on present recharge and draft status. A single layer model has been developed which include both alluvium and underlying weathered formation. Predictive scenarios are generated using the parameters determined during calibration for evolving management strategies. In the first scenario, the flow model was used to determine the effect of withdrawal and recharge hypothetically to be continued upto next 10 years till the year 2024 at the same rate as exist in the present date. In this scenario, certain parts of the area ended in drying up from the second stress period and progressively the area increased till the end of this scenario. The scenario implied that the present rate of ground water development would lead to drying up of the aquifers and therefore an optimum ground water development scenario needs to be evolved. Hence, in the Second scenario, the flow model was used in conjunction with the availability of more recharge. Monsoon recharge was increased by three times and applied to the model. The scenario was selected to see the possible changes in future in case artificial recharge plan is implemented in the study area to mitigate the declining water level. Finally, a third scenario was generated in which the Ground Water flow model used the feasible artificial recharge plan proposed for the study area. The simulation model in the third scenario indicated that

a portion of dried up area generated in the first scenario is recovered due to the effect of the recommended artificial recharge plan.

The ground water management programme envisaged in Baswa-Bandikui watershed include – a. Notification of the Bandikui block for the purpose of ground water regulation, b. artificial recharge to ground water through construction of Percolation Tanks and Recharge Shafts and roof top rainwater harvesting in Government Offices and institutions. And c. concerted mobilization programme of farmers to use water efficiency measures like sprinkler and drip irrigation.

The study has brought out the quantitative assessment of the serious problem of ground water depletion in the area and recommended remedial measures.

1. INTRODUCTION

National Aquifer Mapping and aquifer based Groundwater Management Programme for Sustainable Groundwater Management of India are being taken up by Government of India to address the issues of growing dependency on groundwater, escalating demand and increasing drying up of aquifer. It requires a comprehensive country-wide aquifer map at village or micro-watershed level at 1:50,000 scale. It is a holistic multi-disciplinary scientific approach for aquifer characterization.

In order to establish the efficacy of tools and techniques to be effectively applied in National Aquifer Mapping, Pilot projects were taken up in six different hydrogeological set-up in the country. These projects are known as Pilot project on Aquifer Mapping (Figure 1). The main purpose of the pilot aquifer mapping study is to establish the methodology and technology and the scope of up scaling for the countrywide National Aquifer Mapping Programme.

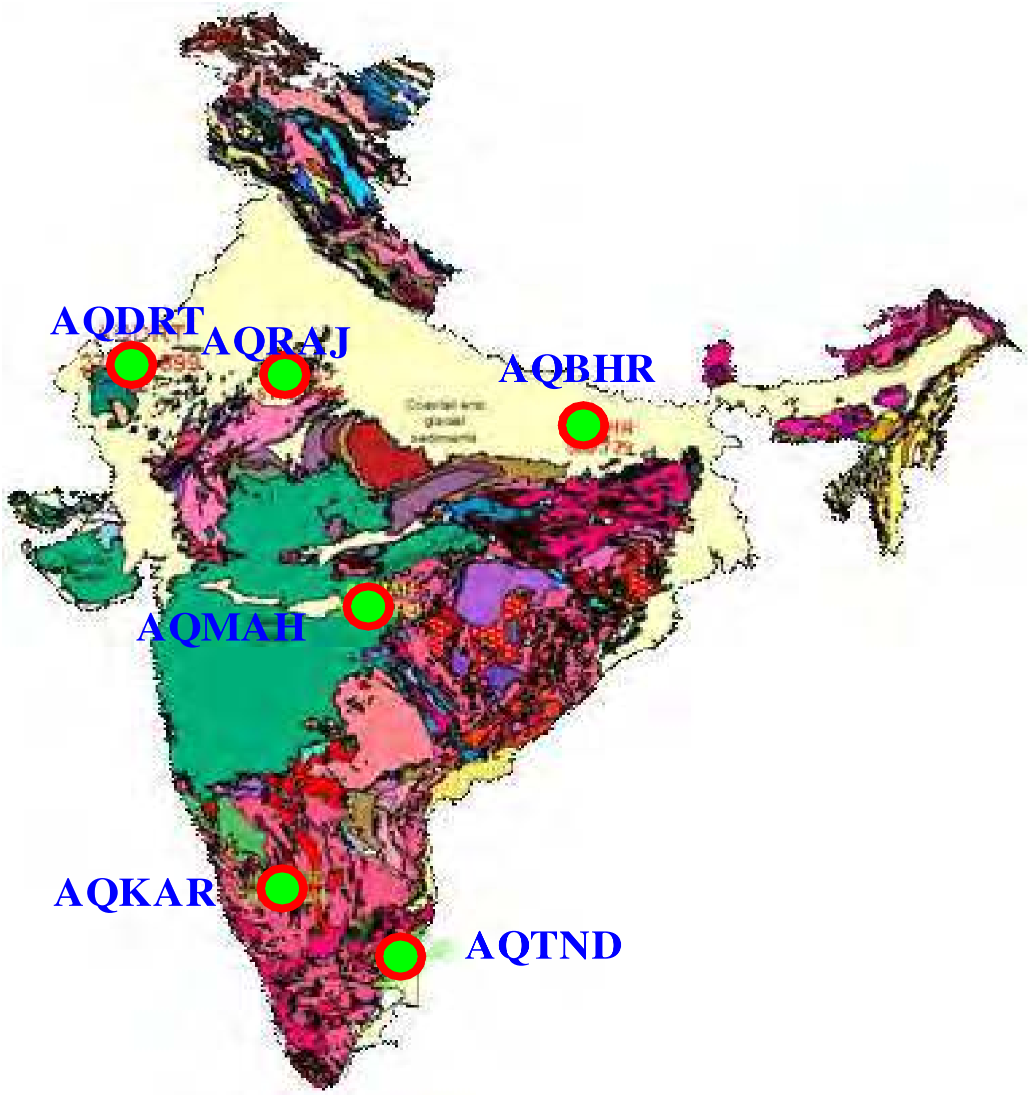


Figure 1. Locations of Pilot Aquifer Mapping project areas: Rajasthan, Desert Area, Maharashtra, Karnataka, Bihar, and Tamil Nadu

Objectives:

The objectives of the pilot project are

i. To define the aquifer geometry, type of aquifers, ground water regime behaviours, hydraulic characteristics and geochemistry of Multi-layered aquifer systems on 1:50,000 scale
ii. Intervention of new geophysical techniques and establishing the utility, efficacy and suitability of these techniques in different hydrogeological setup.
iii. Finalizing the approach and methodology on which National Aquifer mapping programme of the entire country can be implemented.
iv. The experiences gained can be utilized to upscale the activities to prepare micro level aquifer mapping.

Scope:

The activities of the Pilot Project on Aquifer Mapping can be envisaged as follows

1. **Data Compilation & Data Gap Analysis:** One of the important aspect of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe an aquifer system. The data were assembled, analysed, examined, synthesized and interpreted from available sources. These sources were predominantly non-computerized data, which was converted into computer based GIS data sets. On the basis of available data, Data Gaps were identified.
2. **Data Generation:** There was also a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping. This was achieved by multiple activities such as exploratory drilling, geophysical techniques, hydro-geochemical analysis, remote sensing, besides detailed hydrogeological surveys. CSIR-NGRI has been hired as consultant to carry out geophysical studies including advance Heliborne Transient Electro Magnetic Method (Heli-TEM) to delineate multi aquifer system; to bring out the efficacy of various geophysical techniques and a protocol for use of geophysical techniques for aquifer mapping in different hydrogeological environs.
3. **Aquifer Map Preparation:** On the basis of integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out Characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical) in reference aquifer extremities, quality, water level, potential and vulnerability (quality & quantity).
4. **Aquifer Response Model:** On the basis of aquifer characterization, issues pertaining to sustainable aquifer management in the area have been identified. Initially, a conceptual model has been developed for the pilot area and subsequently, a mathematical model has been formulated simulating the field situation, which was calibrated and validated with the field data. Various scenarios have been tested in the model to study the response of the aquifer to various stress conditions and predictive simulations have been carried out up to the year 2024.

5. **Aquifer Management Plan Formulation:** Aquifer response Model has been utilized to identify a suitable strategy for sustainable development of the aquifer in the area.

1.2. APPROACH

The overall implementation of the project has been carried out by Central Ground Water Board (CGWB), Western Region, Ministry of Water Resources, Govt. of India under Hydrology Project II funded by World Bank.

The project work involves collection of existing data from various sources including CGWB records, State Government agencies, literature available in the libraries and internet, NGO and other sources relevant for the purpose of aquifer mapping and management. Some of the baseline reports on the project area include Banganga River Basin Project Report, Central Ground Water Board (1980), Water Resources Planning for Banganga River Basin, TAHAL (1998) and district report of Dausa district, CENTRAL GROUND WATER BOARD (2008).

The data are assembled, analysed, examined, synthesized and interpreted from available sources. These sources are predominantly non-computerized data, which is converted into computer based GIS data sets. Data gap analysis was carried out and additional data are generated through hydrogeological surveys, exploratory drilling, advanced geophysical techniques, hydro-geochemical analysis, remote sensing etc. that broadly describe the aquifer system prevailing in the area.

The data generation work of the CGWB component is being partly outsourced. The exploratory drilling work was outsourced to private contractor through centralized National level tendering. The advanced geophysical investigation was carried out by National Geophysical Research Institute (NGRI), Hyderabad. The Heliborne Geophysical studies was undertaken by Aarhus University, Denmark and SkyTEM (STS), Denmark. Rest of the project work was undertaken through departmental workforce.

The integrated database is transformed into aquifer maps in GIS platforms. The understanding on the disposition of aquifers are refined based on the GIS outputs and a conceptual model is developed. The conceptual model is applied to a numerical flow model to determine the overall water budget and generate predictive scenarios based on the proposed aquifer management strategies. Finally, an aquifer management plan is formulated. The following flow chart highlights the broad steps adopted in the pilot aquifer-mapping project in Baswa-Bandikui watershed, Dausa district, Rajasthan (Figure 2).

1.3 LOCATION

The pilot aquifer mapping area selected for the semi-arid climate condition is Baswa-Bandikui watershed, Bandikui block, Dausa district in Rajasthan. It is around 80 km east of Jaipur, the capital city of Rajasthan state. Distance between Jaipur to Bandikui is 103 km by Road and 84 km by Rails. The project area is about 647 sq.km. The area lies within 26^0 56′ 36′′ N and 27^0 10′ 36′′ N and 76^0 25′ 00′′ E and 76^0 49′ 31′′ E, topo sheets 54A/8, 54A/12, 54A/16, 54B/5 and 54B/9 located in eastern part of Rajasthan. The location of the project area is depicted in Figure 3. It forms a part of Banganga basin, located toward north of the east flowing Banganga River. The aquifers in the area are represented by alluvium underlain by hard rocks. The area is categorized as 'Over-exploited' as per State Government's ground water resources estimates for the year 2013 and is characterized by long term decline in ground water level. The aquifer mapping in the project area was carried out at 1:50,000 scale.

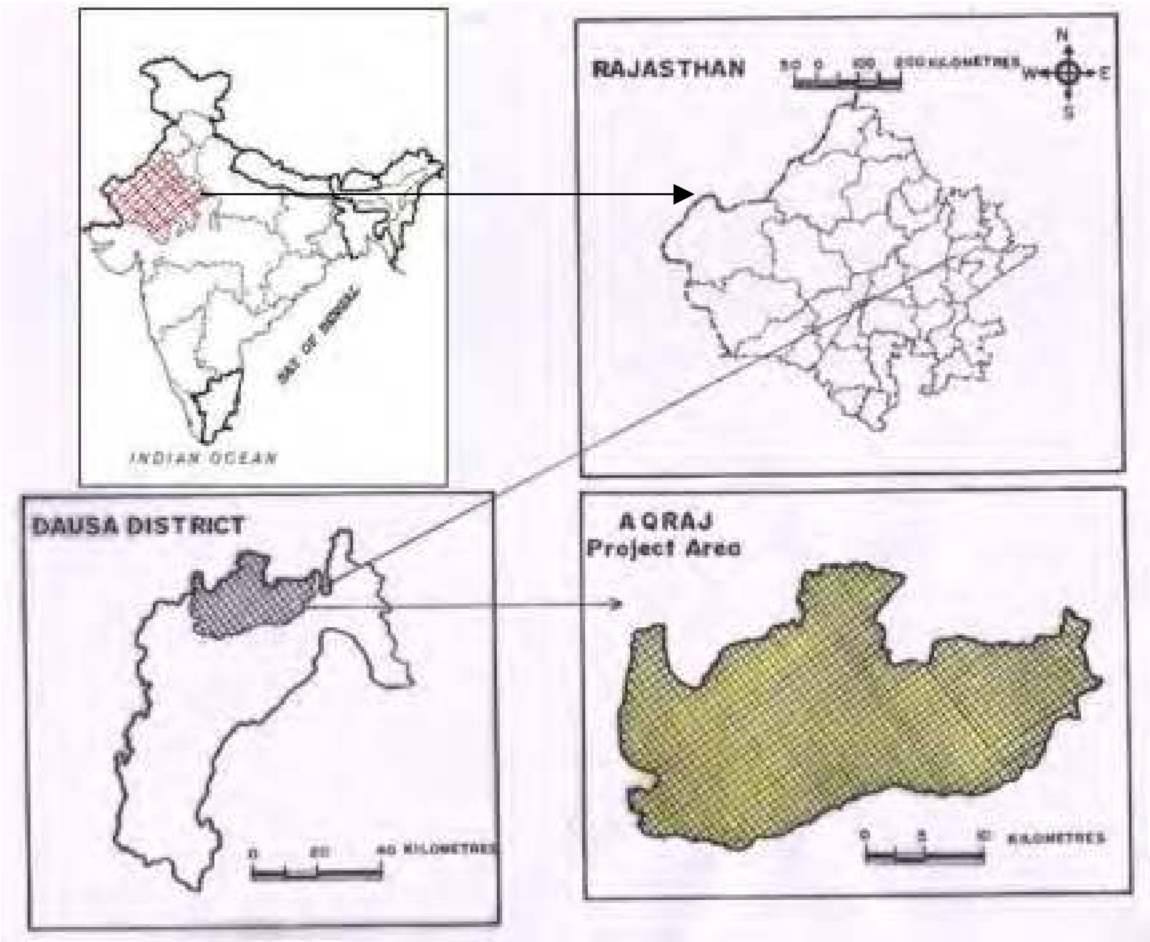


Figure 2. Location map of Baswa-Bandikui watershed, Dausa district, Rajasthan

The base map of the project area is shown in Figure 3.

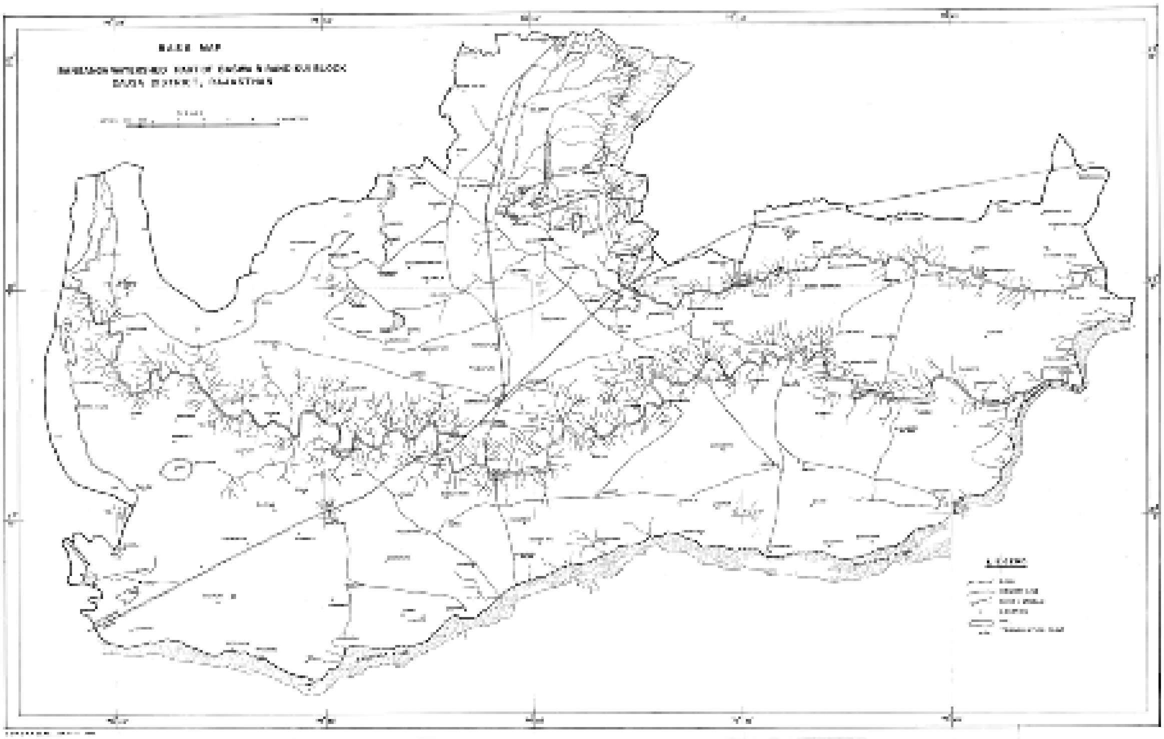


Figure 3. Base map of Baswa-Bandikui watershed, Dausa district, Rajasthan

2. DATA AVAILABILITY & DATA GAP ANALYSIS

The data on various attributes of the study are collected from the available literatures of Central Ground Water Board, State Ground Water Department of Rajasthan and various Central and State Government agencies. The compiled data are plotted on 1:50000 scale map and an analysis of data gap was carried for Exploratory well data, Ground Water Regime Monitoring, Geophysical studies etc. The summerized table presenting the Data Requirement, Data Availability and Data Gap Analysis is presented in table 1.

Table 1. Data Availability and Data Gap Analysis in Baswa-Bandikui Watershed, Dausa District, Rajasthan

Sl. No.	Items	Data Requirement	Data Availability	Data Gap
1	Climate	Metereological Stations spread over the project area	1 Metereological Station in Northern part	At least 5 stations spread over the area
2	Soil	Soil map and Soil Infiltration Rate	Soil map	Soil Infiltration Rate across study area
3	Land use	Latest Land Use pattern	Land use data of 2002-03	Latest data required
4	Geomorphology	Digitized Geomorphological map	Not Available	To obtained digitised Geomorphological map
5	Geophysics	Geophyiscal data in each Quadrant ~50 VES study	20 VES study in 8 Quadrants	No data in 8 Quadrants and Insufficient data in 2 Quadrants
6	Exploration Data	EW in each Quadrant – Total 16 Quadrants	15 EW data in 7 Quadrants	No data in 9 Quadrants
7	Monitoring Regime	2 to 3 wells in each of 16 Quadrants	18 wells in 7 Quadrants	No data in 9 Quadrants
8	Recharge Parameters	Recharge parameters for different soil and aquifer types based on field studies	Recharge parameters given in Ground Water Resources Estimation	Entire study area
9	Discharge Parameters	Discharge parameters for different GW abstraction structures	Discharge parameters given in Ground Water Resources Estimation	Entire study area

2.1 CLIMATE

DATA AVAILABILITY

The information on climate is obtained from the Banganga River Basin project report (1980) and Dausa district report (2008). Various climatological features of the Dausa district, such as rainfall, temperature, potential evapotranspiration, humidity and wind-speed are compiled. Rainfall data (1977– 2006) of one Rain Gauge Station viz. Baswa is obtained. The data of IMD Observatory located at Sanganer have been used to discuss other climatological features.

The average (1977-2006) annual rainfall received in the project area is about 623 mm as per the available data. The mean daily maximum temperature is highest (40.6° C) in the month of May. However, the mean daily minimum temperature is highest (27.3 C) in the month of June. The isohytal map showing normal annual rainfall in Baswa-Bandikui watershed based on the available database is given in Figure 4.

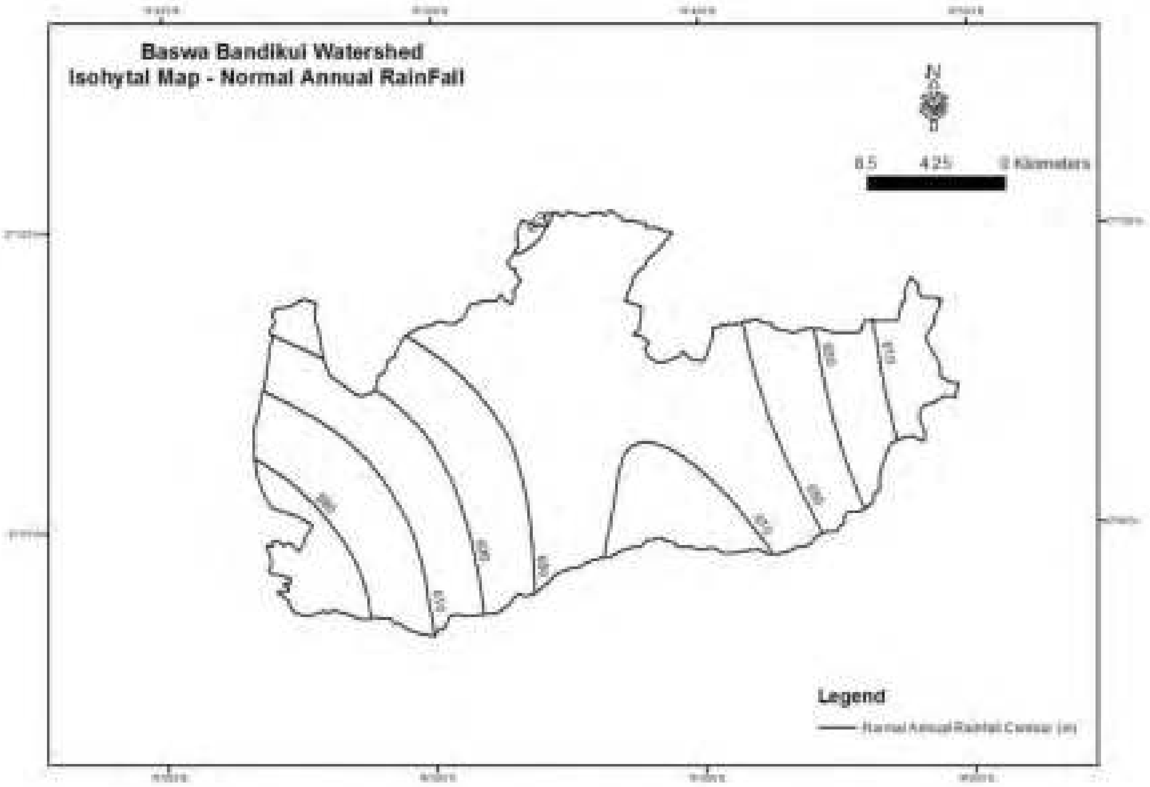


Figure 4. Isohytal map showing normal annual rainfall in Baswa-Bandikui watershed

Data Gap Analysis

A perusal of meteorological data indicates that data gap on rainfall exists in the southern and eastern part of the project area.

2.2 SOIL

Data Availability

The soil types in the project area is obtained from the district report of Dausa (Central Ground Water Board, 2008). The project area is mainly covered with loamy soil characterized by mixture of sand, clay and organic materials. In the northeastern part of the project area, alluvial soil is encountered which is fine grained soil type. The soil map are given in Figure 5.

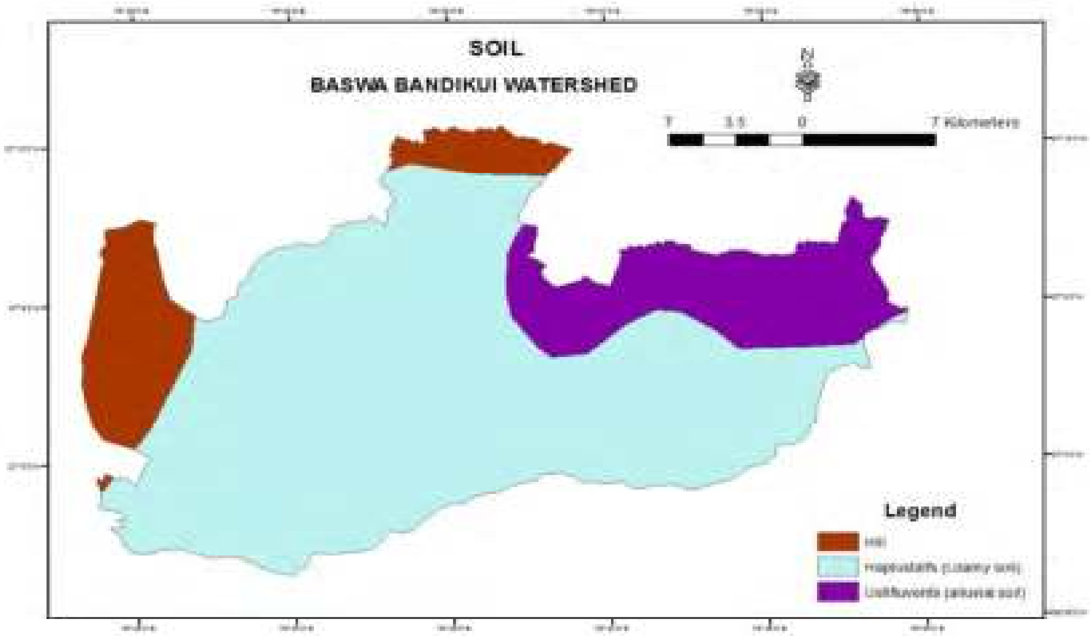


Figure 5. Soil map of Baswa-Bandikui project area, Rajasthan

Data Gap Analysis

Data on soil infiltration rate for various types of soils existing in the project area needs to generated in order to analyse the impact of the soil cover on the ground water regime of the area.

2.3 LAND USE

DATA AVAILABILITY

Land use data are collected from Agriculture Statistics hand book of Rajasthan for the year 2002-03. Agriculture is the predominant occupation in the area. The main source of irrigation is ground water wells. The land use statistics of the area is given in Table2a &2b.

Table 2a. Land use statistics of Baswa-Bandikui watershed, Dausa district, Rajasthan (in ha)

Total geographical area	Area not suitable for cultivation	Forest	Hills	Barren land	Tanks / ponds	Area under cultivation	Area irrigated by wells	Total Irrigated Area
59800	5892	378	4865	242	407	33662	19122	19122

Source – Agriculture statistics, 2002-03, Rajasthan state

Table 2b. Well statistics in Baswa-Bandikui watershed, Dausa district, Rajasthan

Total nos. of wells	No of wells in use	Domestic water supply including hand pumps & tubewells	Irrigation wells fitted with pump sets & tubewells
9129	7111	499	6612

Source – Agriculture statistics, 2002-03, Rajasthan state

DATA GAP ANALYSIS

Land use statistics available at the time of inception of the project was found to be quite out-dated. This needs to be updated with the latest data available with the state / local government agencies.

2.4 GEOMORPHOLOGY

Data Availability

Information on geomorphology is obtained from the district report of Dausa district, Rajasthan (2008). The Baswa-Bandikui Watershed forms part of East Rajasthan upland. The watershed consists of fairly open undulating plain with hillocks in the North eastern border and in the northern part. In general, the watershed has low land topography and sheet & gully erosion of moderate to severe order.

Geomorphological features reported in the area include -
Ridges and valleys - They are confined to hilly terrain mostly lies to north eastern boundary of the watershed and scattered isolated in northern western part.
*Alluvial pl*ain - Major part of the watershed is characterized by undulating plains which are big and large monotonous land scape with fairly thick alluvial cover.
Bad land ravines - These occur in form of longitudinal track in the central and southern part of the watershed and in isolated pockets in the east of Dausa.
Drainage - The area is bounded by the Banganga river in the south and its tributaries are Sanwan Nadi and Palasan Nadi.

Data Gap Analysis

Geomorphological features existing in the area needs to digitized and presented in GIS platform, so that the same can be used in hydrogeological interpretations and formulation of ground water management plan.

2.5 GEOLOGY

The general geological succession in the district (based on the work of the Geological Survey of India) is as follow (Table 3):

Table 3: Geological succession in Basswa-Bandikui watershed

ERA/PERIOD	RANK		LITHOLOGY
Quaternary	Recent to Sub-recent		Clay, kankar and wind blown sand
----------------------Unconformity----------------------			
Proterozoic	Delhi SuperGroup	Ajabgarh Group	Schists, Phyllites, Marble and Quartzites
		Alwar Group	Quartzites, Conglomerates & Schists
		Raialo Group	Dolomitic marble, quartzite
----------------------Unconformity----------------------			
Archaean	Bhilwara Super Group		Granite, Gneisses, Schists and Migmatites

The major part of the area is covered by Quaternary alluvium. The area is occupied by rocks of the Mangalwar complex (Archaean), unconformably overlain by the rocks of the Delhi Supergroup (Palaeo to Meso Proterozoic). Heron (1917) mapped this area under the Aravalli system and the Delhi system. The oldest rocks exposed in the area are granites and quartzite with interlayered phyllite and schist. These rocks were included in the Magalwar complex of the Bhilwara supergroup. Granite is porphyritic, greyish to pinkish in colour, coarsely crystalline with porphyroblast of K-feldspar and at places highly weathered and is associated with granite gneiss granite exposed at the foot hills, and as isolated mounds, hillocks in the central part of the area.

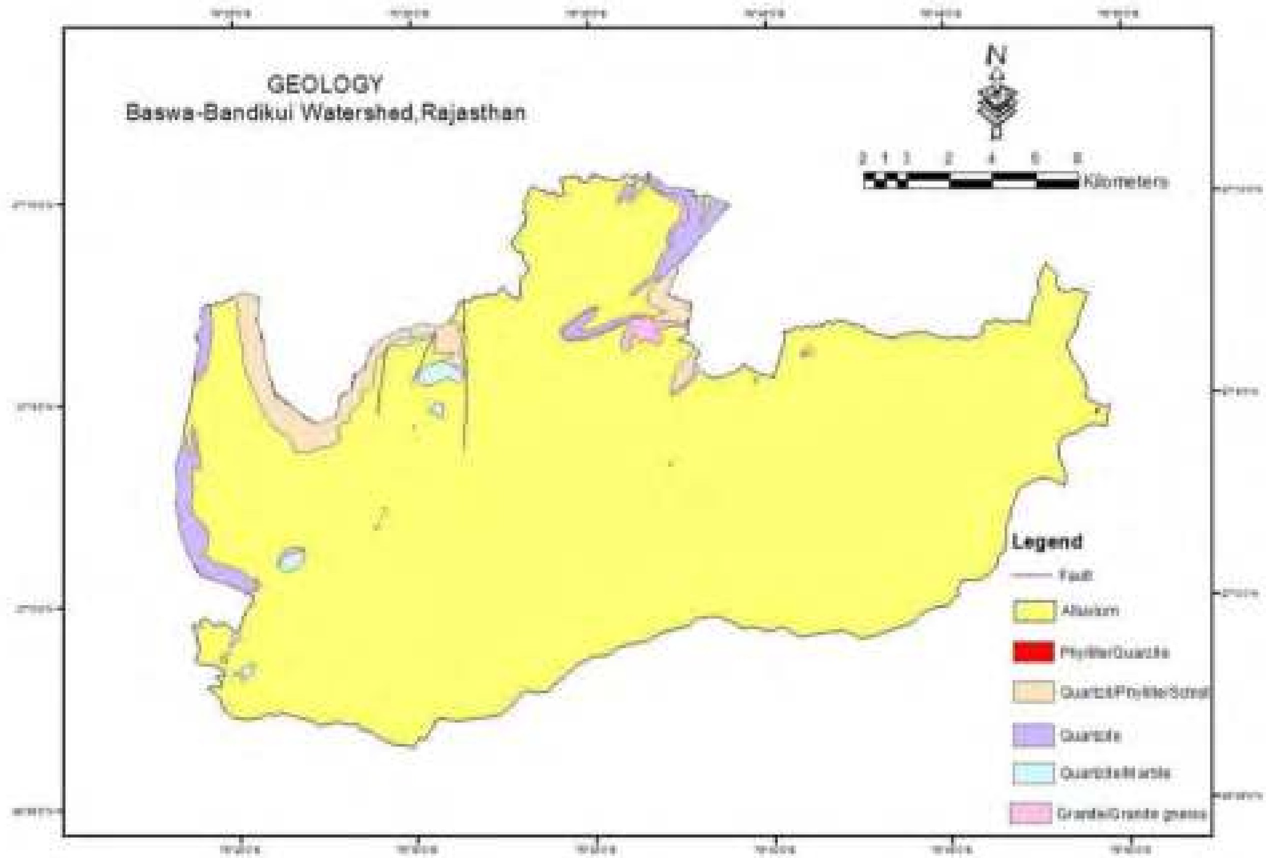
The Delhi supergroup comprises, the Raialo group, the Alwar group and the Ajabgarh Group based upon the lithological charateristics and the order of superposition. The Raialo group comprises dolomitic marble with minor quartzite intercalations and basal quartzite, which is conglomeratic at places in the lower part grouped under Dogheta Formation. The rocks of the raialo group pass unconformably into the rocks of the Alwar group.

The Alwar group comprises mainly Meta arenaceous rocks with interbands of meta argilites and is represented by rocks of the Rajgarh Formation, the Kankwarhi Formation, and the Pratapgarh Formation in ascending orders of superposition. The Alwar group of rocks are conformably overlain by the Ajabgarh group. The Ajabgarh group comprises mainly argillaceous and calcareous rocks represented by the kushalgarh formation, the Sariska Formation and the Thanagazi Formation in ascending orders of superposition.

The rocks of the Delhi super group has undergone intensive deformation resulting in formation series of folds and faults (Plate 1) and the variation in the direction of strikes and dips of the beds. The general trend of the rocks in N-S with steep dips towards east or west. There are number of northly plunging antiforms and synforms and several minor folds have been deciphered in the area. The area is transvered by several faults trending N-S to NE-SSW and NNW-SSE. Most of the faults are related to Post folding phase of deformation.

The Quaternary sediments mostly occupied by gneisses and Schists of the Mangalwar complex (BGC). They consist of sand, silt, clay, soil forming alluvium of both Aeolian and fluvial nature.

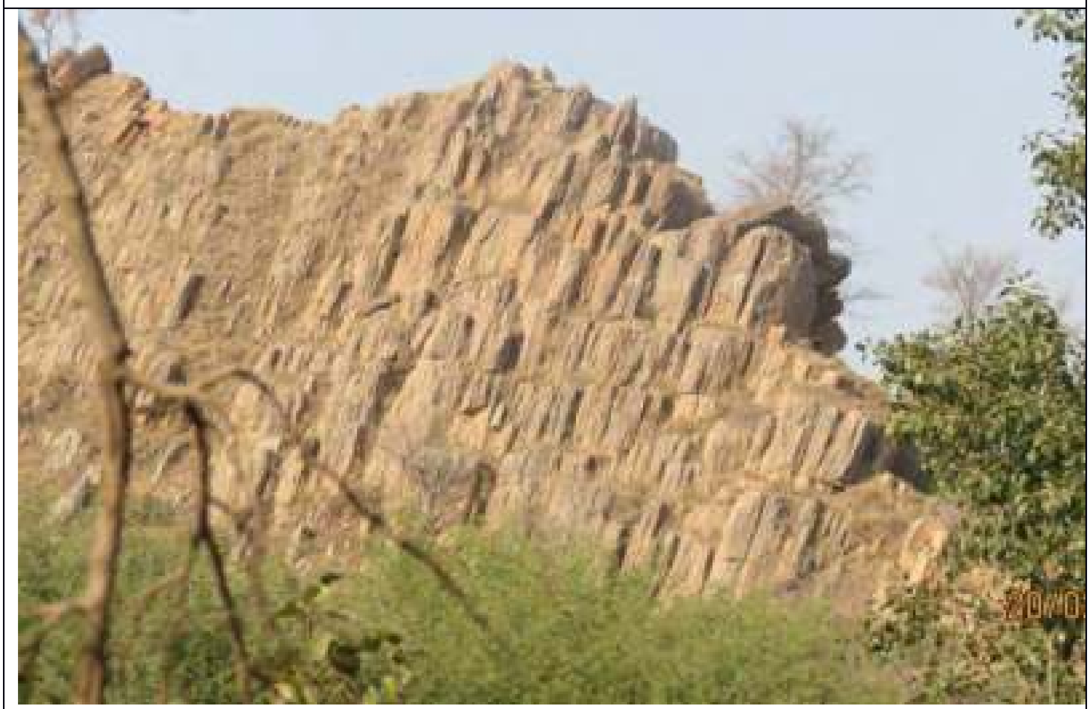
Glass sands are found at Bhankari (26^0 58': 76^0 24'), Khwa(26^0 46': 76^0 30'), Bhedoli. The glass sand is suitable for refractory and glass making purposes. Marble at Kaloata (26^0 58': 76^0 29') and soapstone at khawa hill are also found. The quartzite of this area is quarried locally for construction purpose at many places.



The geology of the Watershed is shown in Figure 6.

Figure 6**.** Geological map of Baswa-Bandikui watershed

(a) Intense Tectonic activity including Folding Faulting and Shear Zones



(b) Well Jointed Quartzite Outcrops

Plate 1. Geological outcrops in Baswa-Bandikui watershed, Dausa district, Rajasthan

2.6 GEOPHYSICS

Data Availability

Geophysical survey has been carried out in Banganga Basin, Bandikui block, Dausa district during the month of October'2011 to decipher the alluvium thickness and different Geoelectrical layers. The surface electrical resistivity methods are commonly used for Hydro geophysical investigation and have been applied in the present study. In order to observe the variation in the order of resistivity, in vertical direction The Schlumberger Vertical Electrical Sounding (VES) method was used. The apparent resistivity values for VES were plotted on double log paper against half current electrode separations. The VES curve has been interpreted by conventional curve matching method using two layer master curves, auxiliary point chart & then by using computer software programmes then final results are obtained.

Surface resistivity measurements have been made with the help of CRM AUTO C Resistivity meter, it is digital sensitive instrument consisting of transmitter and receiver in one unit & it gives the direct resistance values. The data of 20 VES were collected during the field investigations. The data was interpreted by conventional curve matching method and than smoothened by using computer software's. The interpreted layer parameters of VES conducted during the survey are given in Table 4 & 5. The location of VES soundings is shown in Figure 7. The representative VES curves are shown in Figure 8.

Geologically the area is covered by Alluvium. As per the Geophysical data interpretation the thickness of alluvium cover varies from 14 to 63 m bgl. The quality of formation water has been inferred to be fresh.

Table-4: Location of Geophysical Survey (VES) and Depth to bed rock

S.No.	**Location of VES**	**Inferred Depth to Bed rock (in m.)**	**S.No.**	**Location of VES**	**Inferred Depth to Bed rock (in m.)**
1	Bhojawara	21	11	Ralota	43
2	Khuntla	63	12	Khera	48
3	Pratappura	63	13	Kalota	14
4	Muradi	60	14	Gudlia	38
5	Pamaribas	48	15	Rampura	36
6	Abhaneri	64	16	Bagdera	48
7	Kiratpura	58	17	Muhi	33
8	Rani Ka Bas	52	18	Barial	52
9	Sudala	48	19	Kolana	49
10	Lotwara	39	20	Baswa	25

Table-5: Summarized results of Geophysical Survey (VES) conducted in Banganga basin

VES No.	**Layer resistivity (ohm-m)**						**Layer thickness (m)**					**Total Thick-ness (m.)**
	P_1	P_2	P_3	P_4	P_5	P_6	h_1	h_2	h_3	h_4	h_5	H
1	1000	2600	58	5	5750		1.25	1.1	8.7	9.9		21
2	37	23	11	5000			.5	16	46.4			63
3	44	7	28	40	89		.5	0.42	7	56		63
4	41.6	.37	21.8	156	12.9	6124	0.5	0.01	16.9	15	28	59.9
5	31	22	25.3	67			0.6	4.7	42.7			48.17
6	120	40	9	12000			0.5	40	23.6			64.2
7	153	21	217	11000			6.1	4.3	14.2	33.6		58.2
8	27.5	45	16.6	131			3.4	2.2	46.4			52
9	79.7	27	91	4.6	7549		0.6	10.6	12	25		48.2
10	27	4.9	7572				20.5	18.5				39
11	52.8	1.5	14.7	48.1	8.7	604	0.5	0.08	6.8	8.2	28	43.5
12	18.8	112	6.3	146	21	280	0.6	0.64	1.34	2.79	43	48.3
13	16.4	12.6	618				2.1	11.6				13.8
14	93	26.3	40.9	131			0.56	3.36	34.5			38.4
15	228	142	32.8	199			0.92	17.5	17.1			35.6
16	65.7	168	28.4	235	48	2302	0.6	0.64	1.34	2.7	43	48.5
17	30.9	16.9	3463				4.04	29.3				33.3
18	11.9	0.9	3.8	24.2	3542		0.6	0.64	4.21	46		51.5
19	17	4	14.7	5.6	2587		0.5	3.1	23.3	21.9		48.8
20	15.7	11	1634	40205			3	22	37			62

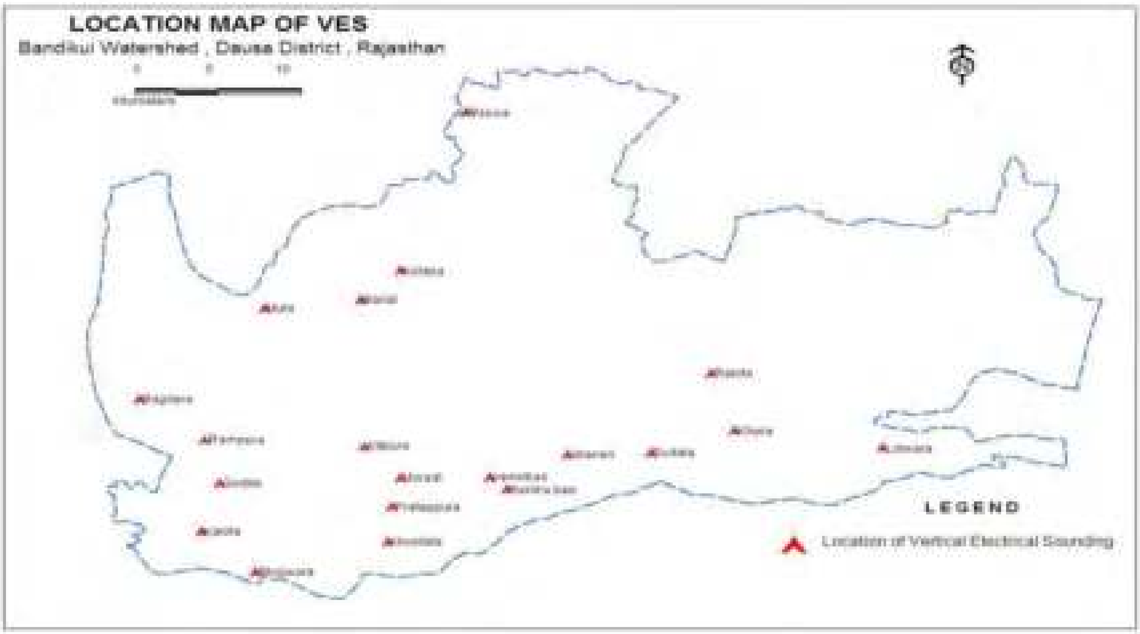
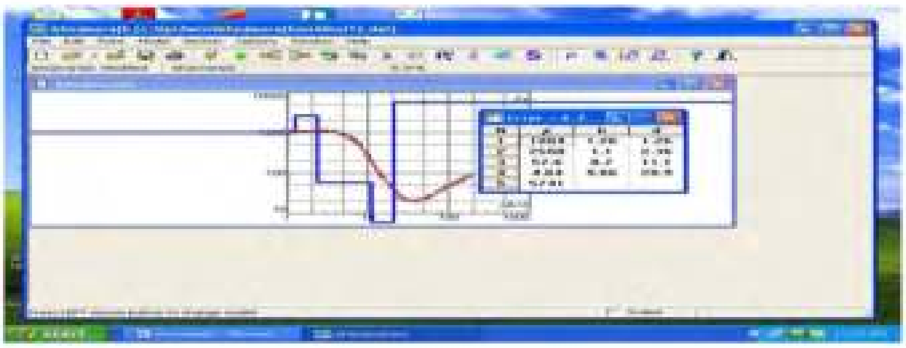
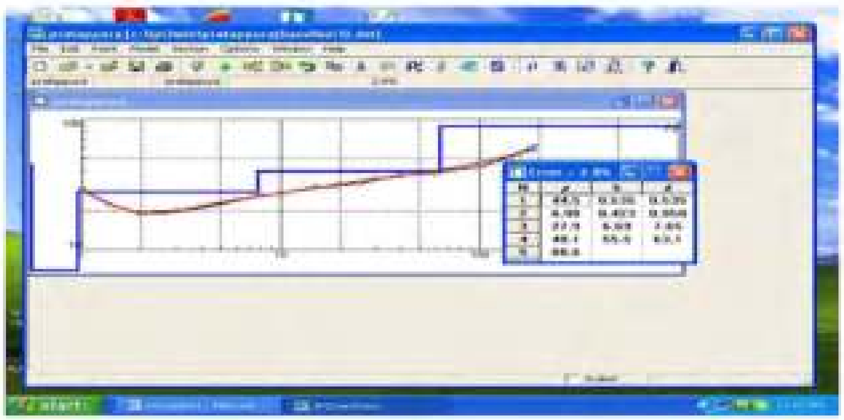


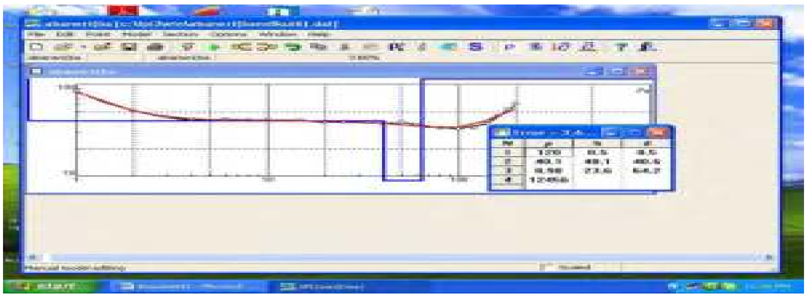
Figure 7. Locations of VES studies carried out in Baswa-Bandikui watershed, Dausa district, Rajasthan



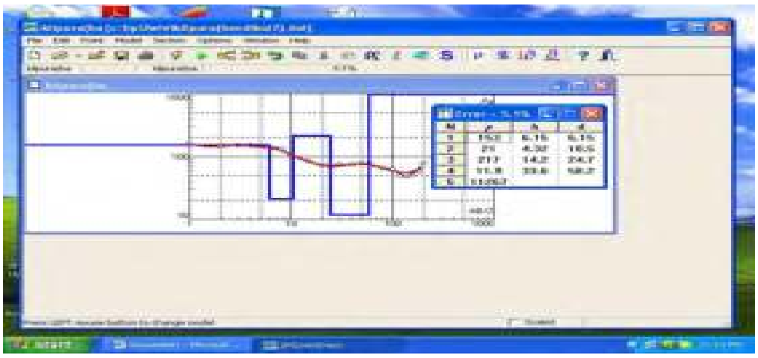
8.1. Bhojwara



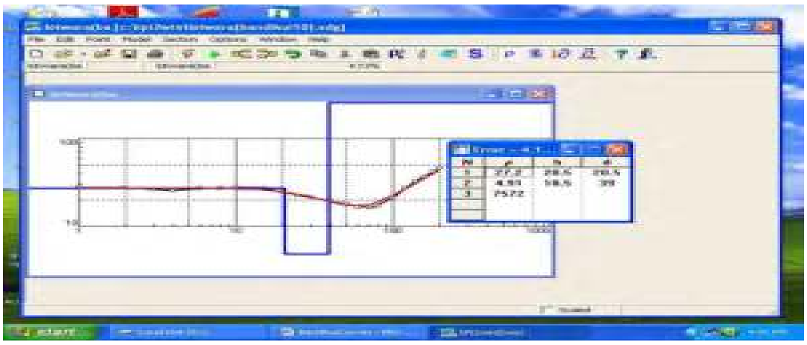
8.2 Pratappura



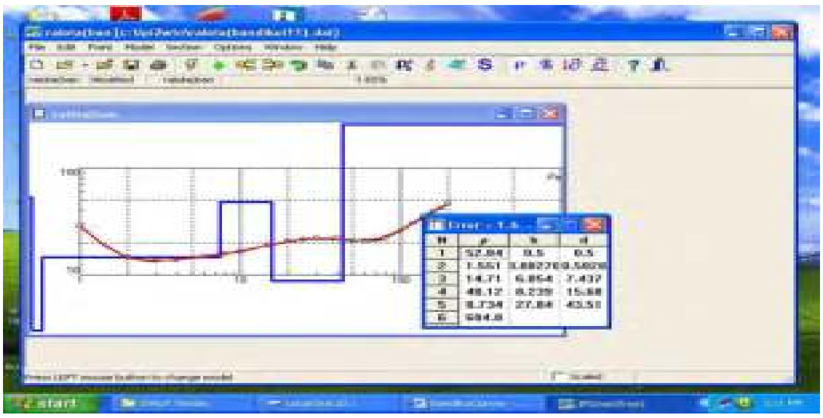
8.3 Abhaneri



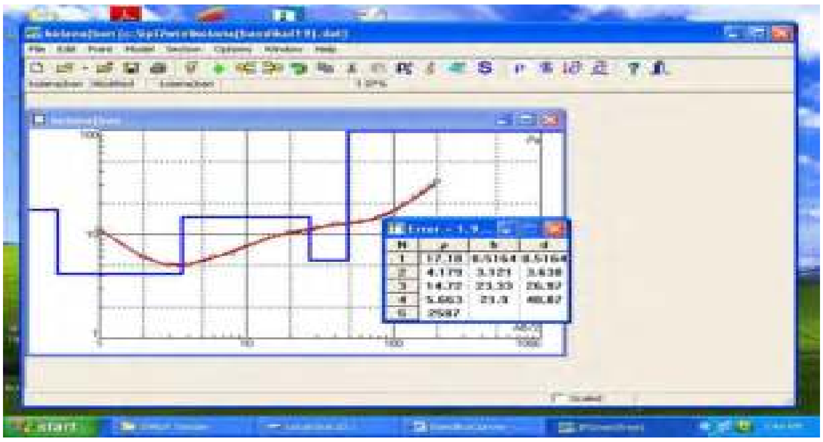
8.4 Kiratpura



8.5 Lotwara



8.6 Ralota



8.7 Kolana

Figure 8. Representative VES curves of the resistivity survey undertaken in Baswa-Bandikui watershed, Dausa district, Rajasthan

Data Gap Analysis

Data gap analysis as shown in Figure 9 and Table 6 indicates that Central and eastern part of the project area remained unexplored since the due to ravine topography, a major portion of the area is unapproachable for conventional surface geophysical studies.

Table 6 Matrix showing data availability on VES studies carried out in AQRAJ area, Dausa district, Rajasthan

	a	b	c	d	e	f
I	TS - 54A/8; Q-B1 [Outside project area]	TS - 54A/8; Q-C1 [Outside project area]	TS-54A/12; Q-A1 [Hilly area]	TS-54A/12; Q-B1 [Hilly area]	TS-54A/12; Q-C1 [Outside project area]	TS-54A/16; Q-A1 [Outside project area]
II	TS - 54A/8; Q-B2 (0)	TS - 54A/8; Q-C2 [Hilly area]	TS-54A/12; Q-A2 (2)	TS-54A/12; Q-B2 (0)	TS-54A/12; Q-C2 (0)	TS-54A/16; Q-A2 (0)
III	TS - 54A/8; Q-B3 (0)	TS - 54A/8; Q-C3 (3)	TS-54A/12; Q-A3 (2)	TS-54A/12; Q-B3 (2)	TS-54A/12; Q-C3 (3)	TS-54A/16; A-3 (0)
IV	TS -54B/5; Q-B1 (0)	TS -54B/5; Q-C1 (3)	TS -54B/9; Q-A1 (4)	TS -54B/9; Q-A1 (1)	TS -54B/9; Q-A1 (0)	[Outside project area]

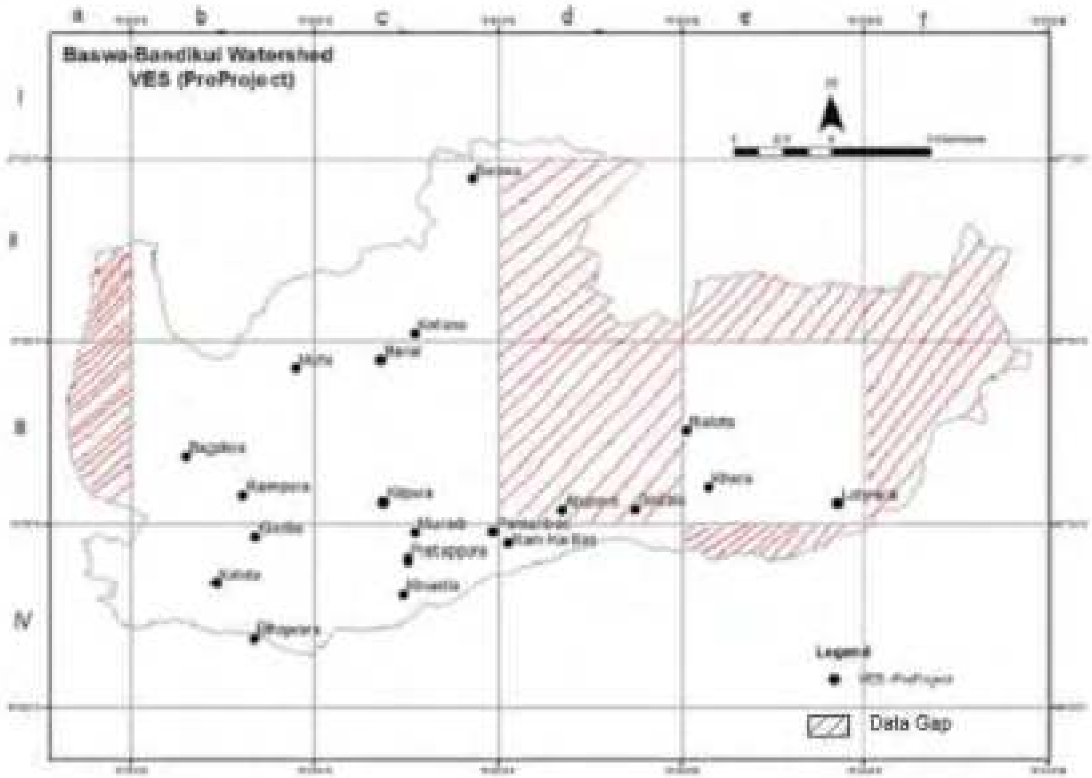


Figure 9. Data gap analysis of geophysical studies undertaken in the AQRAJ project, Dausa district, Rajasthan

2.7 SUB-SURFACE LITHOLOGICAL INFORMATION

DATA AVAILABILITY

Sub-surface lithological information is obtained from the Basic Data Reports of the exploratory wells drilled by Central Ground Water Board and State Ground Water Departments. In all, information of about 20 exploratory wells are available at the time of the inception of the project. The list of the existing tubewells are given in Table 7. In addition to the above, the information from 20 VES results are also used in generating the sub-surface lithological information. The location map showing the exploratory wells based on which the sub-surface lithological information has been constructed is given in Figure 10.

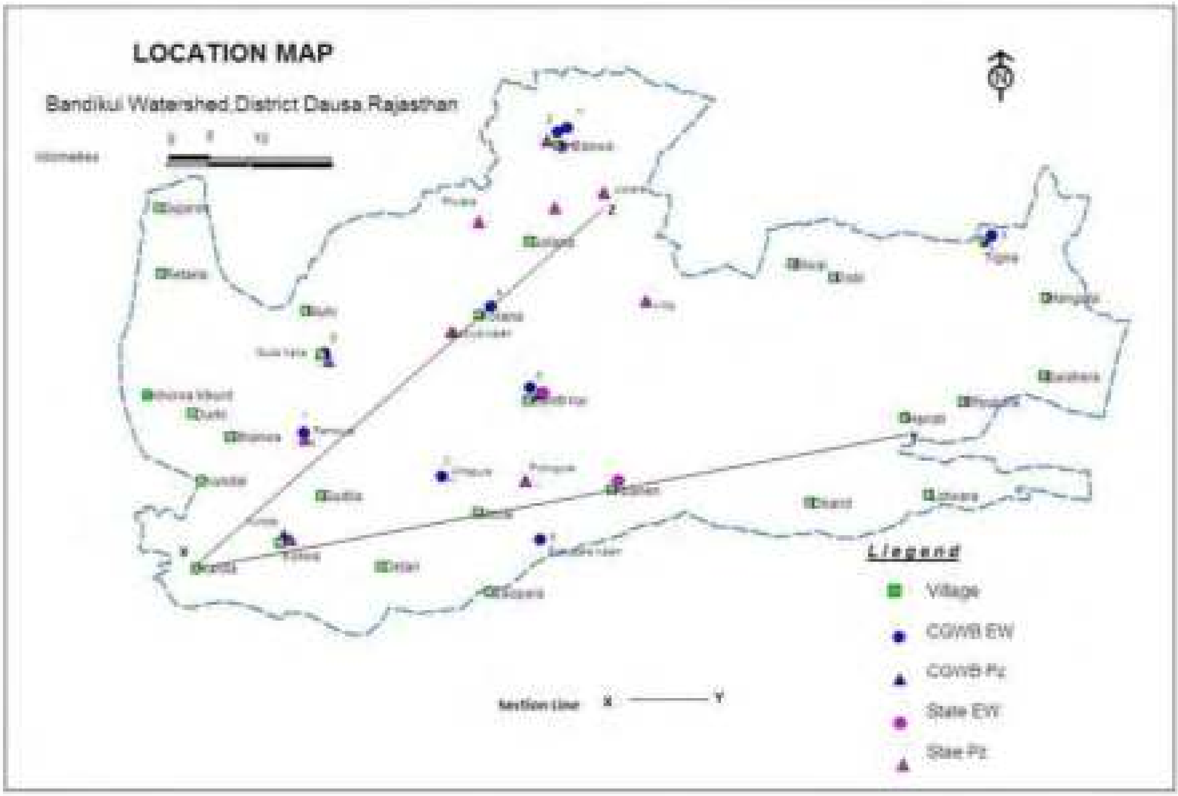


Figure 10. Locations of Exploratory Wells in Baswa-Bandikui watershed (Pre-project)

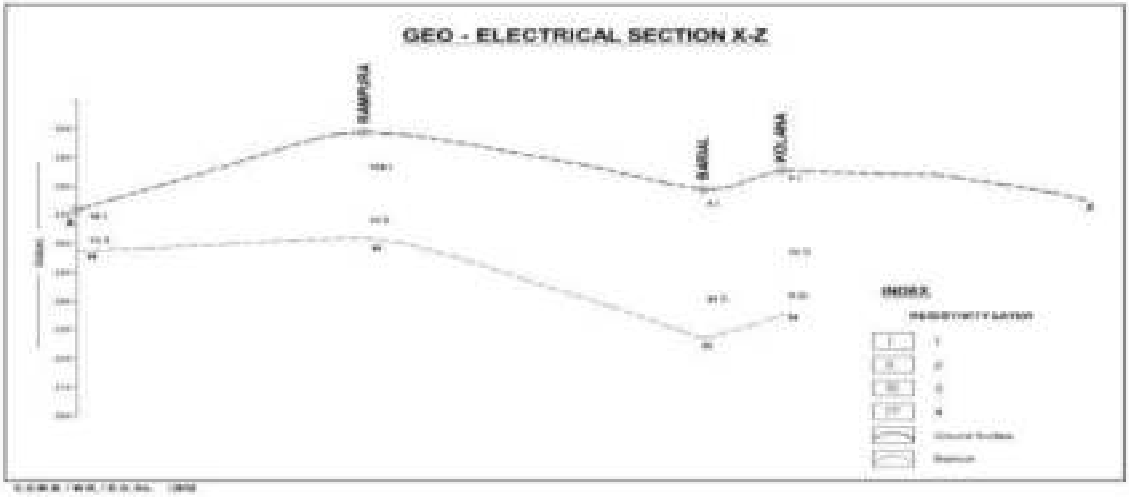
Table 7. Exploratory wells existing in Baswa-Bandikui Watershed (pre-project)

S. No.	Organization	Location	Coordinates		Type of well	Year of cons.	Depth drilled	Zones tapped		Formation tapped	SWL	Disc.	DD	Trans.	Storativity	Chemical Quality		
			Lat.	Long.				(mbgl)			(m)	(lpm)	(m)	m^2/day	(s)	EC	Cl	F
							(m)	From	To							mmhos/cm at 25°C	mg/l	mg/l
1	CGWB	Rampur			EW	69-71	35.60	-	-	Allu	0.81	631	7.278	397	5.00E-04	884	91.00	-
2	CGWB	Baswa	26°56'	76°11	EW	76-79	48.75	15 35	30 40	Allu	7.60	300	-	80 (Slugtest)	-	2070	234	-
3	CGWB	Kiratpur	27°01'	76°31'	EW	76-79	50.36	13 40	28 49	Allu	16.31	130*	-	573 (Slugtest)	-	-	-	-
4	CGWB	Kholana	27°05'	76°30'	EW	76-79	58.45	32 43 51	39 47 57	Allu	22.94	300*	-	92 (Slugtest)	-	-	-	-
5	CGWB	Tigari	27°06'	76°46'	EW	76-79	64.32	20	62	Allu	7.35	176	1.970	576	3.11E-003	977	21	-
6	CGWB	Bandikui	27°02'	76°32'	EW	87-88	53.84	44	52	Allu	21.87	480	2.25	-	-	-	-	-
7	CGWB	Baswa	26°09'	76°34'	EW	87-88	33.00	-	-	Allu	-	-	-	-	-	-	-	-
8	CGWB	Guda katla	27°04'	76°16'	EW	87-88	33.10	25	29	Allu	21.52	43	3.11	7	-	805	46	1.68
9	CGWB	Picnpura kalan	27°01'	76°34'	EW	87-88	60.00	48	56	Allu	21.97	795	6.45	238	2.98E-004	1155	92	1.06
10	CGWB	Bandikui	27°04'	76°32'	PZ	85-86	53.00	40	50	Allu	26.35	840	5.030	275	6.72E-005	1420	113	-
11	CGWB	Kolwa	26°59'	76°29'	PZ	98-99	42.50	23-29	38	Allu	-	220	0.36	-	-	1060	78	0.87

S. No.	Organization	Location	Coordinates		Type of well	Year of cons.	Depth drilled	Zones tapped		Formation tapped	SWL	Disc.	DD	Trans.	Storativity	Chemical Quality		
			Lat.	Long.				(mbgl)			(m)	(lpm)	(m)	m^2/day	(s)	EC	Cl	F
							(m)	From	To							mmhos/cm at 25°C	mg/l	mg/l
									41									
12	GWD	Phullera			PZ	2003	70.00	43	70	Allu+ Mica Schist	38.00	400*						
13	GWD	Kundal	27°00’23”	76°25’35”	PZ	2011	91.25	39	91	All+Sch	33.00	200*						
14	GWD	Rampura	27°01’42”	76°27’54”	PZ	2011	91.70	48	91	All+Sch	28.90	250*						
15	GWD	Gudha Katla	27°01’42”	76°27’54”	PZ	2011	91.50	36	91	All+Sch	27.20	300*						
16	GWD	Lilog	27°04’57”	76°37’15”	PZ	2011	91.70	60	91	All+Gneis	32.80	350*						
17	GWD	Pichupara	27°00'25''	76°34'00''	PZ	2011	102.00	61	102	All+Sch	32.00	250*						
18	GWD	Bandikui Jagri	27°02'43''	76°33'43''	PZ	2011	100.00	54	100	All+Sch	28.00	350*						
19	GWD	Uprera	27°08'08''	76°35'37'	PZ	2011	101.00	30	101	All+Sch	35.00	200*						
20	GWD	Badiyal Kalan	27o3'0"	76o39'8"	PZ	2011	102.00	43	102	All+Sch	35.00	200*						

* Discharge measured during Compressor Development

The area is covered by alluvial formation underlain by hard rock. The basin can be envisaged to have saucer-shape – thickness of alluvium increasing towards east. The overlying alluvium formation consist of sand and gravel, silty sand, clay-kankar, silty clay etc. The thickness of the alluvial formation varies from 20 m in the east to more than 60 m in the west. The underlying weathered formation varies in thickness from less than 2 m to more than 30 m. The hard rock includes Quartizites, schists, granite gneisses etc. The sub-surface lithological information is depicted in the following Figures (11, 12 & 13).



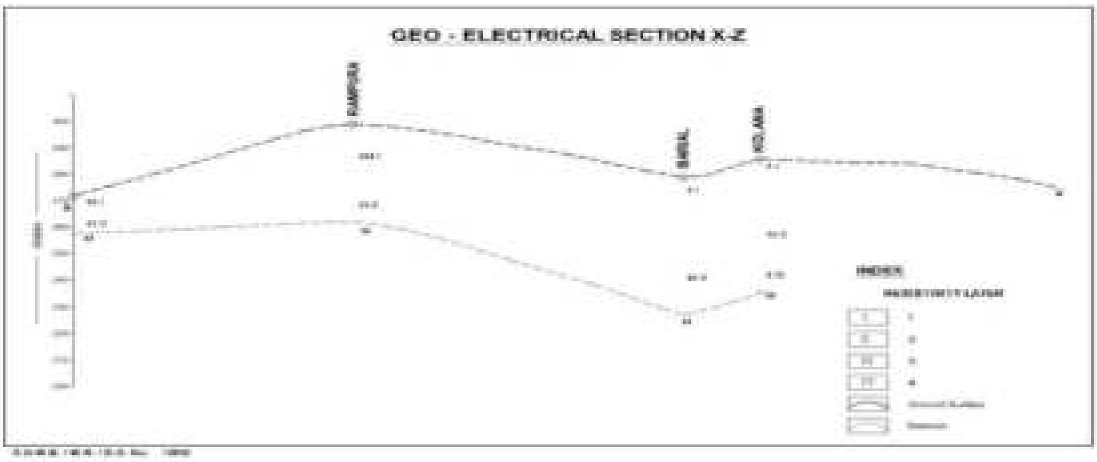


Figure 11. Geo-electrical cross-sections in Baswa-Bandikui watershed (pre-project)

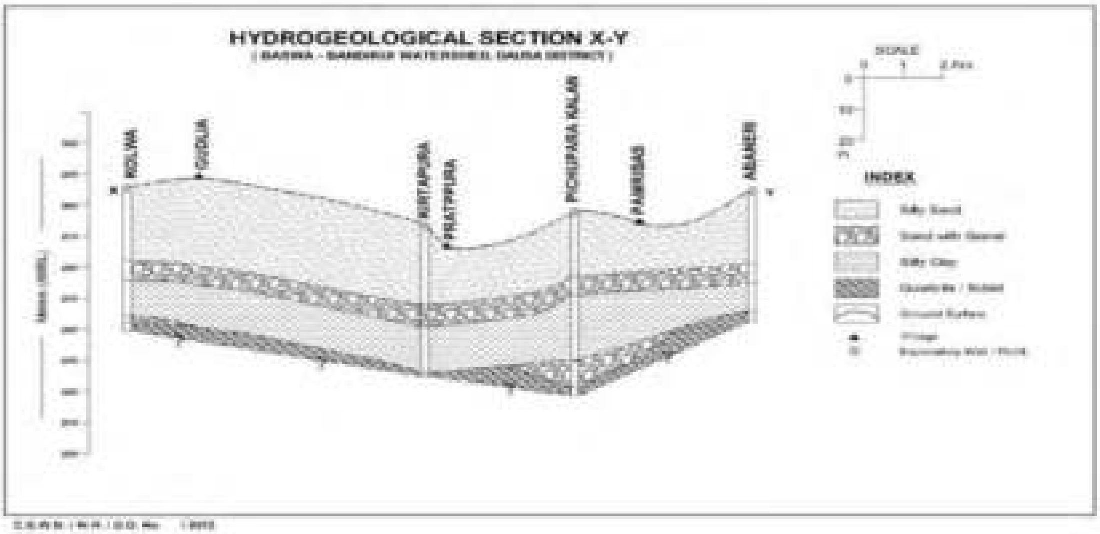


Figure 12. Lithological cross-section in Baswa-Bandikui watershed, Dausa district, Rajasthan

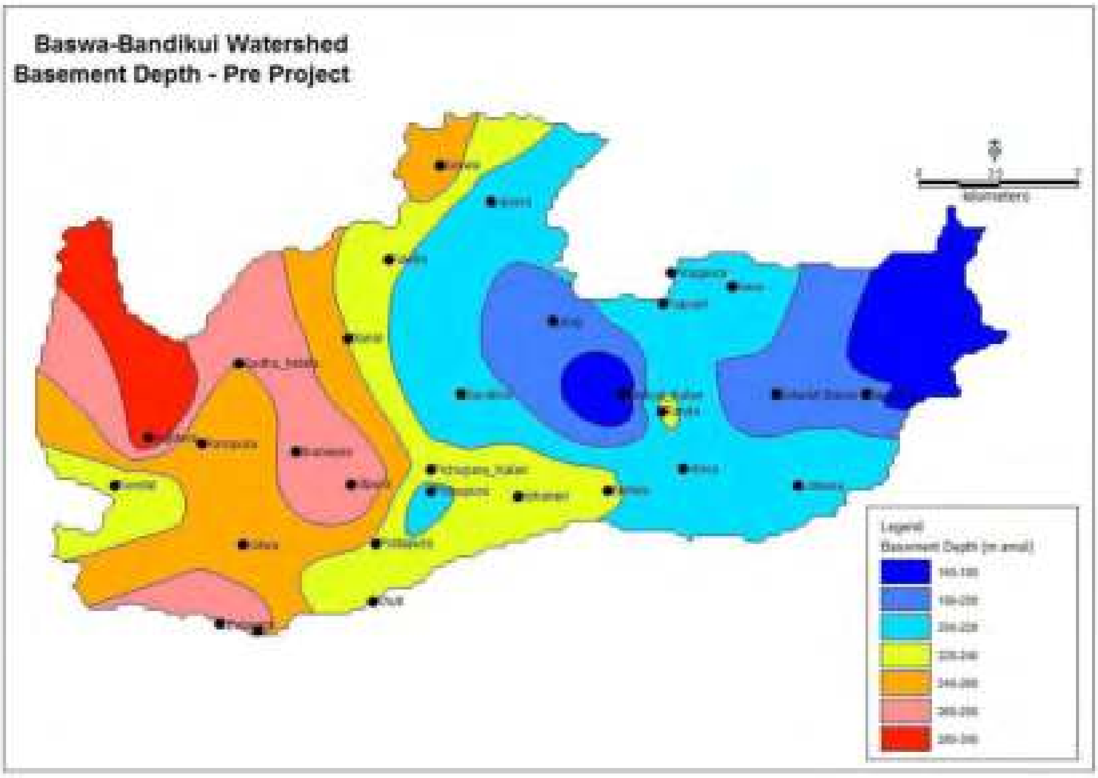


Figure 13. Basement depth in Baswa-Bandikui watershed, Dausa district, Rajasthan

Data Gap Analysis

Data is available for the western part of the Watershed covering an area of about 350 Sq.Km. Remaining about 250 Sq.Km area in the eastern part of the watershed is relatively under-explored. Particularly, Toposheet no. 54A/12, Quadrant C2, C3 and toposheet no. 54A/16, Quadrant A2 and A3 have either no or very little control points.

Table 8. Matrix showing data availability on Exploratory Tubewells in AQRAJ area, Dausa district, Rajasthan

	a	**b**	**c**	**d**	**e**	**f**
I	TS - 54A/8; Q-B1 [Outside project area]	TS - 54A/8; Q-C1 [Outside project area]	TS-54A/12; Q-A1 [Hilly area]	TS-54A/12; Q-B1 [Hilly area]	TS-54A/12; Q-C1 [Outside project area]	TS-54A/16; Q-A1 [Outside project area]
II	TS - 54A/8; Q-B2 (0)	TS - 54A/8; Q-C2 [Hilly area]	TS-54A/12; Q-A2 (2)	TS-54A/12; Q-B2 (1)	TS-54A/12; Q-C2 (0)	TS-54A/16; Q-A2 (1)
III	TS - 54A/8; Q-B3 (0)	TS - 54A/8; Q-C3 (4)	TS-54A/12; Q-A3 (4)	TS-54A/12; Q-B3 (2)	TS-54A/12; Q-C3 (0)	TS-54A/16; Q-A3 0
IV	TS -54B/5; Q-B1 (0)	TS -54B/5; Q-C1 (1)	TS -54B/9; Q-A1 (0)	TS -54B/9; Q-B1 (0)	TS -54B/9; Q-C1 (0)	[Outside project area]

Further ground water exploration needs to be carried out in these areas keeping in view the existing data gap. Additional 15 wells are required to be constructed in the project area to fill in the data gap on sub-surface lithological information. Data gap analysis as shown in Table 8 and Figure 14.

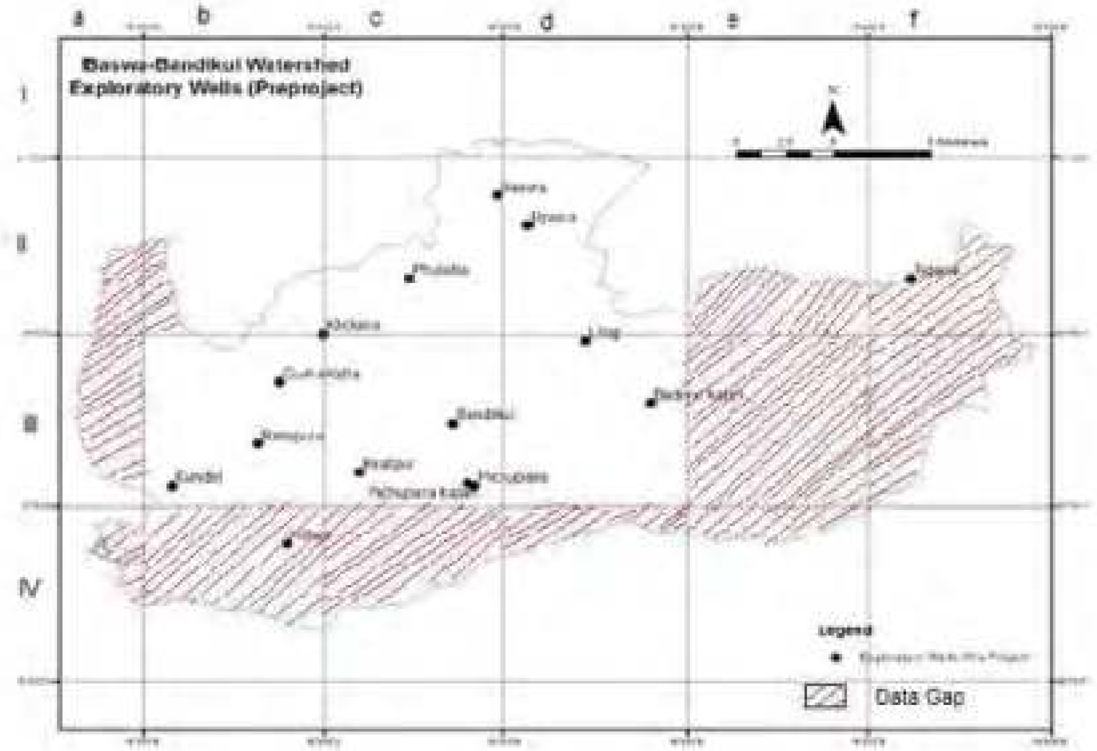


Figure 14. Data gap analysis of exploratory borewells in Baswa-Bandikui watershed, Dausa district, Rajasthan

2.8 HYDROGEOLOGY

DATA AVAILABILITY

Information on hydrogeology of the project area is obtained from the ground water potential map of the State Government, which was prepared for 2009 ground water resources assessment. The hydrogeological information are later refined based on reconnoitory field survey. Alluvium is the main water bearing formation. The sand and gravel layers in the alluvium form the aquifers. Near the northern boundary around hilly region, ground water occurs in the hard rock formations. Ground water generally occurs under water table and semi-confined conditions in Quaternary sediments & weathered and fractured zones of hard rocks. In general depth to bedrock varies from 50-60 meter below ground level (m bgl). Alluvium depth increases eastward. The water level varies from about 15 m in west & northwest to > 60 m in the south east of the block. The ground water level is continuously declining at an average rate of 6.5 cm to 1.25 m/year. Quality of water is potable in general. However, fluoride content in groundwater in excess of the permissible limit have been reported from some places within the project area. In Alluvium, the average yield of wells fitted with pump sets varies from 60,000 litres per day to 75,000 litres per day whereas the average discharge of tubewells varies from 13 to 15m^3/hr. In hard rocks, the average yield of wells fitted with pumpsets varies from 35,000 litres per day to 45,000 litres per day and the average discharge of bore wells is 10m^3/hr. Aquifer tests reveal that transmissivity of the alluvium varies from 200-500 m^2/day and at some places the transmissivity is also found to be low due to lack of adequate granular thickness. Over-exploitation of groundwater resources led in declining of the water level for past several years causing water level confined to deep level close to the bedrock. The hydrogeological map of Baswa-Bandikui project area is given in Figure 15.

Data Gap Analysis

Hydrogeology of the area was constructed based on the previous data available with the State Government. The present scenario of the saturated aquifers both in terms of spatial disposition and hydraulic characteristics are to be established based on - exploratory drilling particularly in the eastern part of the project area, extending monitoring network of water level and quality and determination of aquifer characteristics through additional aquifer tests.

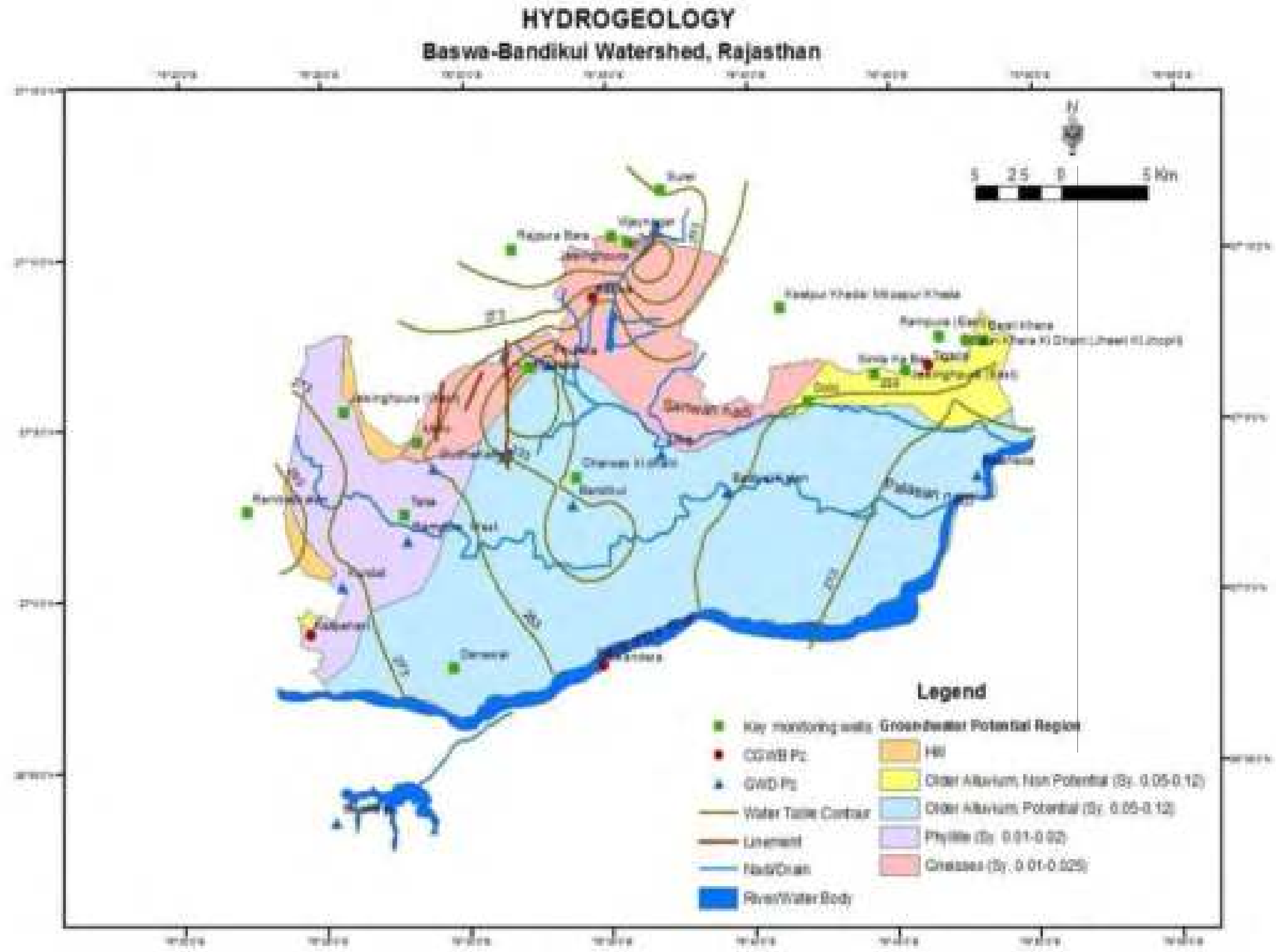


Figure 15. Hydrogeological map of Baswa-Bandikui project area (pre-project)

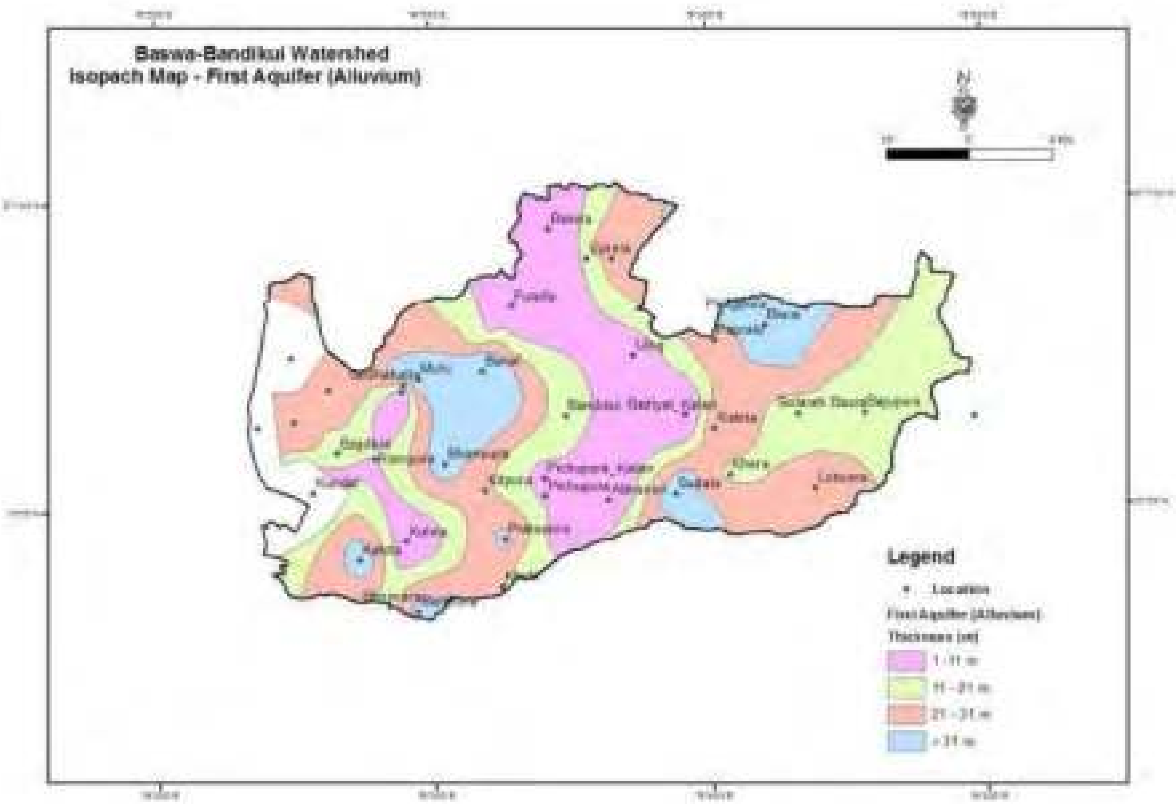
2.9 AQUIFER DISPOSITION

DATA AVAILABILITY

Aquifer disposition is constructed based on the information on the sub-surface lithological information and water level. Alluvium is the predominant aquifer in the major part of the project area, particularly the Central and Eastern part. Hard rock aquifers are mainly the weathered portion of the rocks. These aquifers exist on the western part of the project area. The thicknesses of the aquifers are shown in Figure 16 and the aquifer disposition in the project area is depicted in Figure 17.

DATA GAP ANALYSIS

Additional information on the hydrogeological attributes are required for the eastern part of the project area.



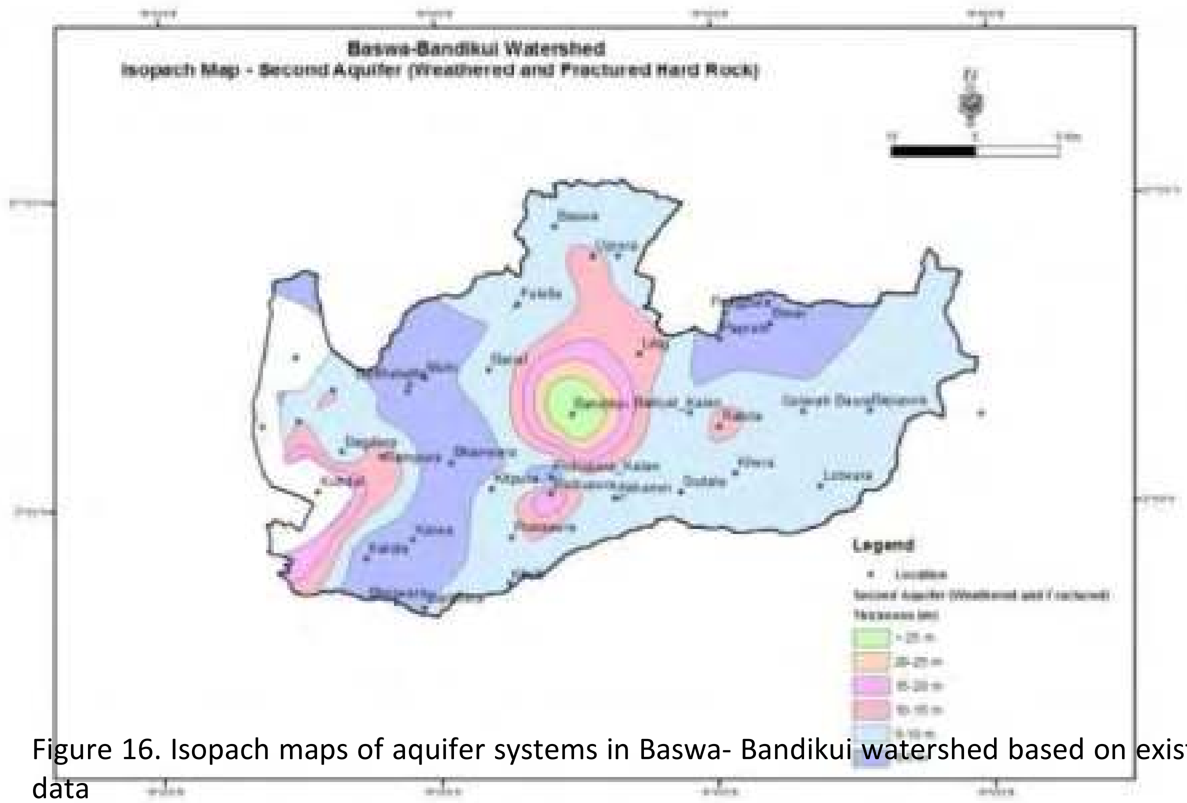


Figure 16. Isopach maps of aquifer systems in Baswa- Bandikui watershed based on existing data

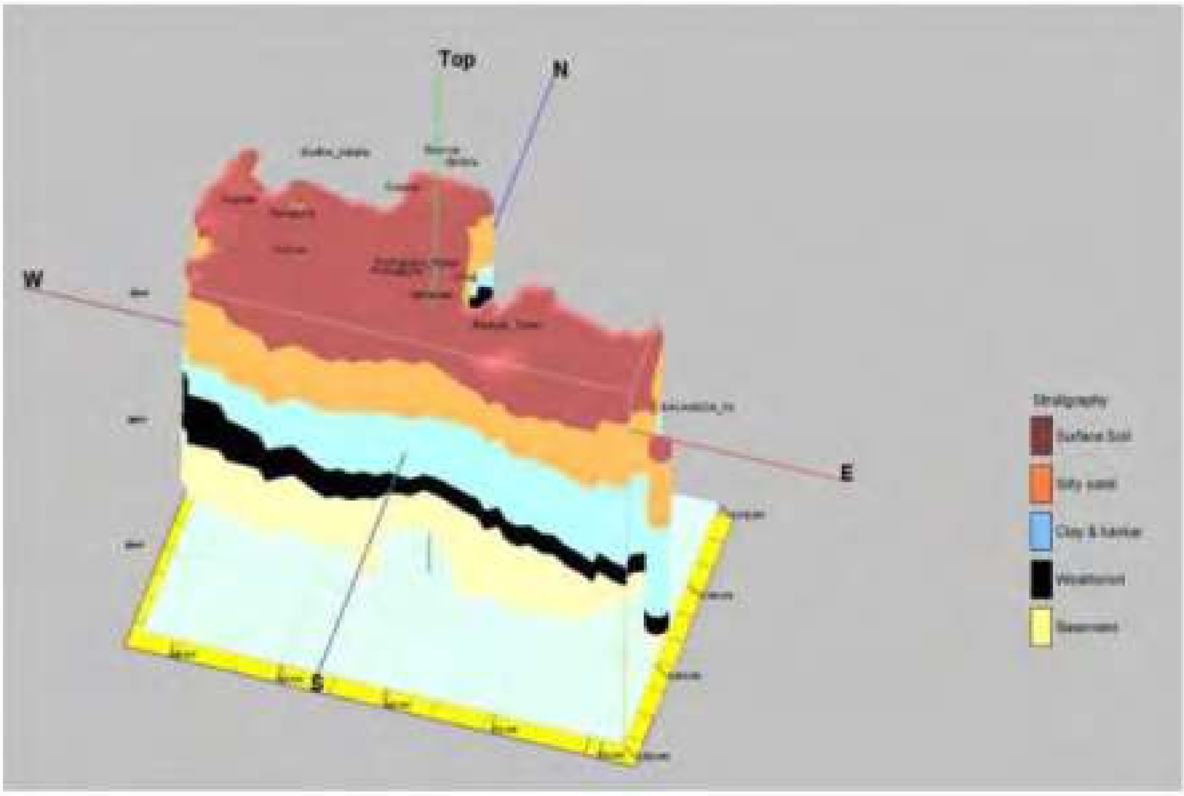


Figure 17. Three Dimensional Aquifer Disposition based on existing data, Baswa-Bandikui watershed

2.10 WATER LEVEL

Data Availability

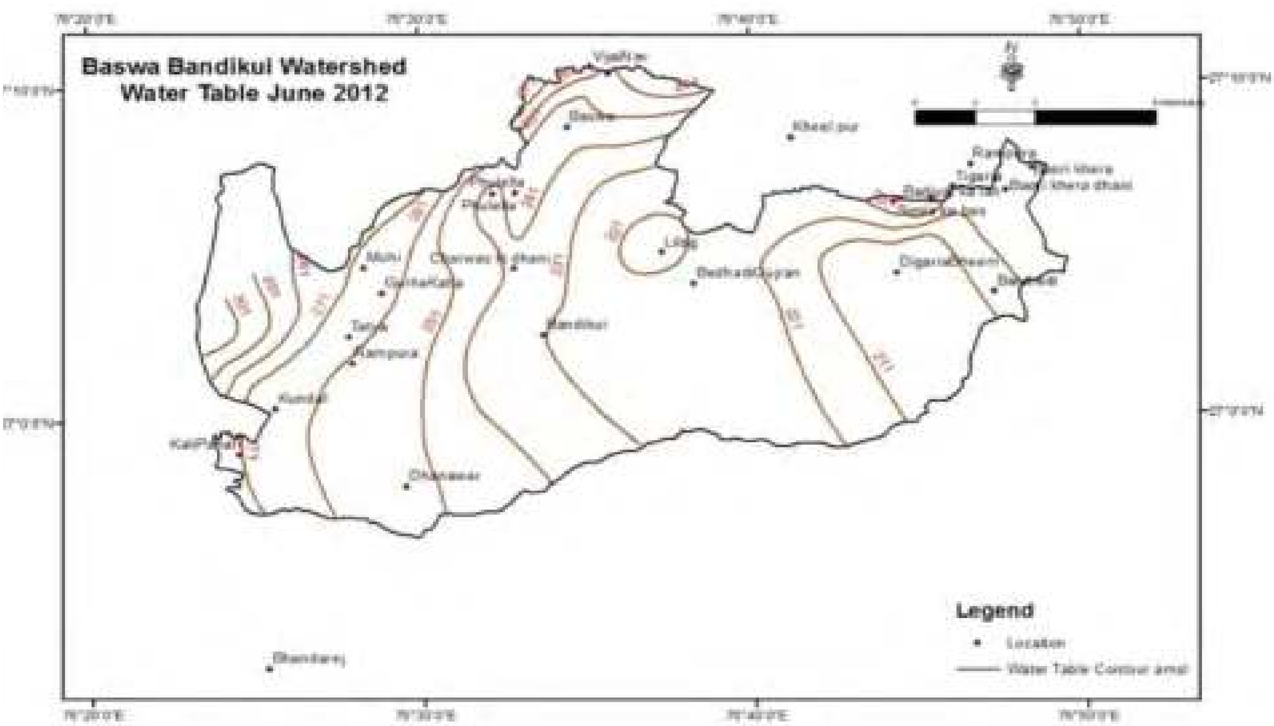
Ground water Department of Rajasthan has established 21 ground water monitoring stations in the area. The list of the stations is given in Table 9. The pre-monsoon water level varies between 12 to 54 m below ground level (mbgl) and post-monsoon water level varies between 9 to 53 mbgl. The water table contour maps of the project area are depicted in Figure 18. As indicated in the maps, the water level flow direction is broadly towards east direction of the project area.

Table 9. List of the Ground water Monitoring stations in Baswa-Bandikui watershed (pre-project)

S. No.	Village	Owner's Name	Location	Co-ordinates		Hydro-geological Formation	Type of well Dugwell/ Piez.	Reduced level (m)	Total Depth (m) bgl
				Longitude	Latitude				
1.	ABHANERI	Public Well	In front of baori	76°36'40"	27°00'28"	ALLUVIUM	Dugwell	273.50	31.40
2.	BADYALKALAN	Public Well	LHS of road to Bandikui from Lotwara	76°39'15"	27°03'10"	ALLUVIUM	Dugwell	265.00	22.00
3.	BALAHEDA	Public Well	In the premises of Secondary School	76°49'38"	27°02'51"	ALLUVIUM	Piez.	335.00	60.00
4.	LOTWARA	Public Well	Near bus stand	76°44'55"	27°00'15"	ALLUVIUM	Dugwell	251.00	18.40
5.	ABHANERI.	GWD	Near transformer & baori	76°36'30"	27°00'10"	ALLUVIUM	Piez.	274.40	60.00
6.	BANDIKUI	Public Well	In the premises of Panchayat Samiti	76°33'58"	27°02'30"	ALLUVIUM	Dugwell	275.00	24.55
7.	GUDHA KATLA	Udai Veer Singh	RHS of road to Kundal	76°28'55"	27°03'32"	ALLUVIUM	Dugwell	293.00	28.00
8.	KOLWA	Shedu Ram	In fron of Railway Station	76°28'15"	26°58'25"	ALLUVIUM	Dugwell	297.00	21.70

S. No.	Village	Owner's Name	Location	Co-ordinates		Hydro-geological Formation	Type of well Dugwell/ Piez.	Reduced level (m)	Total Depth (m) bgl
				Longitude	Latitude				
9.	PRATAPPURA	Mistry Mool Chand	RHS of road to Pratappura	76°32'18"	26°59'35"	ALLUVIUM	Dugwell	298.00	23.10
10.	BANDIKUI	GWD	In the premises of PG College	76°34'00"	27°03'00"	ALLUVIUM	Piez.	275.75	50.00
11.	GUDHA KATLA	GWD		76°28'55"	27°03'32"	ALLUVIUM	Piez.	293.00	92.00
12.	KOLWA	GWD	Near Railway Station	76°28'17"	26°59'02"	ALLUVIUM	Piez.	293.75	50.00
13.	MORADI	GWD	Near transformer & house of Sh.Gurjar on Culvart	76°33'10"	26°59'48"	ALLUVIUM	Piez.	299.00	60.00
14.	FULELLA	Pt.Ram Ji Lal	In the village near tiraha	76°32'13"	27°06'45"	QUARTZITE	Dugwell	281.00	44.60
15.	FULELLA	GWD	RHS of road to Baswa in front of Old PHED office	76°32'55"	27°06'48"	QUARTZITE	Piez.	281.00	70.00
16.	BASWA	Public Well	Near Railway Station	76°35'27"	27°09'00"	GNEISSES	Dugwell	284.00	22.00
17.	LILONG	Public Well	Near temple & Primary School	76°37'20"	27°04'50"	GNEISSES	Dugwell	273.00	20.70
18.	RAMPURA	Ranjeet Meena	RHS of way to village	76°27'45"	27°01'20"	GNEISSES	Dugwell	299.00	35.00
19.	LILONG	GWD	Near Govt. Primary School, LHS of road to village from Bandikui	76°37’15”	27°04’57”	GNEISSES	Piez.		91.70
20.	RAMPURA	GWD	In the Gochar land, Opp. Crimination Ground, LHS of road to village from Dausa-Gudha	76°27'45"	27°01'20"	GNEISSES	Piez.	299.00	91.00

S. No.	Village	Owner's Name	Location	Co-ordinates		Hydro-geological Formation	Type of well Dugwell/ Piez.	Reduced level (m)	Total Depth (m) bgl
				Longitude	Latitude				
			Katla road						
21.	BASWA	CGWB	In the premises of Thsil	76°34'30"	27°08'45"	GNEISSES	Piez.	282.53	50.00



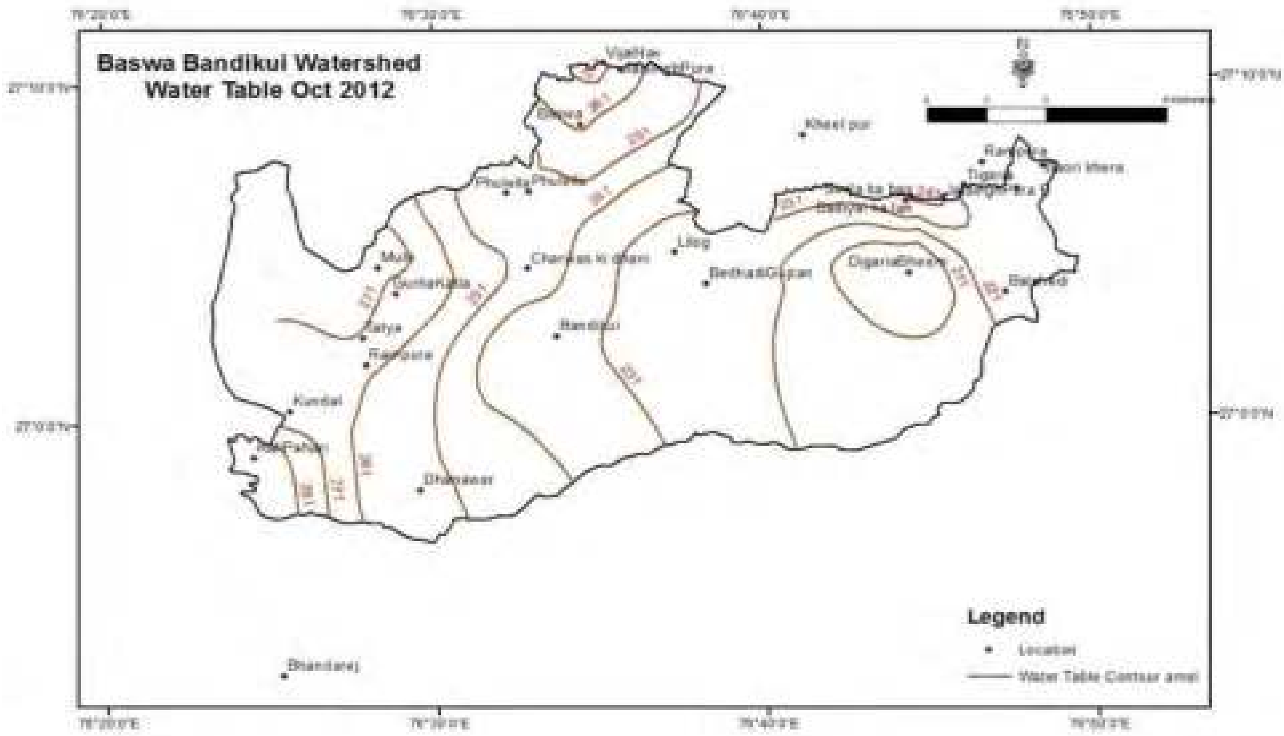


Figure 18. Water Table Contour Maps of Baswa-Bandikui watershed, Dausa District, Rajasthan

Data Gap Analysis

The distribution of the existing data on ground water monitoring is shown in Table 10.

Table 10. Matrix showing data availability of Ground water monitoring stations, Baswa-Bandikui watershed, Dausa district, Rajasthan

	a	b	c	d	e	f
I	TS - 54A/8 Q-B1 [Outside project area]	TS - 54A/8; Q-C1 [Outside project area]	TS-54A/12; Q-A1 [Hilly area]	TS-54A/12; Q-B1 [Hilly area]	TS-54A/12; Q-C1 [Outside project area]	TS-54A/16; Q-A1 [Outside project area]
II	TS - 54A/8; Q-B2 (0)	TS - 54A/8; Q-C2 [Hilly area]	TS-54A/12; Q-A2 (3)	TS-54A/12; Q-B2 (0)	TS-54A/12; Q-C2 (2)	TS-54A/16; Q-A2 (4)
III	TS - 54A/8 Q-B3 (0)	TS - 54A/8; Q-C3 (5)	TS-54A/12; Q-A3 (2)	TS-54A/12; Q-B3 (0)	TS-54A/12; Q-C3 (0)	TS-54A/16; Q-A3 (0)

IV	TS -54B/5 Q-B1 (1)	TS -54B/5 Q-C1 (1)	TS -54B/9 Q-A1 (0)	TS -54B/9 Q-B1 (0)	TS -54B/9 Q-C1 (0)	[Outside project area]

A perusal of the Table 8 and the map depicted in Figure 19 indicates that data gap exist in toposheet no. 54A/8, quadrant B2, 54A/12,quadrant B2, B3, C3, 54A/16, quadrant A3, toposheet no. 54B/9 quadrant A1, B1 and C1, which are mostly located in the Central and Eastern part of the project area.

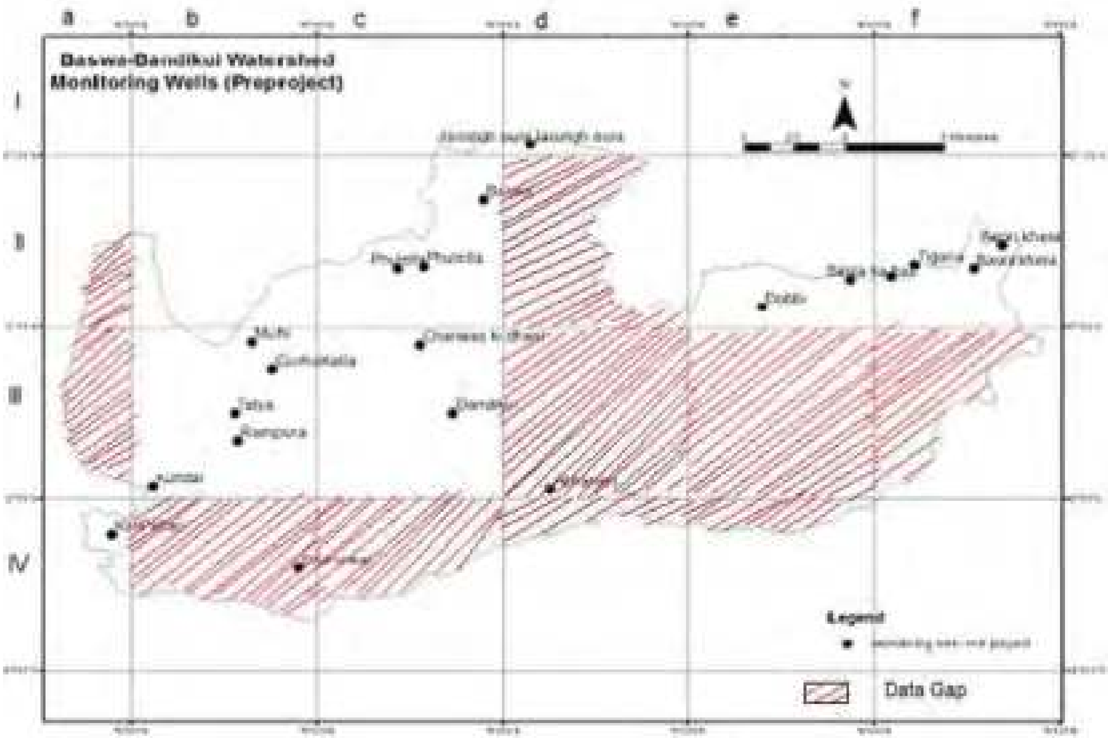


Figure 19. Map showing Data Gap existing on water level in Baswa-Bandikui watershed, Dausa district, Rajasthan

2.11 WATER QUALITY

Data Availability

The water quality is monitored on the stations used for water level. Quality of water in the Baswa-Bandikui watershed is potable in general. However, poor quality ground water is also reported from certain pockets in the project area. Electrical Conductivity which determines the salinity content of the water, is >1500 µS/cm (beyond fresh water limit) in eastern part of the project area. Fluoride content of >1.5mg/l (beyond permissible limit) have been reported from the south west part of the study area. Nitrate content is within desirable limit (45 mg/l) in the entire project area (Figure 20).

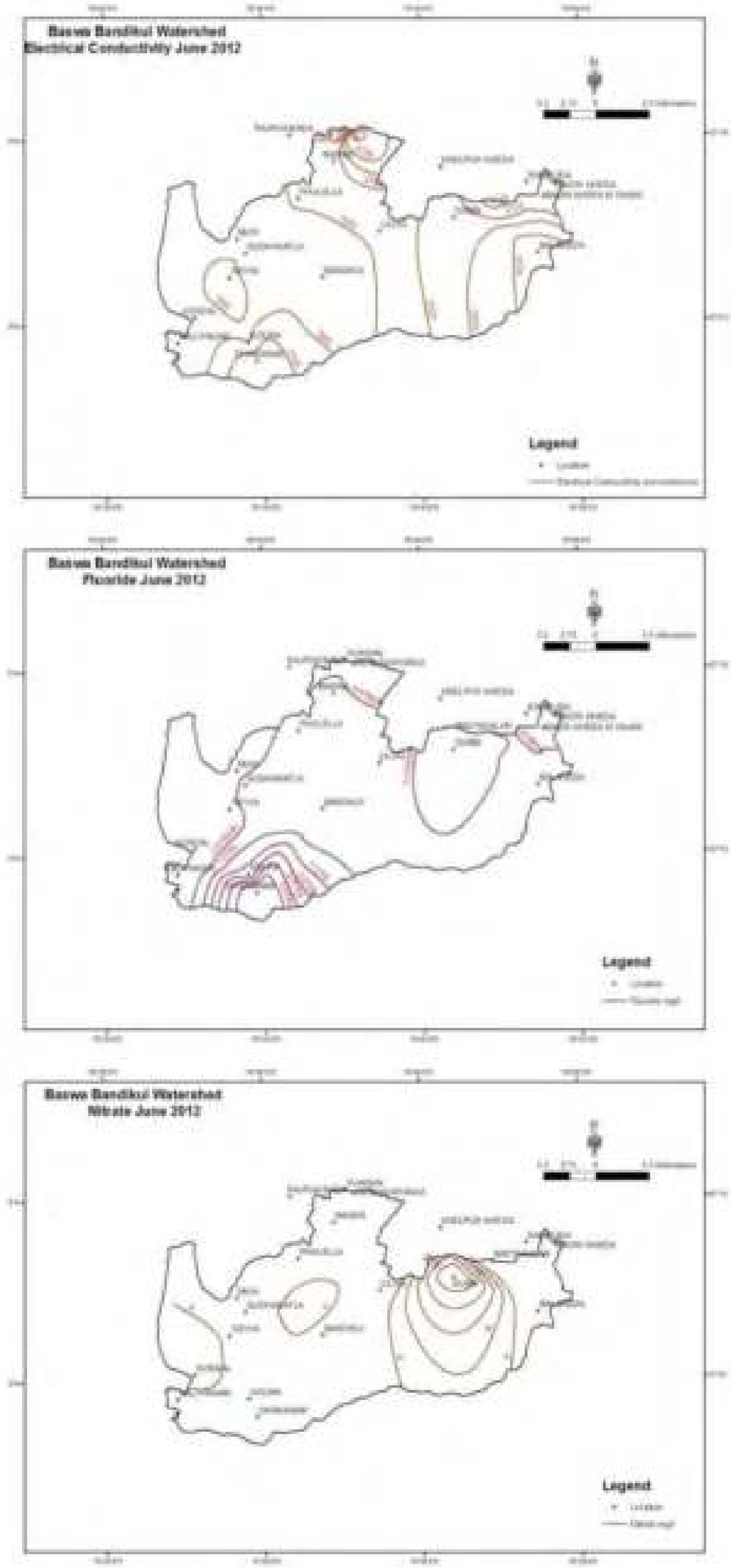


Figure 20. Hydrogeochemical map showing distribution of EC, Flouride and Nitrate in Baswa-Bandikui watershed, Dausa district, Rajasthan

Data Gap Analysis

Data gap existing in water quality is same as that of water level discussed in the previous section.

2.12 Recharge Parameters

DATA AVAILABILITY

Recharge parameters are obtained from State Ground Water Department, which were used in the ground water resources estimation of 2009 for the state of Rajasthan. Table 11 presents the various recharge parameters used for computation of dynamic ground water resources of Bandikui block for the base-year, 2009.

Table 11. Recharge parameters used for computation of ground water resources in Baswa-Bandikui watershed

Ground water Potential Zones	**Specific Yield**	**Rainfall Recharge Factor**	**Return flow from Irrigation**	**Seepage factor - Tanks & Ponds (mm/day)**
Alluvium	0.08 to 0.12	0.12 to 0.15	0.05	1.40
Quartzites	0.02	0.07		
Gneisses	0.015	0.07		

The annual replenishable ground water resources calculated for the base year 2009 for Bandikui block is 44.31 million cubic metre (mcm). Keeping an allocation of 4.22 mcm, Net Annual Ground Water Availability was estimated as 40.09 mcm.

Data Gap Analysis

The recharge parameters mentioned above needs to be updated by compilation of additional information on the field studies undertaken in the area and also through carrying out additional field experiments through pumping tests for specific yield determination and soil infiltration tests for rainfall recharge factor determination.

2.13 DISCHARGE PARAMETERS

DATA AVAILABILITY

Discharge parameters are obtained from State Ground Water Department, which were used in the ground water resources estimation of 2009 for the state of Rajasthan. Table 12 presents the discharge parameters used for computation of dynamic ground water resources of Bandikui block for the base-year, 2009.

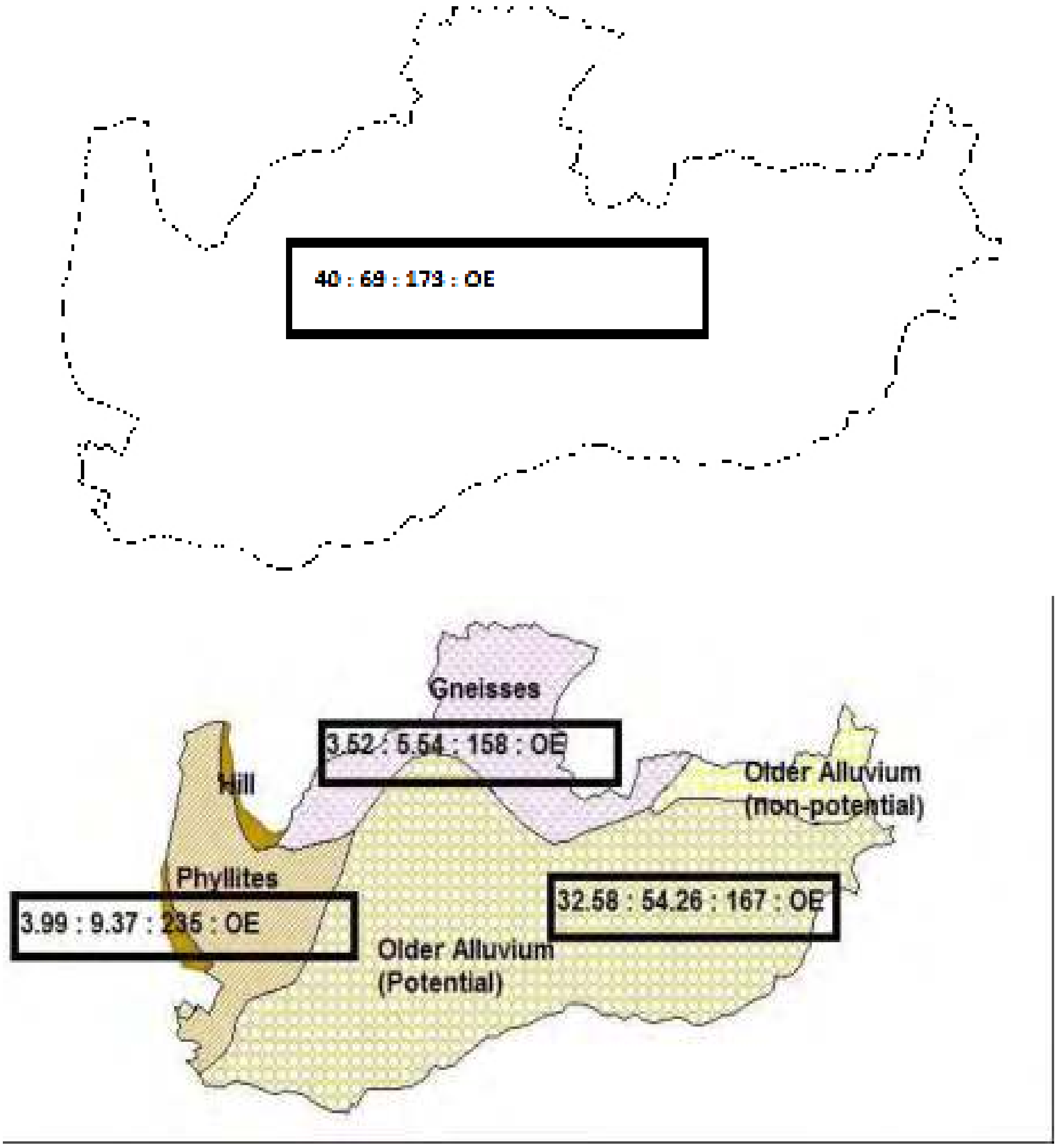
Table 12. Discharge parameters used for computation of ground water resources in Baswa-Bandikui watershed

Mode of Lift	**Irrigation Draft**	**Domestic Draft**
	Average Yield (lpd)	**Average Yield (lpd)**
Wells with pumpset	35000 to 68000	40000 to 68000
Wells without pump		2400
Tubewell	60000 to 68000	100000 to 150000
Cropping Period	**Average Water Requirement (m)**	
Rabi	0.300	
Kharif	0.075	

The annual ground water draft estimated for Bandikui block for 2009 is 69.17 mcm, of which 64.42 mcm is used for irrigation and only 4.75 mcm is used for drinking and domestic purpose. The stage of ground water development which is the percentage of annual ground water draft with respect to net annual ground water availability is 173%. The status of ground water resources estimated for 2009 is shown in Figure 21.

DATA GAP ANALYSIS

The discharge parameters mentioned above needs to be updated by compilation of minor irrigation census for obtaining the numbers of ground water structures and carrying out draft sample survey for updating the unit draft norms of wells.



Net GW Availability (mcm)	Draft (mcm)	SOD (%)	Category

Figure 21. Ground water zone wise resources assessment (March, 2009)

3. DATA GENERATION

Data on various attributes of Aquifer Mapping has been generated based on the data availability and data gap analysis discussed in Chapter 2. The summary of the data generated during pilot aquifer mapping project is given in table 13.

Table 13. Data Generated on various attributes of Aquifer Mapping in Baswa-Bandikui watershed, Dausa District, Rajasthan

Sl. No.	Items	Data Generated
1	Climate	5 metereological stations
2	Soil	Infiltration Test carried out at 23 sites
3	Land use	Land use data/ map generated using Remote Sensing Techniques
4	Geomorphology	Generated Digitized Geomorphological map
5	Geophysical data	Carried out VES, ERT, TEM and SkyTEM in the project area
6	GW Exploration	Construction of 15 EW. Carried out Pumping Tests and Slug Tests for determination of Aquifer parameters
7	GW Regime Monitoring	Established in additional 35 monitoring stations. Total 53 monitoring Stations in the project area
8	Recharge Parameters	Determined Recharge parameters of different aquifer types based on Soil Infiltration Tests
9	Discharge Parameters	Carried out Unit Draft Studies in 39 ground water abstraction structures

3.1 Climate

3.1.1 Rainfall

Considering the data gap existing in the project area, additional data were collected from State Agencies through websites and personal communications from Revenue department, Ajmer, Government of Rajasthan. Additional data are collected for Bandikui (within study area), Dausa (west of the study area), Sikrai (South of study area) and Mahuwa (east of study area). The project area on an average (1971-2013) received 663 mm rainfall annually. The salient statistical information pertaining to the rainfall pattern in the watershed is given in the following Table 14.

Table 14. Statistical Analysis of Annual Rainfall of the Rain Gauge Station located in Baswa-Bandikui Watershed

Rain Gauge Station	Period	Mean annual rainfall (mm)	Standard deviation (mm)	Coefficient of variation	Highest annual rainfall with year (mm)	Lowest annual rainfall with year (mm)
Baswa	1971-2013	625	259	38.2	1207(1977)	252(2002)
Mahuwa	1971-2013	653	303	46.4	1608(1995)	172(1979)
Bandikui	1998-2012	546	198	36.3	956(2012)	231(2006)
Sikrai	1971-2013	675	331	49.0	1650(1995)	209(1983)
Dausa	1971-2013	678	259	38.2	1363(1995)	268(2011)

The normal annual rainfall in the project area is presented in Figure 22.

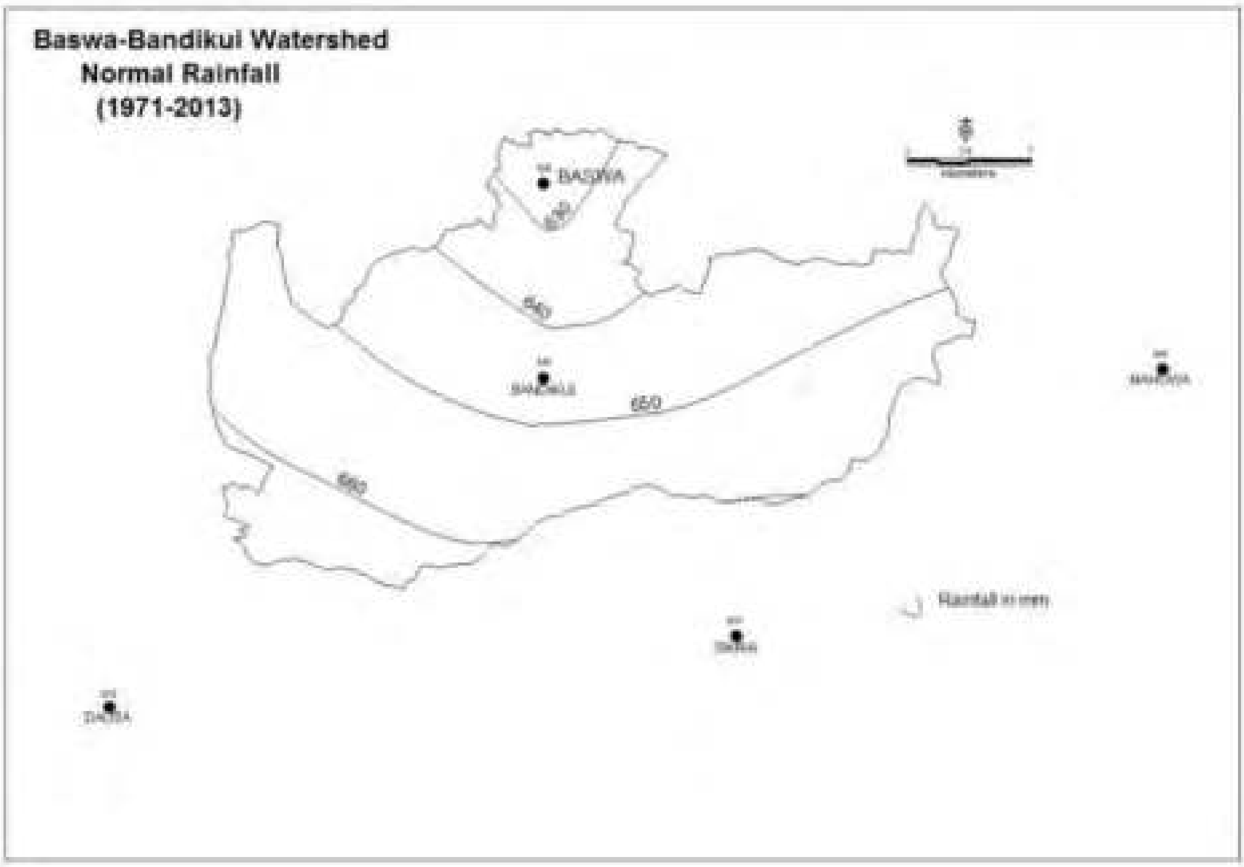


Figure 22. Normal Annual Rainfall in Baswa-Bandikui watershed

As the entire watershed is situated on the windward side of the aravallis, the major climatic divide in Rajasthan, and directly in the path of the summer monsoon, it is to be expected that copious rainfall would occur. On the contrary, the monsoon current is almost depleted of moisture after its sweep over the country. The rainfall generally decreases from south to north. There is not much variation in the annual rainfall received at different places in the watershed.

Seasonal Distribution

The summer monsoon, contributes about 90 percent of the total annual rainfall in the basin. It sets in during the middle of June and withdraws by the middle of September. August and July are the wettest months, each experiencing about 200 mm of rainfall. June and September together receive another 200 mm rainfall. Stretched over 100 days, this period is important for groundwater, as recharge is possible during this period. During the winter period, the area experience negligible rainfall and in general no recharge occurs. The pre-summer and early summer months witness squally weather, dust storms occasionally accompanied by rain. Through the rain is insignificant, it provides for moisture to the soil.

Time-series analysis

Time series analysis of rainfall data was carried out for the 1971 to 2013 and long-term trends in rainfall are established. Table 15 gives long term trend of various meteorological stations existing within and neighbourhood of the study area.

Table 15. Long term trend of meteorological stations in Dausa district, Rajasthan

Sl. No.	Meteorological Station	Long term water level trend (mm/year)
1	Baswa	0.44
2	Dausa	-6.09
3	Sikrai	-1.75
5	Mahuwa	1.86
6	Bandikui*	17.49

* 1998 to 2012

The above mentioned trend analysis indicate that meteorological stations within project area viz. Baswa and Bandikui, the rainfall show increasing trend. Mahuwa station which is located east of the project area also show a rising trend. The very high trend of Bandikui is because of the end value of the time series i.e. 956 mm in 2012 which is much higher than the average rainfall of 546 mm. In contrast, most of the meteorological stations bordering the project area show a declining trend in rainfall over the years. Time series graphs of various meteorological stations is shown in Figure 23.

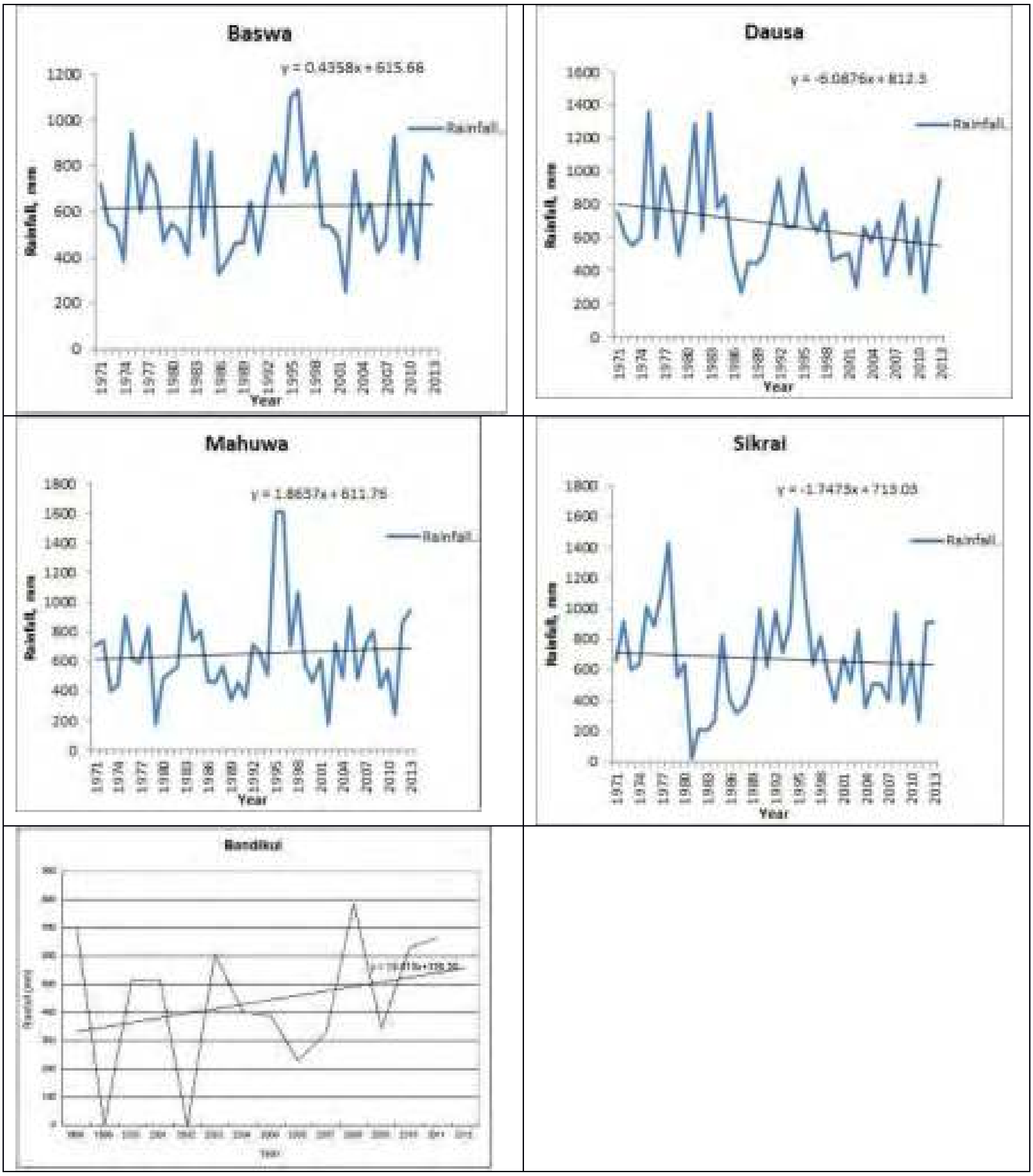


Figure 23. Time series graphs of meteorological stations in and around Baswa-Bandikui Watershed project, Dausa district, Rajasthan

3.1.2 TEMPERATURE

The winter season sets in around middle of November, when both maximum and minimum temperatures begin to drop steadily and attain their respective lowest values in the month of January. The temperatures start rising in the month of February. May and June are the hottest months of the year. The mean daily maximum temperature is highest (40.6° C) in the month of May. However, the mean daily minimum temperature is highest (27.3 C) in the month of June. There is significant decrease in both day and night temperatures with the onset of monsoon by about the last week of June. There is slight increase in day temperature again in the middle of September, after the withdrawal of south- west monsoon. The night temperature continues to fall gradually. The day temperature also starts falling in October.

3.1.3 Humidity

The area has dry climate. The relative humidity is generally low, except during south-west monsoon season. The mean daily relative humidity is highest (82%) in the month of August at 0830 hrs. However, the relative humidities are as low as 20% during afternoons in summer months i.e. from March to May.

3.1.4 WINDS

Winds are generally light with some strengthening in the later half of summer and south-west monsoon season. Westerly to south-westerly winds prevail in the south-west monsoon season. In the post monsoon and winter month's winds are mostly from directions between west and north. In the summer season, the winds blow from directions between south-west and north-west.

3.1.5 EVAPOTRANSPIRATION

Total annual potential evapotranspiration computed by penman's method is 1744.7 mm. The potential evapotranspiration is highest (257.4mm) in the month of May and lowest (67.0 mm) in the month of December. It is observed that potential evapotranspiration is more than rainfall in all the months except in July and August. Therefore, ground recharge is possible only during the peak period of monsoon.

3.2 SOIL

Soil cover plays an important role in the ground water recharge. Hence, data are generated on the attribute of the soil, which characterizes the infiltration capacity of the soil. Soil infiltration tests have been conducted using double ring infiltrometer in different types of soils across the project area to determine the infiltration rate of the soil. Infiltration is the process by which water on the ground surface enters the soil. Infiltration is governed by two forces, gravity, and capillary action. The process of entry of water into the ground is called infiltration while the downward movement after entry into the ground is called percolation.

Infiltration rate is a measure of the rate at which a particular soil is able to absorb water either from rainfall or applied irrigation water. It is measured in centimetre per minute. The rate decreases as the soils become saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier.
The soil infiltration rates are useful in determination of recharge parameters and also in demarcation of areas feasible for artificial recharge. The experiments are conducted at 23 sites in Baswa-Bandikui Watershed project area during post-monsoon season of 2012 and post-monsoon season of 2013.

Procedure

Soil Infiltration Test was conducted using Double Ring Infiltrometer (Plate 2). A Double-ring Infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is determined as the amount of water per surface area and time unit that penetrates the soils.

The final infiltration rate at which the rate of infiltration becomes constant in time scale is taken as the infiltration rate.

Plate 2. Soil Infiltration Test conducted in Baswa-Bandikui watershed

The infiltration rate varies from 0.04 cm/min to 0.70 cm/min in the project area. The details of the infiltration test results are given in Table 14.

Table 16 Soil Infiltration test results, Baswa-Bandikui watershed

Sl. No.	Location	Soil Type	Season	Infiltration Rate (cm/min)
1	Lotwara	Loamy soil	Post-Monsoon'12	0.03
2	Kundal1	Loamy soil	Post-Monsoon'12	0.13
3	Kundal2	Loamy soil	Post-Monsoon'12	0.15
4	Tatia1	Loamy soil	Post-Monsoon'12	0.05
5	Tatia2	Loamy soil	Post-Monsoon'12	0.10
6	Chandera	Hilly area (thin soil cover)	Post-Monsoon'12	0.05
7	Rehadi1	Hilly area (thin soil cover)	Post-Monsoon'12	0.20
8	Rehadi2	Hilly area (thin soil cover)	Post-Monsoon'12	0.50
9	Badiyal Kalan1	Loamy soil	Post-Monsoon'12	0.70
10	Badiyal Kalan2	Loamy soil	Post-Monsoon'12	0.31
11	Muhi1	Loamy soil	Post-Monsoon'12	0.05
12	Muhi2	Loamy soil	Post-Monsoon'12	0.05
13	Shalawas	Loamy soil	Post-Monsoon'12	0.10

Sl. No.	Location	Soil Type	Season	Infiltration Rate (cm/min)
	Khurd			
14	Balaheda1	Alluvial soil	Post-Monsoon'12	0.03
15	Nehalpura	Alluvial soil	Post-Monsoon'12	0.05
16	Lotwara east	Loamy soil	Post-Monsoon'12	0.03
17	Kheda	Loamy soil	Post-Monsoon'12	0.16
18	Salawas Khurd	Loamy soil	Pre-Monsoon'13	0.06
19	Phullela	Loamy soil	Pre-Monsoon'13	0.24
20	Abhaneri	Loamy soil	Pre-Monsoon'13	0.02
21	Dedhadi	Loamy soil	Pre-Monsoon'13	0.03
22	Simla Ka Bas	Alluvial soil	Pre-Monsoon'13	0.03
23	Tigariya	Alluvial soil	Pre-Monsoon'13	0.02

A perusal of the above table would indicate that the loamy soils i.e. Haplustaffs have higher infiltration rate ranging from 0.03 to 0.70 cm/min as compared to alluvial soil, i.e. Ustifluvents, where infiltration rate varies from 0.02 to 0.05 cm/min. Maps showing the spatial distribution of soil infiltration rate is given in Figure 24 & 25. It can be seen from the above mentioned maps that the infiltration rate of the soil is more in the eastern and western flank of the project area, than other places.

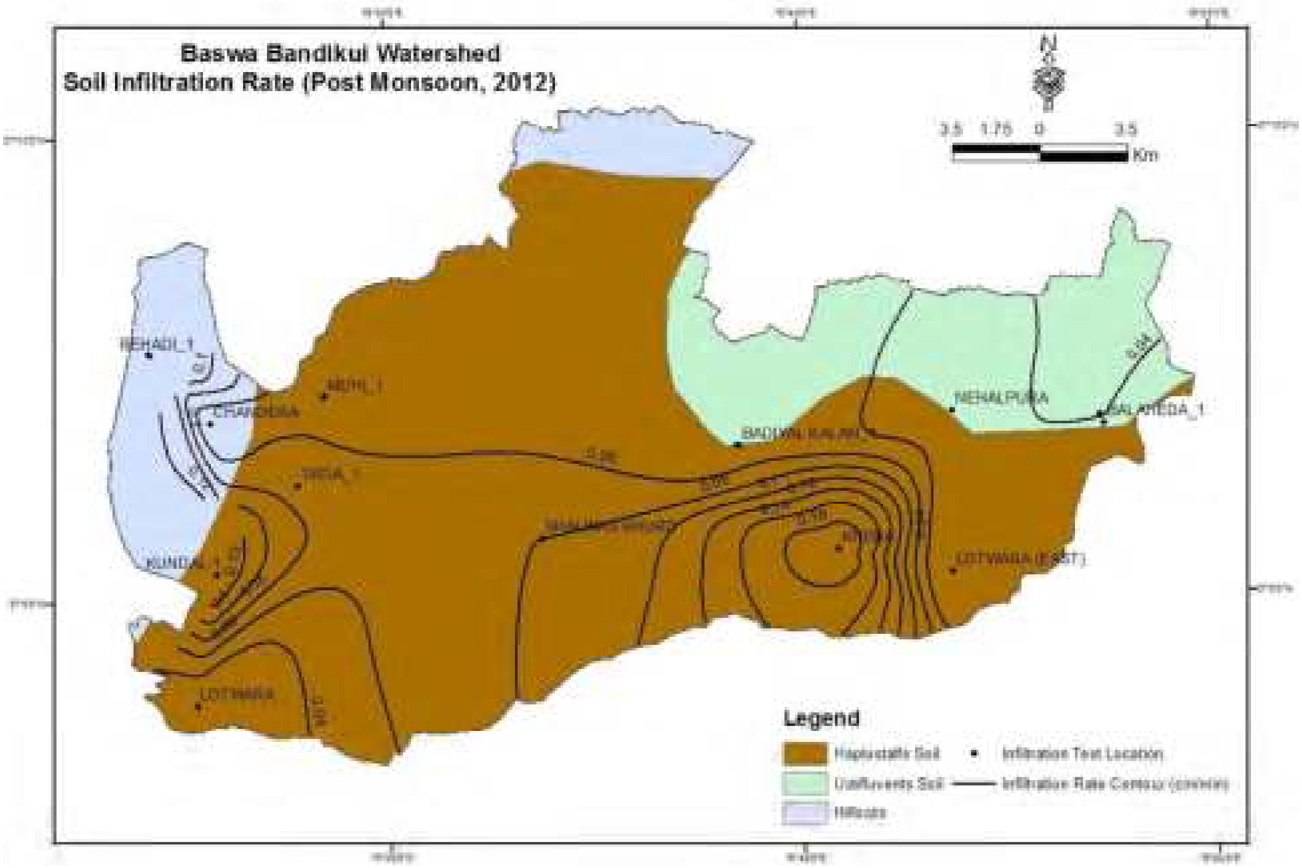


Figure 24. Soil Infiltration map of Baswa-Bandikui project area, Rajasthan (post-monsoon, 2012)

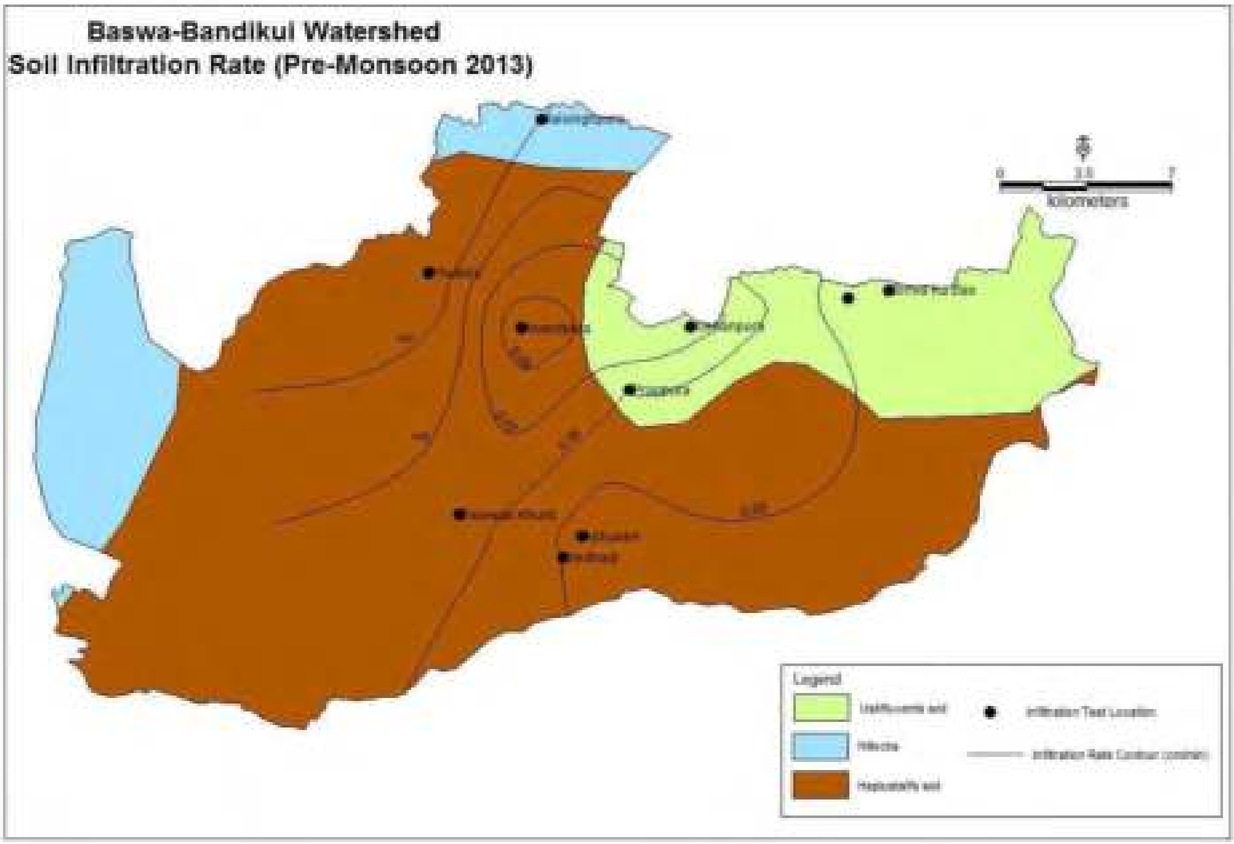


Figure 25. Soil Infiltration map of Baswa-Bandikui project area, Rajasthan (pre-monsoon, 2013)

3.3 LAND USE

Land use map is prepared based on remote sensing studies carried out by State Remote Sensing Application Centre located at Jodhpur (Figure 26).

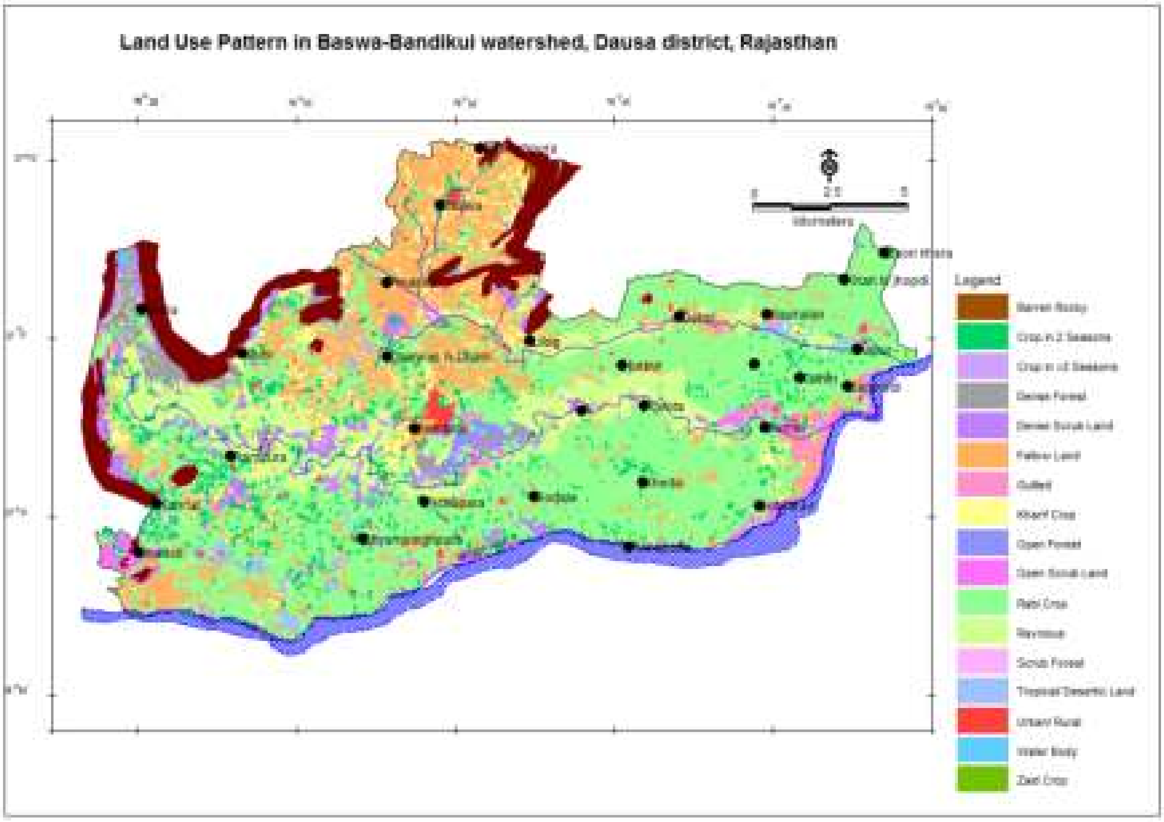


Figure 26. Land use pattern in Baswa-Bandikui watershed (source: SRSAC, Jodhpur)

The area for different land use pattern are computed from the digitized data of the GIS layers. The main purpose of the table for land Use is to indicate broadly the ways in which the land in the area is utilised. The distribution of land use pattern in Baswa-Bandikui watershed is given in Table 17.

Table 17. Land use statistics of Baswa tehsil, Dausa district, Rajasthan (in ha)

Land Use	**Area(sq km)**	**Land Use**	**Area (sq km)**
Urban/Rural	8.66	Scrub Forest	3.07
Kharif crop	44.05	Tropical/ Desertic land	7.44
Rabi crop	279.30	Gullied	6.49
Zaid crop	0.23	Ravnious	56.83
Crop in 2 seasons	36.25	Dense Scrub land	26.10
Crop in >2 seasons	3.57	Open Scrub land	12.65
Fallow land	112.20	Barren Rocky	5.96
Dense Forest	28.55	Water Body	0.635
Open Forest	17.76	**Total Area**	649.74

Source – State Remote Sensing Application Centre, Jodhpur

The descriptions of various land uses are as follows.
Urban/ Rural – Areas covered by urban and rural habitations
Kharif crop - Crops which are sown in the rainy season (monsoon) and harvested in the autumn.

Rabi crop - Crops which are sown in the winters and harvested in the spring season.
Zaid crop - Crops that are grown in the season between the growing seasons of kharif and Rabi crops means from March to June.
Fallow Land- A piece of land that is normally used for farming but that is left with no crops on it for a season in order to let it recover its fertility.

Forest- ecosystem with a minimum of 10 percent crown cover of trees and/or bamboos generally associated with wild flora, fauna and natural soil conditions, and not subject to agricultural practices. If the tree crown cover (stand density) is about 5–20 percent of the area, it is called *Open forest.* If the crown cover is more than 20%, then it is called *Dense Forest. Scrub forest* is the result of of both biotic and abiotic influences. Scrub is a stunted tree or bush/shrub.

Tropical/ Desertic land - Rainfall is sporadic and in some years no measurable precipitation falls at all. The terribly dry conditions of the deserts is due to the year-round influence of subtropical high pressure and continentality.
Gullied - A narrow steep sided channel formed in loose earth by running water. A gully is usually dry except after periods of heavy rainfall or after the melting of snow or ice.
Ravines - The word 'ravine' is usually associated with a network of deep gullies formed generally in thick alluvium and entering a nearby river, flowing much lower than the surrounding high grounds. The ravines, are extensive systems of gullies developed along river courses.
Scrubland **-** diverse assortment of vegetation types sharing the common physical characteristic of dominance by shrubs. A shrub is defined as a woody plant not exceeding 5 metres (16.4 feet) in height if it has a single main stem, or 8 metres if it is multistemmed.
Barren rocky – area covered with rock outcrops.
Water Body- area of impounded water, areal in extent and often with a regulated flow of water. It includes man-made reservoirs/lakes/tank/canals, besides natural lakes, rivers/streams and creeks.
Wells - The number of wells used for irrigation purpose are obtained from IVth Minor Irrigation Census (2006-2007), the latest data available on public domain. An incremental factor of 1% per year was added to the data to obtain current data. The number of wells are given in Table 18.

Table 18. Number of wells used for irrigation purpose in Bandikui block, Dausa district

Sl. No.	**Type of Well**	**Numbers**
1	Dug well	3691
2	Shallow Tubewell	3436
3	Deep Tubewell	246
	TOTAL	**7373**

Based on IV Minor Irrigation Census (2006-07)

3.4 GEOMORPHOLOGY

The study area is a part of Aravalli hill system. The altitude of relief in Baswa-Bandikui project area ranges from 250 to 589 metre above mean sea level (mamsl) in the north eastern part of the watershed with north to south and west to east slope and from 250 to 273 mamsl in the southern part with north west to south east slope. The highest point in the area is 589 mamsl on the top of hillock located north east of village Redia in the northwest part of the watershed. Figure 27 shows digital elevation map (DEM) of Baswa-Bandikui Watershed area.

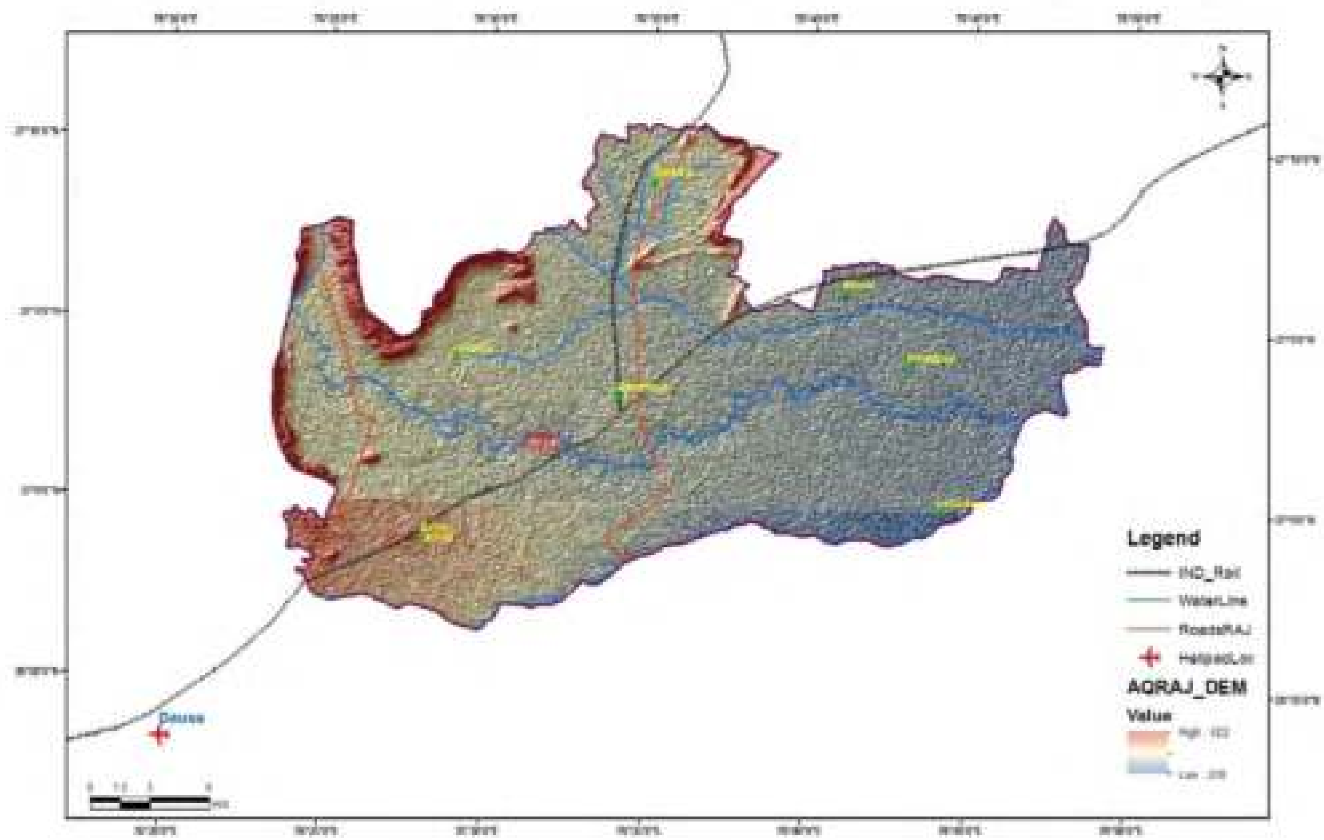


Figure 27. Digital Elevation Map of Baswa-Bandikui Watershed pilot project area

The northern part of watershed characterized by structurally controlled NNE-SSW & NNW-SSE trending hill ranges comprising of quartzites of Delhi Super Group. Escarpments are common. The high dips and the nature of rocks are responsible for the formation of escarpments. Denudational hills comprising of Quartzitic sandstone outcrops are found. The geomorphologycal features of Baswa-Bandikui Watershed area are given in Figure 28 and Plate 3.

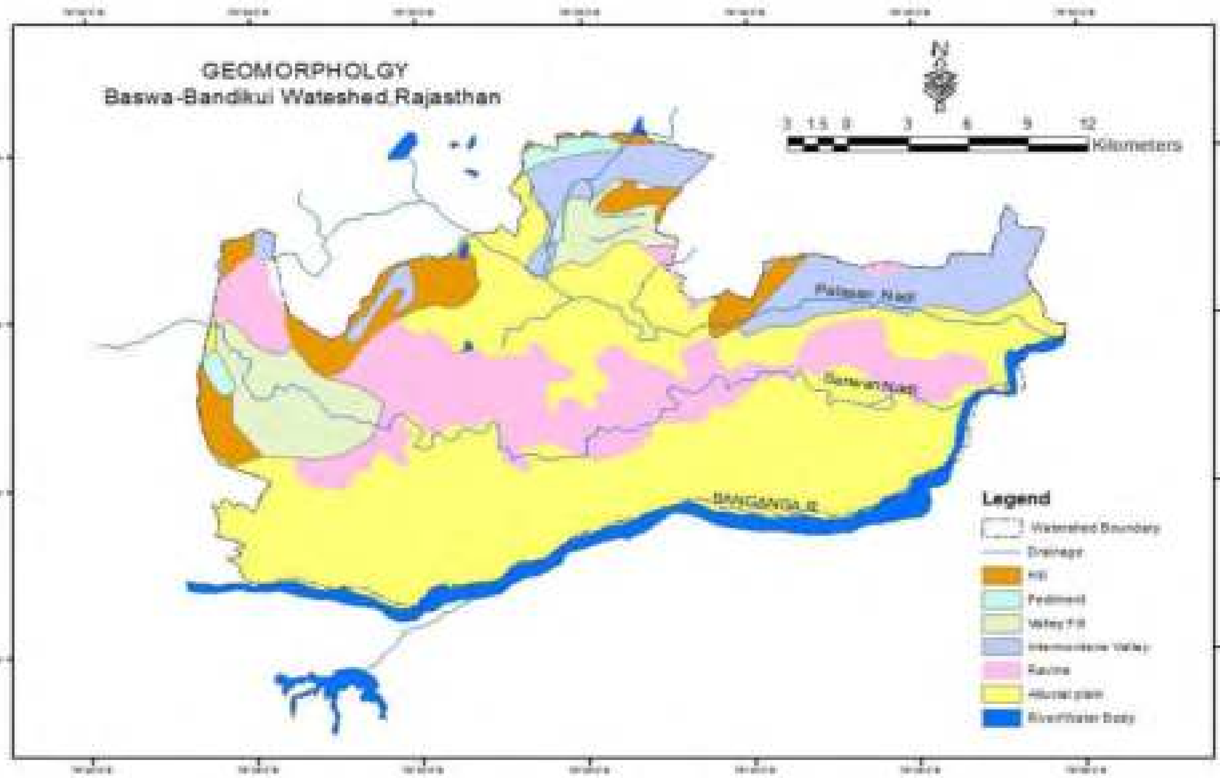


Figure 28. Geomorphological features in Baswa-Bandikui Watershed project area

B. Ravines

Plate 3. Prominent geomorphological units in Baswa-Bandikui watershed - a. Hillocks, b. Ravines

Drainage

All the three streams including Banganga, Sanwan and Palasan nadis flows from west to east. However, all of them are ephemeral streams. Very thin flow is observed on stream beds only during monsoon season whenever rainfall is good.

3.5 GEOPHYSICS

Geophysical studies carried out in the project include VES, ERT, G-TEM, SkyTEM, HeliMAG, and borehole geophysics. Table 19 shows details of geophysical data acquisition with brief remark on instrument used and system parameters.

Table 19. Total Geophysical data collected in Baswa-Bandikui Watershed

Data summary at Baswa-Bandikui Watershed, Dausa (Rajasthan)							
Name of Activity		Target	pre SkyTEM	SkyTEM	Post SkyTEM	Total	Remarks
1-D GEOPHYSICS	VES (no.)	150	51		15	66	Syscal (IRIS) and Terrameter-LS (ABEM) systems were used
	TEM (no.)	25	73		0	73	TEMfast48HPC system with 50m x 50m loop size, 1 and 4 A current were used
2-D GEOPHYSICS	ERT (LKM)	0	2		33.74	35.74	Syscal (IRIS) and Terrameter-LS (ABEM) systems were used
Borehole Logging	Wells (No.)	20	0		13	13	Short normal (16), Long normal (64), Lateral, SP and Gamma logging were done
HeliTEM	Dual moment SkyTEM304 (LKM)			3525		3525	TEM data using Line/Tie line spacing : 200/2000 ms
HeliMAG	Geometrics Cesium Vapour type 822A (LKM)			3525		3525	Magnetic data using Line/Tie line spacing : 200/2000 ms

HELITEM RESULTS

The collected SkyTEM data located at every ~2.5 m spacing along the flight line were processed on Aarhus Workbench with advanced state-of-art processing schemes to remove couplings arising from roads and man-made installations such as iron pipes, buried cables and possibly also closed iron sheep fences. The survey area, flight lines are shown in figure 29.

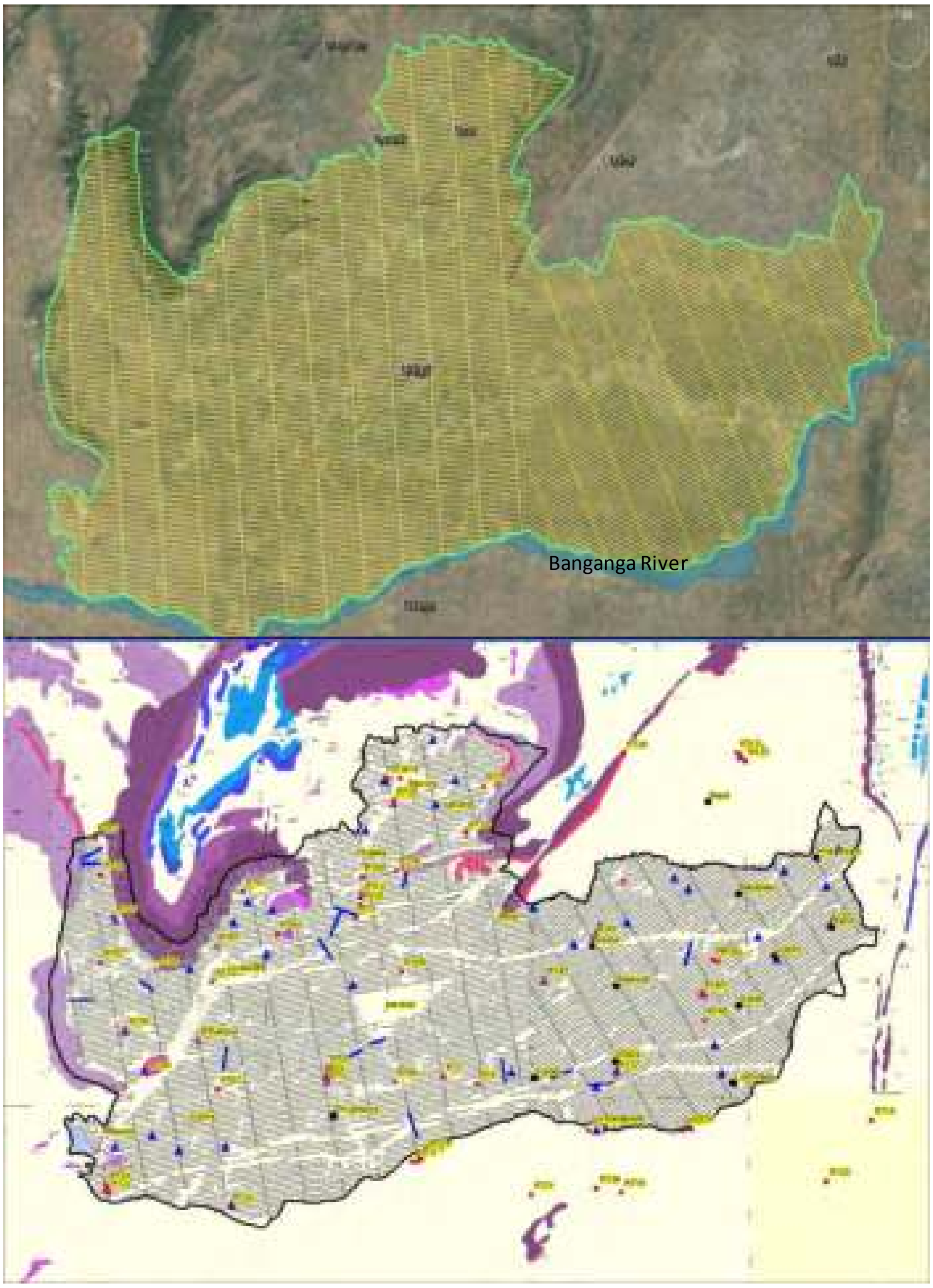


Figure 29. HeliTEM flight lines in Baswa-Bandikui Watershed project area

The survey area, the flight lines are shown as yellow lines. Afterwards the data were applied an average filter to improve the signal to noise (S/N) ratio and finally converted into representative individual sounding data spaced roughly at every 30 m interval. The averaged data were inverted with preliminary laterally constrained inversion to make sure all the coupled and noisy data had been removed, and furthermore to establish a suitable starting model for the entire survey area. The preliminary inversions thus suits as a quality check of the previous processing. Finally the data were inverted with a smooth model using the spatially constrained inversion (SCI) approach. Mean resistivity maps are prepared for every 5 m depth interval till 200 m depth.

HORIZONTAL PLANAR RESISTIVITY SECTION

The mean resistivity maps have been generated at 5 m depth intervals down to a depth of 150 m. The maps are prepared by gridding the data using the Kriging interpolation method with a node spacing of 25 m and a search radius of 500 m. The nodes have further been subdivided by a factor of 4 to obtain the interpolated resistivity pixels for the bitmaps that make up the maps.

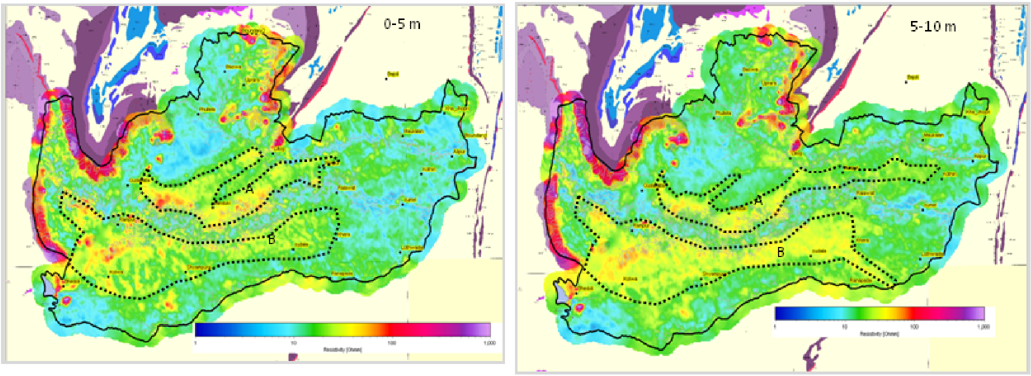


Figure 30.Mean resistivity maps: 1) 0-5 m and 2) 5-10 m depths.

The mean resistivity map of 0-5 m depth, which is the outcome of the low moment data, recorded high resistivity (≥100 Ωm) in northwestern part over the hill indicating resistive, hard and compact quartzite. The high resistivity is found over the quartzite outcrops that are mostly folded or faulted in this area (Figure 30).

Moderate resistivity in the range of 30-50 Ωm, shown in yellow colour, are found mostly on the riverbanks and the adjoining areas in patches. Two major zones A and B with moderate resistivity are marked with dotted line indicating the existence of higher degree of granular zones such as sand. However, the blue coloured patches with 5-10 Ωm resistivity reveal soil with dominant occurrence of clay and or silt. These results are important from the point of managing the aquifer recharge.

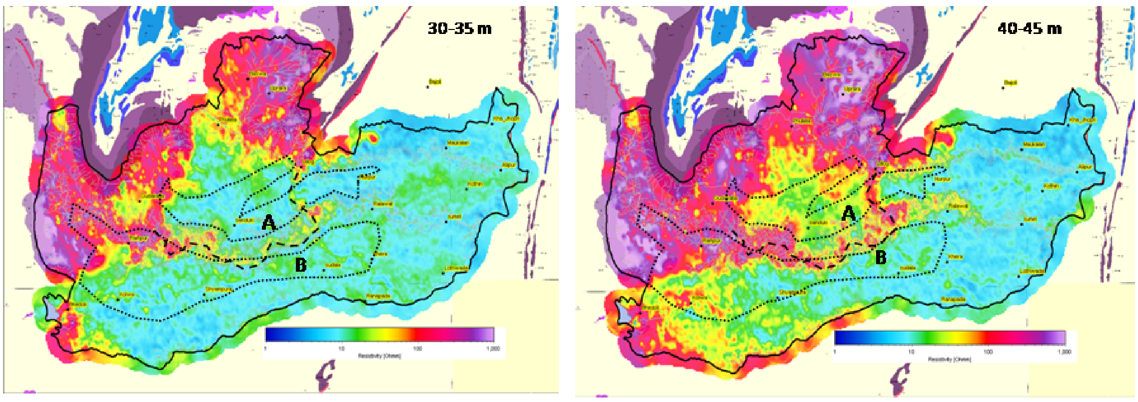


Figure 31.Mean resistivity maps: 1) 30-35 m and 2) 40-45 m depths

However, the degree of granularity has changed in the underlying map at 5-10 m depth. Granularity improved in zone B. The silt occurrences over the rivers are still preserved in both the maps. The low resistivity along the present river could also be due to the higher degree of moisture presence than the surroundings. The low resistivity along the river continues till the depth of 30 m below ground and then it turns resistive in comparison to the surroundings in the western two-third portion of the study area that are marked with the dotted line in Figure 31. This high resistivity is indicative of occurrences of granular sediments.

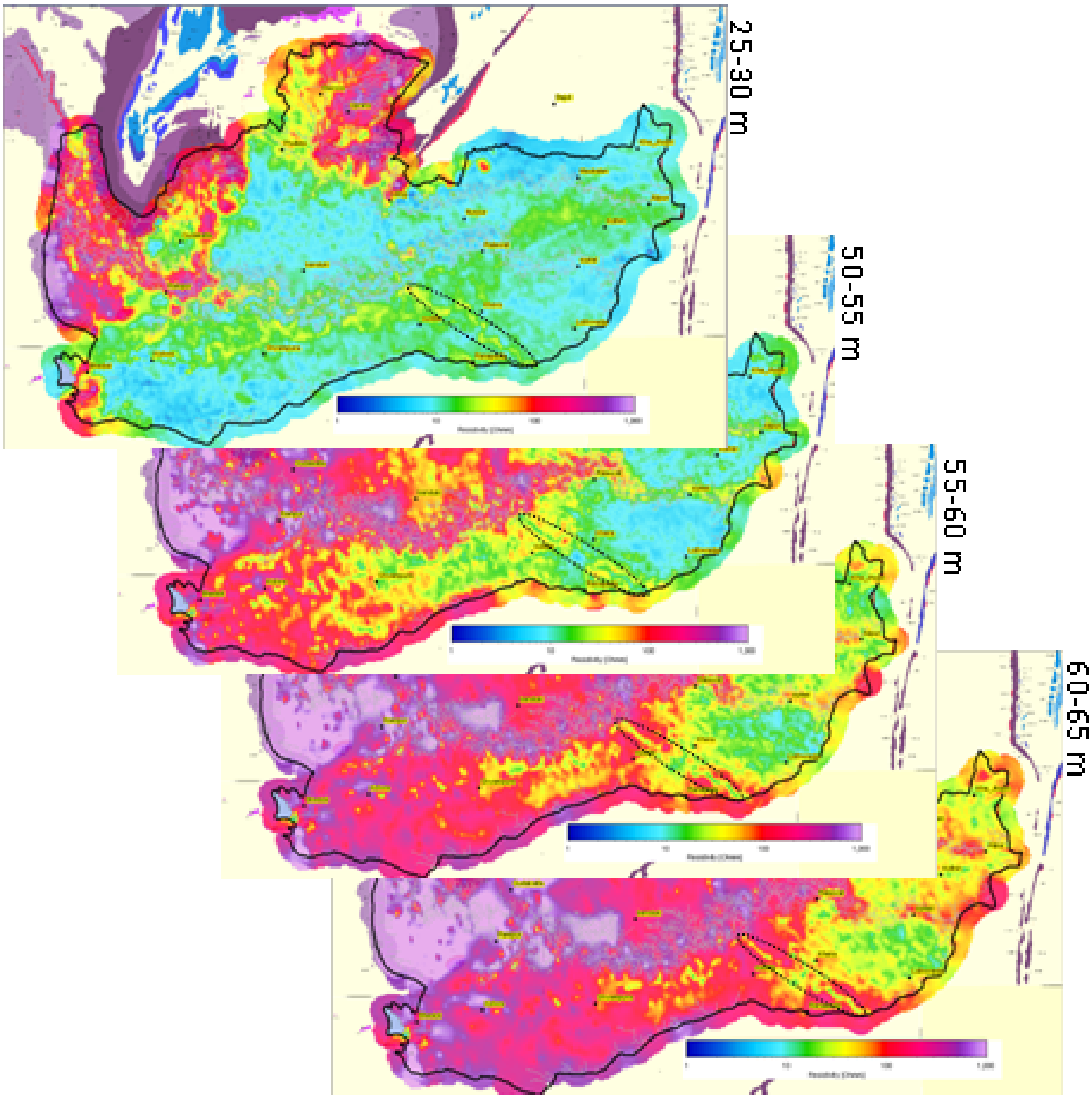


Figure 32.Mean resistivity maps: from top 25-30 m, 50-55 m, 55-65, 65-70 m depths

The mean resistivity maps shown in Figure 32 for depths from 25 m to 65 m reveal different stages of river based on their resistivity patterns. Encircled zone elongated in NW-SE direction shows an anomalously resistive zone connected with the river (i.e. popularly known as Sanwan Nadi). This anomalous track indicates a palaeo river channel, where granular sediment deposition has taken place. Moving downward the high resistivity track turns into a low resistivity anomaly between 50-65 m depth ranges. Since the quartzite bedrock is encountered at 50 m depth the palaeo river channel appears to have low resistivity as compared to the quartzite host medium. The inferred palaeo channel is roughly 50 m wide at 60 m depth. It decreases with depth and disappears at around 85 m depth bellow the ground. The vertically V-shape cross section of the river indicates youth stage that usually has rapid and energetic flow through the rocky hill capable of cutting and

eroding the rock mass. However at old stage of the river, flow of water gets slowed down and loses the capability of transporting the large sediments that gets settled down along the river course producing the resistive anomaly observed at 25-30 m depth.
The mapping of the 50 m wide zone at ~80 m depth shows the capability of the SkyTEM system in high-resolution mapping. Mapping of such a target is challenging even by the ground geophysical measurements. This was possible only because of the dense data acquisition with high S/N ratio by the SkyTEM system and an advance level of processing.
The quartzite bedrock is encountered at roughly 35 m depth in the west, which is found, in general, deepening towards the east. However, there is anomalous change in the resistivity pattern in the east of the line MN. This could be due to deepening of bedrock as well as dominance of deteriorations of the groundwater quality.

Vertical Planar Resistivity Section

The study area has been divided into 2 km x 2 km grid by WE and NS lines (Figure 33). The smooth layered SCI inverted models have been imported within 100 m search radius to the grid lines. The generalized depth of investigation (GDI) line indicates that the 80% global sensitivity comes from above the line. However, still 20% comes from below the GDI line. In other words, interpretation of geophysical result below GDI line should be done with utmost care.

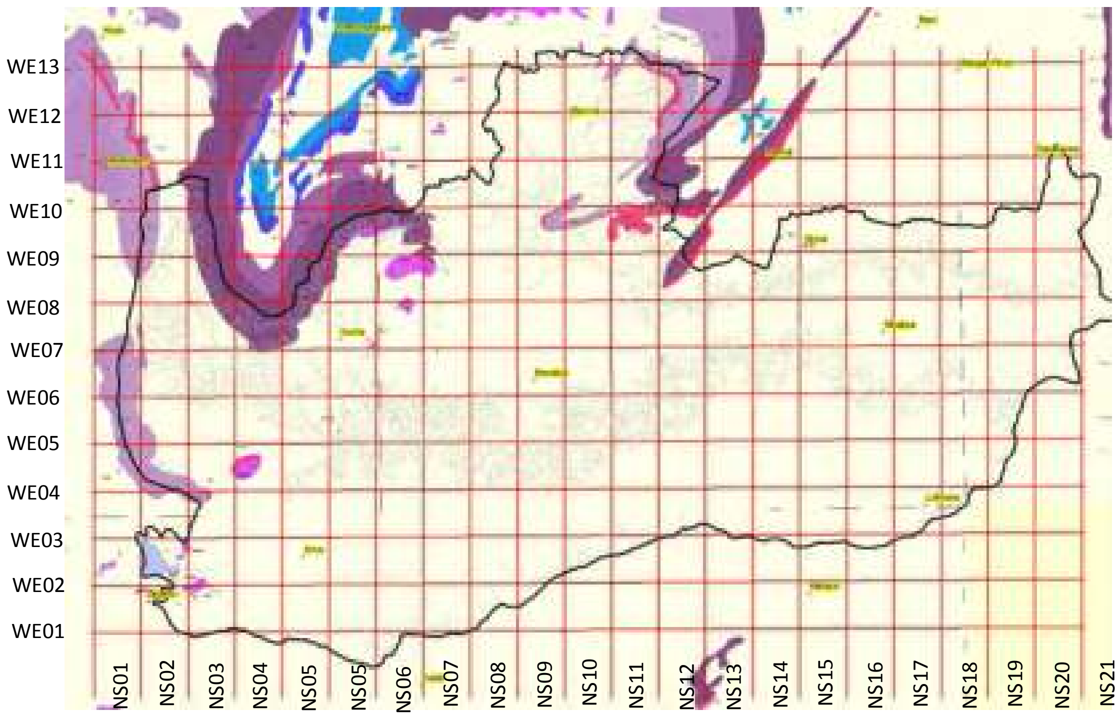


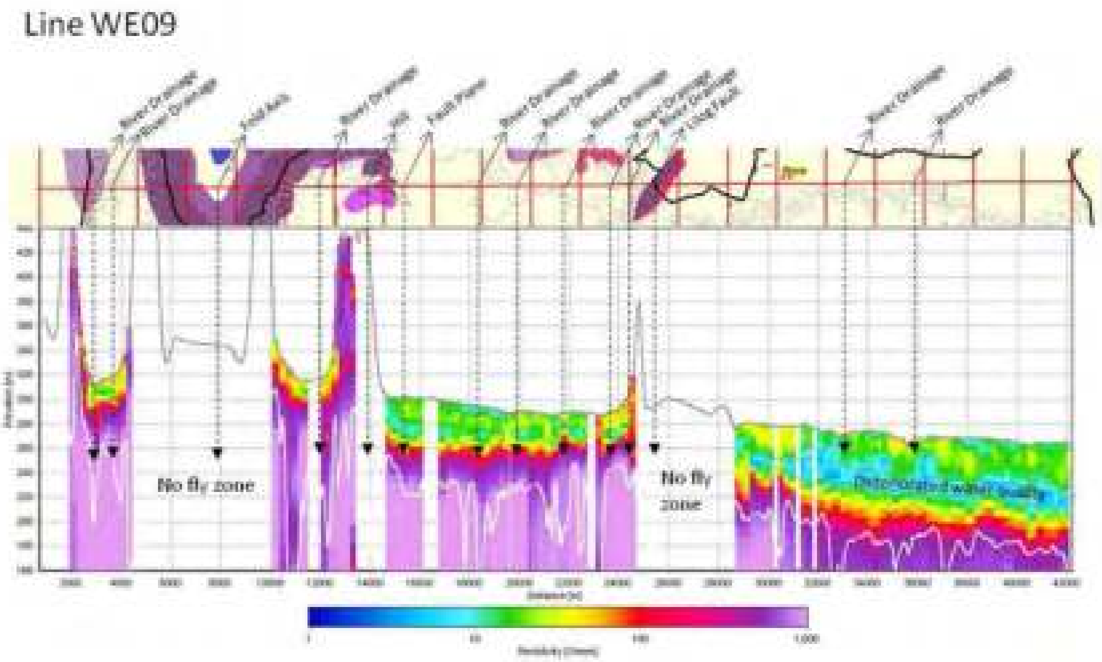
Figure 33. Grid map with 2km x 2 km lines running in WE and NS directions.

To have an idea about the impact of geomorphic features on the subsurface four typical vertical cross sections have been presented along the 42 km long line west-east profiles viz., WE03, WE05, WE07 and WE09.
The section WE09 clearly shows hills with high topography and high resistivity and low resistivity in the valley fills between 2 to 4 kms (Figure 34). Higher GDI over the drainage and

the river indicates better S/N ratio due to increased conductivity from the surroundings. This revealed the deep weathering and fracturing of the quartzite bedrock. In general, higher GDI is an indication of better inductive subsurface and better S/N ratio, which could be due to tectonically disturbed zone in the form of weathered-fractured water saturated quartzite in the present case.

Along the fault plane at 14 km on lateral scale, there is a sudden deepening of weathered-fractured quartzite with higher GDI. The anomalous deeper weathered fractured quartzite continues till the fault passing through Lilog village (hereafter called as Lilog Fault) fault in the eastern side at 25 km on lateral scale. Overall deeper weathered-fractured quartzite and GDI between the two fault planes due to disturbed and weak zone, (which is the most expected situation) strongly reflects the high sensitivity of the SkyTEM measurement and hence it validates the HeliTEM results indirectly.

Deteriorated water quality also could be seen on the eastern one third part of the section starting roughly from 30 km to the end of the profile. In general, inverted resistivity model falling in the range of 6-20 Ωm is basically due to the lithological predominance of clay (and or silt). However, further decrease in the resistivity could be primarily due to the deteriorated groundwater quality.



Data Gap- cultural interference zone

Figure 34. SkyTEM SCI resistivity image along line WE09 showing geomorphic signature on subsurface

Similarly the SkyTEM results along the Profile WE07 have revealed impact of the geomorphology on the subsurface till the quartzite bedrock with the deeper GDI from the surrounding (Fig. 34). Deepening of the weathered-fractured quartzite and thick sediment in the valley fill has also been confirmed between the two hill ranges located at 2 and 7 km on lateral scale.

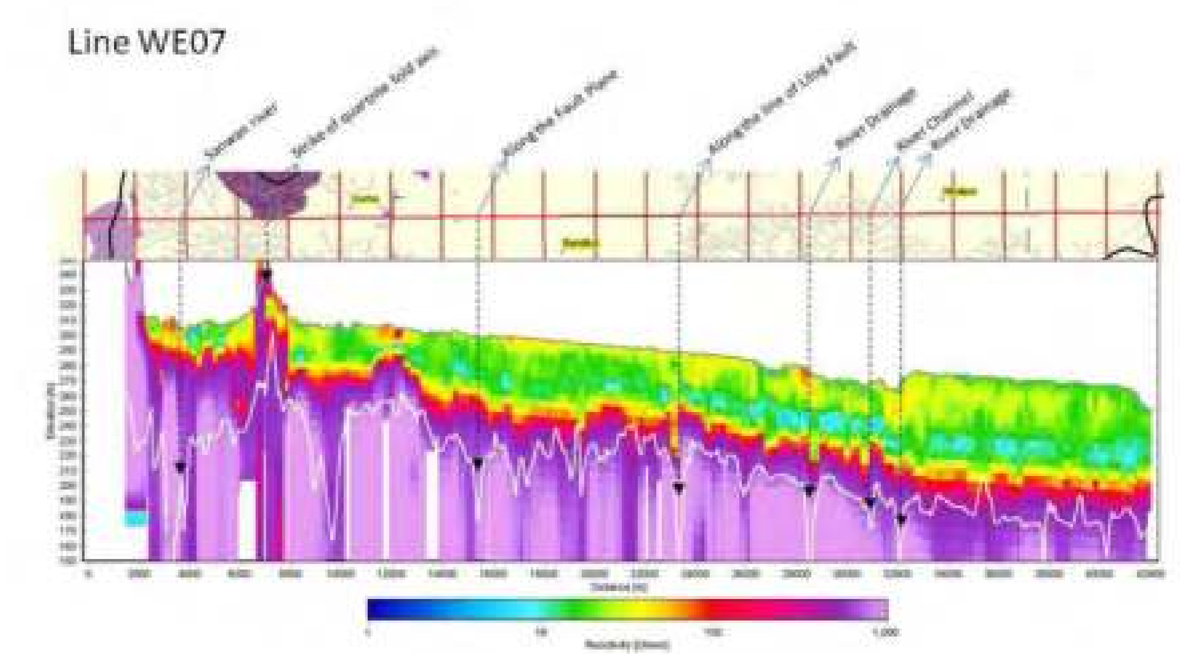


Figure 35. SkyTEM SCI resistivity image along line WE07 showing geomorphic signature on subsurface and its extension.

The Profile WE05 (Figure 35) passes along the Sanwan Nadi. Though the river is found mostly dry, it is likely to contain a high degree of moisture/water saturation underneath. Since the section cuts the river at multiple points in addition to the drainage, the surface topography is highly disturbed. The geomorphic features at the surface once again are found to be corroborating well with the line of GDI. Another feature representing a palaeo river channel is observed at around 26 km on lateral scale, which was discussed in horizontal planar section of 50-65 m.

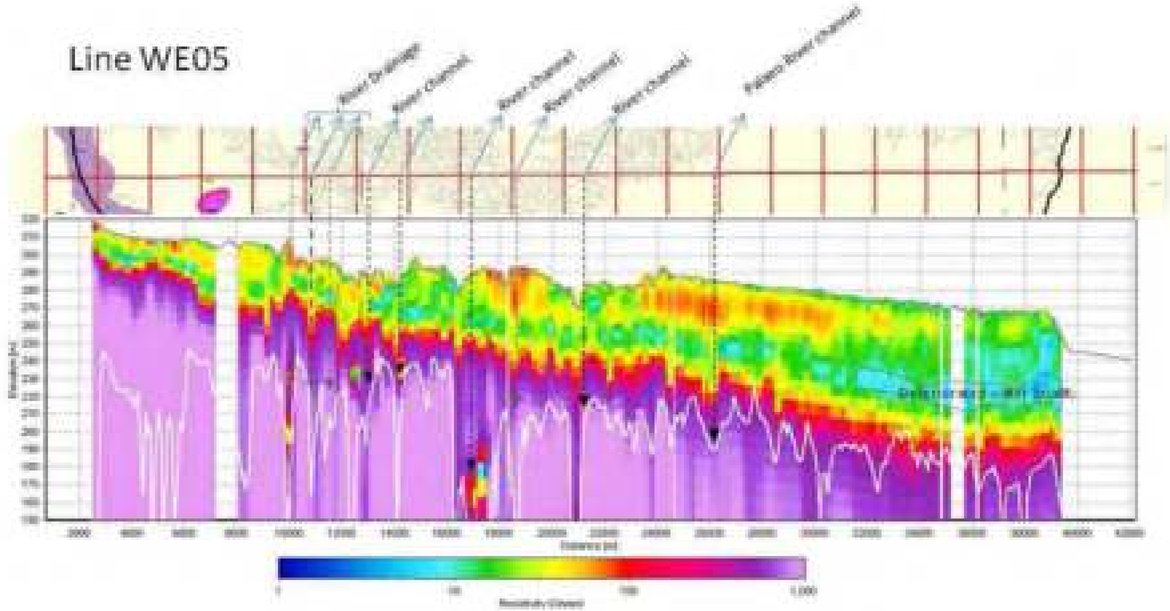


Figure 36. SkyTEM SCI resistivity image along line WE05 showing the influence of geomorphology on the subsurface.

Figure 37 once again confirms the findings of the SkyTEM results showing a strong correspondence of the geomorphology on the subsurface topography. This has further shown the palaeo tectonic plane, which is younger than the palaeo river channel as it has disturbed the palaeo river course at around 29 km on lateral scale. It seems the river courses in the study area are strongly controlled by tectonics, which is also evident by parallel shift of the entire three river course.

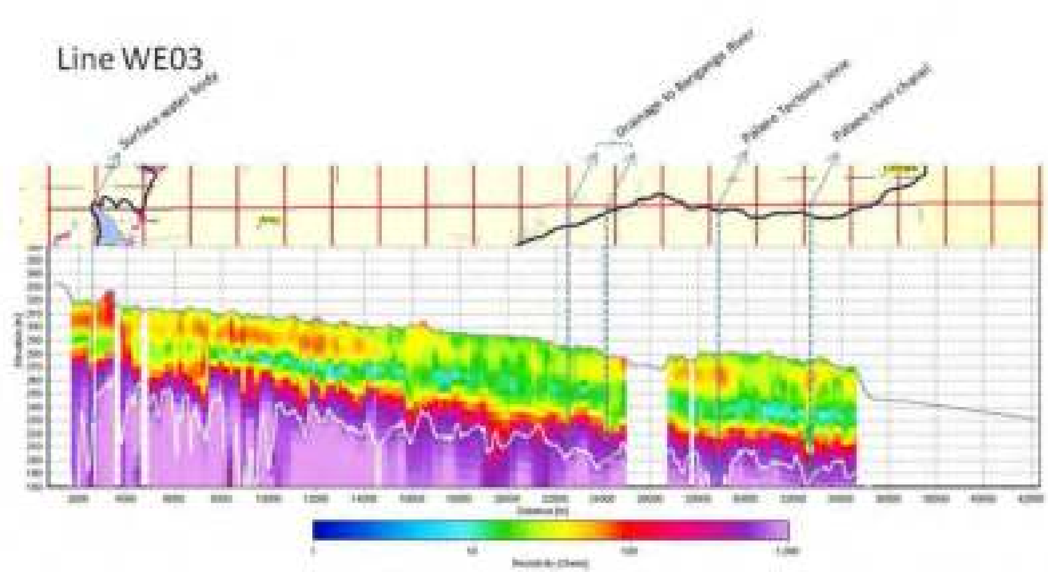


Figure 37. SkyTEM SCI resistivity image along line WE03 showing geomorphic signature on subsurface and its extension.

HELIMAG RESULTS

HeliMag survey was carried out along with the HeliTEM using Geometrix Caesium vapour type having sensitivity 0.1 nT. Magnetic sensor was synchronized with TEM measurements. The position of the magnetometer sensor is located at the front panel as shown in Figure 38.

Figure 38. Sketch showing the frame and the position of the basic instruments including the GPS position

A base station was used for continuous magnetic measurement to record the temporal changes, which is applied for correcting the magnetic data recorded by the by main magnetometer attached with HeliTEM transmitter. Final processing of the magnetic data involved an application of traditional corrections to compensate for diurnal variation and heading effects prior to gridding. Advanced full processing of magnetic data was implemented in Geosoft's Oasis Montaj software as follows:

- Processing of static magnetic data acquired on magnetic base station
- Pre-processing of airborne magnetic data
- Stacking of data to 10 Hz in SkyLab (SkyTEM in-house software).
- Moving positions to the center of the sensor in SkyLab.
- Processing and filtering of airborne magnetic data
- Standard corrections to compensate the diurnal variation and heading effect
- IGRF correction
- Statistical and full leveling
- Micro leveling
- Gridding

Finally total magnetic field intensity map has been prepared after all correction and data leveling (Figure 39). Magnetic data is found varying from 46860 nT to 47119 nT. The high magnetic field intensity corresponds with the followings:

1. Mica schist, gneiss and amphibolites with marble that belongs to Mangalwar complex of Bhilwara super Group of Archean age. This is located at the western boundary in the form of folded hill ranges
2. Granite, an intrusive that belongs to Delhi Super Group of Palaeo proterozoic to Mesoproterozoic
3. Black banded marble with cal-schsist and phylite of Kushaigarh Formation of Alwar group under Delhi Super Group.
4. Ferruginous, spongy quart and chert-jesper quartz breccias with intercalated meta tuff and phyllite that belongs to Ajabgarh Group

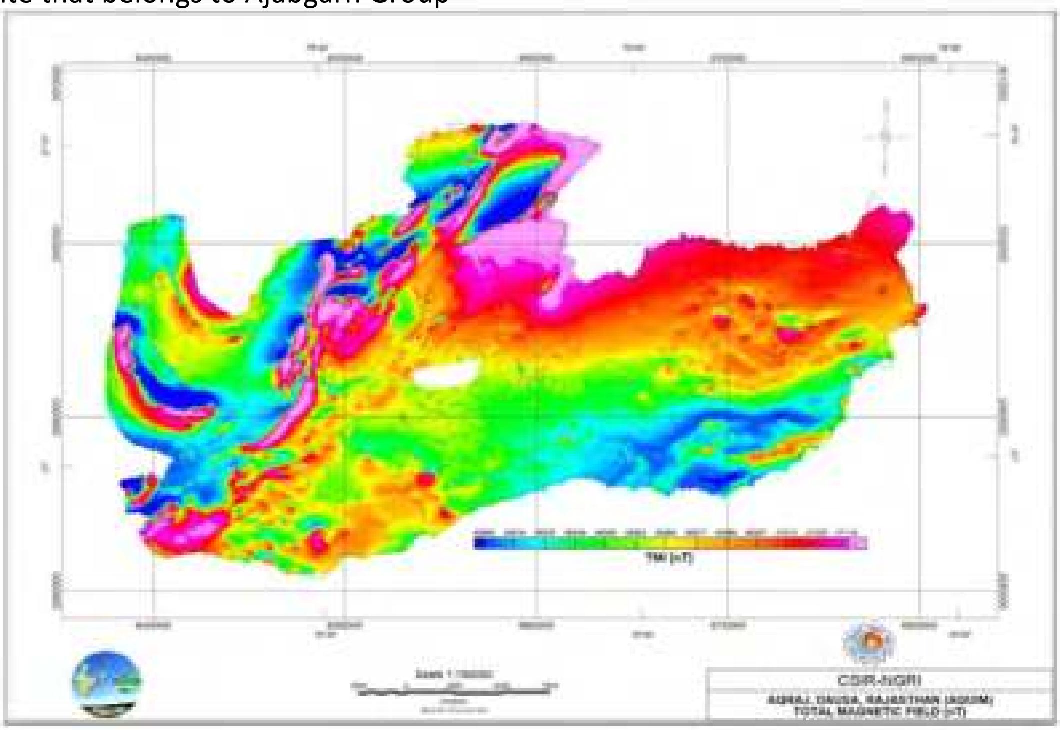


Figure 39.Total magnetic field intensity map (nT) of Baswa-Bandikui Watershed.

Figure 40 shows magnetic map superimposed over geological maps that shows one to one correspondence with the structural features as well as the banded marble, ferruginous formation and granite. Broadly there are three sets of faults running NS and NE-SW. The NE-SW fault shown in the geological map marked in the NE of Baswa village (hereafter Baswa Fault) observed continuous high magnetic anomaly along the strike within the study area. This could be inferred as extension of the fault. Southern half of the fault is folded as well as traversed by NS fault. The Lilog fault is almost parallel to the Baswa NE-SW fault. Two palaeo river channels have also been marked in the SE part of the watershed. This is a highly disturbed watershed with sets of folds and faults, where associated weak zones could be potential for the occurrence of groundwater. Pattern of folding and faulting also indirectly explain why three river channels got parallel shift.

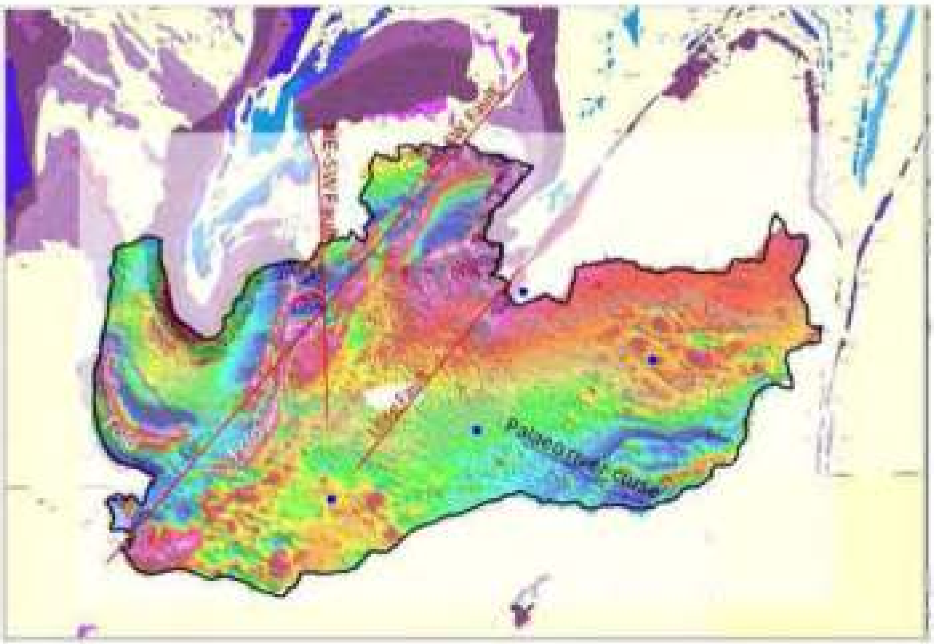


Figure 40.Helimag map superimposed over geological map showing the inferred structural features

3.6 SUB-SURFACE INFORMATION

Data on sub-surface information was generated through ground water exploration carried out in the Baswa-Bandikui Watershed project area. The objective of the construction of exploratory tubewells are to integrate the hydrogeological information with the geophysical findings arrived through surface and airborne geophysical studies particularly VES, GroundTEM, ERT and SkyTEM carried out by NGRI and to fill up the data gap existing in the area with respect to exploratory well information. The objective of the study is to configure the Aquifer Geometry and its characterization. In total, 15 wells were constructed in the area during the project study period. The location of exploratory well sites constructed during the project is given in Figure 41. In addition, information of 20 exploratory wells constructed earlier in the area was also available. Thus, in total, 35 exploratory wells information are used in the analysis of sub-surface hydrogeology of the study area.

Ground water explorations of 15 wells were carried out through outsourcing in the soft rock formations upto a maximum depth of 83 m. The salient features of the exploratory wells are given in Table 20.

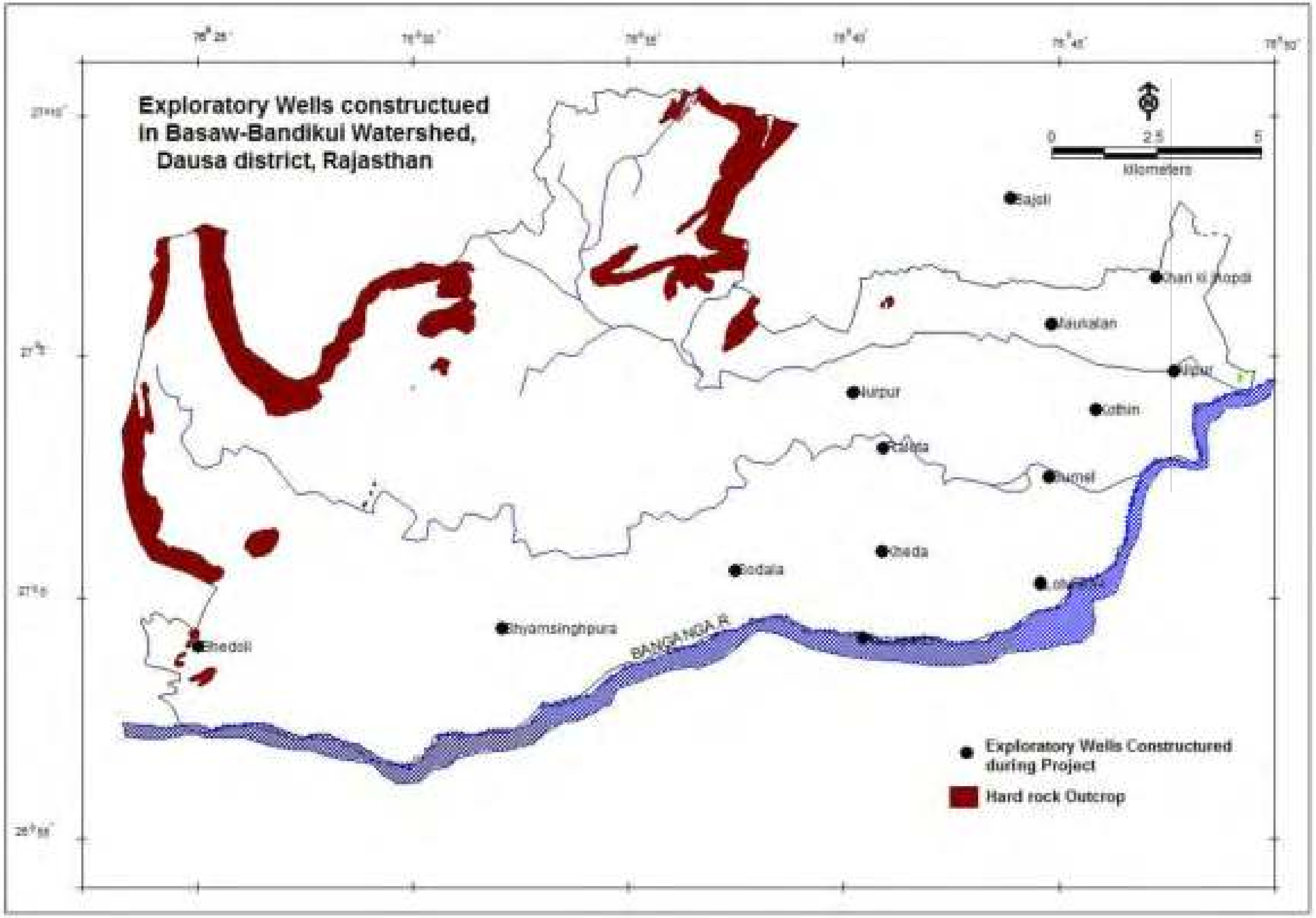


Figure 41. Location of new exploratory wells drilled in Baswa-Bandikui Watershed project

Table 20. Salient features of exploratory wells constructed in Baswa-Bandikui Watershed, Dausa district, Rajasthan

S. No.	Location	Coordinates		Elevation	Drill depth	constructed depth	Zones Tapped		Formation	Disc	DD
		Long.	Lat.	(m)	(m)	(m)	From	To		(lpm)	(m)
EW1	Lotwara-I	76.7425	27.0054	259	79.03	76	30	32	Allu , Wh rock	220	10
							44	47			
							59	62			
							72	75			
EW2	Ranapada	76.6740	26.9863	268	63.68	61	43	55	Allu	60	17
EW3	Kheda	76.6814	27.0164	263	63	60	36	39	Allu	Neg.	
							50	59			
EW4	Nurpur	76.6703	27.0712	268	55	54	48	50	Wh rock	Neg.	
							51	53			
EW5	Ralota	76.6820	27.0521	267	61.32	61	40	46	Allu , Wh rock	Neg.	
							54	57			
EW6	Kothin	76.7636	27.0651	255	61	61	48	54	Allu	Neg.	
EW7	Alipur	76.7939	27.0785	249	63.63	63	39	45	Allu	47.4	12
EW8	Sodala	76.7636	27.0651	268	59.51	57	50	55	Allu , Wh rock	Neg.	
EW9	Sumel	76.7457	27.0421	253	67.56	67	44	47	Allu , Wh rock	90	5
							48	51			
							55	61			
EW10	Shyamsinghpura	76.5344	26.9899	285	52	52	44	51	Allu , Wh rock	Neg.	
EW11	Khare ki Jhopdi	76.7870	27.1110	250	67	67	42	45	Allu	Neg.	
							49	55			
							57	60			
EW12	Maukalan	76.7466	27.0948	256	91	60	48	60	Allu ,	78.6	29

S. No.	Location	Coordinates		Elevation	Drill depth	constructed depth	Zones Tapped		Formation	Disc	DD
		Long.	Lat.	(m)	(m)	(m)	From	To		(lpm)	(m)
									Wh rock		
EW13	LOTWARA-II	76.7425	27.0052	259	83.23	83.23	46	49	Allu , Wh rock	228	14
							59	62			
							76	79			
EW14	Bajoli	76.7314	27.1384	256	50.98	50	40	46	Wh rock	90	17
EW15	Bhedoli	76.4169	26.9835	306	38.22	38	23	26	Wh rock	-	

Selection of Drilling Sites

Sites for construction of Exploratory Well were initially selected based on data gap analysis. Since most of the existing information on exploratory drilling was available for western part of the project area, out of 15, except one, rest 14 sites are located in the central and eastern part of the project area. Site selection was followed by Ground geophysical studies by NGRI to explore the feasibility of the sites. Some of the sites were changed based on the geophysical recommendations and alternate sites were chosen. All the sites are located in the Government land.

Construction of Exploratory Borewells

The conventional direct Rotary Method of drilling was adopted since the formations are soft rocks. Drag bits are used for drilling the hole. The pilot holes are drilled of 215 mm diameter. During drilling, drill time log and lithological log are maintained. Geophysical loggings are carried out in the pilot hole to identify the potential fresh water zones. Geophysical loggings include Spontaneous Potential and Resistivity logging as well as Gamma logging. Well assembly are recommended based on the combined interpretation of drill time log (Figure 42), lithological log and geophysical logs. The detailed lithological logs, drill time logs and borehole geophysical logs are given in Annexure -1. Few representative logs are shown in Figure 43.

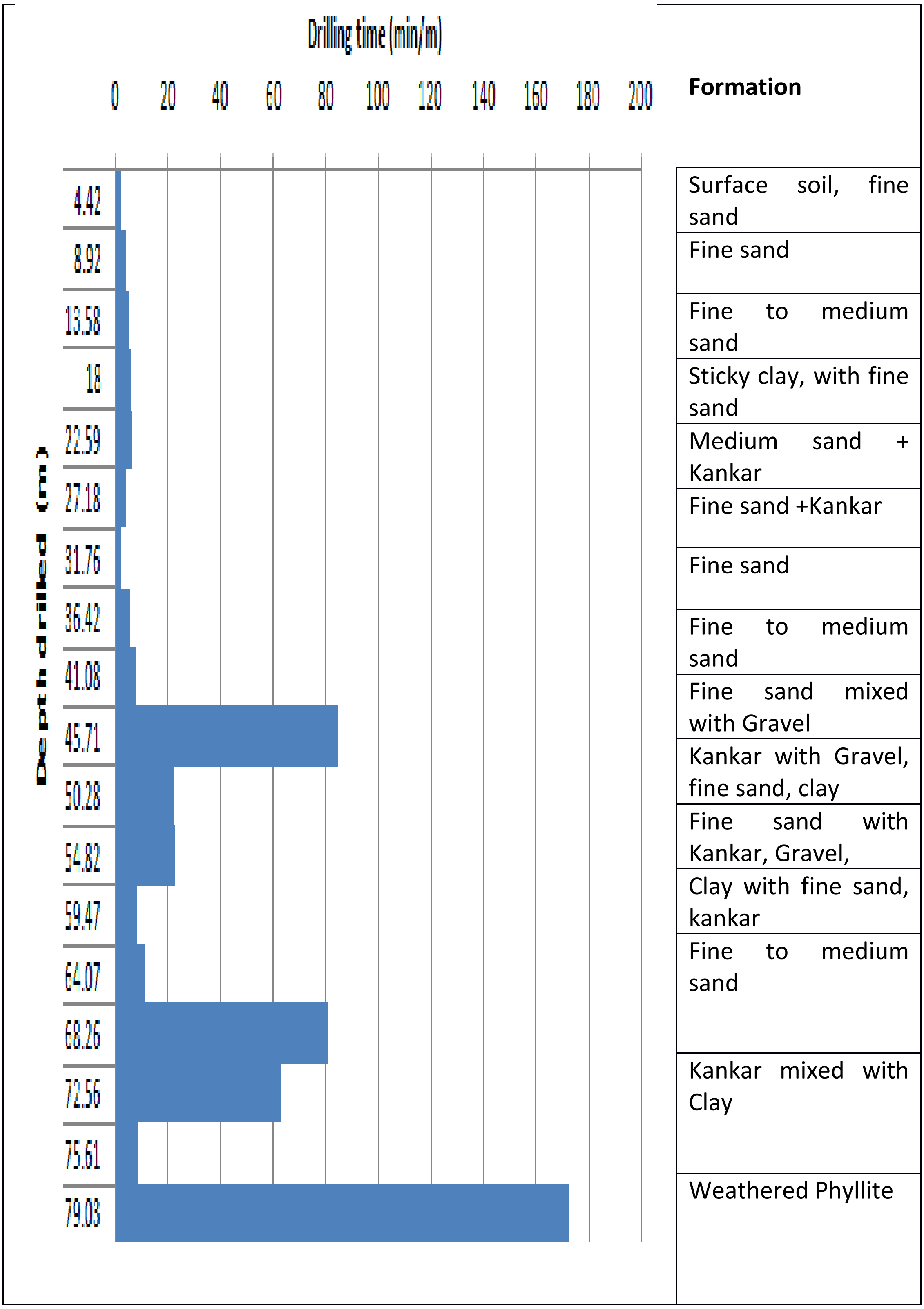


Figure 42. Drill time log of Lotwara-1 Exploratory Borewell, Baswa-Bandikui Watershed, Rajasthan

Location: Lotwara-1; Depth of logging: 67 mbgl; Date of logging: 09.06.13

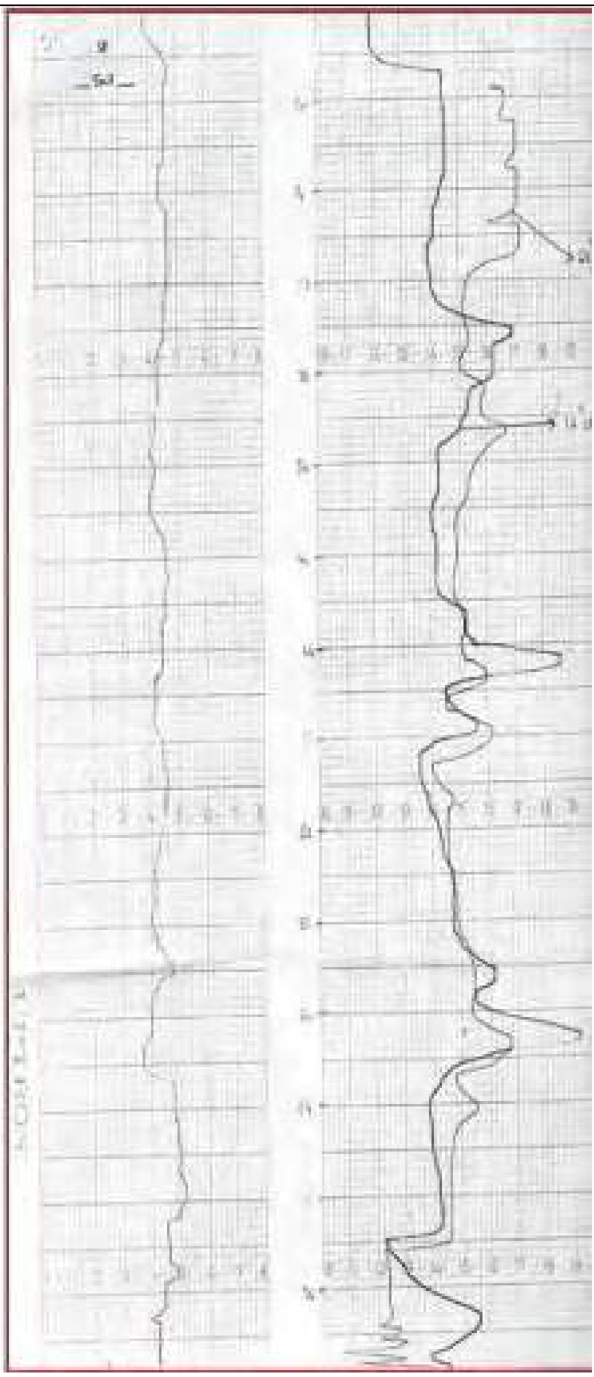
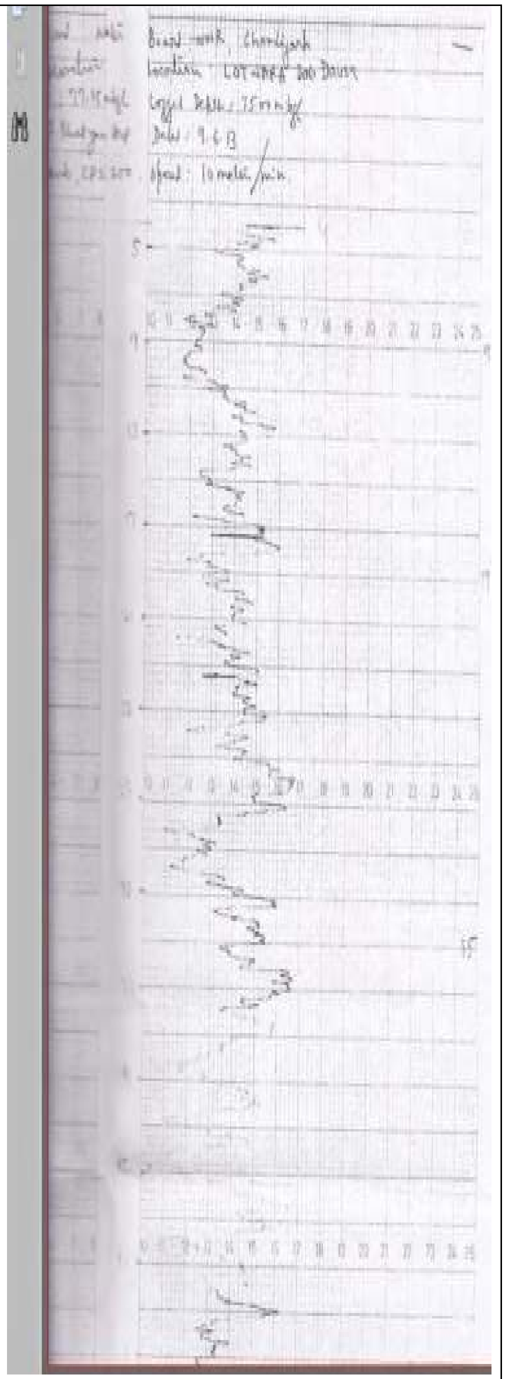
	
Electrical log: SP, Resistivity – Normal-Short 16”, Long 64”	Gamma Log

Figure 43. Geophyical log of Lotwara-1, Dausa district, Rajasthan

Once, well assembly is recommended, reaming of pilot hole is carried out for 349 mm diameter to accommodate well assembly of 203 mm diameter and pea gravel pack thickness of 76 mm. The well assembly consist of ERW casing pipe of 7.1 mm thickness conforming to IS-4270 (Plate 4). The length of the well screens varies from 6 to 12 m depending on the aquifer material. ERW slotted pipe of 203 mm diameter and 1/16" slot opening are installed at the recommended screen positions. The wells are shrouded with gravel pack with 3 to 5 mm size pea gravel.

The water wells are developed with the aim to remove mud cake and also finer material from the aquifer, thereby cleaning out, opening up and/ or enlarging passages in the formations so that water can enter the well more freely. All the wells are developed through air surging and pumping with the help of compressor. Air is injected with the help of air compressor such that aerated slugs of water are lifted irregularly out the top of the well casing. Well developments by air compressor were carried out in the exploratory wells in Baswa-Bandikui Watershed project area for a maximum duration of 10 hours. In some of the wells, developments through over-pumping were carried out after the well is developed by air compressor. Developments by pumps were carried out in 5 wells for 10 hours in each well.

A fence diagram showing sub-surface lithological disposition is presented in Figure 44.

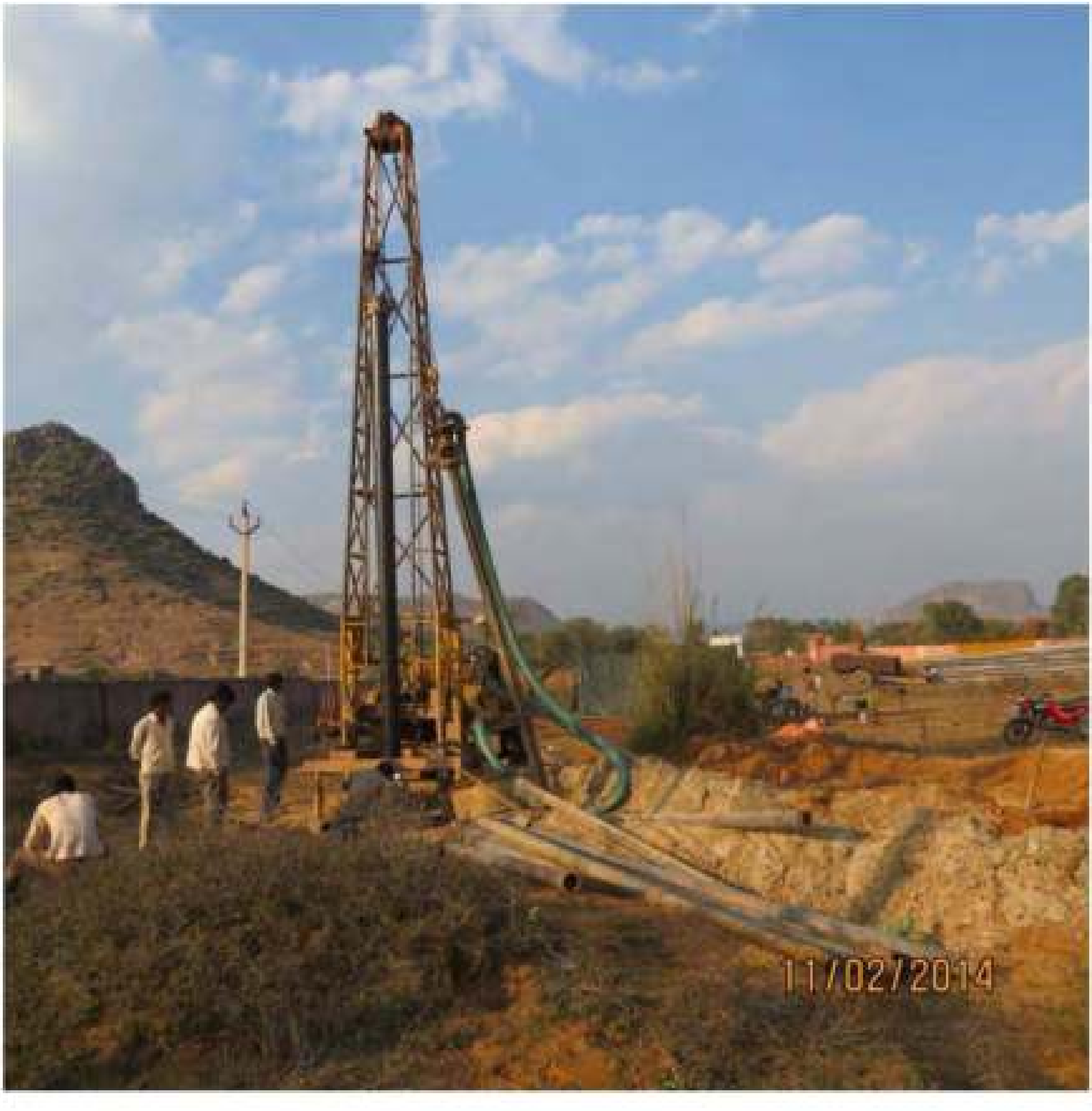


Plate 4. Exploratory drilling operation in Baswa-Bandikui Watershed project, Dausa district, Rajasthan

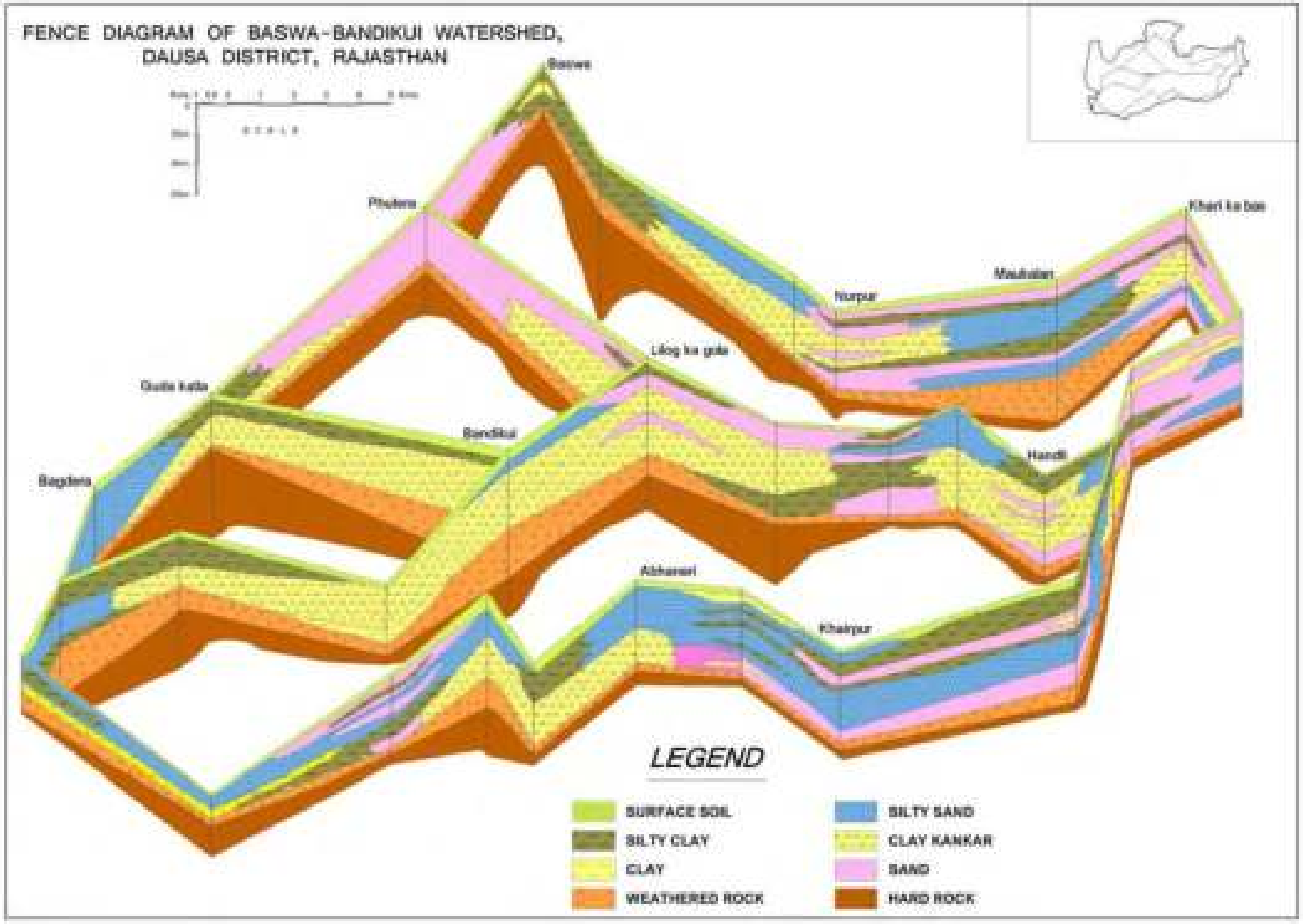


Figure 44. Fence diagram showing sub-surface lithological disposition in the project area

A perusal of the above Figure indicate that the thickness of alluvium is more towards the eastern part of the project area. Finer grained sediments including clay-kankar, silty clay are thicker in the central part of the project area.

3.7 WATER LEVEL

At the onset of the project, 38 monitoring wells including dugwells and piezometers are established for monthly water levels measurement. These include 21 monitoring stations of CGWB and State Government already existing in the project area and additional 17 dug wells/ tubewells owned by individuals. In addition to the above, another 15 wells were drilled in 2013-14 considering the data gap existing in the study area. The total number of monitoring wells in the Baswa-Bandikui Watershed project area are 53 Map showing locations of monitoring wells are given in Figure 45. The basic attributes of the monitoring wells are given in Table 21.

Monthly water level data of all the 53 monitoring wells of the area is given in the Annexure 2. It is observed that in the majority of cases, the maximum depth to water level was observed during June-July and minimum during September-October, thereby indicating that the recharge to ground water body starts after June and completes by September.

Based on monthly water level data, hydrographs of representative monitoring stations were prepared and are shown in Figure 46. A perusal of the hydrographs would indicate that even within the short span of just over two years, the monthly water level trend of most fo the wells shows declining trend.

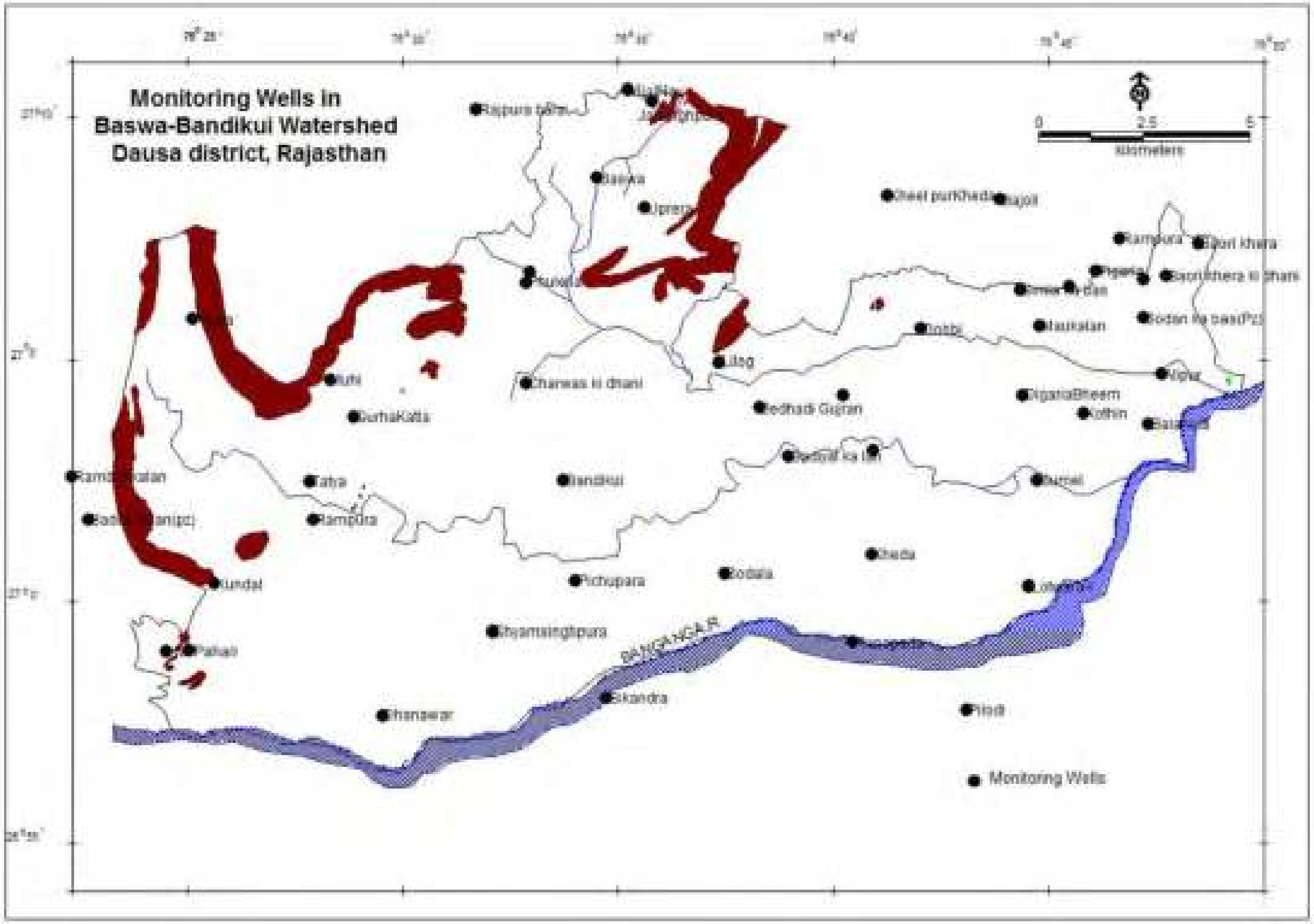


Figure 45 Monitoring wells in Baswa-Bandikui Watershed, Dausa District, Rajasthan

Table 21. Monitoring Wells established in the Baswa-Bandikui Watershed, Dausa district, Rajasthan

Sl. No.	Location	Lat.	Long.	Elevation	Block	District	Type	MP agl	Owner	Location
MW1	KaliPahari	76.41	26.98	309.31	Dausa	Dausa	Pz	0.93	CGWB	Near Powerhouse
MW2	Sikandra	76.58	27.83	283.4	Sikrai	Dausa	Pz	0.7	CGWB	Adjscent RSEB boundry
MW3	Balahedi	76.79	27.06	262.43	Bandikui	Dausa	Pz	0.64	GWD	In the premises of School.
MW4	Baswa	76.58	27.15	285.09	Bandikui	Dausa	Pz	0.45	GWD	In the premises of Tehsil Near bus stand&Temple
MW5	Phulella	76.54	27.11	281.85	Bandikui	Dausa	Dg	0.8	GWD	In the village near tiraha
MW6	Phulella	76.55	27.11	281.45	Bandikui	Dausa	Pz	1.13	GWD	Rhs.Bandikui-Baswa road
MW7	Jaisinghpura	76.6	27.17	294.28	Bandikui	Dausa	Dg	0.1	MoolChand	South of village.
MW8	VijaiNav	76.59	27.18	296.39	Rajgarh	Alwar	Dg	0.37	Study	Near Rly.line Kajod Meena.
MW9	Rampura	76.78	27.13	256.24	Reni	Alwar	Dg	0.51	GWD	SW of village.Roop narayan Sharma
MW10	Charwas ki dhani	76.55	27.08	281.45	Bandikui	Dausa	Dg	0.5	Study- Moolchand	LHS of road.Bandikui-Baswa 2km. From Bandikui
MW11	Kheel purKheda	76.69	27.14	273.03	Reni	Alwar	Dg	1	Study	Lhs. Of Tatheda-Sainthal road 1km.from village 3km
MW12	Muhi	76.47	27.08	293.51	Bandikui	Dausa	Dg	0.75	Study	E.of Gurha katla-Muhi road In the field ofChhitarMal
MW13	GurhaKatla	76.48	27.06	288.93	Bandikui	Dausa	Pz	0.97	GWD	In the premises of Sr.Sec.School
MW14	Rampura	76.47	27.03	288.48	Bandikui	Dausa	Pz	1.15	GWD	In Samshan bhoomi 500mtr.before village
MW15	Rajpura bara	76.53	27.17	301.12	Rajgarh	Alwar	Dg	1.2	Study	RHS.Nimla-Bigota road Near Hanuman temple
MW16	Surer	76.62	27.2	304.07	Rajgarh	Alwar	Dg	1.3	Study	LHS.Rajgarh-Surer road opp.junction.Kaniya-Bheru Meena
MW17	Tatya	76.46	27.04	279.18	Bandikui	Dausa	Dg	0.85	Study	W. of Gurha katla-Bhanwta rd.Near Pipal tree&Tempal
MW18	Rambaskalan	76.37	27.04	320.07	Dausa	Dausa	Dg	1	Study- Laxman meena	RHS. Of Kundal-Santhal roadNear two big pippal tree.
MW19	Kundal	76.43	27.01	297.17	Bandikui	Dausa	Pz	1.15	GWD	In front of vetenery hospital.In open ground.
MW20	Dhanawar	76.49	26.97	286.155	Bandikui	Dausa	Dg	0.25	Study	W.of Dhanawar-Dhigariya rd.Ram sukh meena.
MW21	Tigaria	76.77	27.11	254.65	Bandikui	Dausa	Pz	0.72	CGWB	Near village pond& primarySchool.
MW22	Jaisinghpura (east)	76.76	27.11	256.81	Bandikui	Dausa	Dg	1.2	Study	S. of village to Simla ka basroad. Saumtya patel.
MW23	Simla ka bas	76.74	27.11	255.15	Bandikui	Dausa	Dg	1	Study	1km.South of village
MW24	Baori khera	76.81	27.12	254.5	Bandikui	Dausa	Dg	0.27	Study	E. of village road.Near primarySchool. (Jhiri ki jhopdi)
MW25	Baori khera ki dhani	76.8	27.11	254.76	Bandikui	Dausa	Dg	0.6	Study	N.of Dagawadi-Rampura rd.Kaluram Meena.
MW26	Bandikui	76.56	27.04	281.99	Bandikui	Dausa	Pz	1	Study	In the premises of IrrigationRest house.
MW27	Lilog	76.62	27.08	253.43	Bandikui	Dausa	Pz	1.1	G W D	Near school boundary.RHS of Bandikui to Biwai road.
MW28	Badiyal ka lan	76.65	27.05	271.28	Bandikui	Dausa	Pz	1	G W D	In the campas of Govt.Sec.school. LHS of road toLotwara
MW29	Bhandarej	76.42	26.88	294.23	Dausa	Dausa	Pz	1.39	GWD	IN front of Govt.Hospital.LHSof link road NH-11 to village.
MW30	Bedhadi Gujran	76.64	27.07	270.25	Bandikui	Dausa	Pz	0.85	CGWB	In the campas of Govt primaryschool.50mtr before village.
MW31	DigariaBheem	76.74	27.07	251.6	Bandikui	Dausa	Pz	1.12	CGWB	LHS of road Bandikui-Mandawar_-Front of school.
MW32	Pilodi	76.72	26.96	258.21		Dausa	Pz	1.3	GWD	Lhs.Sikandra-Manpur road.front ofGovt.middle school.

Sl. No.	Location	Lat.	Long.	Elevation	Block	District	Type	MP agl	Owner	Location
MW33	Dobbi	76.7	27.09	252.52	Bandikui	Dausa	Dg	0.85	Study	On the N.bank of Palasan river.
MW34	Badoli kalan(pz)	76.38	27.03	317.035	Bandikui	Dausa	Pz	1.06	GWD	outside the primary school on kolwa-senthal rd
MW35	Sodan ka bas(Pz)	76.79	27.1	250.07	Bandikui	Dausa	Pz	0.7	CGWB	in campus of primary school,on hingota-khari ki jhopdi rd
MW36	Pichupara	76.57	27.01	271.07	Bandikui	Dausa	Pz	1.1	Gwd	LHS of road to Bandikui
MW37	Redia	76.42	27.1	306.685	Bandikui	Dausa	Pz	1.11	Gwd	Village on gudhakatla-redia dam,well at trijunction
MW38	Lotwara-I	76.74	27.01	259.32	Bandikui	Dausa	EW	1	CGWB	In the premises of Government Hospital
MW39	Ranapada	76.67	26.99	267.53	Bandikui	Dausa	EW	1	CGWB	At the entrance of village near river bed, behind temple
MW40	Kheda	76.68	27.02	263.07	Bandikui	Dausa	EW	1	CGWB	In the premises of Government School.
MW41	Ralota	76.68	27.05	266.735	Bandikui	Dausa	EW	1	CGWB	Near Temple of the village
MW42	Nurpur	76.67	27.07	267.585	Bandikui	Dausa	EW	1	CGWB	In the premises of Government School
MW43	Kothin	76.76	27.07	255.365	Bandikui	Dausa	EW	1	CGWB	In front of govt primary school on govt land
MW44	Alipur	76.79	27.08	248.68	Bandikui	Dausa	EW	1	CGWB	In the campus of govt primary school
MW45	Sodala	76.62	27.01	267.63	Bandikui	Dausa	EW	1	CGWB	In the campus of Govt Middle School
MW46	Sumel	76.75	27.04	253.045	Bandikui	Dausa	EW	1	CGWB	In the campus of Govt Primary School
MW47	Shyamsinghpura	76.53	26.99	284.875	Bandikui	Dausa	EW	1	CGWB	In the campus of Govt Middle School
MW48	Maukalan	76.75	27.09	255.625	Bandikui	Dausa	EW	1	CGWB	In the premises of Primary School
MW49	Khari ki jhopdi	76.79	27.11	250.175	Bandikui	Dausa	EW	1	CGWB	In the premises of Primary School
MW50	Lotwara-II	76.74	27.01	259.32	Bandikui	Dausa	EW	1	CGWB	In the premises of Upper Primary girls School
MW51	Bajoli	76.73	27.14	256.14	Reni	Alwar	EW	1	CGWB	Near Temple of the village
MW52	Bhedoli	76.42	26.98	306.00	Dausa	Dausa	EW	1	CGWB	In the campus of govt middle school
MW53	Uprera	76.59	27.13	286.30	Bandikui	Dausa	Pz	1.1	GWD	Road side

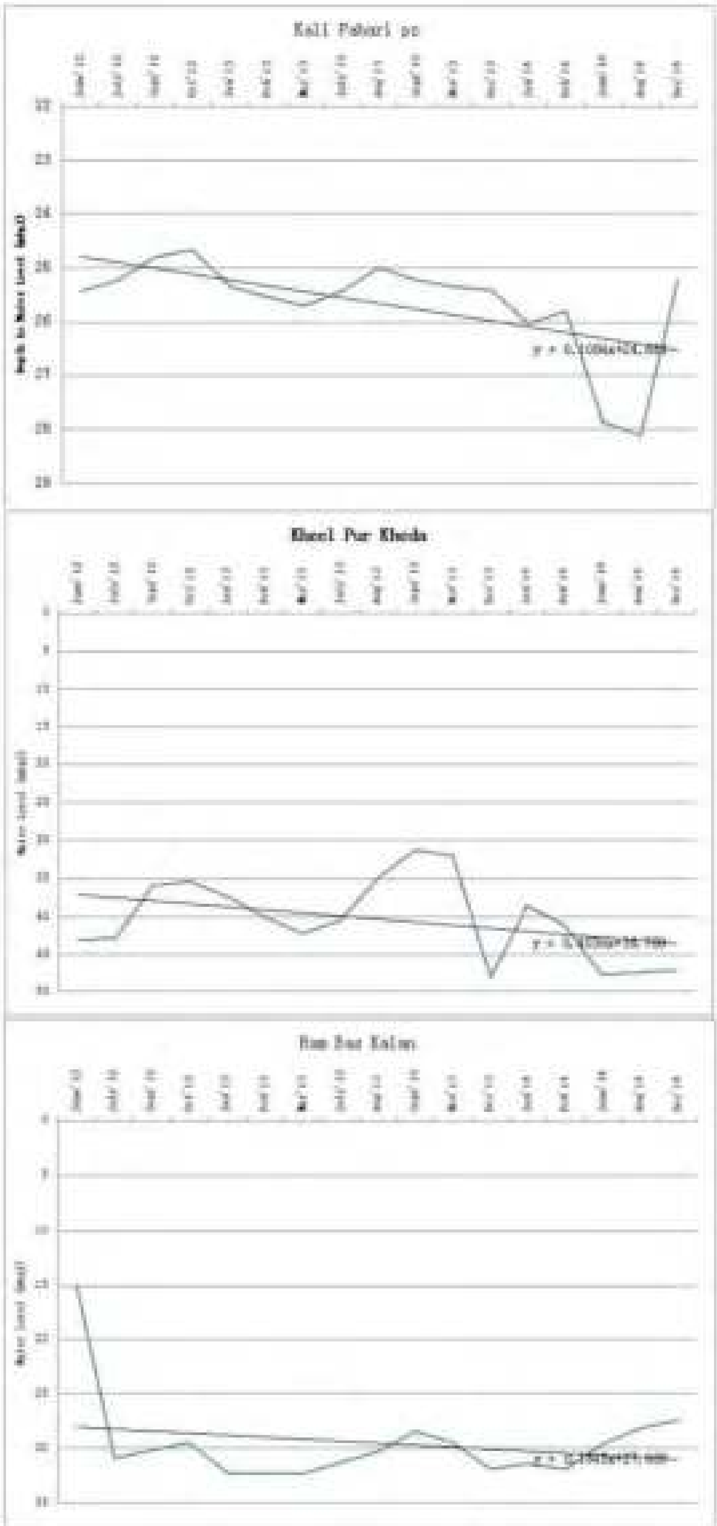


Figure 46. Hydrographs showing monthly water level of representative monitoring stations in Baswa-Bandikui Watershed, Dausa district, Rajasthan

A description of the pre-monsoon and post-monsoon water level scenario of the project area during the study period is given in the following paragraphs.

Pre-monsoon 2012

In the month of June 2012 the depth to water level in the area varies from 11.52 m b.g.l at Rajpura village in the north to 49.86 m b.g.l at Pichupura village in the south. The depth to water level map of the watershed was prepared based on the water level measurements taken in the period 15th to 20th of the month. The thematic water level map for the month (Figure 47) shows that in the higher reaches of the watershed, the depth to water level is mainly controlled by location of the well with respect to topography. In general, the depth to water level is deepest in the Central part of the area and gradually decreases towards East and West.

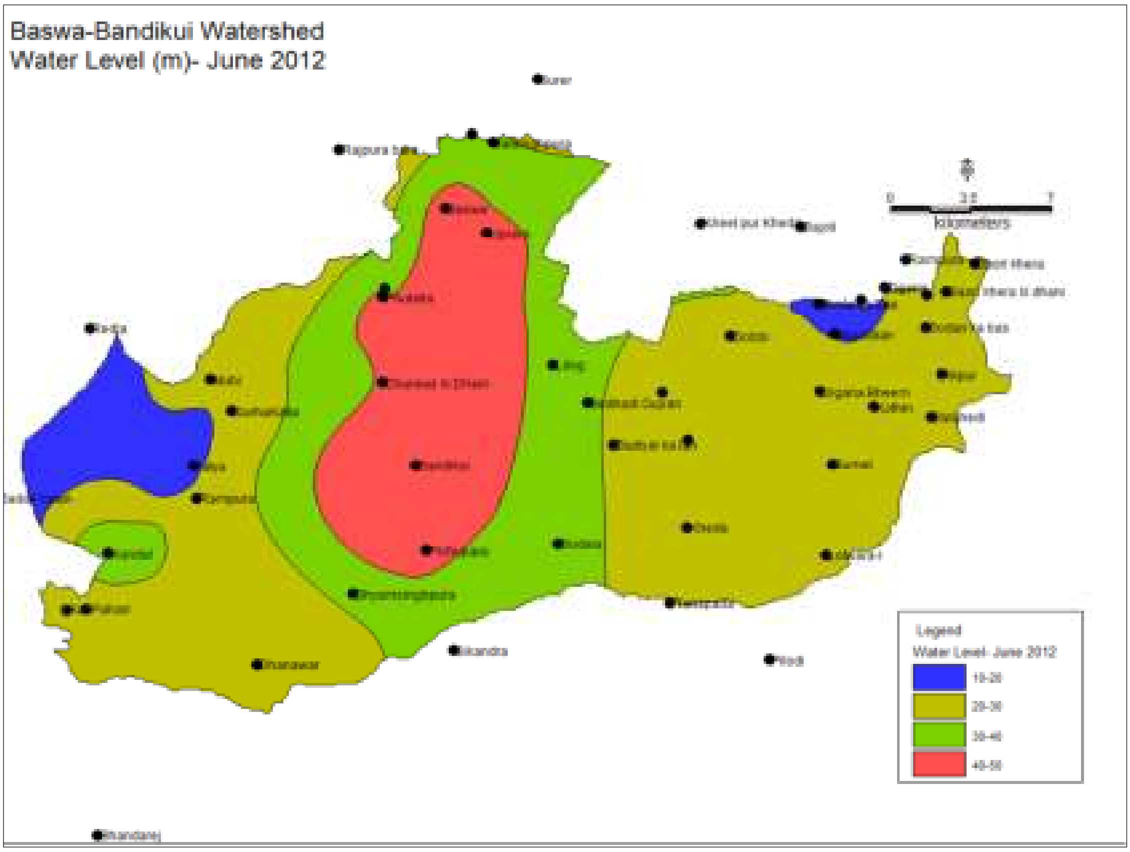


Figure 47. Depth to water level map of June, 2012, Baswa-Bandikui Watershed, Dausa district, Rajasthan

Post-monsoon, 2012

In the month of October 2012, the depth to water level in the area varies from 6.56 m bgl at Rajpura village to 51.20 m bgl at Pichupura village. The depth to water level is within 10 m in the north-eastern part of the project area (Figure 48). The north-eastern tip of the study area is marked with foot hill zone. Deepest water level is observed in the central portion around Bandikui where water level was 48.42 m bgl and in the western part around Digiria Bheem where water level was 48.56 m bgl.

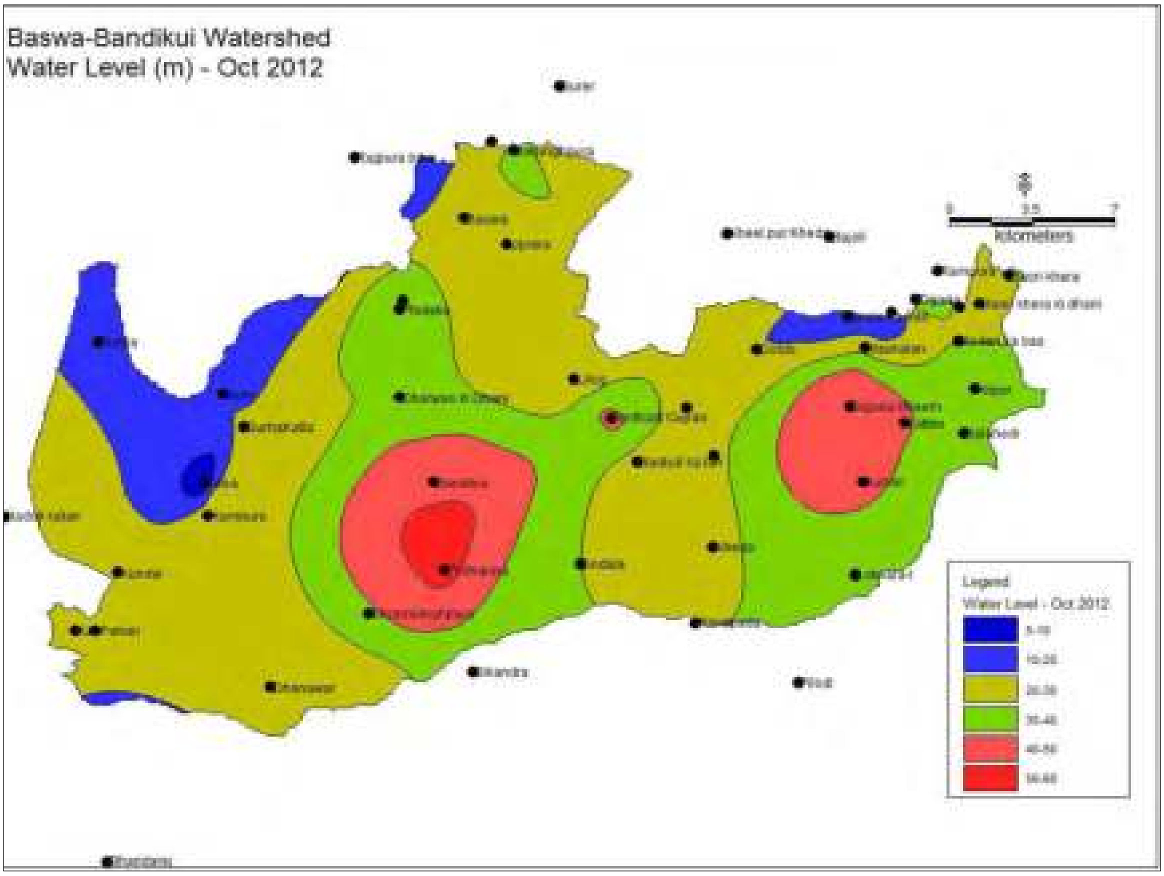


Figure 48. Depth to water level map of October, 2012, Baswa-Bandikui Watershed, Dausa district, Rajasthan

Pre-monsoon, 2013

In the month of May 2013, the depth to water level in the area varies from 8.01 m bgl at Bhandaraj village to 51.9 m bgl at Pichupura village. The depth to water level in the higher reaches particularly is very erratic and, therefore, no definite zone could be demarcated. In the central part of the area, the depth to water level is deepest (Figure 49). Ground water depression developed around Bandikui, which recorded 49.26 m bgl water level. Similar deep water level zone is also observed in the west central part of the study area around Digiria Bheem, where water level was 50.91 m bgl.

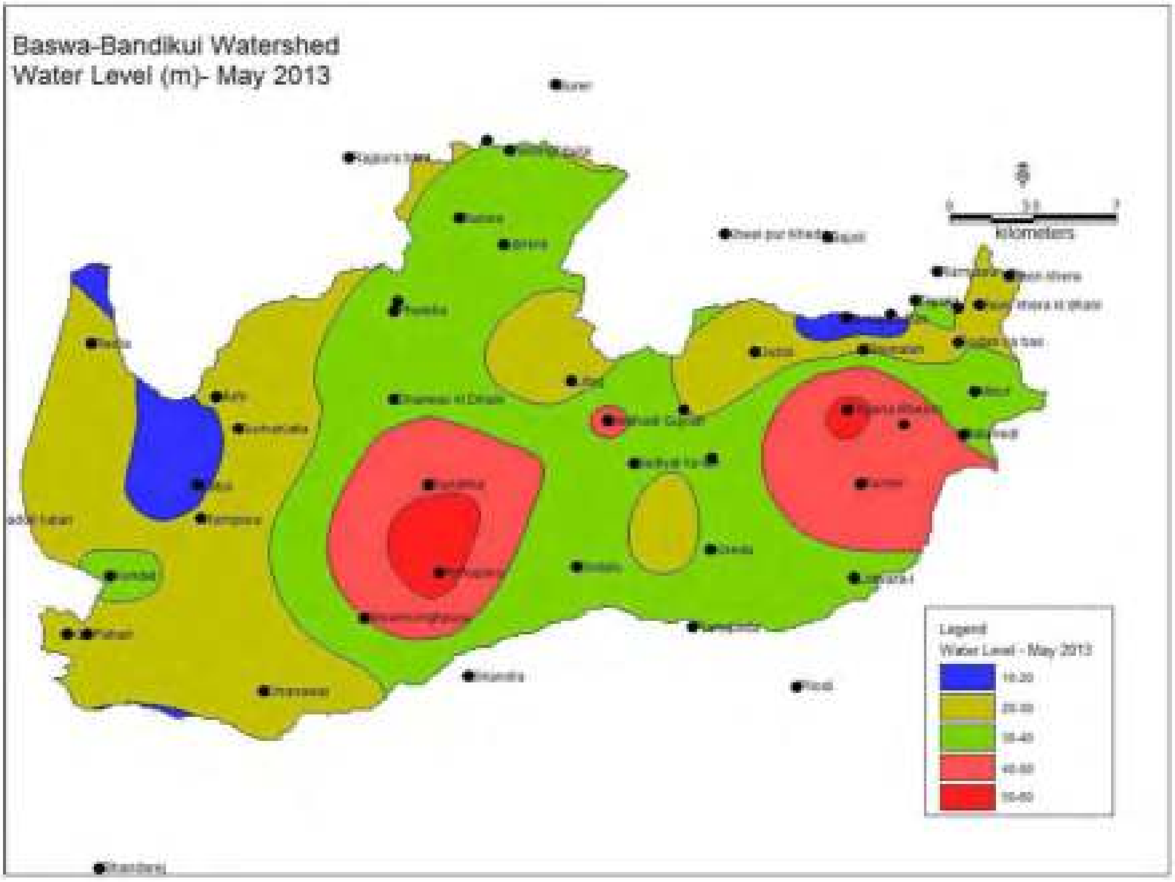


Figure 49. Depth to water level map of May, 2013, Baswa-Bandikui Watershed, Dausa district, Rajasthan

Post-monsoon, 2013

In the month of November 2013, the depth to water level in the area varies from 7.67 m b.g.l at Tatya village to 50.97 m b.g.l at Pichupura village. In the central part of the area, the depth to water level is highest generally more than 30 to 51 meters but around western and northern part of the area in Rampura, Tatiya, Redia, Surer and Muhi villages, the depth to water level is around 10 to 35 meter (Figure 50). In eastern part of the area, the depth to water level ranges from 10 to 30 meters in Alipur, Dhigaria Bheem and Kothin villages.

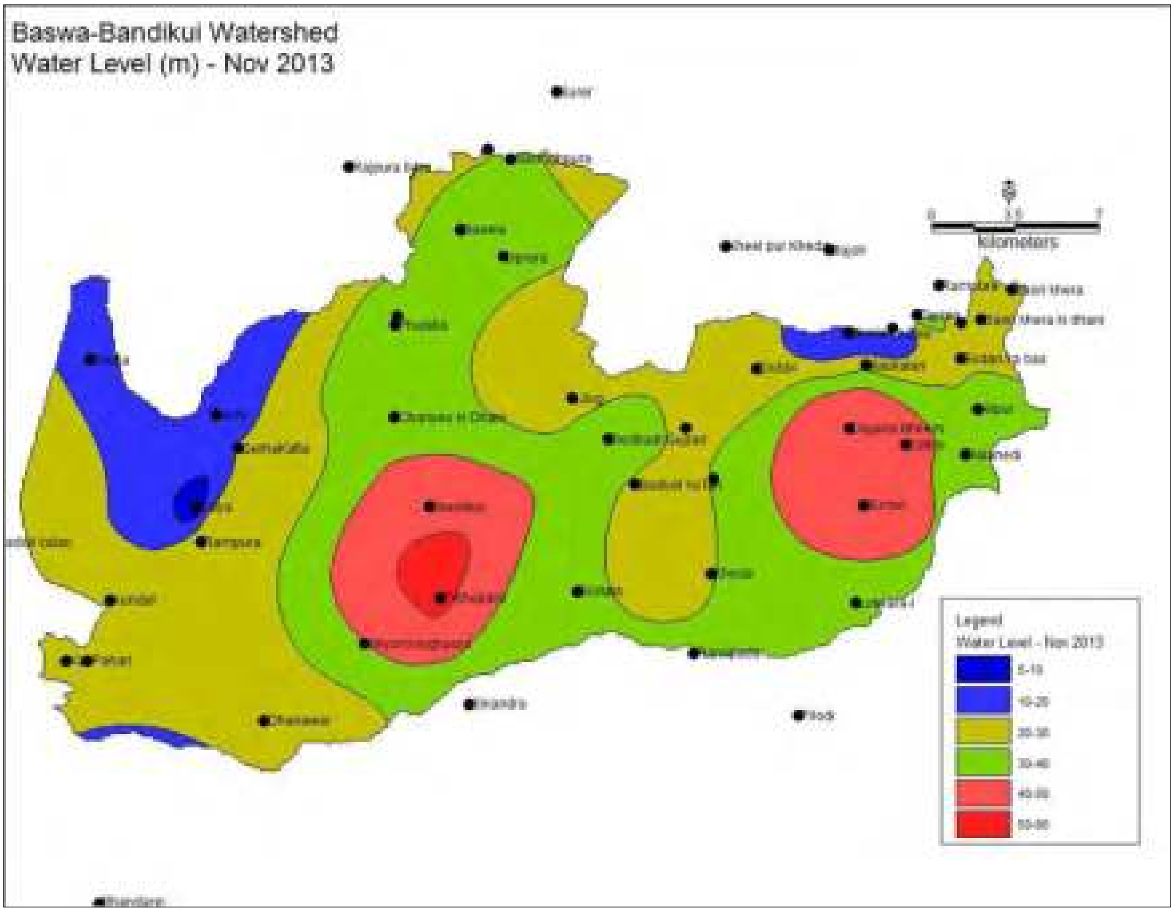


Figure 50. Depth to water level map of November, 2013, Baswa-Bandikui Watershed, Dausa district, Rajasthan

Pre-monsoon, 2014

In the month of May 2014, the depth to water level in the area varies from 9.81 m bgl at Bhandarej village to 55.07 m bgl at Ralota village. The major part of the project area has water level between 40 to 60 m bgl (Figure 51). The establishment of additional monitoring stations over the time period brought out a detailed picture of the ground water level in the area.

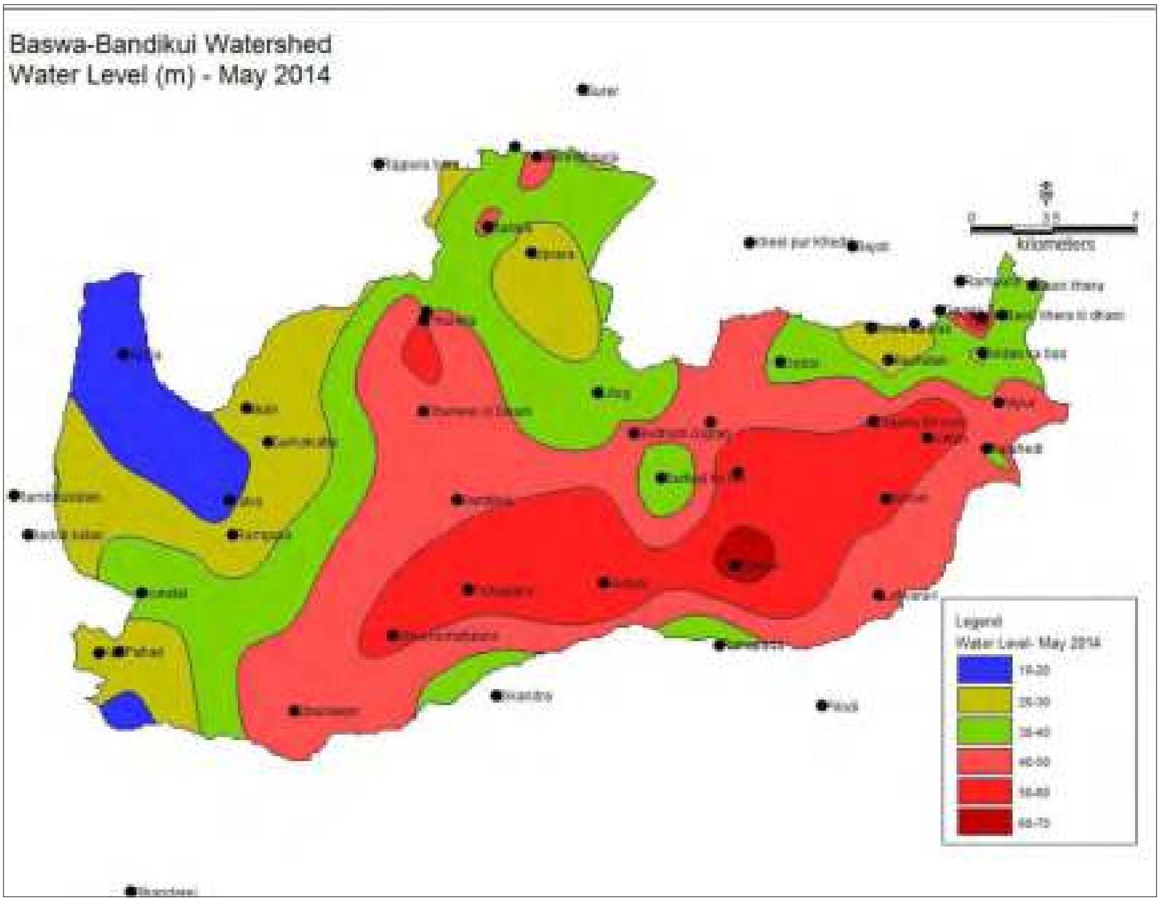


Figure 51. Depth to water level map of May, 2014, Baswa-Bandikui Watershed, Dausa district, Rajasthan

Post-monsoon, 2014

In the major part of the project area, the depth to water level ranges from 30 mbgl to 50 mbgl (figure 52). The water level in the western part of the project area is shallower, in the range of 10 mbgl to 30 mbgl as compared to the eastern part where it ranges from 30 mbgl to more than 50mbgl. The shallowest water level of 10mbgl to 20mbgl have been recorded in the downstream of Redia dam in the vicinity of Redia, Tatia and also in a small pocket around Simla ka Bas. The deepest water level of more than 50mbgl have been recorded in small pockets around Pichupara, Sumel and Dhigaria Bheem.

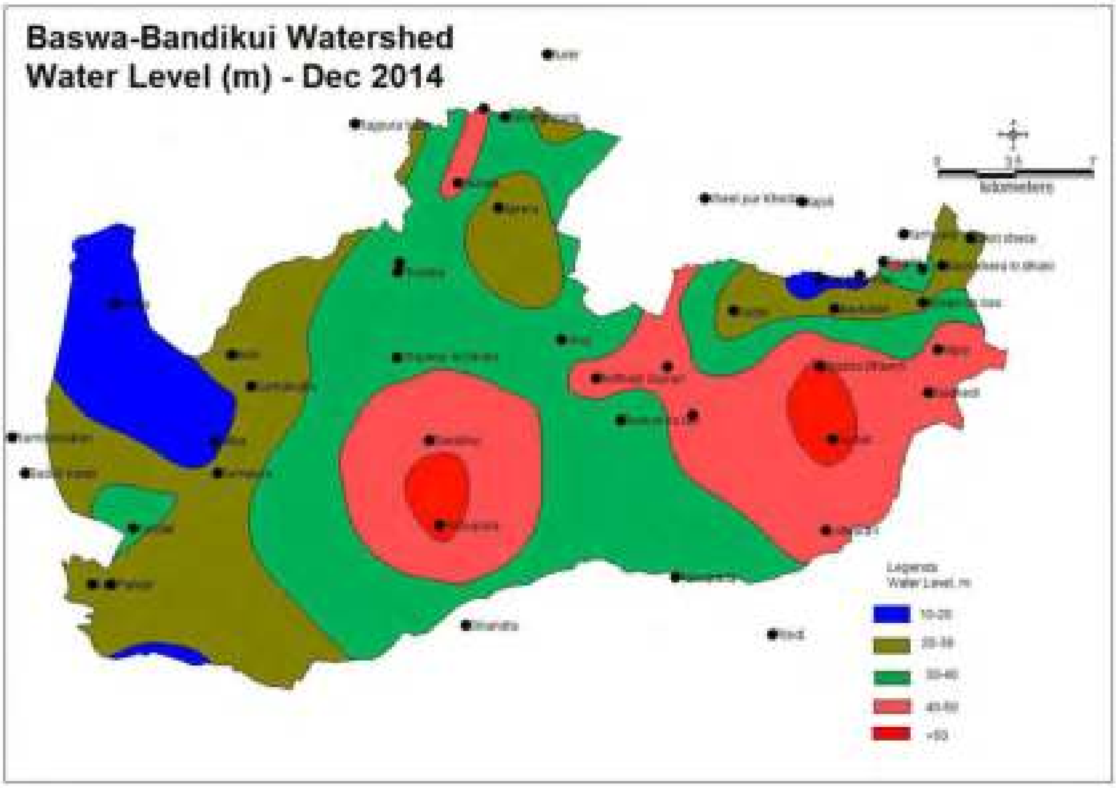


Figure 52. Depth to water level map of December, 2014, Baswa-Bandikui Watershed, Dausa district, Rajasthan

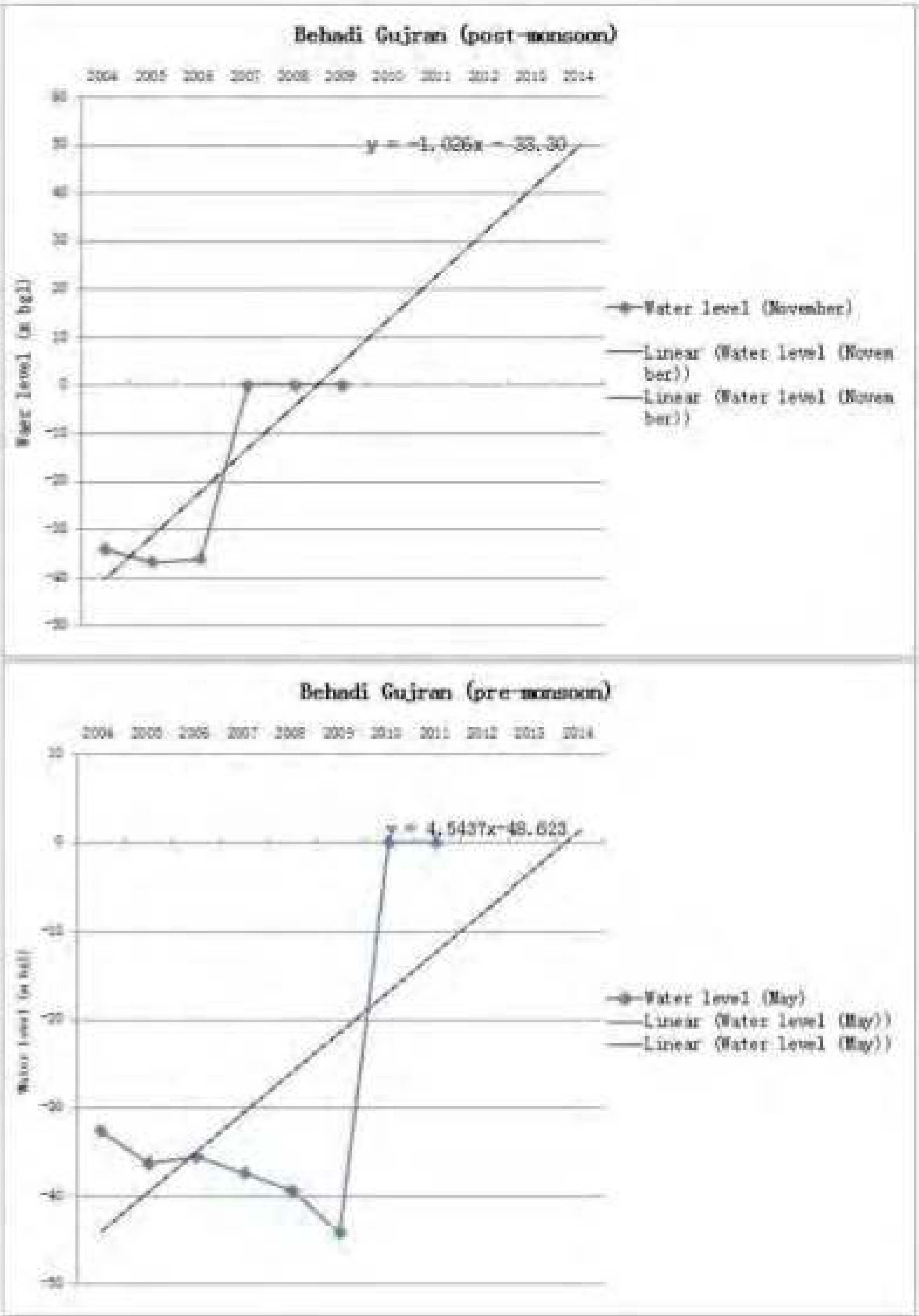
Long term ground water level trend

The long-term water level trend was computed for two national hydrograph monitoring stations of CGWB existing within the project area. These are Baswa, in northern part of the study area and Behadi Gujran station in the central part of the area. The water level data of Baswa is available from 2005 to 2014 and that of Behadi Gujran, from 2004 to 2014 with some intermittent data gap in the time series. The water level trend analysis as given in figure 53 and table 22 indicate a mixed trend. The water level is declining in Behadi Gujran by the rate of more than 1 metre per year, while in Baswa, slight rising trend of 0.03 to 0.13 metre per year have been registered.

Table 22. Long term water level trend of National Hydrograph Monitoring Stations, CGWB

Sl. No.	Location	Longitude	Latitude	Data Availability	Pre-monsoon Trend (m/yr.)	Post-monsoon Trend (m/yr.)
1	Baswa	76.58	27.15	2005-2014	0.13	0.03
2	Behadi Gujran	76.64	27.07	2004-2014	(-) 1.02	(-) 1.03

The Hydrographs of the Long-term water level trend stations are shown in Figure 52 below.



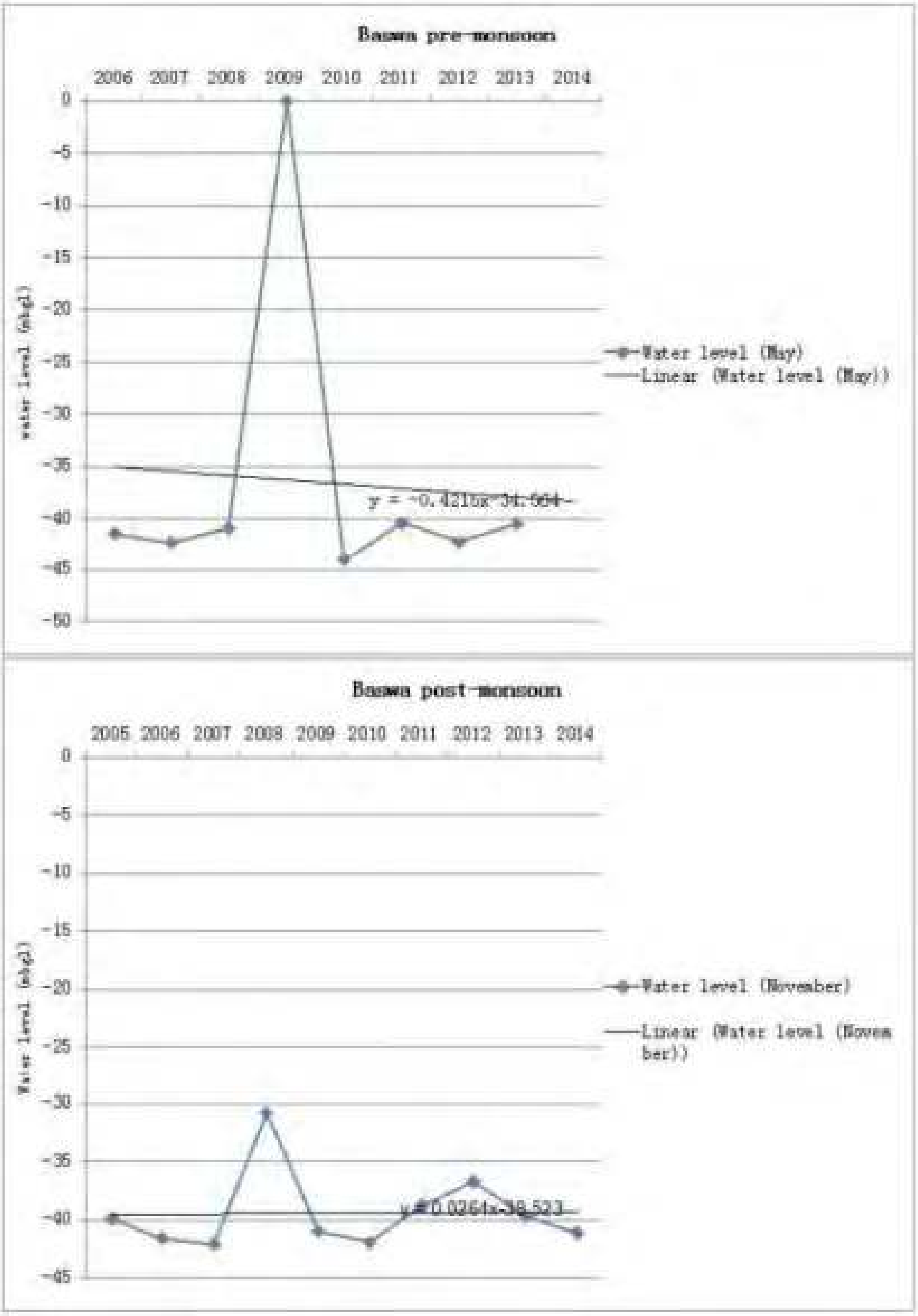
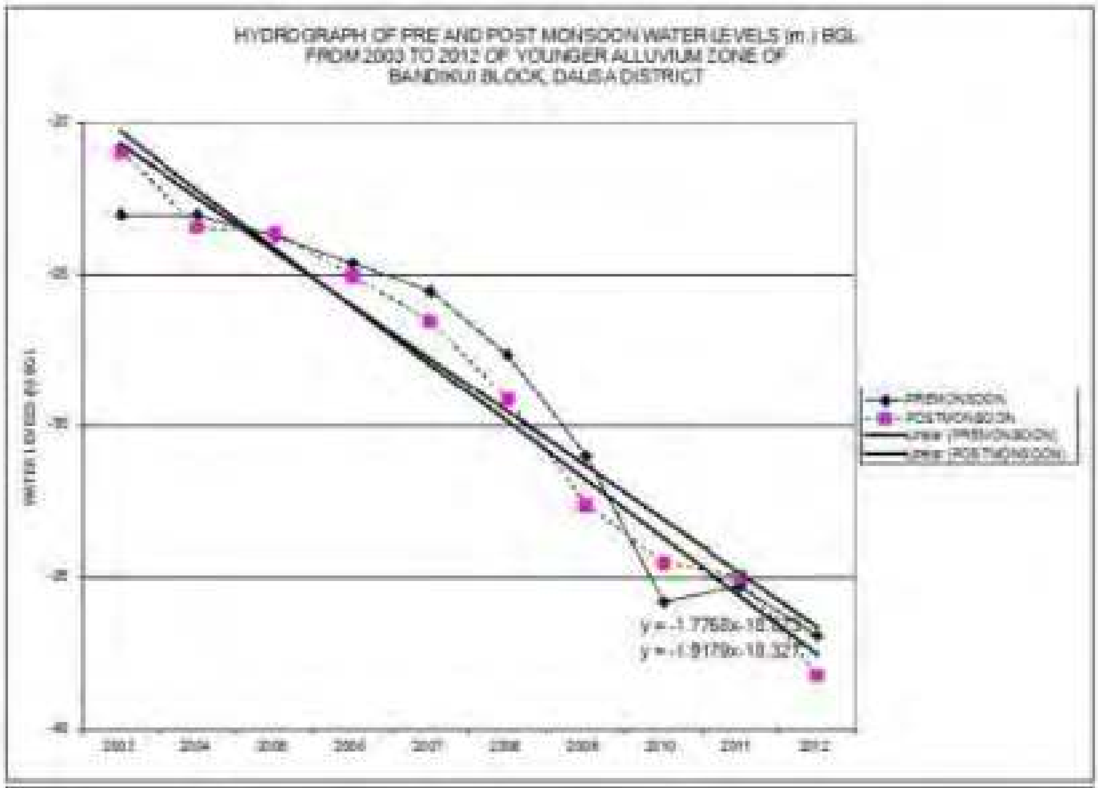


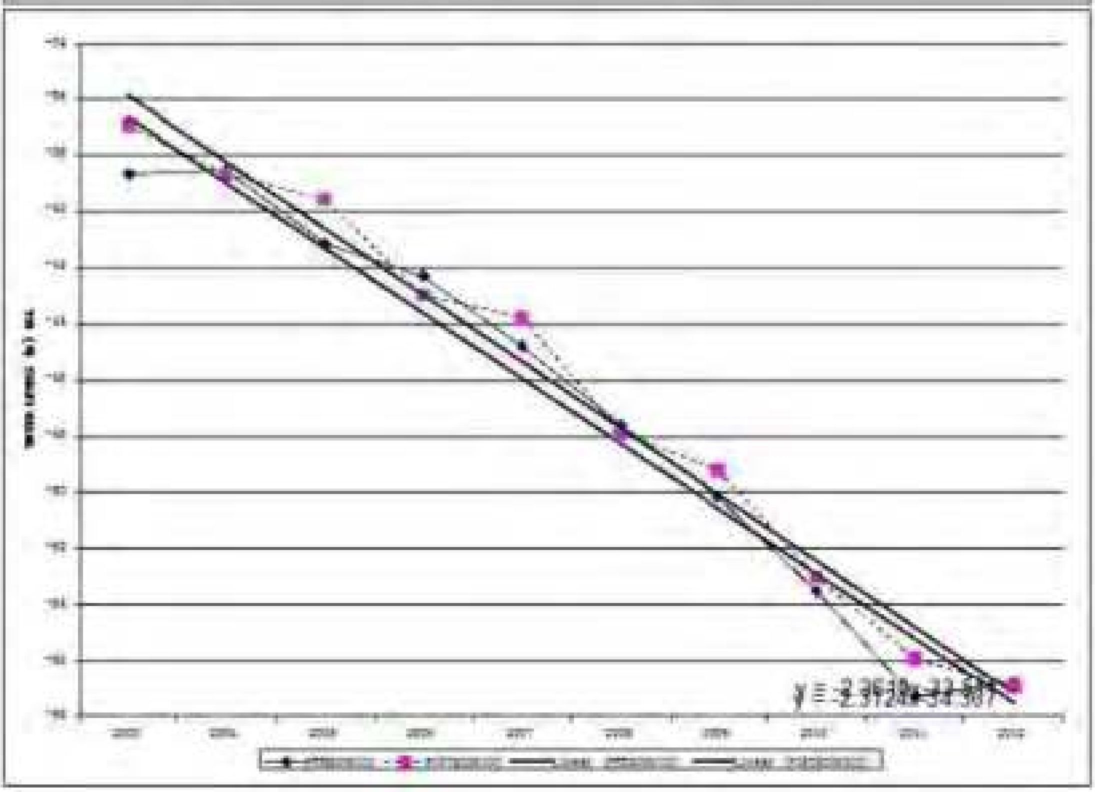
Figure 53. Time series data of the National Hydrograph Stations of CGWB in Baswa-Bandikui Watershed, Dausa district, Rajasthan

The average water level trends of the different ground water potential zones as computed in the ground water resources assessment, 2013 jointly assessed by State Ground Water Department and CGWB is given in Table 23 and Figure 54. A perusal of the data clearly indicates that the water level in the region is declining at an alarming rate.

Table 23 Average long term water level trend computed in Ground water resources assessment, 2013

Sl. No.	**Ground Water Potential Zone**	**Pre-monsoon trend (m/year)**	**Post-monsoon trend (m/year)**
1	Younger Alluvium	-1.78	-1.92
2	Older Alluvium	-2.31	-2.36
3	Quartzite	-0.16	-0.19
4	Gneiss	-0.47	-0.32


HYDROGRAPH OF PRE AND POST MONSOON WATER LEVELS (m.) BGL
FROM 2003 TO 2012 OF YOUNGER ALLUVIUM ZONE OF
BANDIKUI BLOCK, DAUSA DISTRICT
PREMONSOON
POSTMONSOON
Linear (PREMONSOON)
Linear (POSTMONSOON)
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012



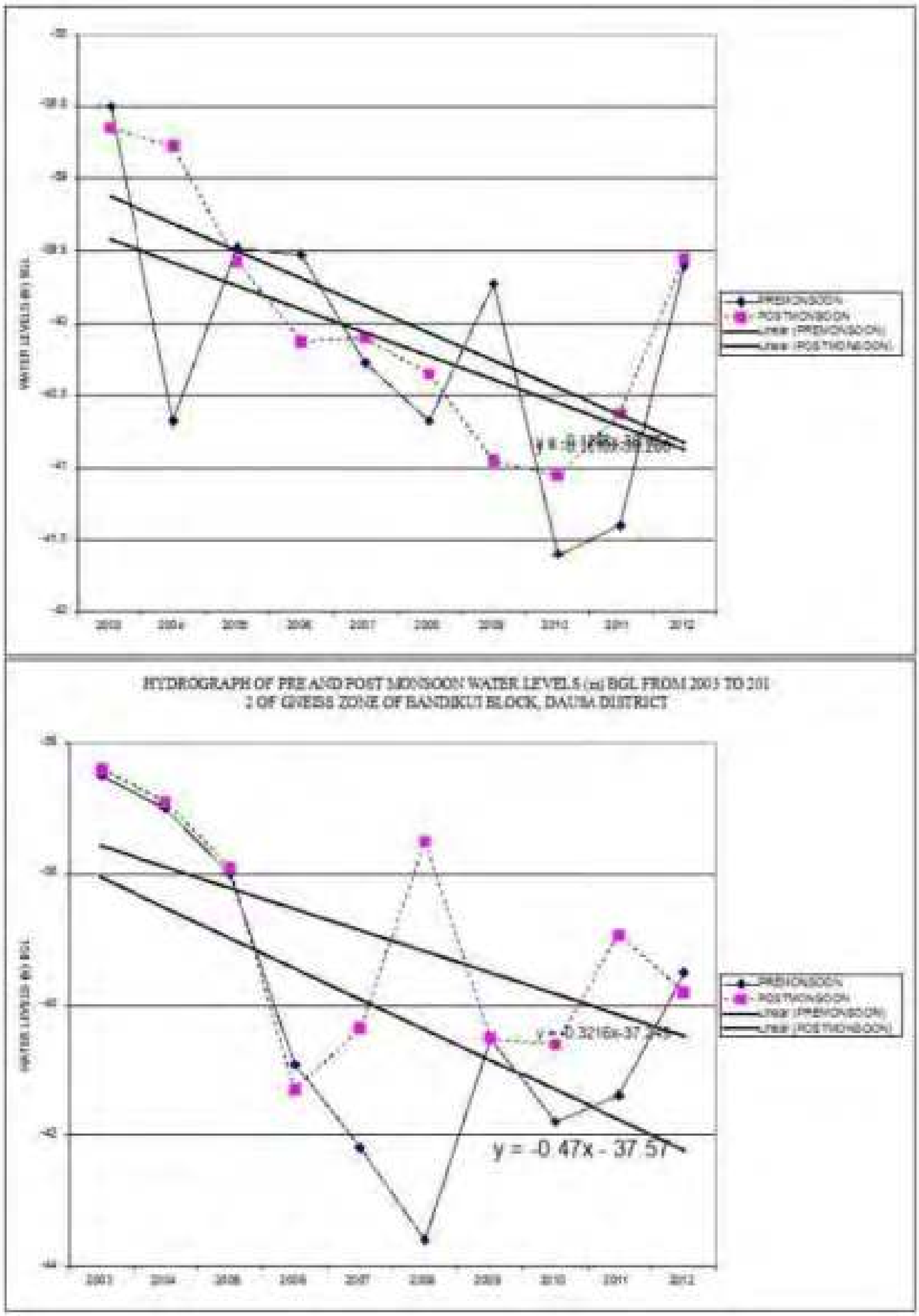


Figure. 54. Hydrographs showing average long term trend of water level of the Ground Water Potential Zones of Bandikui block

3.8 WATER QUALITY

The basic chemical parameters were determined for evaluating the groundwater quality of Baswa-Bandikui watershed are pH, EC, TDS, CO_3, HCO_3, Cl, NO_3, $S0_4$, PO_4, F, Ca, Mg, TH, Alkalinity, Na, K, and Fe. These elements are determined using instruments such as pH meter, EC Meter, Flame Photometer, UV/Visible spectrophotometer and titrimetric methods. Water samples are collected from both dug wells and tubewells. The chemical analysis results are given in Annexure-3. The water quality distribution maps are prepared and described separately for dug wells as well as tubewells. From the analytical results it has been observed that the area suffers from fluoride, sodium hazards & salinity problems in patches. The major quality findings are described as under.

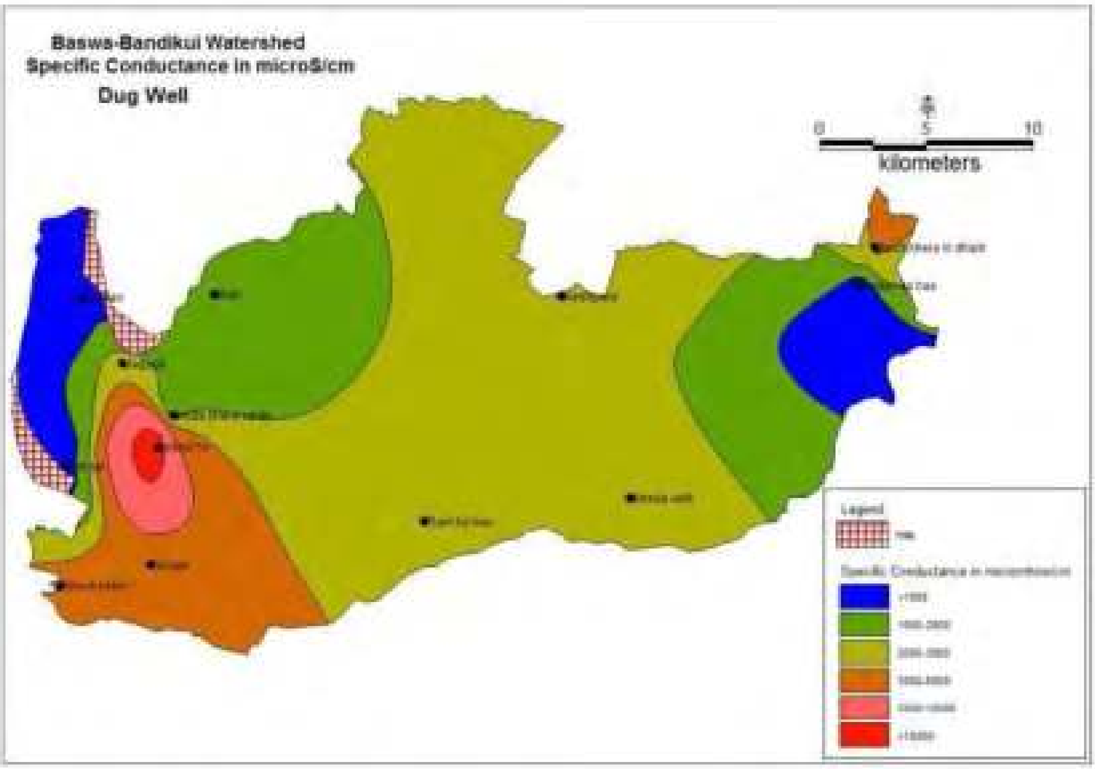
1. Electrical conductivity

Electrical conductivity or total dissolved solids or salinity is the saltiness or dissolved salt contents of a body. Electrical conductivity represents total number of cations and anions present in ground water indicating ionic mobility of different ions, total dissolved solids and saline nature of water. Salinity can be caused due to the intrinsic property of the aquifer. Over exploitation of fresh ground water, lack of recharge, average rainfall and strong evaporation in area with shallow water tables may also lead to salinization.

Ground water is generally classified into fresh water, Brackish water and Saline water. In Banganga basin the potability of groundwater was considered upto 3000µS/cm.

The Water samples collected from different dug well locations analyzed and found that the electrical conductivity of ground water of Baswa-Bandikui watershed area varies from 680 µS/cm -3840 µS/cm. It is observed that most of central and Northwestern part of the area experienced EC within 680-1710 µS/cm, which can be categoried under fresh water category having potable ground water. Rest of the area shows EC value more than 1500 µS/cm indicating the gravity of salinity problem. Villages having high specific conductance are mostly located in the South-western part of the study area. These include Nimali (3840 µS/cm), Khora kalan (3310µS/cm) and one well in northeastern part Baori khera ki dhani (3050 µS/cm). The map showing the distribution of specific conductance in area is shown in Figure 55.

The electrical conductivity of tubewell samples varies from 580 µS/cm to 6480 µS/cm. Most of the area except Northeastern part of the area experienced EC within 1500 µS/cm, these include Kali Pahari (580µS/cm), Baroli (650µS/cm), Ranapada (760µS/cm), Kolana (1250µS/cm) and Phullela (1310µS/cm) which can be categories under fresh water category having potable ground water. Villages having high specific conductance are mostly located in the northeastern part of the study area. These include Biwai (3180 µS/cm), Maukalan (3010µS/cm), Uprera (3550µS/cm), Khari ki Jhopdi (5400µS/cm) and Tigaria (6480µS/cm). One well in Bhawta, in the south eastern part of the watershed, is having more than 10000 µS/cm. However this appears to be an outlier and hence not considered in the final aquifer characterization map. The spatial extent of the salinity in the area is given in Table 24.



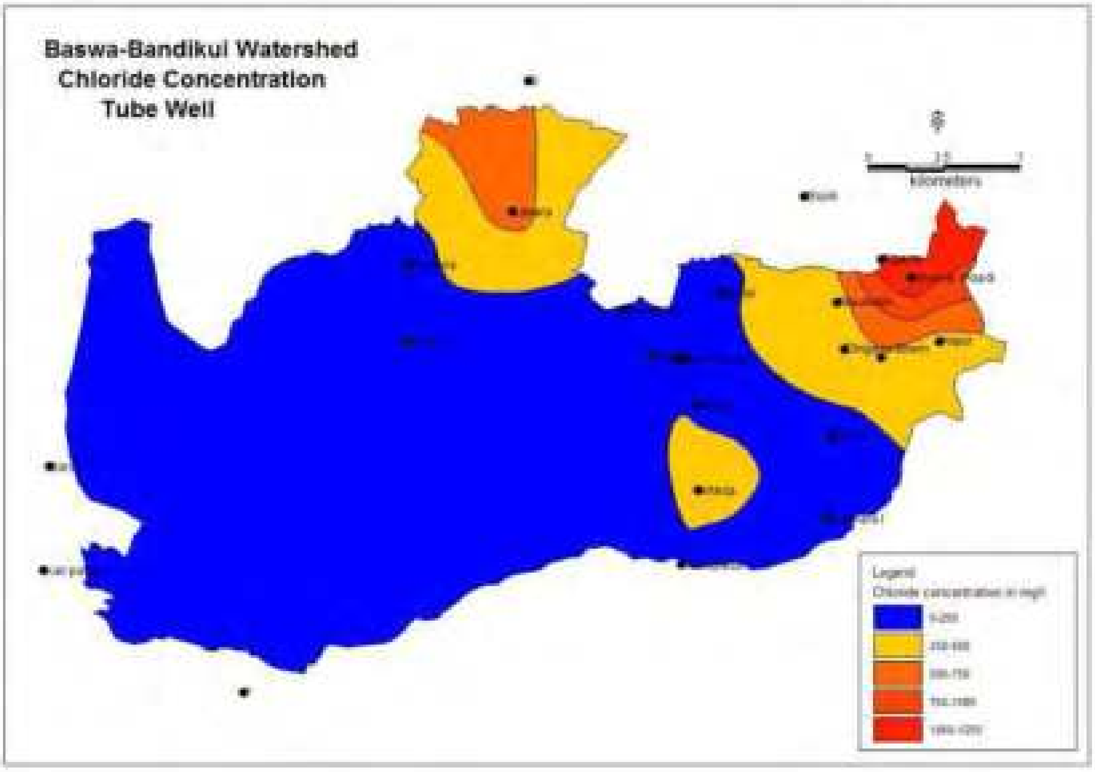


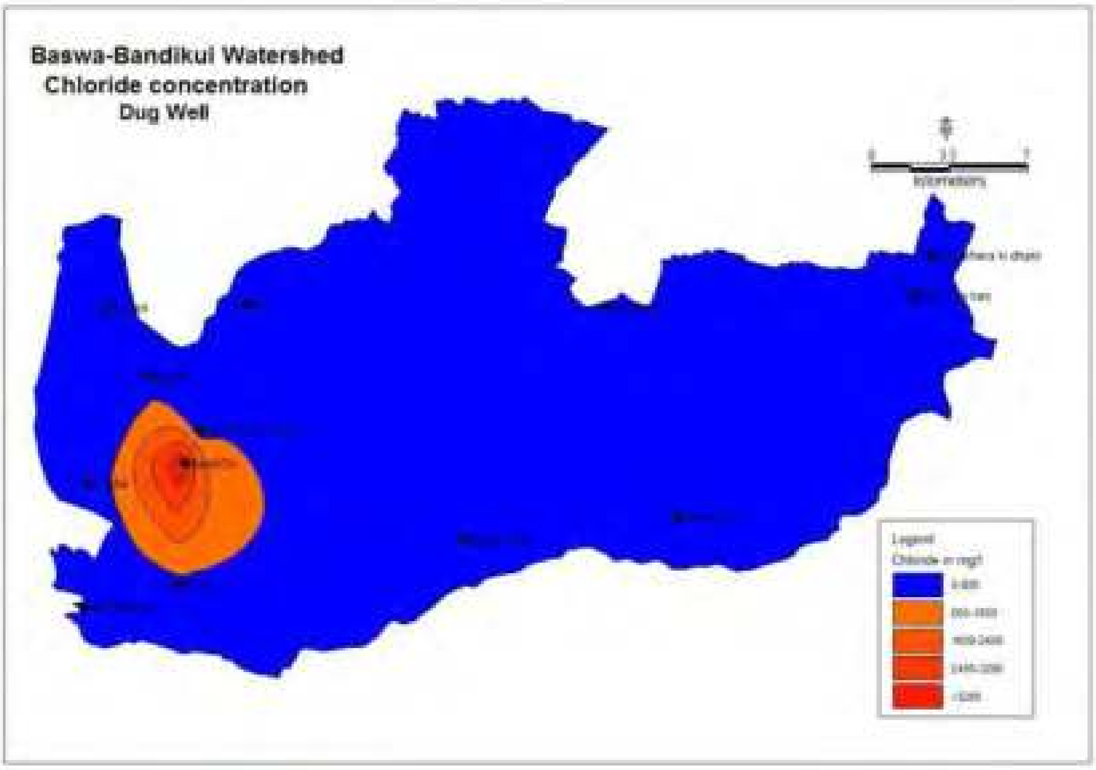
Figure 55. Distribution of Specific Conductance in Baswa-Bandikui Watershed, Dausa district, Rajasthan

Table 24 Areal distribution of different EC ranges in ground water

Range of EC in µS/cm at 25^0	**Area in sq. km (No. of site)**	**Percent of total area**
Less than 1000	10	16.4
1000-2000	30	49
2000-3000	11	18
3000-5000	6	10
>5000	4	6.6

2. Chloride

Chloride is present in all natural water. Being highly soluble, it moves freely through soil and rock. The salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water. BIS has recommended a desirable limit of 250 mg/l of chloride in drinking water; this concentration limit can be extended to 1000 mg/l of chloride in cases where no alternative sources of water with desired concentration is available.



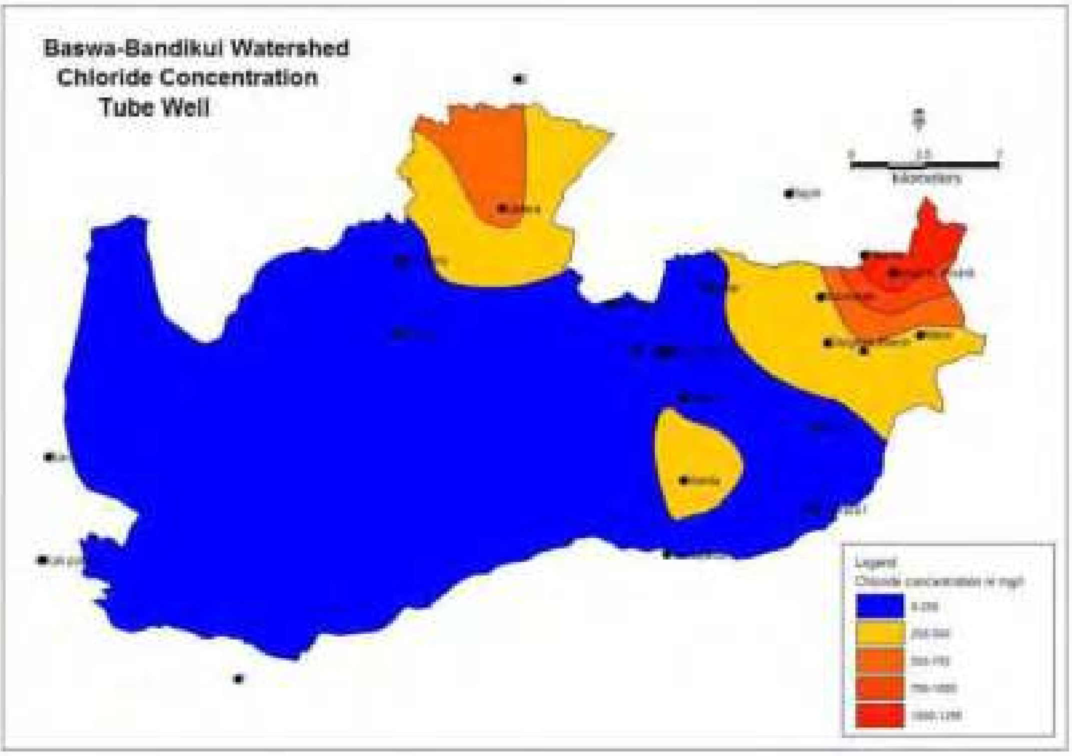


Figure 56. Distribution of Chloride concentration in Dug well and Tubewell in Baswa-Bandikui watershed

Perusal of the above cited map (Figure 56) reveals that dugwells in the study area do not show serious problem in chloride concentration in ground water except for a small patch in the south-western part of the project area around Nimali (640 mg/l). Chemical analysis of the tubewell samples show that in major portion of the Northern, Central and Western part of the area, chloride content in ground water is less than 250 mg/l. This part of the pilot project area is less saline as compare to eastern part of the area, where most of the samples have chloride concentration between 250 mg/l and 500 mg/l. Chloride value ranging between 500 mg/l – 800 mg/l have been found in Rani ka Bas (510 mg/l), kheda (510 mg/l), Jagsoli (518 mg/l), Uprera (600 mg/l), Balahedi (675 mg/l) and Jaisingh Pura (E) (781 mg/l). High chloride >1000 mg/l have been found in Tigaria (1172) and Khari ki Jhopdi (1250 mg/l). These locations are also situated in eastern part of area. The maximum chloride value is observed in south-western part of the area in Bhawta (4254 mg/l). A mentioned earlier, this may be an isolated case which may not have regional significance.

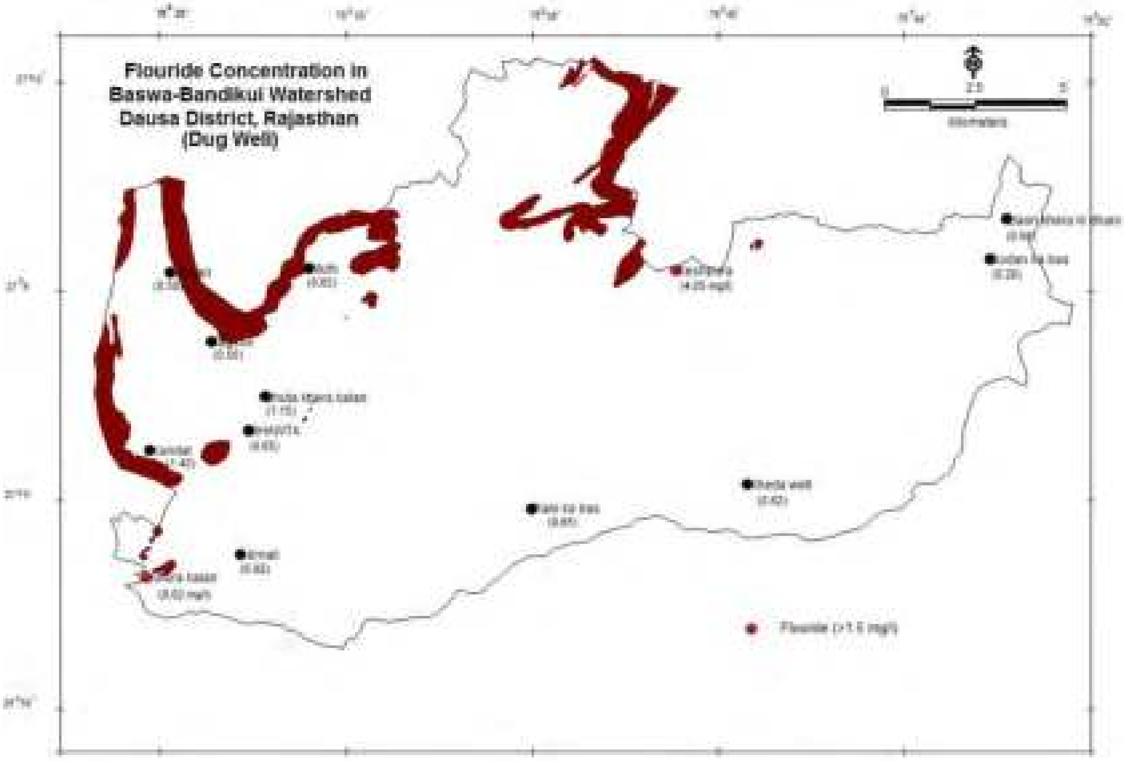
3. Fluoride

The main source of fluoride in ground water is naturally occurring from the breakdown of rocks and sails or weathering and deposition of atmospheric particles. The type of climatic conditions, nature of hydrogeological strata and time of contact between rocks and the circulating ground water also affect the occurrence of Fluoride in natural water.

The minerals that influence high fluoride Concentration in ground water are - fluorspar, Cryolite, fluorite and fluorapatite. Excess fluoride concentration in drinking water has detrirous effects on human health. It causes a dreadful disease known as Fluorosis.

Fluoride concentration in the dug wells in Baswa-Bandikui watershed ranges from 0.58 mg/l to 8.2 mg/l in ground water samples with lowest value 0.58 mg/l (Urwari, Baori Khera) and highest value 8.2 mg/l in (Khora Kalan). In case of tubewells, 4 locations have recorded higher fluoride value more than the permissible limit of 1.45 mg/l. The values of fluoride at Sumel, Raja Khera, Kesupur and Sonadi ranges between 1.6 mg/l and 3.5 mg/l.

The map showing fluoride(mg/l) in area is shown in Figure 57.



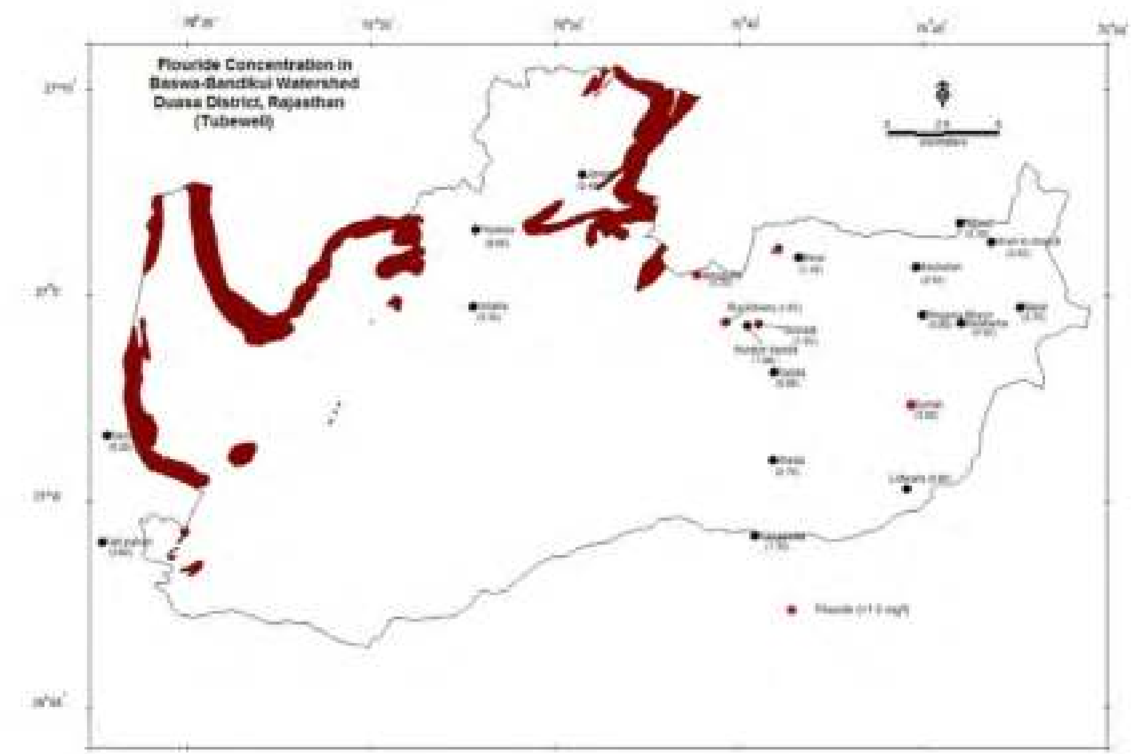
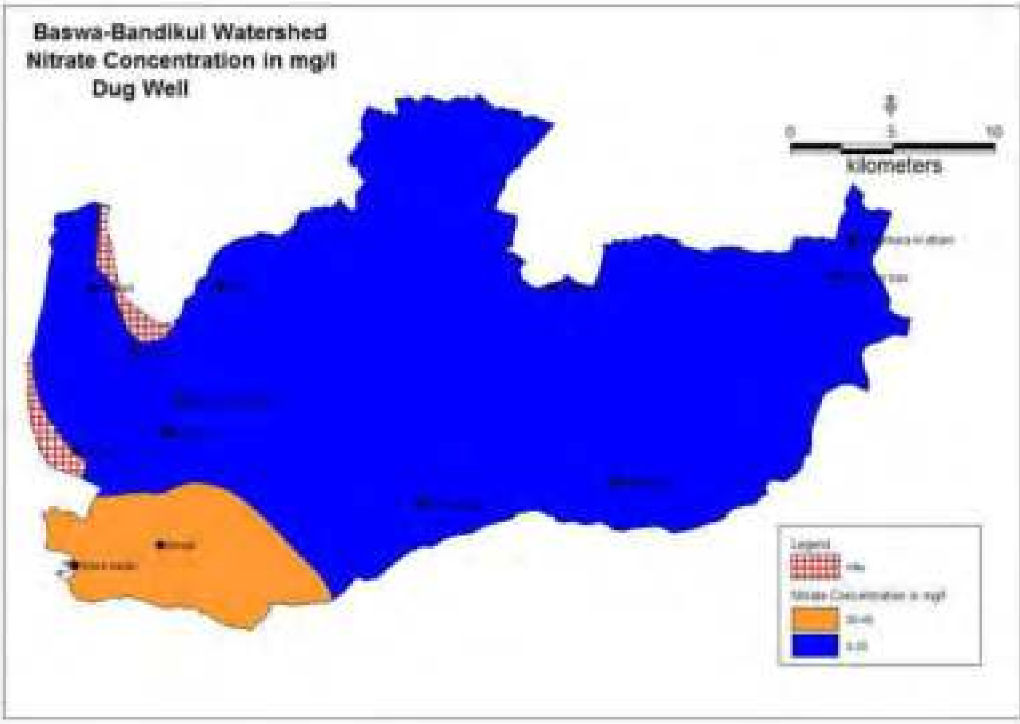


Figure 57. Distribution of Fluoride concentration in Dug well and Tubewell in Baswa-Bandikui watershed.

4. Nitrate

As per the BIS standard for drinking water the desirable limit of nitrate concentration in ground water is 45 mg/l with relaxation up to 100 mg/l. Though nitrate is considered relatively no toxic, a high nitrate concentration in drinking water is an environmental health concern arising from increased risks of methoemoglobinomial particularly in infants.

The map (Figure 58) showing distribution of nitrate in the Baswa-Bandikui watershed reveals that out of 60 number of ground water samples maximum numbers of samples have nitrate value < 45 mg/l there is no problem with respect to nitrate pollution. In tubewells, 5 samples have been found to contain nitrate in the range of 45 mg/l to 100 mg/l representing permissible limit of nitrate content e.g. Lilog & Rambas Kalan (48 mg/l), Biwai (60 mg/l) and Kundal (80 mg/l).



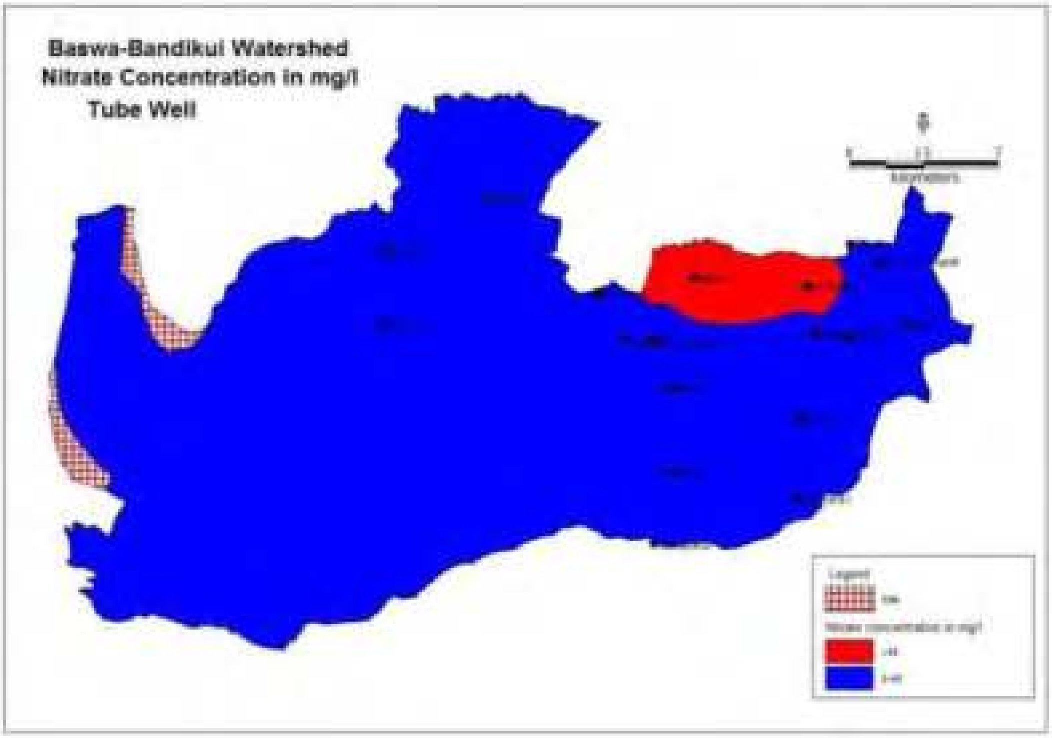


Figure 58. Distribution of Nitrate concentration in Dug well and Tube well in Baswa-Bandikui watershed.

5. U.S. Salinity Classification for Irrigation purpose

The ground water of Baswa-Bandikui watershed has been classified using U.S. Salinity laboratory diagram (1954) and electrical conductivity values. This diagram is commonly used for the classification of irrigation water based on salinity and sodium hazard designated with formulae.

SAR = Na^{+}/ (□Ca^{2+}+Mg^{2+})

Where ionic concentrations are expressed in meq/l when total hardness is expressed as $CaCo_3$ and sodium is expressed in mg/l.

U.S. salinity diagram are prepared for dug wells and tubewells (Figure 59).

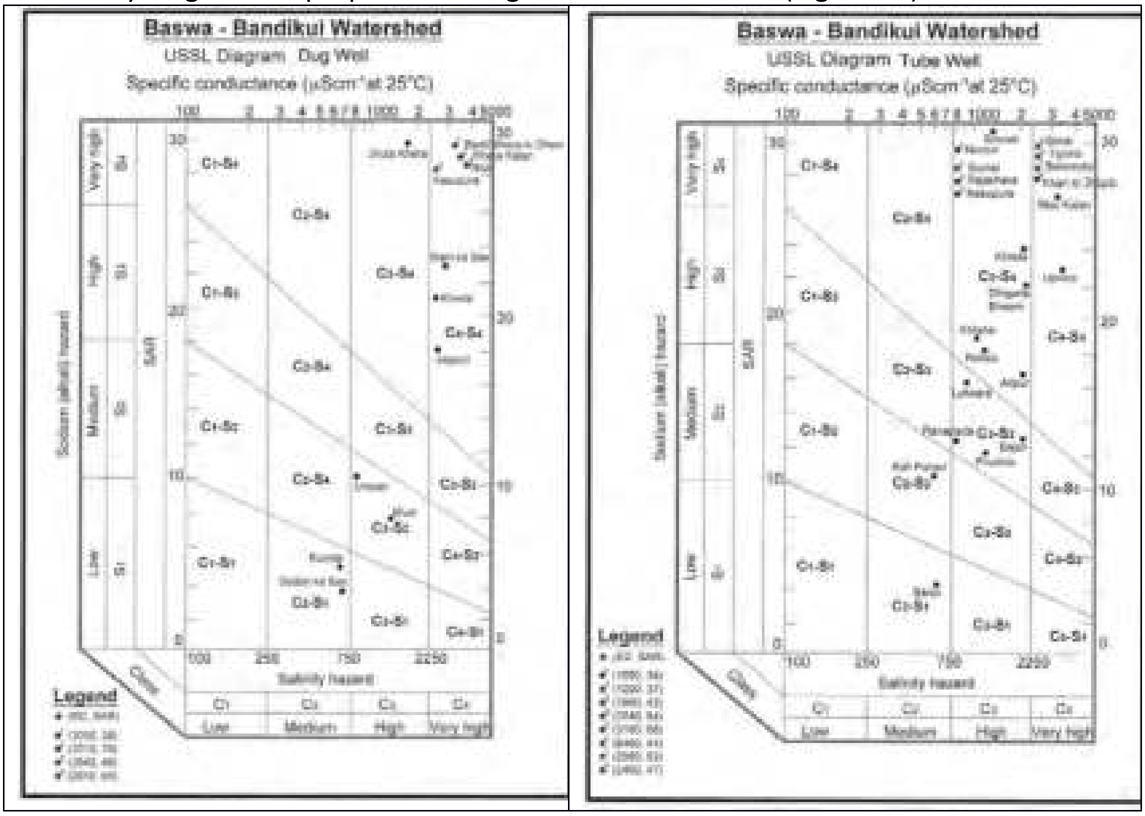


Figure 59. U.S. salinity diagram of dug wells and tubewells in Baswa-Bandikui watershed

The percentages of different classes of water occurring in Baswa-Bandikui watershed is given in Table 25.

Table 25 Types of water in dug wells for irrigation suitability based on U.S. salinity diagram

Class	Dug well (Percentage)	Tubewell (Percentage)
C_1S_1	0	4.5
C_2S_1	17	0
C_2S_2	0	4.5
C_3S_2	17	0
C_3S_3	0	18
C_3S_4	8	45
C_4S_4	58	28

The table shows that about 42% of the dug well samples are under medium and high salinity ($C_{2,}$ C_3) hazard and 17% of samples are under medium sodium hazard (S_2). About 58% of the dug well samples are under high salinity and high sodium hazard (C_4S_4) which is quite alarming. In comparison, the ground water of tubewells are more suitable for irrigation purposed. The Table shows that about 72% of samples are under medium and high salinity hazard and 9% of samples are under low & medium sodium hazard. Only 28% of samples are under high salinity and high sodium hazard.

The suitability of ground water for irrigation as classified above is however a generalized conclusion. Actually, in addition to water quality, other factors like soil type, crop type, crop pattern frequency and recharge (rainfall climate etc.) also have important role to play in determining the suitability of water. Water that is not suitable based on the above classification, may be suitable in well-drained soils. A modern agricultural management has to be taken into account for effective water management techniques. Involving economic distribution of water maintaining minimum pumping hours and also be selecting most suitable cost effective crops patterns i.e. for getting maximum agriculture production through minimum withdrawal. Proper soil and water management even the ground water with same what dissolved solids (TDS) may also be suitable for irrigation for salt tolerant crop like Bajra, Gvoar, Moong, Jera, Isbgoal etc. in the area having high salinity.

The maps showing distribution of US Salinity classes in dug wells and tubewells are shown in Figure 60.

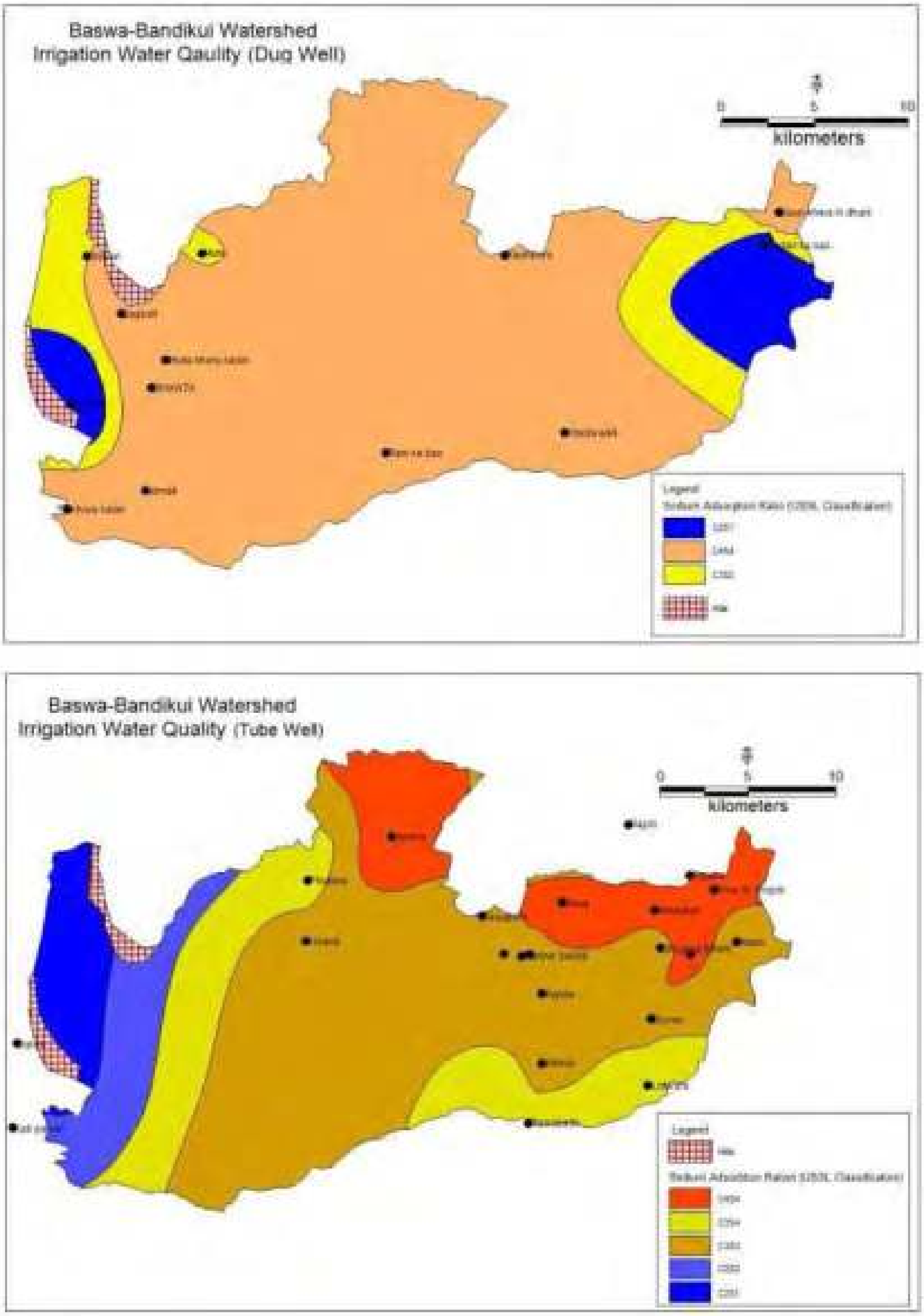


Figure 60. Distribution of US salinity classes in Dug wells and Tubewells

A perusal of the above cited map reveals that in ground water quality in dugwells in the major portion of the area comes are under C_4S_4 class. However, eastern and western extremes of the watershed are having good quality of water which is suitable for irrigation use. In tubewells of the area, poor quality ground water i.e. C_4S_4 class was come across the North and north east part of the area. Western and southeast part is categorized in C_2S_1 and C_2S_2 and C_2S_2 class. Rest of central part is under C_3S_4 class. Ground water in these areas under good drainage, high leaching and special soil management condition, is suitable for agriculture purpose.

PIPER DIAGRAM

The evaluation of water and relationship between rock types and water composition can be evaluated by the Trilinear Piper diagram. The groundwater often consists of seven major chemical ions Ca++, Mg++, Cl-, HCO3′ Na+, K+ and SO $_4$. These chemical parameters play a significant role in classifying and assessing water quality. The piper diagram consists of two triangular diagrams at the lower left and lower right, describing the relative composition of cation and anions and an intervening diamond shaped diagram that combines the composition of cations or anions is plotted in the appropriate triangle as a point. The cation and anion points are projected to meet at a point within the diamond. The meeting points falls in an area representing a water type as the diamond can be subdivided according to water types. This diagram also brings out the trends in water quality variations.

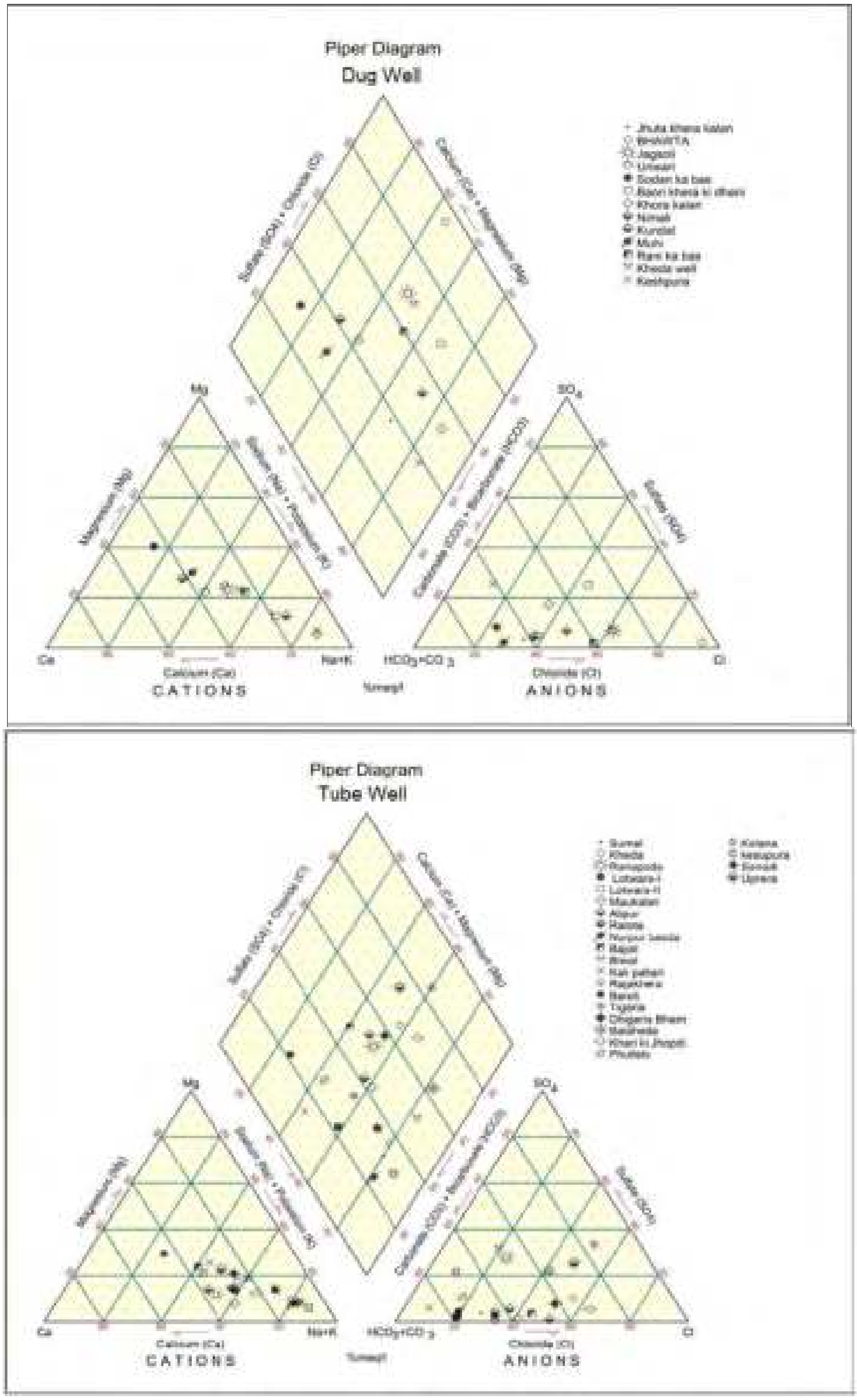


Figure 61. Piper diagram of Dug wells and tubewells of Baswa- Bandikui Watershed

The Piper diagram reveals the analogies, dissimilarities and different types of waters in the study area as follows.

Table 26. Characterization of groundwater type on the basis of Piper Diagram in Dug wells and tubewells

Type of Water	Dug well No of Wells (%)	Tubewell No of Wells (%)
Sodium Calcium-Bicarbonate type	15	30
Calcium Magnesium-Chloride Type	15	9
Magnesium Bicarbonate type	31	17
Sodium-Chloride type	39	35
Sodium Bicarbonate type	0	9

a) Calcium Magnesim-Chloride Type: Calcium and magnesium with chloride give rise to salinity in water. So such type of water is not suitable for irrigation purposes .

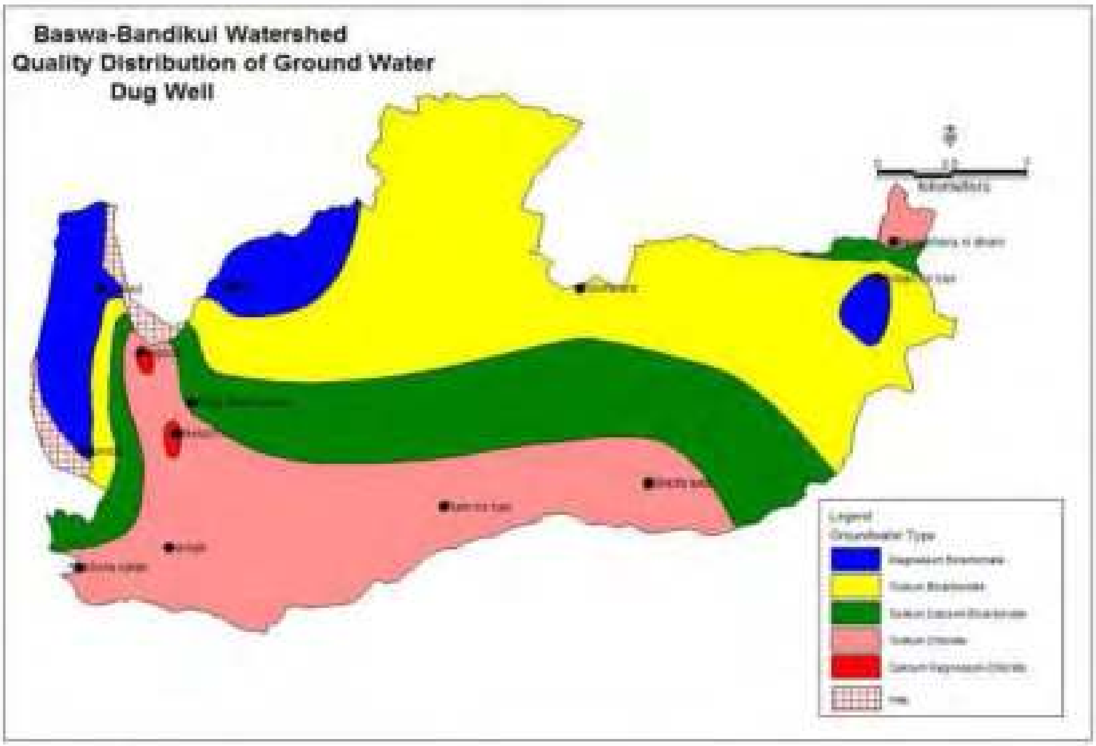
b) Sodium Bicarbonate Type: In such type of waters dominence of alkali metals and alkaline bicarbonates are high. Such types of waters can be useful for saline tolerent crops.

c) Magnesium Bicarbonate Type: In such type of water the ground water dominated by alkaline earths and weal acids. The bicarbonate concentration is groundwater is mainly depend upon pH and CO_2 content. Such type of water is fit for irrigation purposes.

d) Sodium Chloride Type: The water falling in this type are dominated by alkalies metals and strong acids. The non-carbonate alkalies (primary salinity) are more than 50%. Such types of waters can be useful for saline tolerant crops.

e) Sodium Calcium-Bicarbonate Type: The water falling in this type are dominated by alkalies alkalines and weak acids. Such type of water is fit for irrigation purposes.

Maps showing the distribution of chemical facies is depicted in Figure 62. The figure reveals that in both dug wells and tubewells, a considerable portion of the study area is marked with calcium-magnesium-chloride type of water which is generally not considered to be suitable for irrigation. The dugwells in the northern half of the study area has magnesium-bicarbonate and sodium-calcium-bicarbonate types of water that is considered to be suitable for irrigation. In tubewells, magnesium-bicarbonate and sodium-calcium-bicarbonate types of water is found in major part of north-western, central and eastern part of the watershed. Rest of the area has sodium-bicarbonate and sodium-chloride type of water in both dugwells and tubewells.



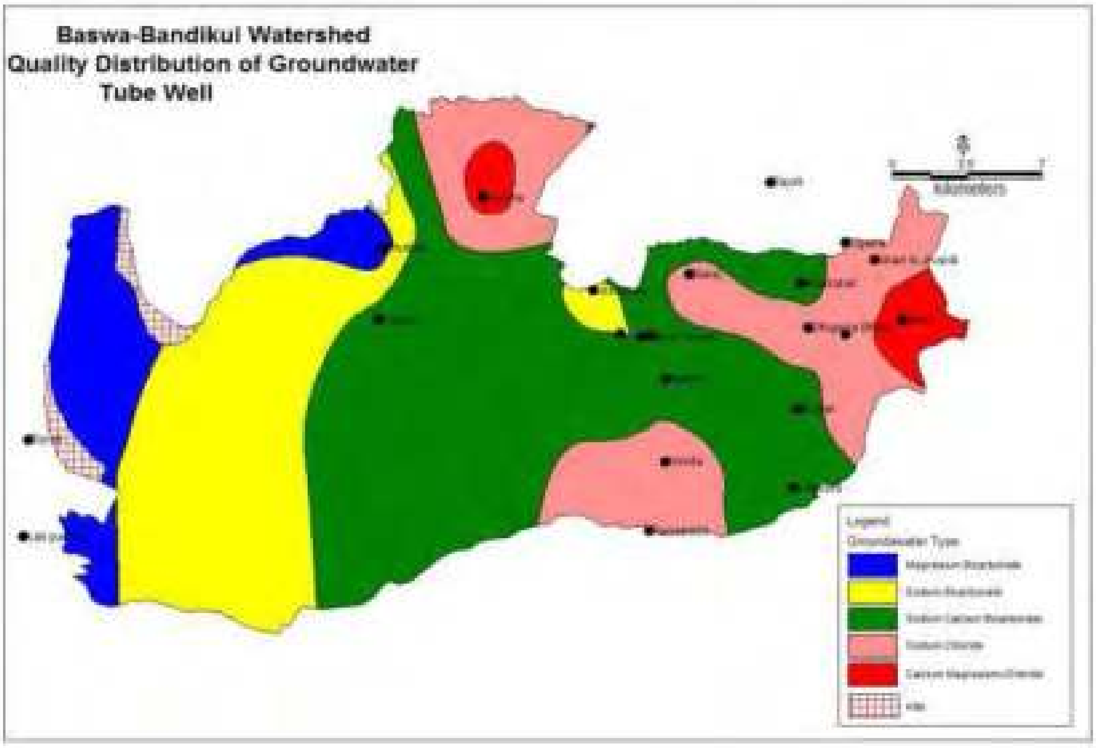


Figure 62. Quality distribution of ground water in dug wells and tubewells

3.9 RECHARGE PARAMETERS

Rainfall recharge factor or Infiltration factor is a recharge parameter, which can estimate using various techniques including soil infiltration test. Infiltration test can be defined as a ratio of quantum of water applied, in other words it indicates a quantum of water recharged to the groundwater system in relation to the rainfall. It is a function of rate of infiltration and ability of the system to accept the infiltrated water. The infiltration factor can be expressed as follows

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

Where,
IF = Infiltration Factor
Qi = Quantum of water infiltrated over the test period in m
Qa = Quantum of water applied in m
SY = Specific Yield
Qi and Qa are derived from the soil infiltration test as discussed in section 3.2. The specific yield values are obtained from dynamic ground water resources assessment report of 2013 for Bandikui block. Infiltration factors computed for various test sites are given in Table 27. The average Infiltration / Recharge factor of various ground water potential zones as deducted from the above mentioned study are as follows
Alluvium – 0.06; Phyllites/ Schists/ Quartzites –0.03 and Granite Gneisses – 0.02

Table 27. Infiltration Test results carried out in Baswa-Bandikui watershed, Dausa district

S. No.	Site	Longitude	Latitude	Soil Type	Ground water Potential Zone*	Season	Initial Infiltration rate (cm/min)	Final Infiltration rate (cm/min)	Duration of Test (min)	Total Quantum of water added (m)	Total Quantum of Water infiltrated (m)	Sp. Yld (Soil)	Total quantum of water recharged (m) [12*13]	IF (Recharged water/added water) [Col 14/ Col 11]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Lotwara	76.422	26.963	Loamy soil	A	Post-Monsoon'12	0.20	0.03	70	0.108	0.032	0.18	0.006	0.05
2	Kundal2	76.431	27.010	Loamy soil	A	Post-Monsoon'12	0.40	0.13	49	0.136	0.085	0.18	0.015	0.11
3	Kundal1	76.431	27.010	Loamy soil	A	Post-Monsoon'12	0.60	0.15	52	0.154	0.089	0.18	0.016	0.10
4	Tatia1	76.464	27.041	Loamy soil	Q	Post-Monsoon'12	0.3	0.05	30	0.137	0.024	0.18	0.0043	0.032
5	Tatia2	76.462	27.041	Loamy soil	Q	Post-Monsoon'12	1.00	0.10	40	0.138	0.067	0.18	0.012	0.09
6	Chandera	76.429	27.064	Hilly area (thin soil cover)	Q	Post-Monsoon'12	0.80	0.05	34	0.168	0.038	0.02	0.001	0.005
7	Rehadi1	76.405	27.089	Hilly area (thin soil cover)	Q	Post-Monsoon'12	1.00	0.20	34	0.170	0.075	0.02	0.002	0.01
8	Rehadi2	76.402	27.089	Hilly area (thin soil	Q	Post-Monsoon'12	0.90	0.50	33	0.265	0.035	0.02	0.001	0.003

S. No.	Site	Longitude	Latitude	Soil Type	Ground water Potential Zone*	Season	Initial Infiltration rate (cm/min)	Final Infiltration rate (cm/min)	Duration of Test (min)	Total Quantum of water added (m)	Total Quantum of Water infiltrated (m)	Sp. Yld (Soil cover)	Total quantum of water recharged (m) [12*13]	IF (Recharged water/added water) [Col 14/ Col 11]
9	Badiyal Kalan1	76.642	27.054	Loamy soil	A	Post-Monsoon'12	1.30	0.70	40	0.210	0.050	0.18	0.009	0.04
10	Badiyal Kalan2	76.641	27.052	Loamy soil	A	Post-Monsoon'12	1.30	0.31	30	0.250	0.105	0.18	0.019	0.08
11	Muhi1	76.475	27.073	Loamy soil	Gn	Post-Monsoon'12	0.50	0.05	30	0.200	0.029	0.18	0.005	0.03
12	Muhi2	76.475	27.074	Loamy soil	Gn	Post-Monsoon'12	0.30	0.05	30	0.190	0.027	0.18	0.005	0.03
13	Shalawas Khurd	76.562	27.021	Loamy soil	A	Post-Monsoon'12	0.60	0.10	50	0.2	0.07	0.18	0.013	0.06
14	Balaheda 1	76.789	27.061	Alluvial soil	A	Post-Monsoon'12	0.60	0.03	45	0.220	0.030	0.26	0.008	0.03
15	Nehalpura	76.728	27.066	Alluvial soil	A	Post-Monsoon'12	0.60	0.05	35	0.190	0.033	0.26	0.008	0.04
16	Lotwara east	76.727	27.008	Loamy soil	A	Post-Monsoon'12	2.20	0.03	35	0.215	0.041	0.18	0.007	0.03
17	Kheda	76.681	27.016	Loamy soil	A	Post-Monsoon'12	1.10	0.16	40	0.190	0.088	0.18	0.016	0.08
18	Salawas Khurd	76.562	27.021	Loamy soil	A	Pre-Monsoon'13	0.17	0.06	120	0.35	0.11	0.18	0.020	0.06

S. No.	Site	Longitude	Latitude	Soil Type	Ground water Potential Zone*	Season	Initial Infiltration rate (cm/min)	Final Infiltration rate (cm/min)	Duration of Test (min)	Total Quantum of water added (m)	Total Quantum of Water infiltrated (m)	Sp. Yld (Soil)	Total quantum of water recharged (m) [12*13]	IF (Recharged water/added water) [Col 14/ Col 11]
19	Phullela	76.549	27.113	Loamy soil	G	Pre-Monsoon'13	0.33	0.01	120	0.25	0.01	0.18	0.0018	0.007
20	Abhaneri	76.605	27.005	Loamy soil	A	Pre-Monsoon'13	0.08	0.02	120	0.313	0.043	0.18	0.008	0.02
21	Balahedi	76.605	27.005	Loamy soil	A	Pre-Monsoon'13	0.10	0.03	180	0.36	0.1	0.18	0.018	0.05
22	Simla Ka Bas	76.739	27.107	Alluvial soil	A	Pre-Monsoon'13	0.10	0.03	120	0.218	0.038	0.26	0.010	0.05
23	Tigariya	76.722	27.103	Alluvial soil	A	Pre-Monsoon'13	0.65	0.02	120	0.25	0.03	0.26	0.008	0.03

*Ground water Potential Zone - A- Alluvium, Q- Quartzite, G - Gneiess

Map showing distribution of Recharge factor is presented in Figure 63. The infiltration factor is less than 0.02 in the north-west and north of the project area occupied by hard rock aquifers. Recharge factor is between 0.02 to 1.0 in major part of the area covered with alluvium aquifer.

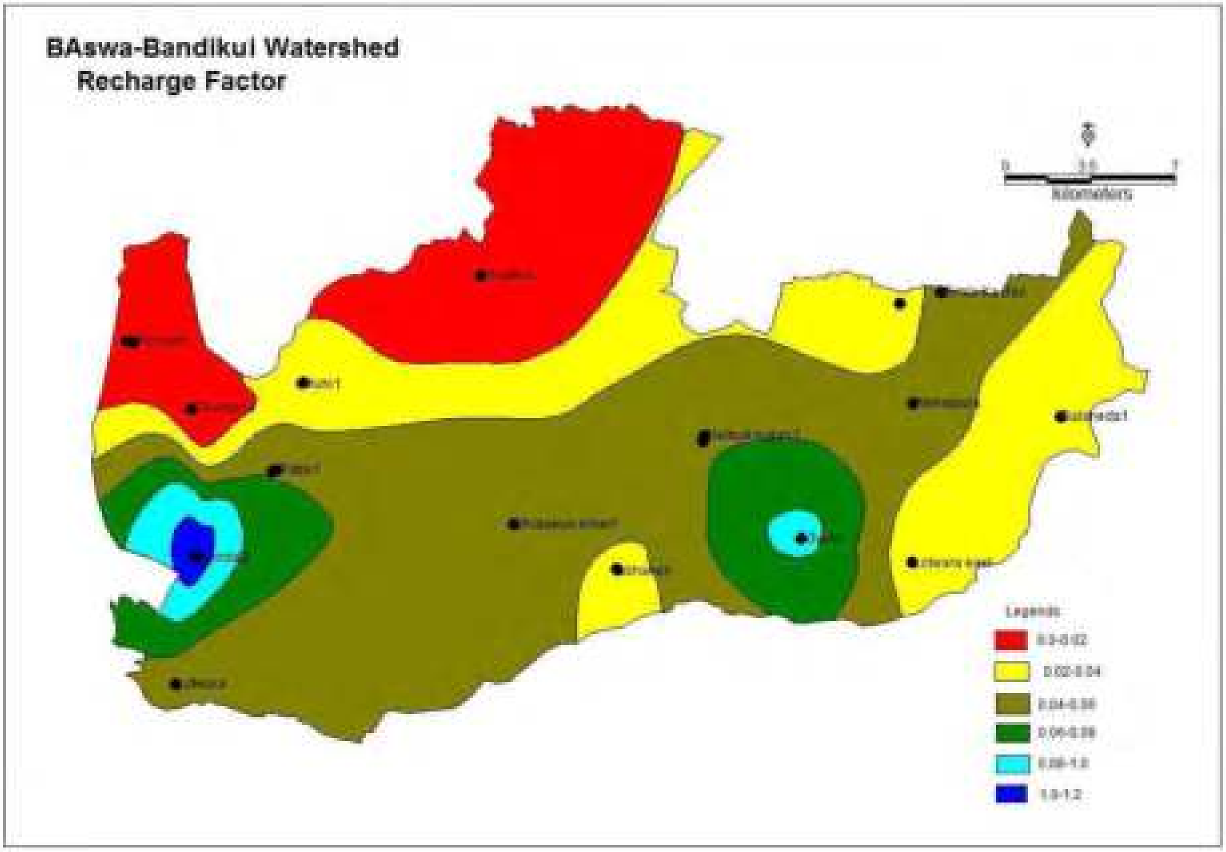


Figure 63. Distribution of recharge factors in Baswa-Bandikui Watershed, Dausa district, Rajasthan

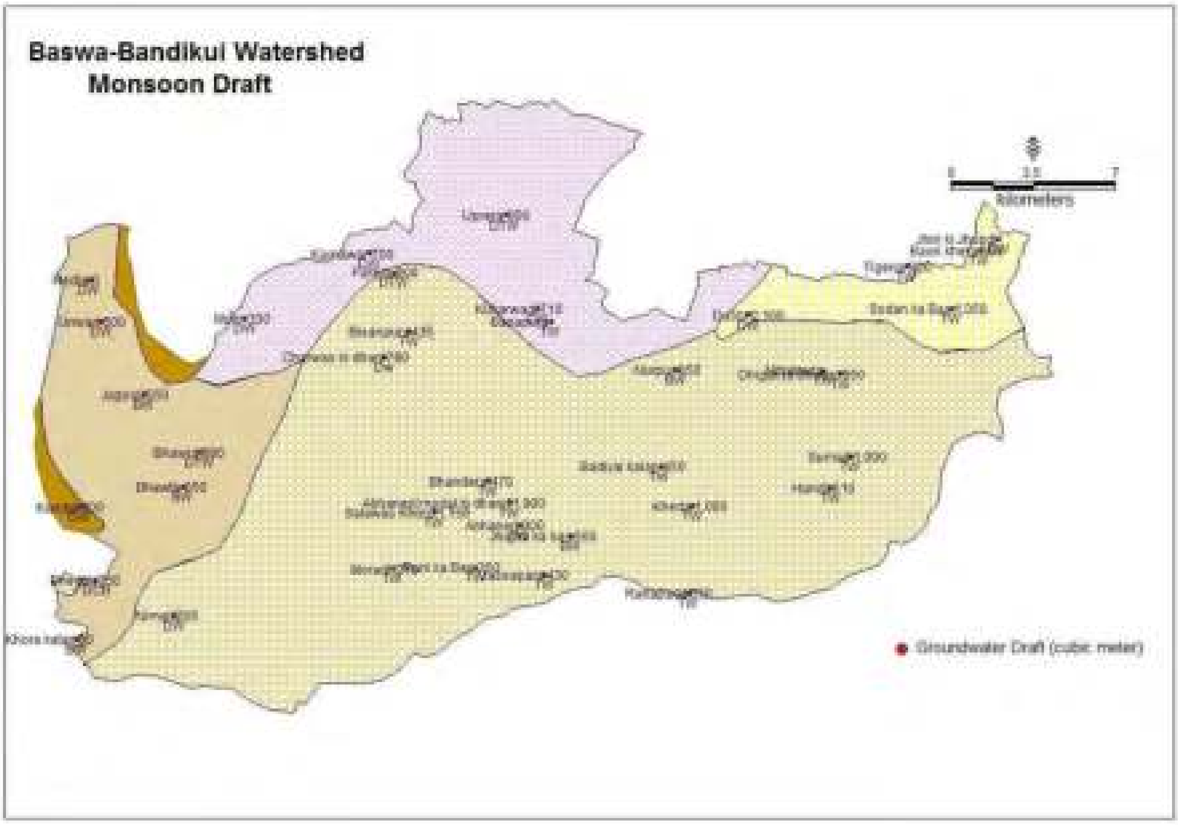
3.10 Discharge Parameters

Ground water discharge in the study area is mainly through ground water abstraction by wells. Unit draft study was carried out in the project area to determine the average unit draft of various ground water structures used for irrigation and domestic purposes. In total 39 wells are inventoried for the purpose (Figure 64). The information collected include type of lifting device, engergination details, discharge, use of the inventoried well, utilization pattern including area irrigated/ number of persons using, cropping pattern, irrigation details and other relevant information required for analysis of estimation of unit draft of wells. The unit draft of the wells are computed taking into consideration the discharge of the well and consumptive utilization pattern. Table 28 shows the average unit draft of various types of wells existing in the Baswa-Bandikui watershed. The details of unit draft assessment is given in Annexure-4.

Table 28. Unit draft of wells in Baswa-Bandikui watershed, Dausa district, Rajasthan

GW Potential zone	Type of Structure	Annual Draft (m^3)		
		Domestic	**Irrigation**	**Total draft**
Quartzite	BW	731	1218	1949
	DCB	700	1400	2100
	DW	675	1175	1850
Gneiss	BW	1325	1135	2458
	DW	1300	110	1410
Alluvium	DTW	5120	2175	7300
	STW	1410	3211	4622
	DW	2067	577	2643

BW - Bore well; DCB - Dug cum Borewell; DW - Dug well; STW – Shallow Tube well; DTW - Deep Tubewell



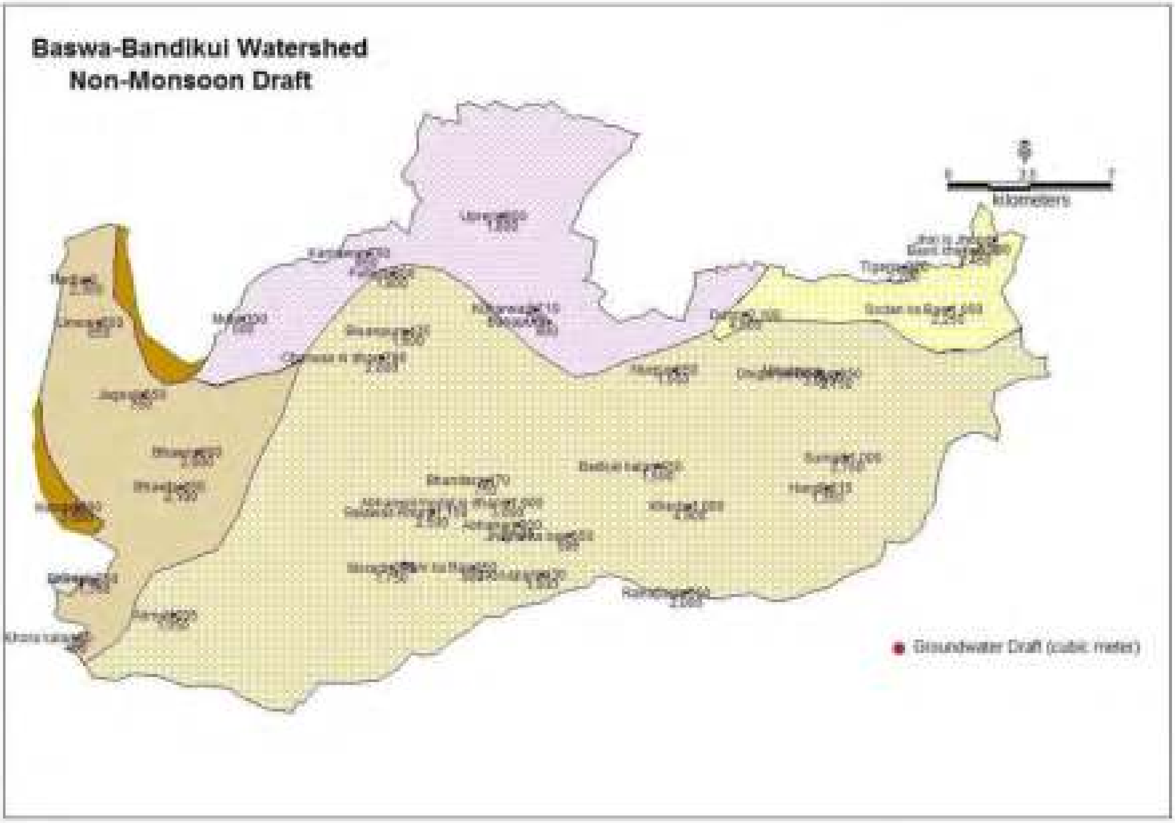


Figure 64. Unit ground water draft – monsoon, non-monsoon season, Baswa-Bandikui watershed, Dausa district, Rajasthan

4. DATA INTEGRATION

4.1 VALIDATIONS AND DATA INTEGRATION

Validation of the heilborne and surface geophysical data with the drilling log results has been done on the WellCAD platform using the evaluation version, an excellent platform for data validation and integration. Finally we integrated all sorts of available information from heliborne, surface, borehole geophysics and drilling logs and prepared composite and integrated litholog up to 150 m depth. Although it was easy to prepare an integrated log of 200 m depth as per the project objective, it was limited to only 150 m due to unavailability of reference drilling log to 200 m depth. In addition, the 200 m log reduces the resolution of top 30-70 m alluvium resting over hard rock.

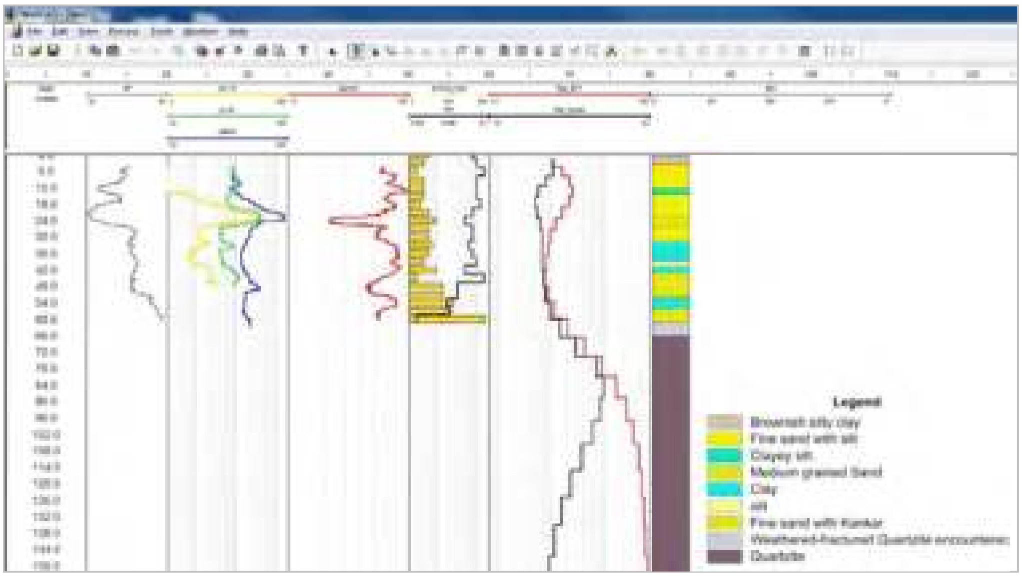


Figure 64. Borehole geophysical logs i.e. self potential (SP), resistivity (short normal, long normal and lateral), natural gamma, drill time, penetration rate (PR), SkyTEM smooth model, and its first derivative as well as composite and integrated litholog of Kothin village. The drill time record, penetration rate and composite litholog received from CGWB, which was for calibration and validation resulting into a revised and an integrated litholog.

Figure 64 shows an example of integrated litholog of Kothin village, which shows self potential (mV), resistivity (short normal, long normal and lateral in Ωm), natural gamma (CPM), drilling time (min.), penetration rate (min./m), SkyTEM smooth resistivity model (Ωm), first derivative of SkyTEM resistivity (Ω) and the integrated lithlog. The litholog shows from top brownish silty clay soil, followed by fine sand with silt till 22 m depth with inclusion of thin clayey silt layer between 12-14 m depth. There is 4 m thick medium grained sand between 22 to 26 m, but it does not form a part of the present existing aquifer as water level was located at ~42 m bgl in the month of February 2014 and ~ 60 m in the month of May, 2014 as per the CGWB record. Fine sand with kankar between 42 to 60 m forms the present aquifer with poor water quality.

The SkyTEM has recorded high resistivity against the granular zone down to 30 m depth. However, resistivity gradually falls down as it approaches the clay layer encountered between 30 to 42 m. Though the present aquifer, composed of fine sand with kankar between 42-60 m, is expected to yield high resistivity value, the existence of deteriorated water quality as well as 4 m thick clays sandwiched in-between kept it low. The first derivative of the HeliTEM result shows two possible boundaries between the weathered-fractured and compact quartzite to be respectively at 66 m and 79 m. In the lack of reference log adequately deep enough to penetrate inside the hard ensuring measurement of weathered-fractured and compact profiles, the bedrock boundary has been conservatively inferred to be at 66 m bgl. No further deviation in the smooth resistivity model reveals continued existence of the compact hard rock (quartzite) till 200 m and beyond.

Figure 65 shows another case of Nurpur Basada village, which is located 9 km in the west of the Kothin. This site is predominantly composed of clays. This is at the fringe of the inferred boundary, which divides the western and eastern part of the watershed based on the shallow and deeper quartzite bedrock. The SkyTEM resistivity is found varying more or less in the range of 10-15 Ωm till the depth of 36 m. Resistivity decreases as it approaches the thick clay layer located between 36 to 53 m resting over weathered-fractured quartzite. Inferred compact quartzite starts from 60 m depth.

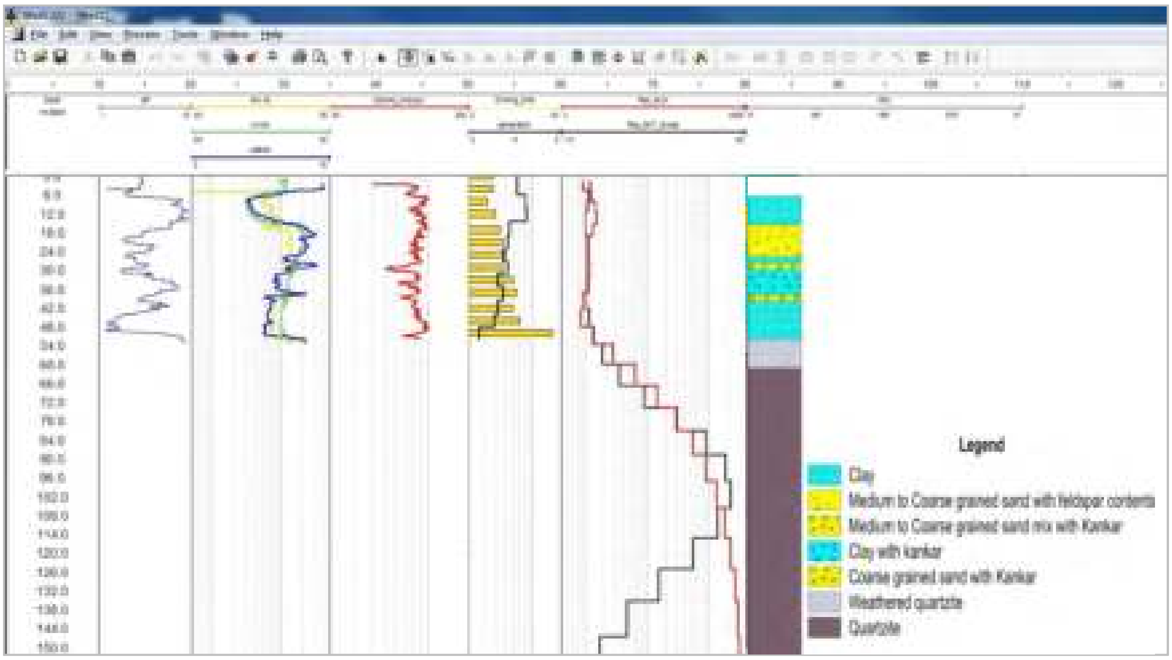


Figure 65. Borehole geophysical logs i.e. self potential (SP), resistivity (short normal, long normal and lateral), natural gamma, drill time, penetration rate (PR), SkyTEM smooth model, and its first derivative as well as composite and integrated Litholog of Nurpur Basada village. The drill time record, penetration rate and composite litholog received from CGWB, which was for calibration and validation resulting into a revised and an integrated litholog.

Rest of the mean resistivity maps and sections are given in the Appendix-III

4.2 TRANSLATION INTO HYDROGEOLOGICAL MODEL

Annexure V shows elevation of the all the principal lithological layers along with the ground elevation at each grid intersection points with the UTM coordinates. Thickness of the layers could be found negligible at places. This is important from the point of selecting the sites of artificial recharge in areas of favourable surface topography. For example the sites with negligible confining layer shows interconnectivity between desaturated aquifer and productive aquifer-I & II. Such sites can be used for constructing percolation tank for development of groundwater resources.

Other than the grid intersection, some additional points are also selected at uncovered boundaries to have better representation with full coverage. Four typical profiles viz., WE03, WE05, WE07 and WE09, each 42 km long running from west to east as shown in figure 66 are presented incorporating various steps involved in translating geophysical data into hydrogeological model. The significance of such models is discussed.

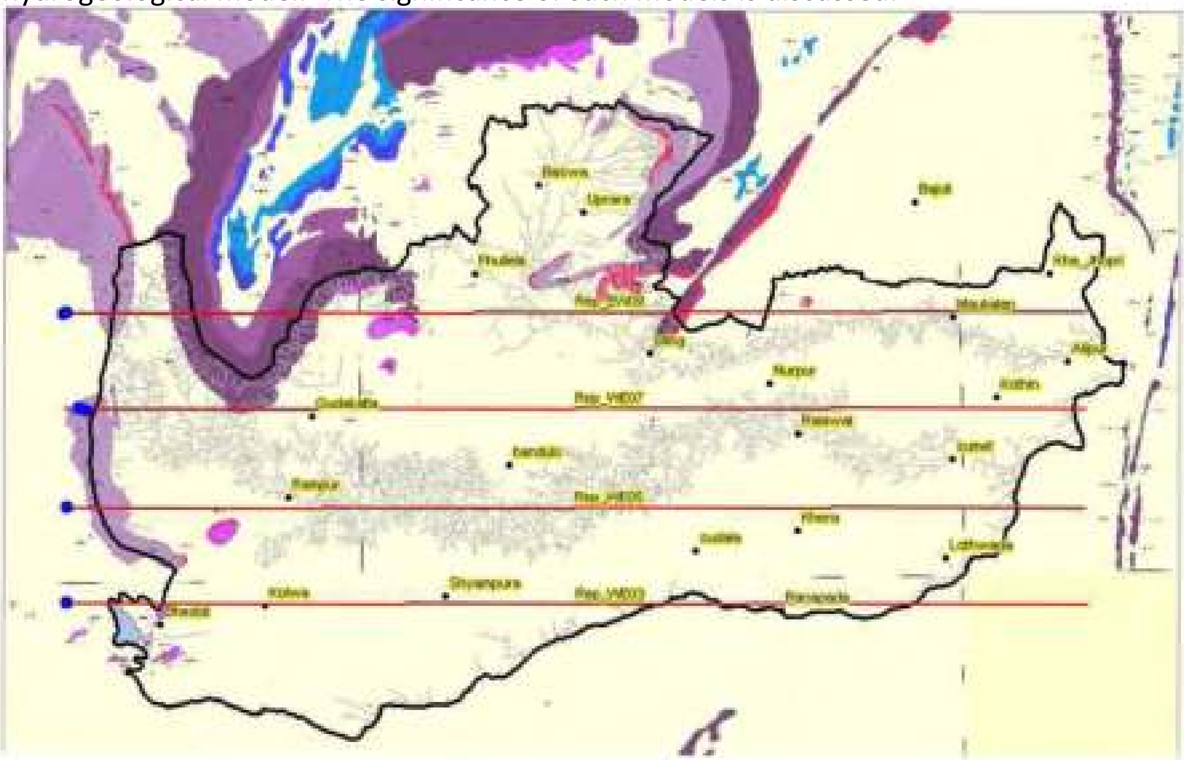


Figure 66. Four typical profiles running west to east direction viz., 'WE03', 'WE05', WE07', and 'WE09' marked in the study area

Profile WE03

This is a 33 km long profile that runs roughly along the Banganga Nadi that forms the southern boundary of the study area. Upper section of the Figure 67 shows SCI resistivity image. As the Banganga river and its drainage intersects the profile in the eastern half, its impact on the resistivity section could be seen in the form of low order of corresponding resistivity range compared to western half. The well-preserved upper high resistive sandy layer below the surface seen in the western half, are found disturbed retaining roughly the same thickness.

The middle section shows calibrated and interpolated litho interfaces. The digitized interfaces are marked by thin lines with 5% error bar. There are corresponding thicker lines that have emerged after interpolation. The interpolated litho interfaces shows relatively smooth variations, where the sharp changes corresponding to tectonic features, etc. are averaged out. Resistivity in the violet colour is of the order of 10^3 that represent quartzite hard rock, which forms the bedrock. The red colour index (60-300 Ωm) overlying the violet represents weathered-fractured (WF) quartzite. At few places the WF quartzite is also inclusive and or associated with the calcareous concretion and micaceuos rock.

In general, the top surface of red colour coincides with a line dividing the upper sediments from the underlying quartzite hard rock. The zone above the red divider represents the sedimentary deposits, where resistivity is found in yellow to reddish yellow color having resistivity in the range of 30-70 Ωm. Sand is encountered having fine, medium to coarse-grained texture, usually associated with calcareous pebbles called Kankar. The light blue to yellowish green (5-35Ωm) reveals the clay and or silt. These are also usually associated with Kankar as reported in the CGWB drilling logs. Resistivity falling further below shown in blue colour reveals deteriorated (brackish to saline) groundwater quality.

With the above logic the calibrated and interpolated principal layers of the SCI section have been attributed as surface soil followed by sand, clay, sand, WF hard rock and bedrock successively downward in series as shown in the lower section of figure 23. The overlying sediments are thickening gradually in east. The sharp undulation in the bedrock is mostly linked with structural features such as folds, faults, palaeo channels, etc.

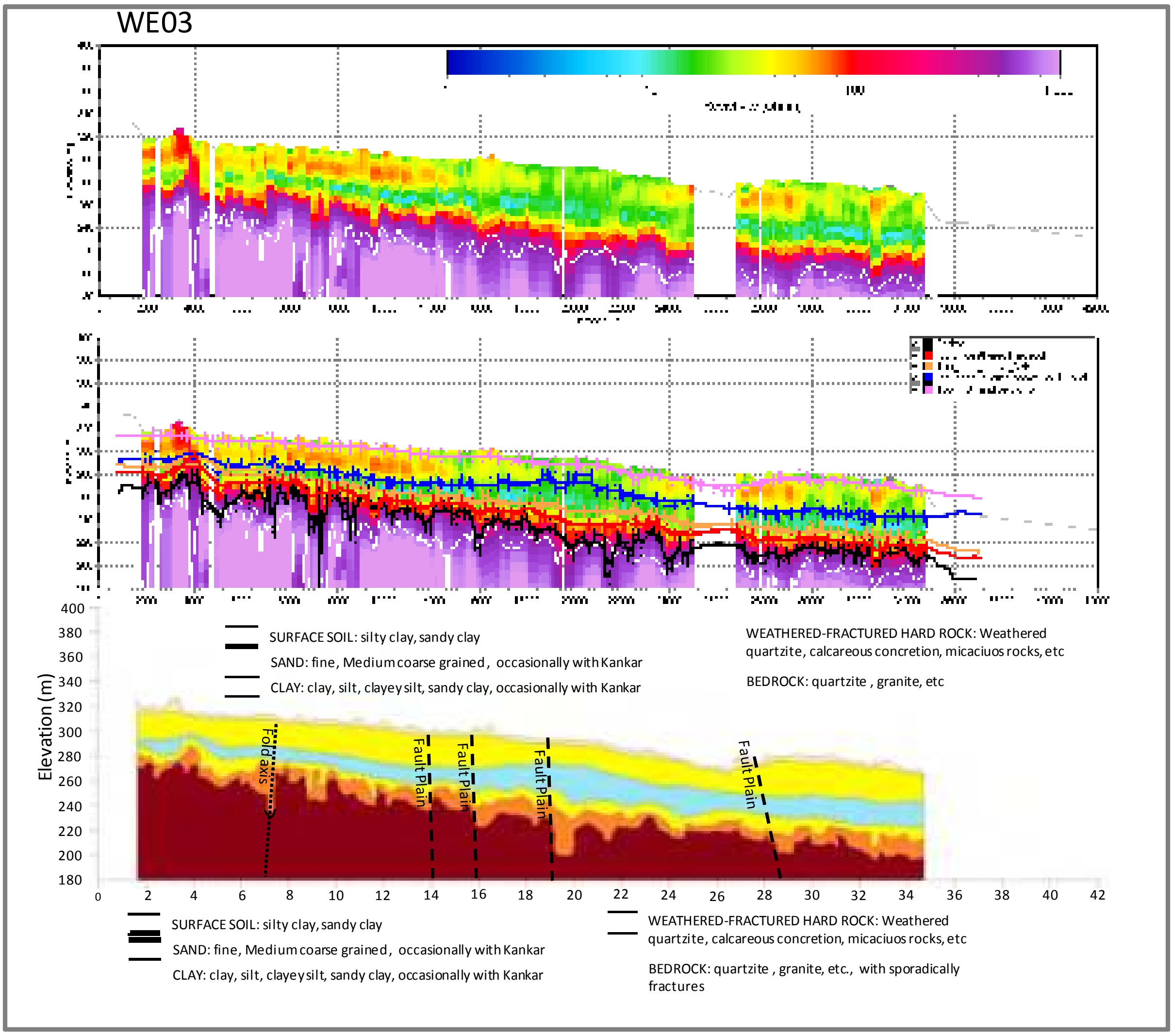


Figure 67. Profiles WE03 contains: SCI resistivity section (upper), calibrated and interpolated lithological interfaces (middle) and Lithological model with structural feature (lower). The calibrated and interpolated layer interfaces are categorized as: (i) top of bedrock, (ii) top of weathered-fractured (WF) hard rock (quartzite), (iii) top of sand above WF hard rock, (iv) top of conductive layer above the sand and WH hard rock, and top of sand below surface soil.

Profile WE05

This profile runs through the central river “Sanwan”, where hard rock is exposed as hill range in the west and Banganga river at the eastern margin. The sediments are almost negligible in the west, however, it gradually starts thickening towards east with abrupt

thickening from 30 km onward in the east (Fig. 68). The abrupt thickening is located close to the inferred palaeo channel and palaeo tectonics. The palaeo tectonics is the most plausible cause behind the parallel shift of the all the three rivers in this zones.
White colour line marked in the SCI section of the Figure 24 is the line of GDI. There is low resistivity anomaly at two places encircled with the black coloured dotted lines, which fall within the quartzite bedrock. Normally such anomalous observations are ignored considering them to be outliers. However presence of line of GDI below the anomalously low resistive encircled zone, reveals data driven SCI image with good quality data and reliability. Therefore, it cannot be ignored. These two anomalous zones coincide with the Baswa and Lilog fault planes as shown in Figure 68. Though the presence of the Lilog fault is shown at the north boundary of the watershed in geological map of India, its underground impact is seen extended to the Sanwan Nadi, where the river takes U-turn. In other words, GDI line is very important while developing hydrogeological model from the geophysical data.

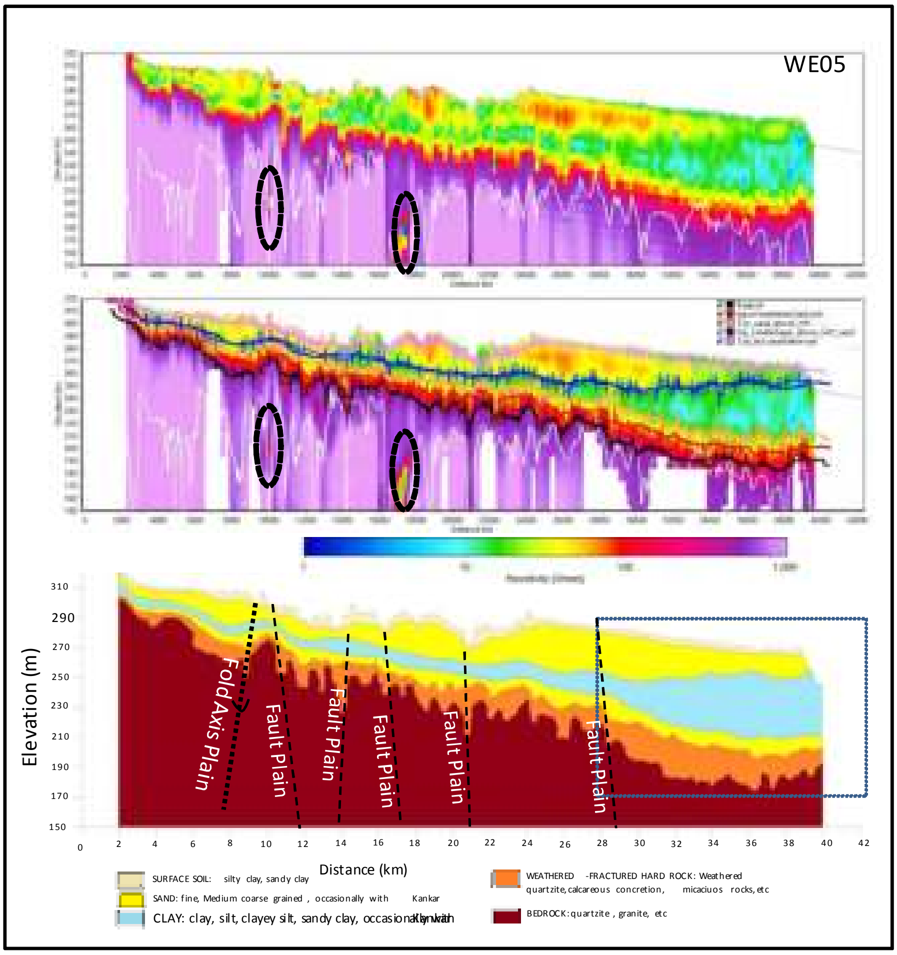


Figure 68 Profiles WE05 contains: SCI resistivity section (upper), calibrated and interpolated lithological interfaces (middle) and Lithological model with structural feature (lower). The calibrated and interpolated layer interfaces are categorized as: (i) top of bedrock, (ii) top of weathered-fractured (WF) hard rock (quartzite), (iii) top of sand above WF hard rock, (iv) top of conductive layer above the sand and WH hard rock, and top of sand below surface soil.

Profile WE07

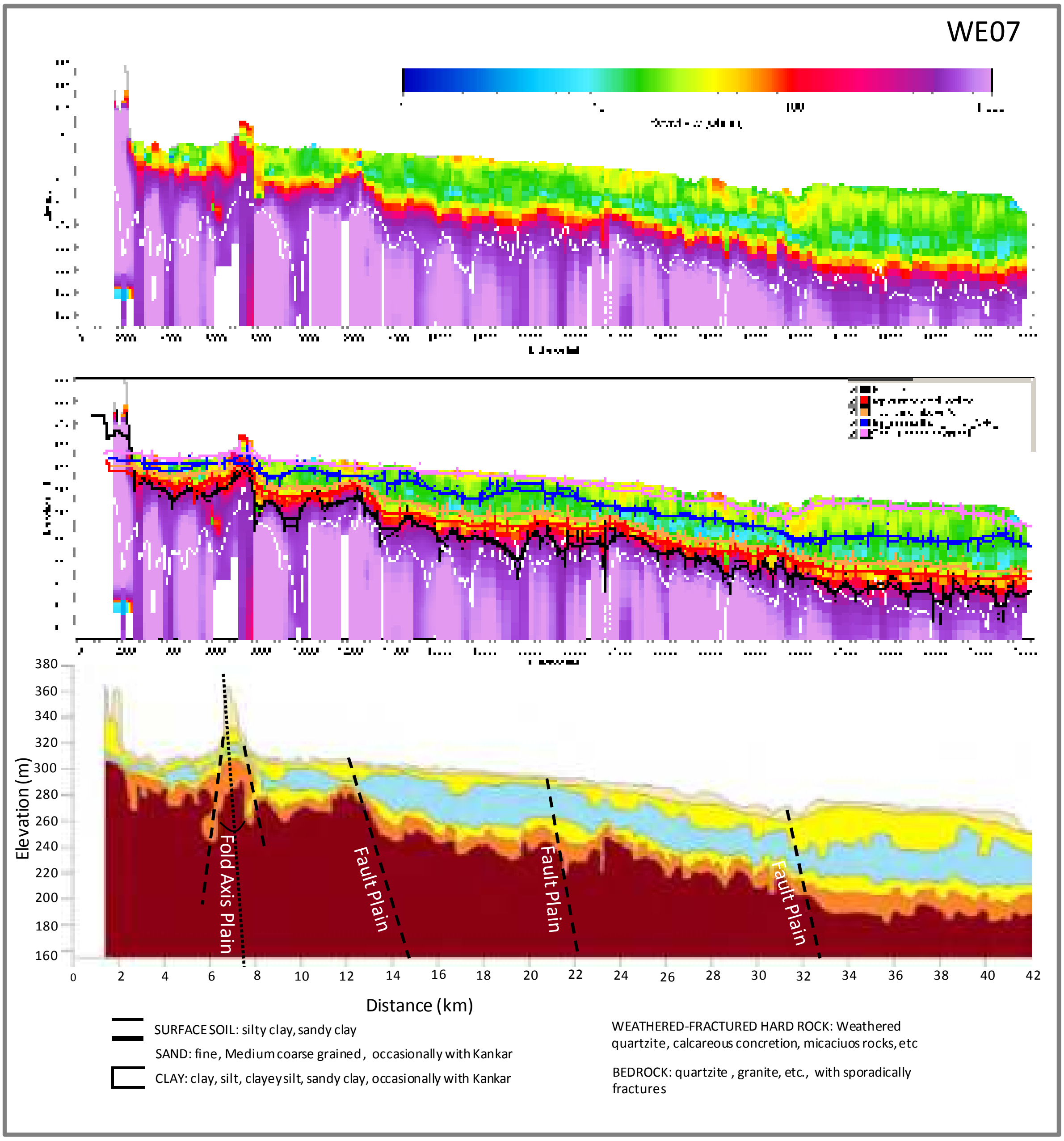


Figure 69. Profiles WE07 contains: SCI resistivity section (upper), calibrated and interpolated lithological interfaces (middle) and Lithological model with structural feature (lower). The calibrated and interpolated layer interfaces are categorized as: (i) top of bedrock, (ii) top of weathered-fractured (WF) hard rock (quartzite), (iii) top of sand above WF hard rock, (iv) top of conductive layer above the sand and WH hard rock, and top of sand below surface soil.

Figure 69 shows the translational steps of SCI heliTEM image into the lithological model. This profile touches two fold hill ranges in the west, Baswa and Lilog fault planes in the center and a river in the east. Zone between 2 and 8 km is basically valley fill between the two hills that have different hydrogeological conditions compared to the eastern part. Sudden thickening of sediments are found from 23 km onward in the east marked by rectangle with dotted line. The abrupt thickening sediments, which were marked roughly at

29 m in WE03, 30 m in WE05 and 32 m in WE07 reveal NNE-SSW strike direction and coincide with the line MN marked in Figure 18.

Profile WE09

The profile WE09 passes through the northern boundary of the study area falling out of the survey area boundary at two places i.e. 6-10 km and 26-29 km on lateral scales, which are marked as no fly zones. The western valley fill is at the fringe of the limestone formation that is located at the tip of the watershed boundary. The presence of the limestone was encountered as deep low resistivity zone in the ground TEM measurements and discussed in the AQUIM midterm report (Chandra et al., 2014). Five hills divide the section into five units as shown in figure 70. The first unit (Unit I) is valley fill at the western end. The Unit II falls out of boundary, which is masked with the white transparent colour. The Unit III is located in the foothill plane between the two folded quartzite hills. Unit IV is the zone between the two faults NS in the west and Lilog fault in the east. Unit V is located in the easternmost part of the section with deteriorated water quality.

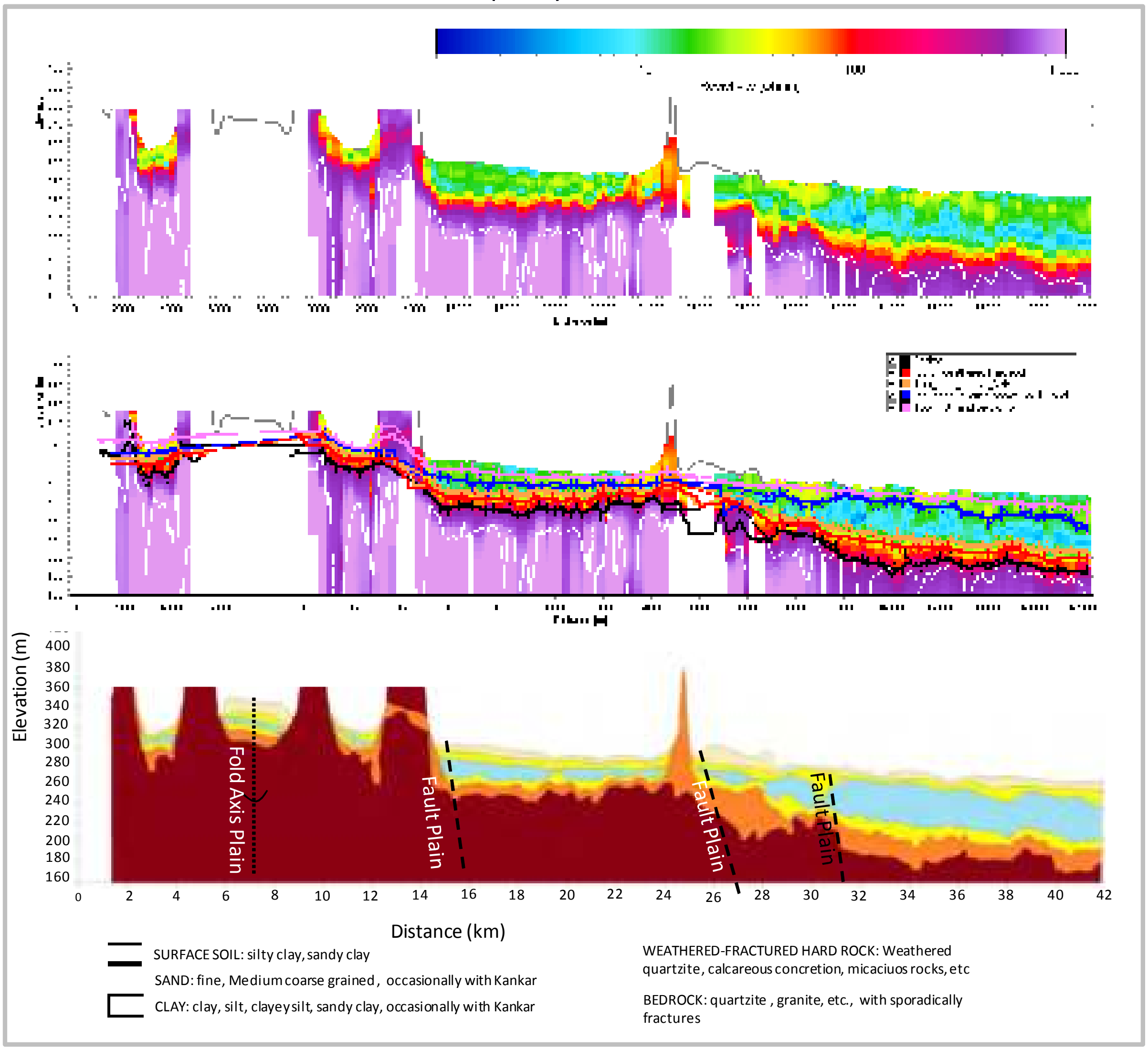


Figure 70. Profiles WE09 contains: SCI resistivity section (upper), calibrated and interpolated lithological interfaces (middle) and Lithological model with structural feature (lower). The calibrated and interpolated layer interfaces are categorized as: (i) top of bedrock, (ii) top of weathered-fractured (WF) hard rock (quartzite), (iii) top of sand above WF hard rock, (iv) top of conductive layer above the sand and WH hard rock, and top of sand below surface soil.

AQUIFER SECTIONS

Profile WE03

The cross section shown in the Figure 71 prepared on the basis of SkyTEM result in WE direction running parallel to the Banganga river has been selected since it forms the southern boundary of the study area. The section depicted a simple four layered hydrogeological layering in which the bottom most is the bedrock. The top thin layer which represent the top soil varying in its thickness 2-5 m is followed by sandy loam which could be basically the unsaturated as of now of the aquifer system persisted earlier. This layer is followed by saturated clayey loam, which is represented with low resistivity forming the base of the first aquifer in the sandy loam layer lying above. Within this clayey loam SkyTEM results indicated some of the areas that are saturated with poor quality of water in mid central and eastern most parts of the section. Below this layer there is a sandy-to-sandy loam, which lies above the inferred weathered-fractured quartzite that forms the main water bearing aquifer of the area along the section. Underlying this layer the weathered-fractured quartzite layer with varying thickness is clearly seen all along the section. Exploitation of this aquifer zone lying below the main aquifer zone may have interconnectivity with the aquifer system.

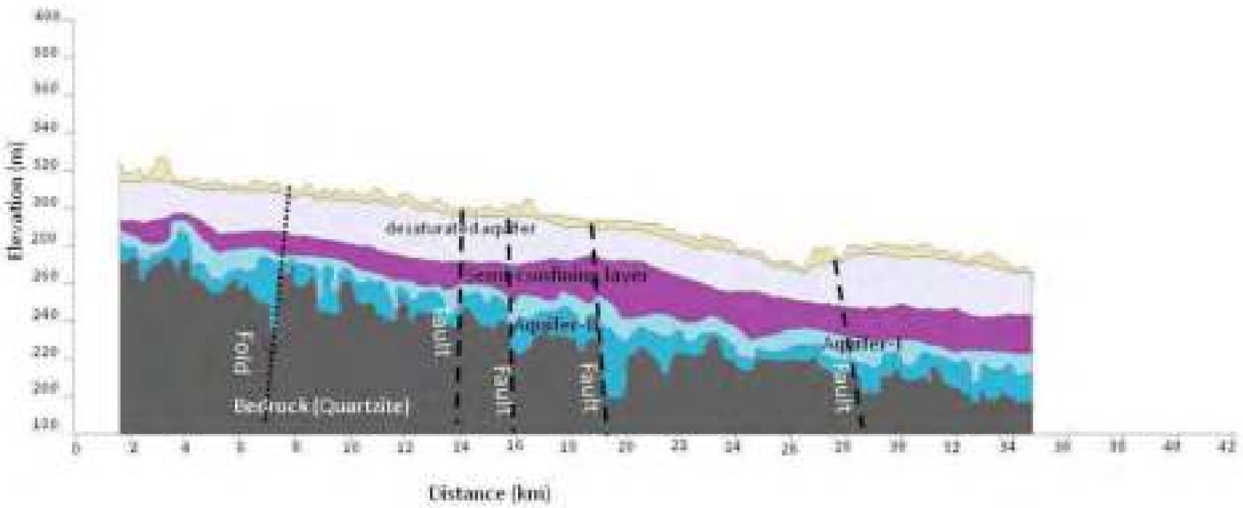


Figure 71. Hydrogeological section along profile WE03 containing surface soil, desaturated aquifer (sand), semi-confining layer (silt and clay), aquifer-I (sand) and aquifer-II (Hard rock).

Most of the area along this section is continuously dipping towards east following the trend of the present day topographical feature. The increasing weathered-fractured quartzite layer in the central part of the section with significant variations marks probably the Banganga River flow that might have migrated from north to south and the course of the river might have been varied. These are the locations, which could be potential aquifer zones to be proved by drilling.

Profile WE05

The cross section revealed similar trend of increasing thickness of sediments above the quartzite bedrock. The compact bedrock is roughly found at 90-100 m depth below the ground surface in the east (Fig. 72). The semi-confining layer thickness has increased by a factor of ~3 at the eastern most part where groundwater quality is found to be poor.

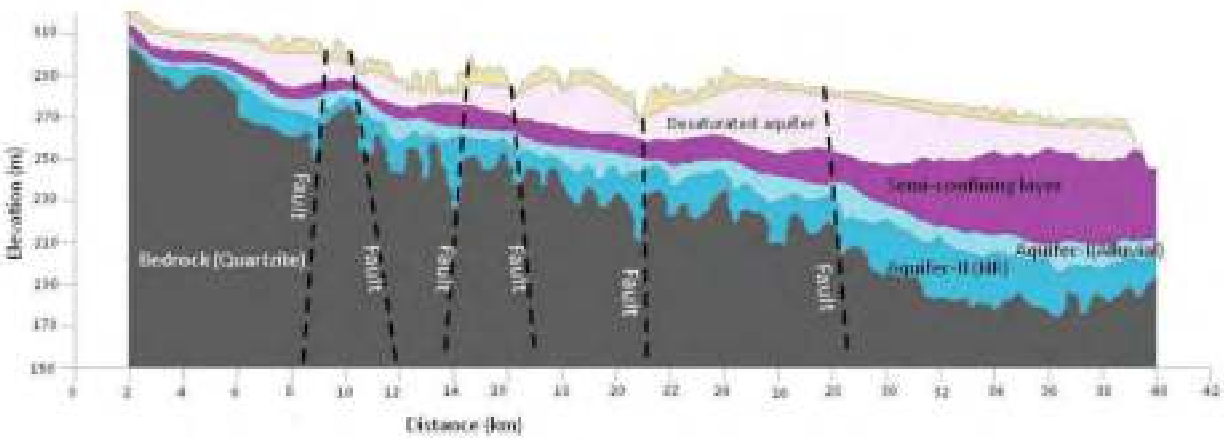


Figure 72. Hydrogeological section along profile WE05 containing surface soil, desaturated aquifer (sand), semi-confining layer (silt and clay), aquifer-I (sand) and aquifer-II (WF quartzite).

Profile WE07

This section shows considerably thick semi-confining layer from 14 km onward till the end of the profile (Fig. 73). However it is almost negligible close to the hills, which is obvious. There is associated deep fractured bedrock at ~6 km. The site near 12 km, could be developed for managing aquifer recharge by making percolation tank, etc.

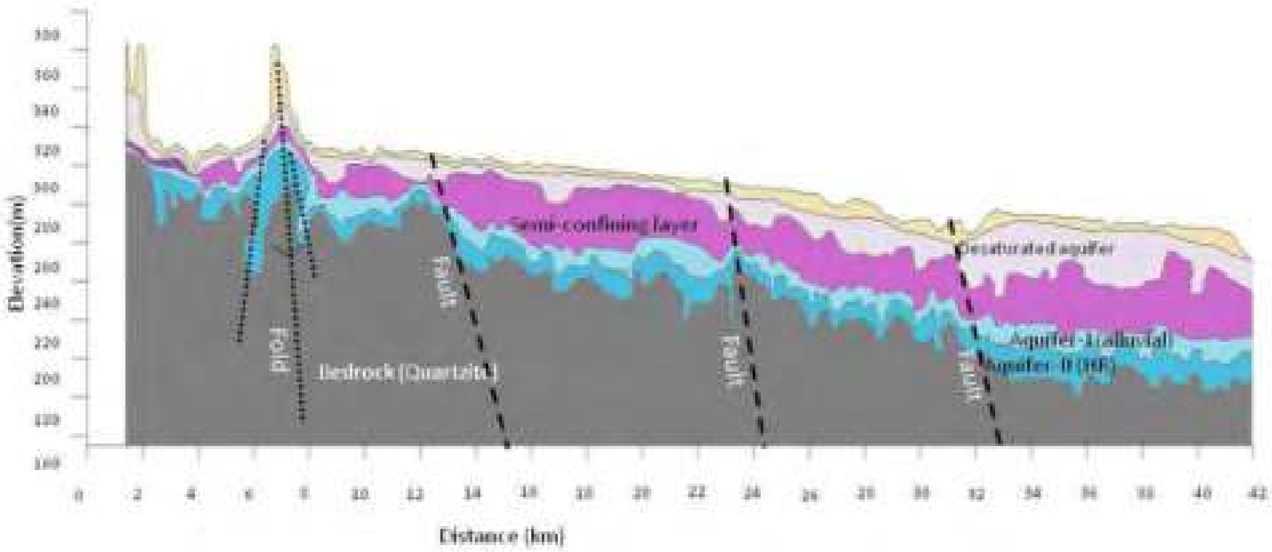


Figure 73. Hydrogeological section along profile WE07 containing surface soil, desaturated aquifer (sand), semi-confining layer (silt and clay), aquifer-I (sand) and aquifer-II (WF quartzite).

Profile WE09

The cross section along west-east on the northern part of the study area which is influenced by the high topographical variations makes this aquifer system into five units essentially separated by the exposure of different rock types which are found to be extending into the subsurface also (Fig. 74). Depending upon the geological terrain condition the aquifers unit I, II, III essentially attain a closed system phenomenon, which probably could be supplemented by quality of the groundwater system occurring within these units. Hydrogeologically aquifer units IV and V cover large part of the section and follow a four tier subsurface unit depicting the aquifer condition. The aquifer unit-IV having a four-tier layering is representative of topsoil followed by desaturated aquifer and semi-confining layer. Below this the main aquifer unit lies which has low thickness overlying the weathered-fractured quartzite, which is also having meager thickness. From exploitation point of view and potentiality, this unit seems to be non-favourable, but however the unit-IV might have been subjected to tectonic disturbances forming some limited potential sites within them in isolation.

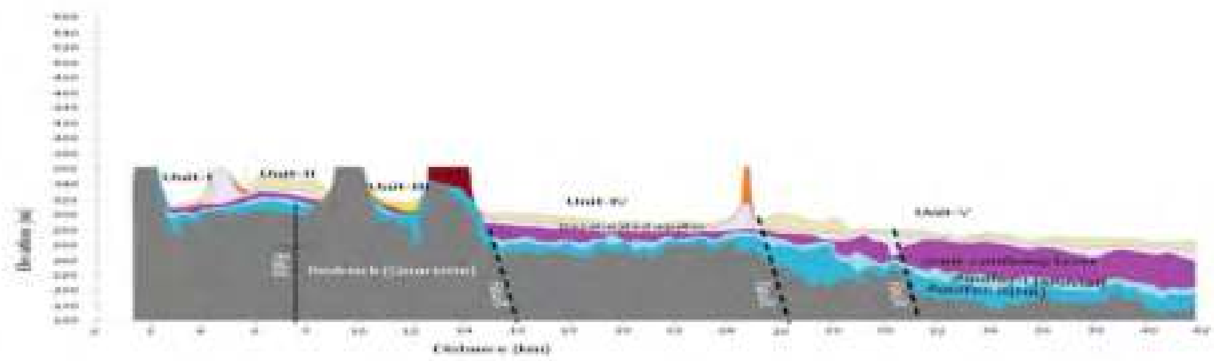


Figure 74. Hydrogeological section along profile WE09 containing surface soil, desaturated aquifer (sand), semi-confining layer (silt and clay), aquifer-I (sand) and aquifer-II (WF quartzite).

The unit-V until the eastern boundary has very distinguishable thick weathered-fractured quartzite layer forming the main potential aquifer system along mid eastern part of this section. Similarly inferred semi-confined layer is also found to be attaining considerable thickness along this part, which might be saturated with poor quality water. The well drilled at Khare ki Jhopari was reported to be of poor quality well. It is yet to be understood whether the migration of the poor quality of water has continued further downward contaminating the deeper aquifer system of aquifer-I and aquifer-II. This needs to be ascertained by further hydrogeological and hydrochemical surveys.

AQUIFER MAPS

Using the above logic and methodology of translating the geophysical data into hydrogeological model, aquifer maps are prepared in the entire area by digitizing the SCI resistivity model with reference to the integrated lithologs. The upper surface of the hydrogeological layers forming aquifer maps are prepared showing the following: i) upper surface of the desaturated aquifer made of sand of different texture varying from fine to coarse with the inclusion of kankar at places (Fig. 75), (ii) upper surface of semi- confining layer made of silt and clay mixed with kankar at places (Fig. 76), (iii) upper surface of aquifer-I composed of sand mainly inclusive of very thin clayey and silty lenses as well as kankar at places(Fig. 77), (iv) upper surface of aquifer-II composed of WF quartzite with inclusion of thin micaceous schist at places shown in Figure 78 and (v) bed rock topography shown in Figure 79.

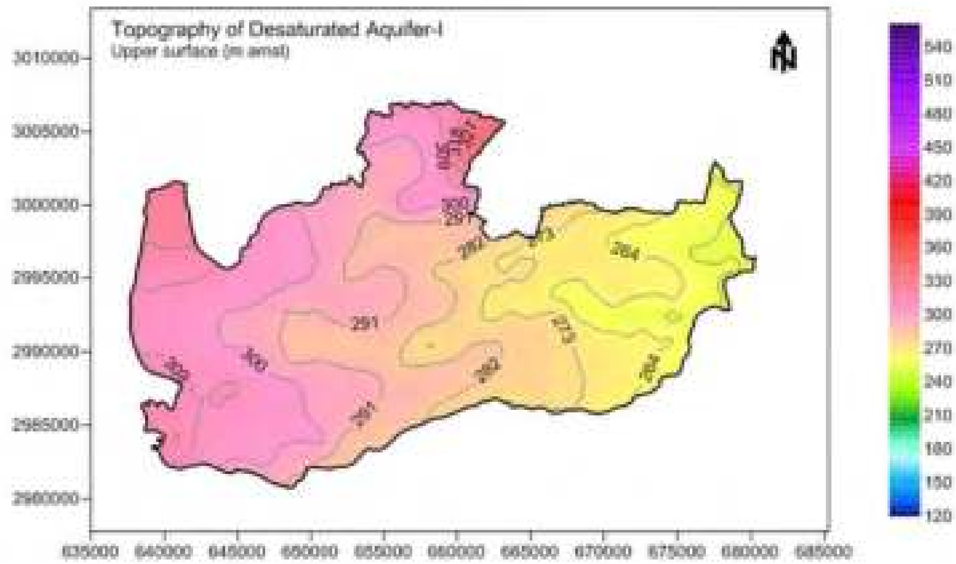


Figure 75. Upper surface topography (m amsl) of top desaturated aquifer.

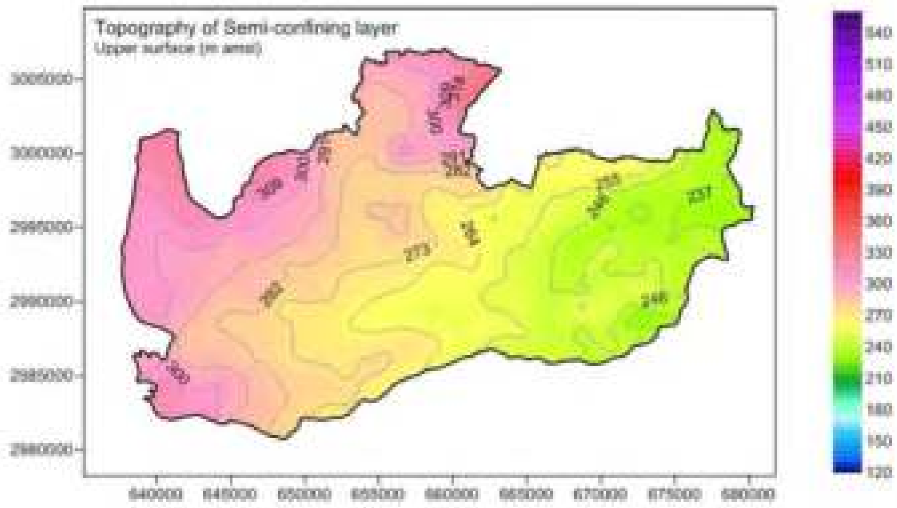


Figure 76. Upper surface topography (m amsl) of semi confining layer.

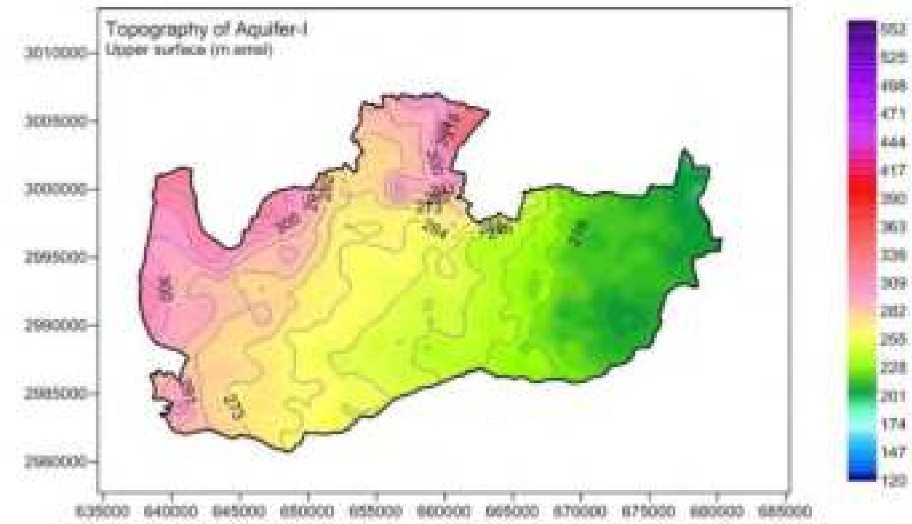


Figure 77. Upper surface topography (m amsl) of aquifer-I.

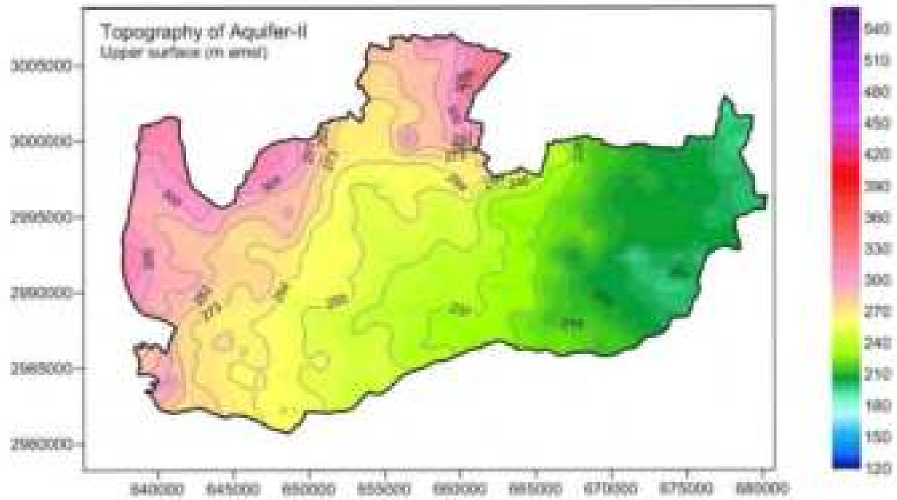


Figure 78. Upper surface topography (m amsl) of aquifer-II.

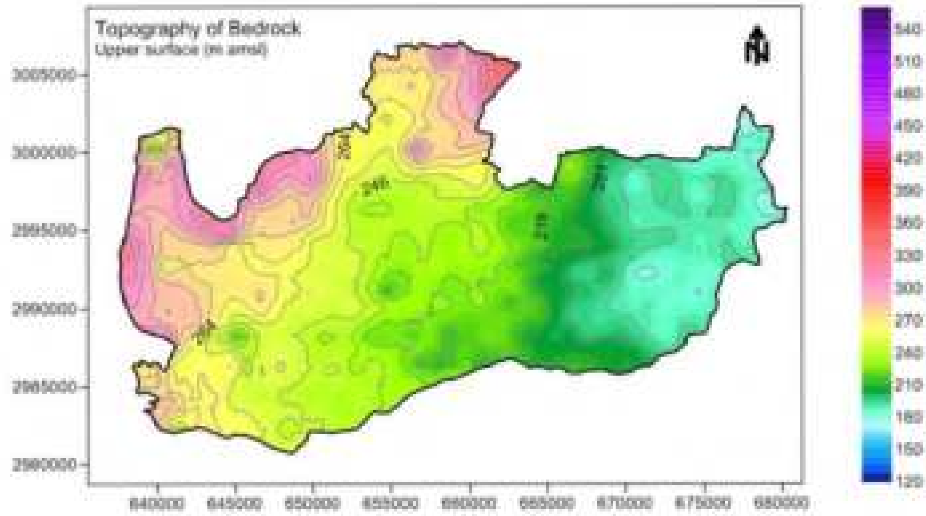


Figure 79. Bedrock topography (m amsl) map.

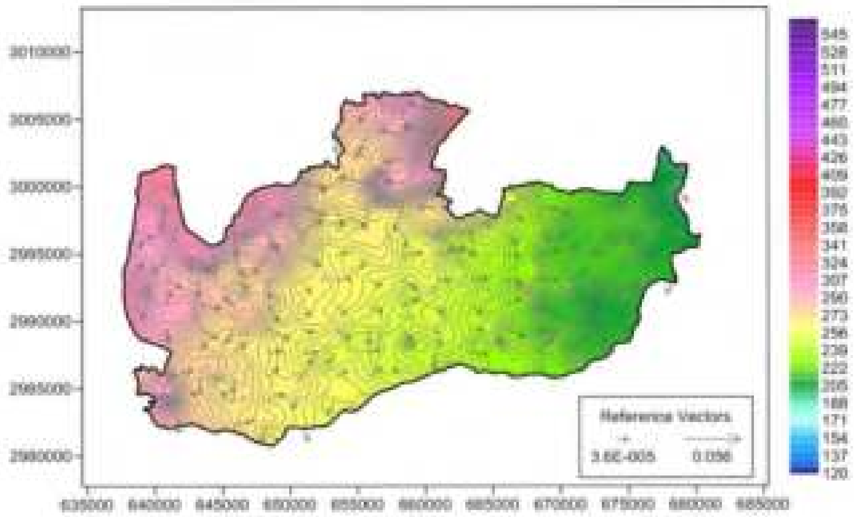


Figure 80. Upper surface topography (m amsl) of aquifer-I superimposed by first derivative map of topography shown as vector.

All the hydrogeological map shown above in this chapter clearly reveals totally different scenario after 665000 m UTM coordinate which was shown as line MN in figure 88. The layers are deepening towards east after MN line.

Relatively deeper bedrock is seen over the NW corner of the area, which falls over the limestone terrain.The bedrock topography corroborate well with the surface topography and the tectonics of the area.

Vector map representing the topographic slope is expected to coincide most likely with the groundwater flow direction, which is well accepted analogy published in various journals such as Chand et al., 2004, etc. Quality of the aquifer map can be taken from the mean resistivity map given in appendix.

THREE-DIMENSIONAL RESISTIVITY SECTION

Figure 81 shows 3-D map of the aquifer system by slicing the two vertical sections in the EW and NE-SW direction keeping 200 m thickness. Since aquifer system is limited within the upper one-third to one-fourth part of the profiles consisting three sets of aquifer system, the resolution of the profiles are getting lost. This is the reason why all the profiles and integrated lithologs are limited down to 150 m depth maximum. As usual depth to bedrock is found deepening towards east and almost in the same NE-SW direction coinciding with the bedrock topography.

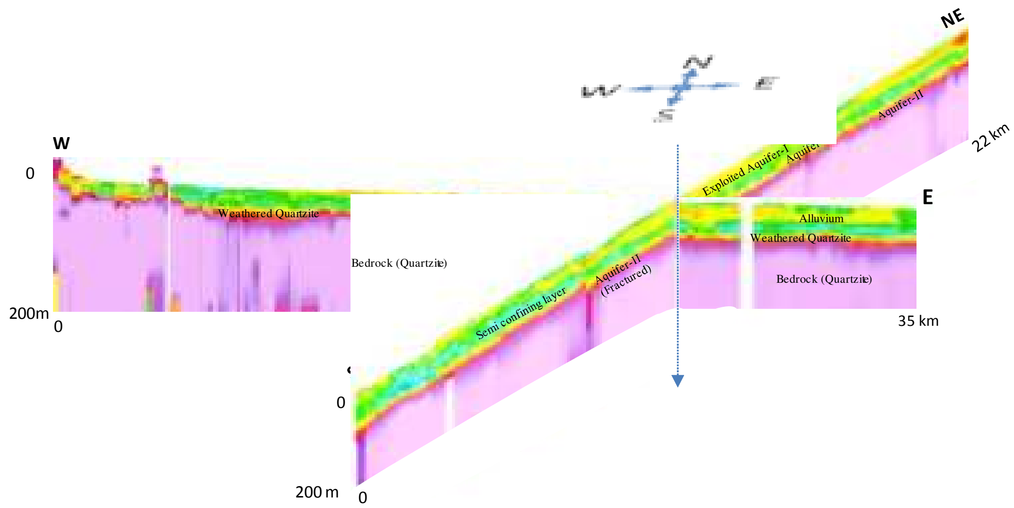


Figure 81.Three- dimensional aquifer section represented by EW and NE-SW profiles of 200 m thickness.

4.3 Efficacy of various Geophysical Techniques for different Hydrogeological terrain

An attempt has been made to have comparative analysis between SkyTEM and ground geophysical results. The comparison has been done in two ways as: i) SkyTEM vs. 1-d geophysics i.e. VES and TEM; and ii) SkyTEM vs. ERT.

SkyTEM vs. VES and TEM

The SkyTEM gave almost continuous measurement in meters. Whereas VES and TEM are point measurement located sparsely in kilometers. Hydrogeophysical thematic map of mean resistivity were prepared using 500 m search radius for SkyTEM, which result into dot maps in case of VES and TEM. To prepare a map, the search radius was increased to 15 km to have weightage of 10 points at least. The mean resistivity map of 40-50m depth range prepared from VES and TEM models are found broadly corroborating with each other that shows NW part of the area has encountered resistive hard rock at shallow depth. The difference in the resistivity pattern could mostly due to differences in number of measurement points and its distributions. Though, these two maps broadly corroborating with SkyTEM derived mean resistivity map, but later gives detailed subsurface characteristics that can be attributed in terms of alluvium (sand, clay, silt and their mixing), schist, weathered hard rock, bedrock, etc. For example, the violet coloured patches could be attributed as compact quartzite and or granite. However, resistivity 200 ohm.m or below could be attributed as altered hard rock and alluvium with varying textures. The dark blue coloured patches having resistivity ~ 5 ohm.m or below could be attributed to deteriorated water quality. This has been shown in the next chapter after calibrating with reference model.

Three-D grids of mean resistivity interpolated models are imported to the line AA' running from NW to SE (Figure 69). Once again all the sections are found corroborating with each other. However, the existing surface water reservoir over limestone terrain in NW most corner of the area is completely absent, unlike to the TEM and SkyTEM sections. The bedrock by VES is found roughly at ~ 275 m amsl (i.e. ~35 m bgl). Whereas the TEM and SkyTEM showed the bedrock at ~220 m elevation (i.e.~ 80-100 m). As a matter of fact, there is no VES observation in the NW portion. The VES resistivity section in NW is mainly extrapolated image. Such interpolation works well in an area with gentle subsurface variations. However such interpolation/extrapolation, with insufficient data density over a heterogeneous ground or a ground with abrupt changes, may be completely mislead.

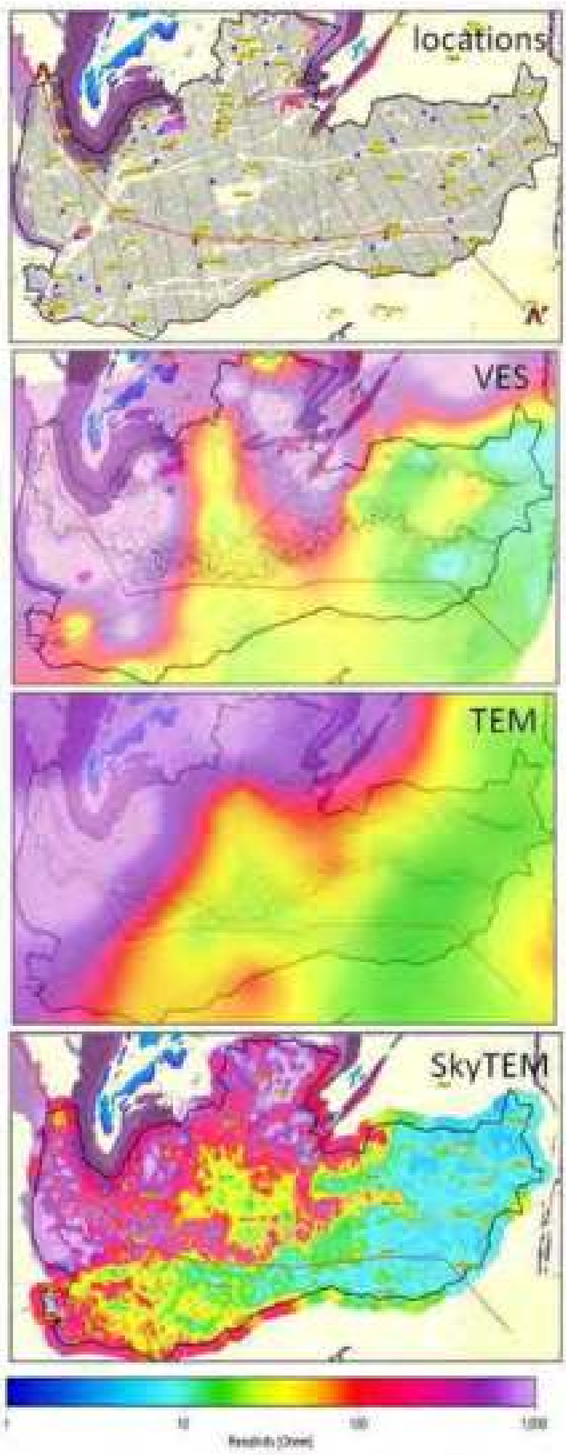


Figure 82. AQRAJ maps with i) location map showing flight line, VES and TEM points and a line AA’ running from north west to south east: ii) mean resistivity map from VES; iii) mean resistivity map from TEM; iv) mean resistivity map from SkyTEM

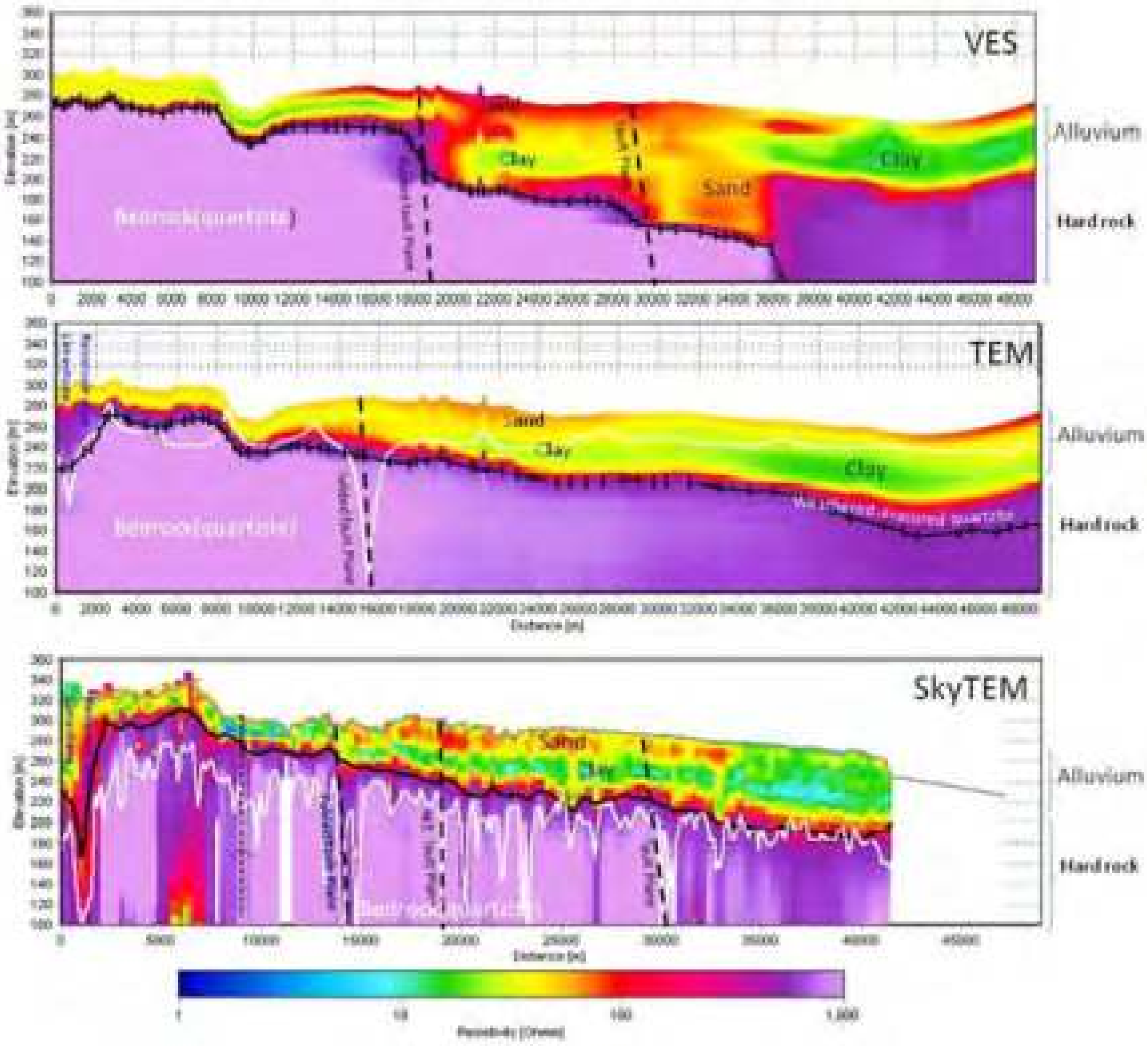


Figure 83. Area map showing flight line, VES and TEM points and a line AA' running from west to east

VES resistivity section revealed two fault planes at 19 km and 30 km lateral scale. Both faults are absent in TEM section. However, an additional fault is seen at 16 km distance revealed by sharp low peak of GDI. This fault plane is clearly described in HeliMAG chapter. The SkyTEM mapped all tectonic features discussed above in this chapter with high precession. The line of GDI in TEM section has smooth slope. However, SkyTEM section poses sharp variation with high frequency revealing sets of fractures and faults and hence highly disturbed bedrock.

SkyTEM vs. ERT

An example of ERT and SkyTEM coparative analysis is presented from Nurpur Basada village (Fig. 71). It is learnt that the ERT is better in mapping the surface soil than the SkyTEM. The resistive bedrock is seen at ~205 m elevation. However ERT shows at ~ 150 m as per the resistivity distribution. This difference is quite high, which looks to be unrealistic in terms of lithology. It is important to note that physics of both the methds are different. The TEM is sensitive to conductive layer and VES is sensitive to resistive layer. Therefore, the resistivity range demarcating the bedrock boundary should also be different for TEM and VES.

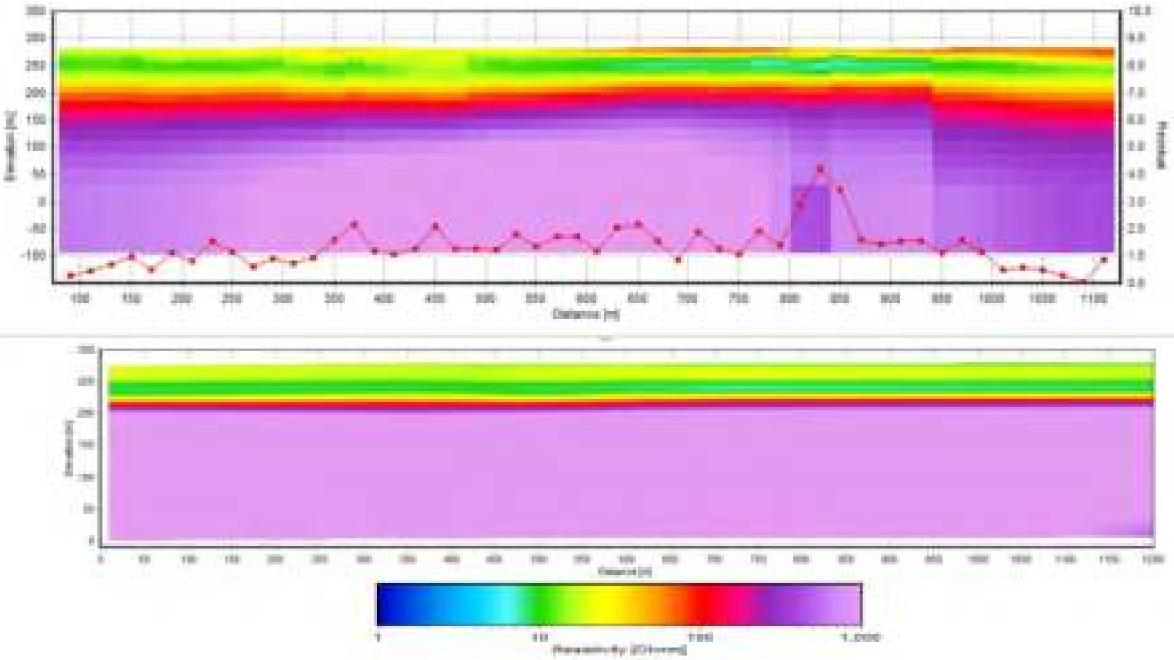


Figure 84. ERT and SkyTEM resistivity section at Nurpur Basada village.

Overall, SkyTEM survey with dense and high quality data has added great value in mapping the subsurface that revealed several features of high significance in terms of groundwater occurrence and dynamics and hence aquifer mapping.
Alll the images are given in appendix-II

4.4 MAJOR FINDINGS

The field campaign was performed and good quality data were obtained. The collected data were afterwards carefully processed to remove couplings and noise before the inversion. The inversion was done with a smooth model using the spatially constrained inversion (SCI) approach.

The SkyTEM data gave a new and comprehensive three-dimensional picture of the subsurface. The low moment data ensured the high resolution mapping of near surface and high moment data to the deeper level. Thus the dual moment provided high resolution mapping of the subsurface from top to ~ 200 m depths. The results revealed a clear contrast between the ranges of resistivity of alluvial (i.e. up to 100 ⍰m) and quartzite/granite hard rock (80 – 1000 ⍰m). The sandy layers are found with the esis-tivities ranging from 15-35 ⍰m. The sand layers that form the porous horizon for groundwater occurrences in the top alluvial were clearly mapped. Both the HeliTEM as well as HeliMAG are found effective in mapping aquifers in the alluvial cover and the underlying bedrock with high degree of folding and faulting in the western and northwestern parts. The results revealed a strong bearing of structural features on the groundwater dynamics.

The efficacy of the dual moment SkyTEM surveys in delineating the 3D configuration of aquifers is clearly established. Results of the heliborne surveys correlated well with the available geological, hydrogeological and borehole information logs. Combining all the borehole logs, surface and heliborne data have been put together with the drilling log and integrated lithologs are prepared at point scale, which were used to calibrate and interpolate the SkyTEM data of the entire area to demarcate the principal litho interfaces and finally convert them into aquifer maps including the groundwater quality. Lithological and hydrogeological sections are prepared demarcating clearly the tectonic features and disposition of principal aquifer and aquitard.

A comparative performance of the VES, ERT, G-TEM and SkyTEM revealed that the SkyTEM survey with dense and high quality data has added great value in mapping the subsurface that revealed several features of high significance in terms of groundwater occurrence and dynamics and hence aquifer mapping.

The salient deliverables resulting primarily from the heliborne geophysics in this area are the delineation of:

- Sand and clay beds within the alluvium overlying the bedrock and their lateral continuity,
- Quartzite bed rock throughout the area,
- Fracture zones in quartzite underlying the alluvium at places and their lateral extents which could form potential aquifers at depths in hard rock,
- Cavernous limestone forming the aquifer in NW part,
- The subsurface extent of geologic structures and their impacts on aquifer dispositions,
- Brackish/saline groundwater zones at depths,
- Subsurface channel continuing down to quartzite bedrock and its connection with the present river course,
- Near surface sand predominance layers suitable for artificial recharge structure and selection of sites for drilling on the basis of the inferences drawn from heliborne surveys.

4.5 PERFORMANCE MATRIX

The result and outcome of various geophysical methods employed in the project area are summarized in the following tables

Table 29. Performance of SkyTEM in Aquifer Mapping in Baswa-Bandikui watershed, Dauas district, Rajasthan

Hydrogeology	**Objective/Target**	**Status / Achievements**				**Remarks & Additional Achievements**
		Delineated	**Partially Delineated**	**Not Delineated**	**Reason for non-Delination**	
35-70 thick alluvium overlying the hard rock (quartzite)	Aquifers in the alluvial covers	Yes	-	-	-	*Weathered-fractured quartzite has been delineated in majority of the places of low DOI due to saline zone overlying hard rock. A 50-60 m wide subsurface channel continuing from alluvium to quartzite bedrock to the depth of 40 – 60 m has been delineated. The subsurface extent of geologic structures have been identified
	Aquifers within underlying weathered-fractured hard rocks	-	Yes*	-	-	

Table 30. Performance of various Geophysical methods in Aquifer Mapping in Baswa-Bandikui watershed, Dausa district, Rajasthan

Hydrogeological Objective	Geophysical Objective	Performance of Geophysical Methods Used					Borehole Logging
		Surface			Heliborne		
		VES	GRP	TEM	TEM	MAG	
Sand and Gravel aquifers in alluvium	Moderately Resistive Layers	1	NA	2	1	NA	1
Weathered zone aquifer	Moderately Resistive layers	4		4	2	NA	1
Fractured zone aquifers	Relatively low Resistivity (fracture) zones in the underlying highly resistive bed rock	3		4	3	NA	3
	Geological Structures	5		5	NA	1	NA
(Maximum depth – 200 m)							

Index on Five point Scale : 1- Excellent, 2 – Very Good, 3 - Good, 4 - Fair, 5 – Poor, NA – Not Applicable

4.6 PROTOCOL FOR UP-SCALING THE FINDINGS OF GEOPHYICAL METHODS IN SIMILAR HYDROGEOLOGICAL TERRAIN CONDITIONS

The advanced Geophysical techniques can be applied in an area of ~464783 sq.km. in North-western India based on the parameters mentioned in table 31.

Table 31. Parameters for up-scaling the advanced Geophysical techniques in National Aquifer Mapping

Upscaling Parameters	Quantity/ Nos.
Heli TEM	Dual Moment
Flight/ Tie Line Spacing	1/10 km
Frequency	12.5 – 25 Hz
Additional Ground based measurements	G-TEM, Drilling, logging, Water Quality
Deliverables	High Resolution 3-D Aquifer maps with Characterization

Following supplementary survey needs to be carried out in this region –

1. A few G-TEM to cover the non-flown area as well as to supplement the HTEM survey.
2. A number of ERT to determine the boundary conditions.
3. Selected drilling for validation and calibration of Heliborne survey
4. Water quality measurement to apply suitable correction.

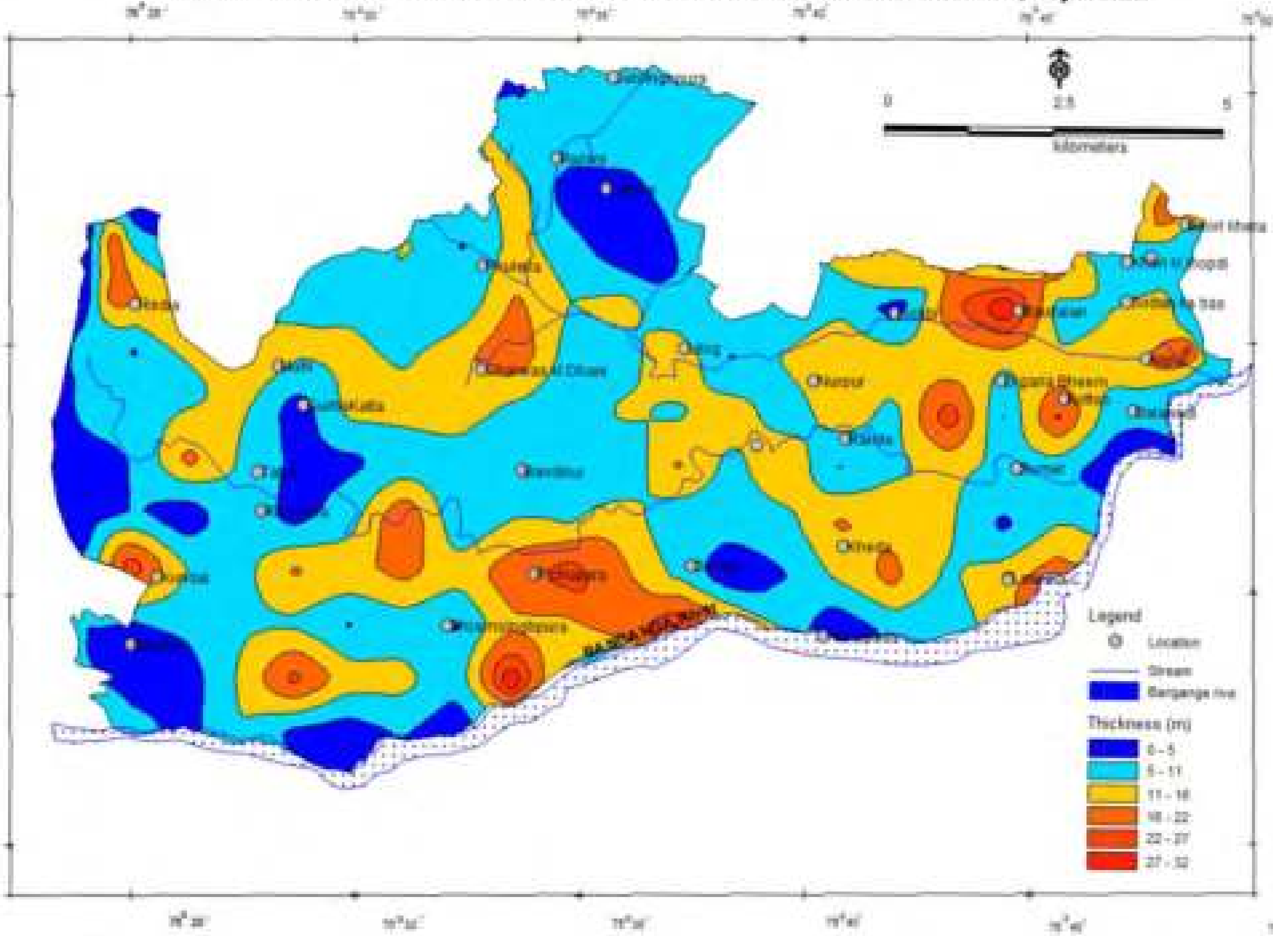
5. GENARATION OF AQUFIER MAP

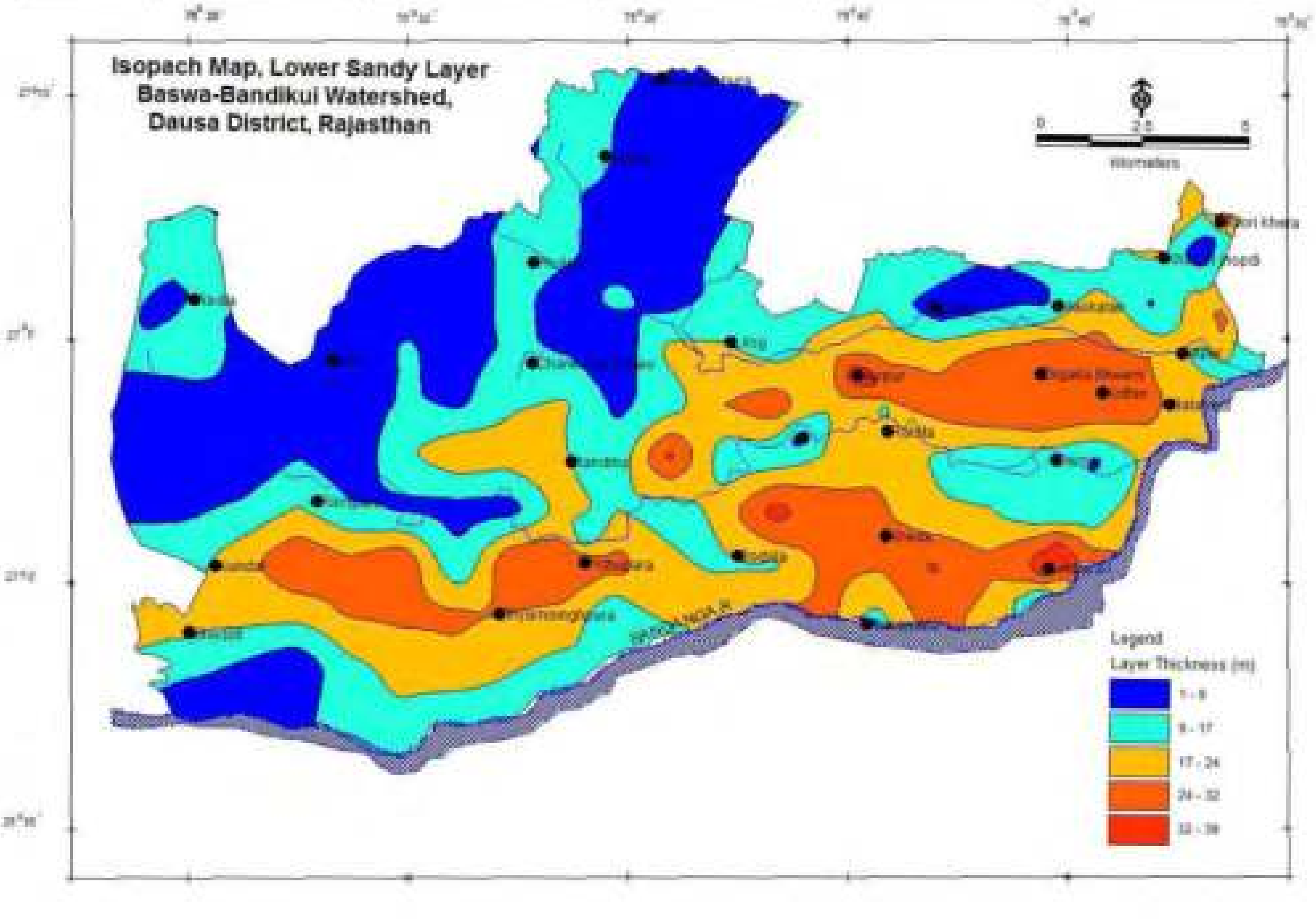
5.1 Aquifer Disposition

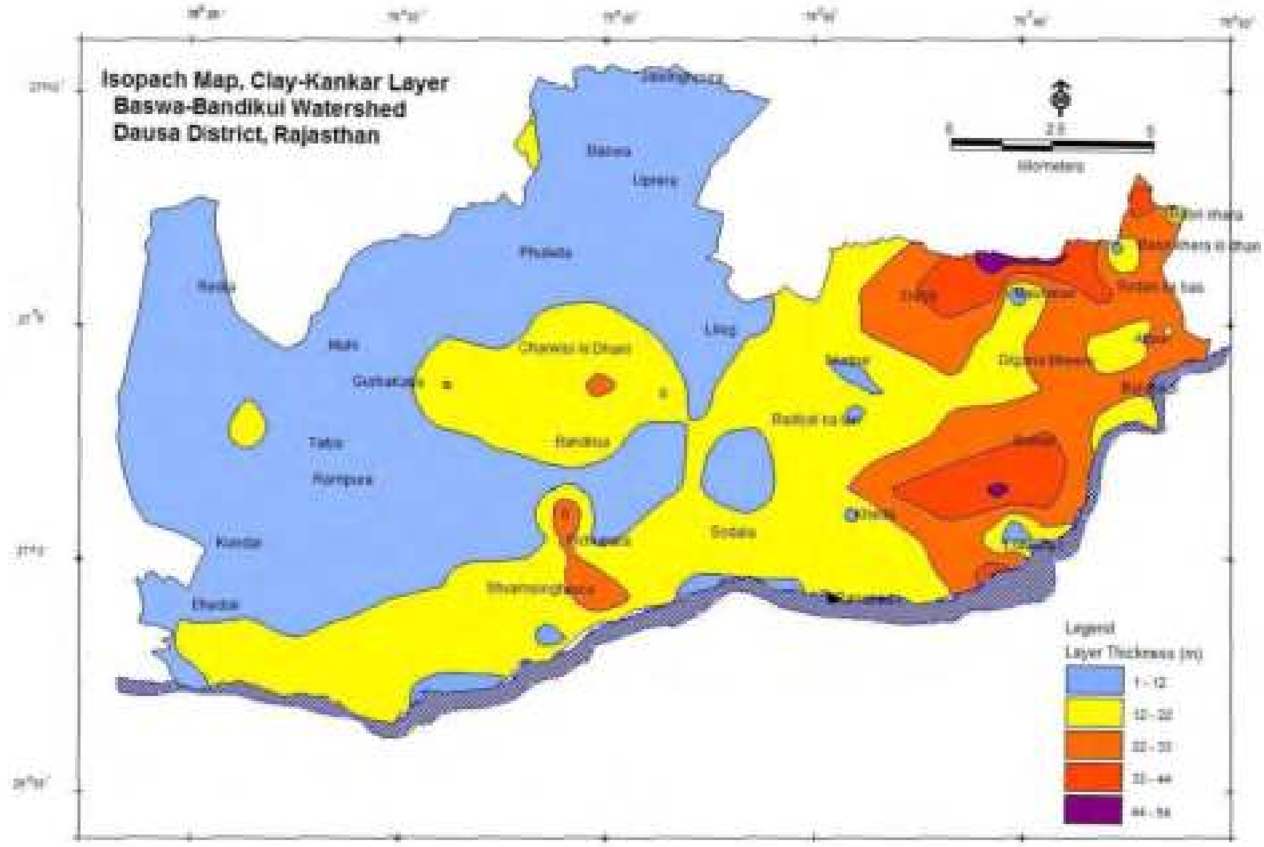
The integrated lithological layers are generated using borehole data and advanced geophysical techniques. The layers are broadly classified into - Bed Rock, Weathered Hard Rock, Lower sand dominated layer (Sand 2), Clay dominated layer and Upper Sand dominated layer (Sand 1). Isopach maps of weathered hard rock, lower sand, clay and upper sand are generated (Figure 85).

Thickness of weathered hard rock in major part of the study area is between 5 m to 20 m. Thickness of weathered hard rock is uniformly distributed through out the Baswa-Bandikui watershed. Thickness of more than 25 m are encountered only at 2 places, at the south-central corner and north-eastern corner. Thickness of lower sand is distinctly more in the eastern part of the study area where it is between 10 m and 20m than in the western part, where it is within 10 m in major part of the area. Clay layer also follow the similar trend as that of lower sand. Thickness is more in the eastern side than in the western side. In the western side it is within 10m and in the eastern side, it is from 10 m to 30m. Upper sand layer also has more thickness in eastern side (10m to 30m) than in western side (within 20m). The 3-D aquifer models are depicted in Figure 86.

Isopach map, Weathered rock, Baswa-Bandikui watershed, Dausa district, Rajasthan







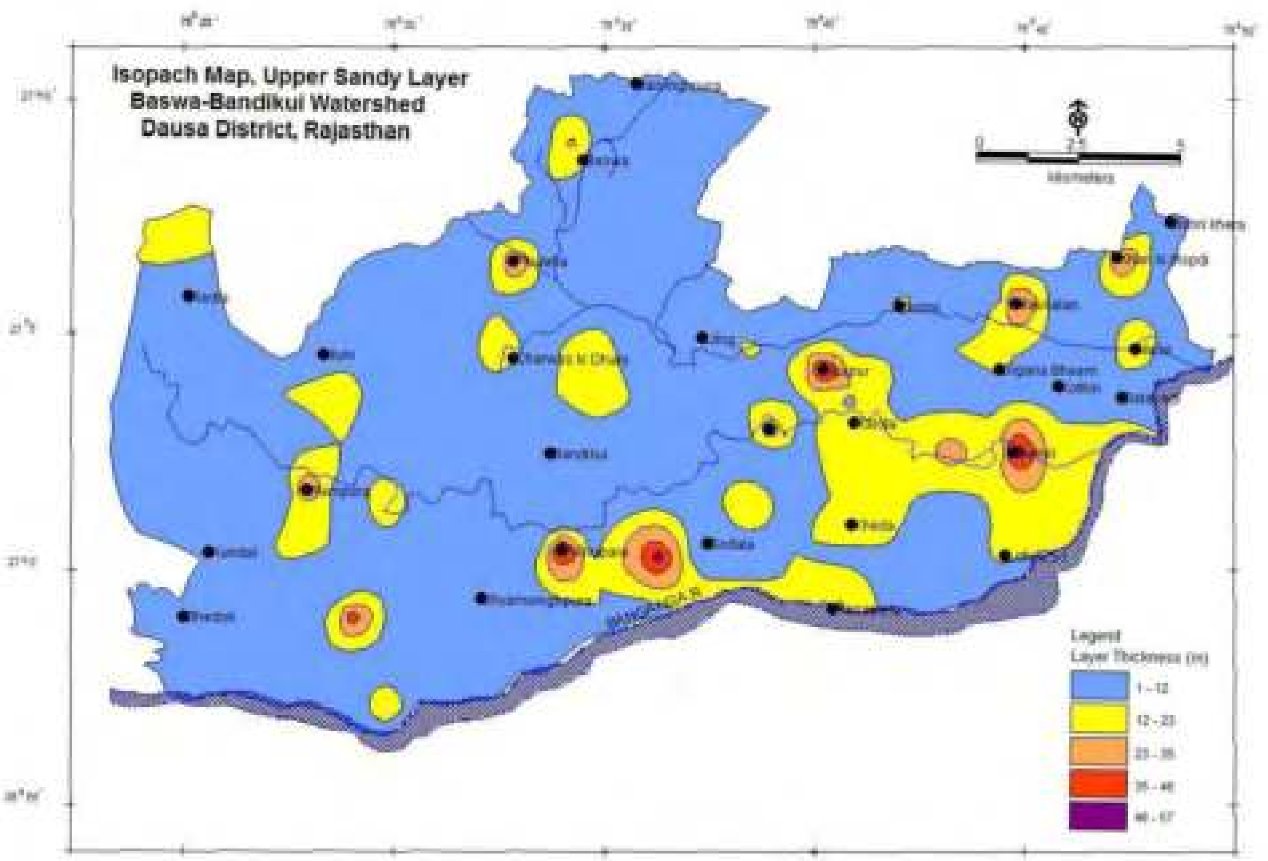


Figure 85. Isopach maps of the Aquifer Layers, Baswa-Bandikui Watershed, Dausa.

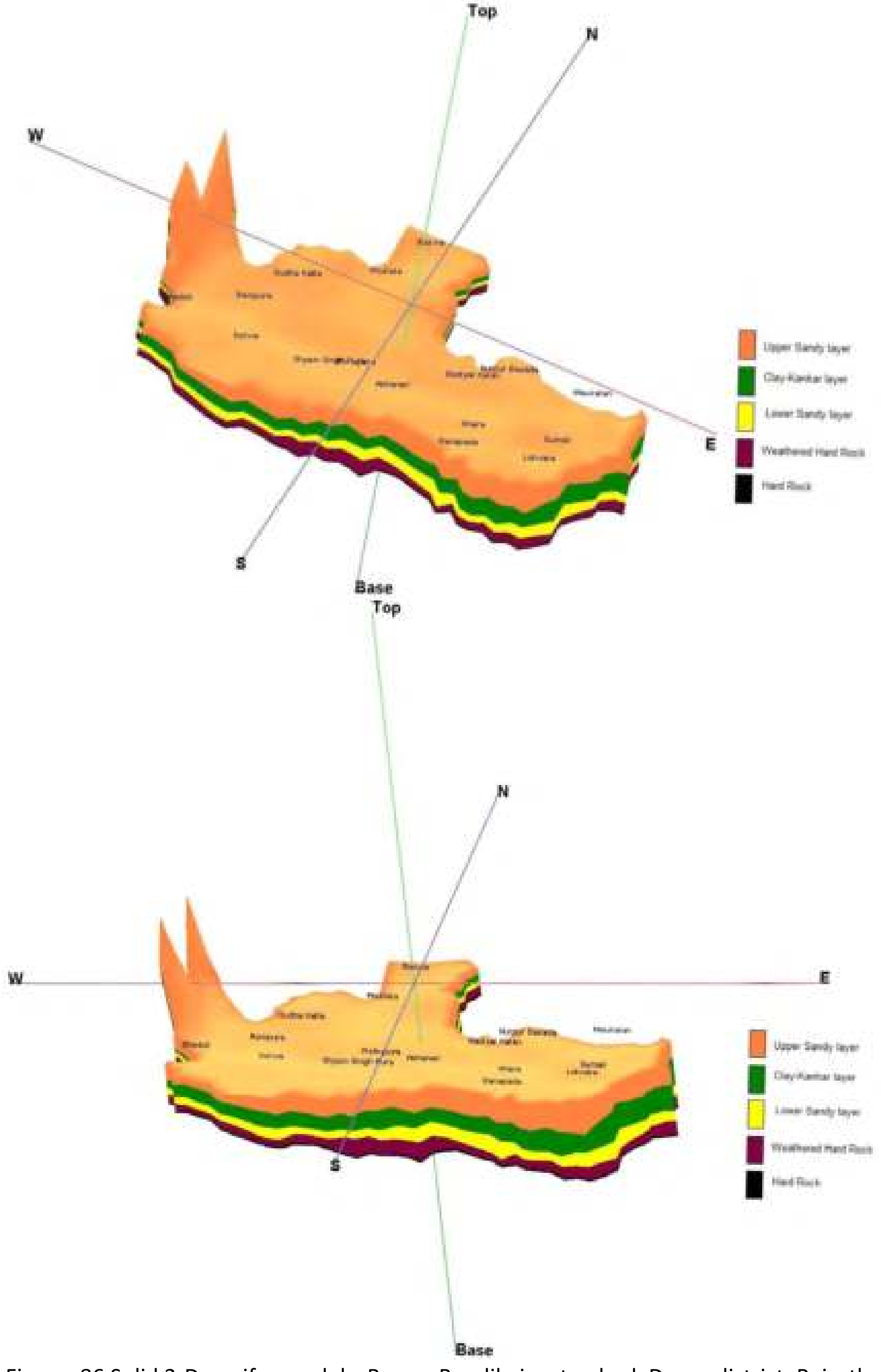


Figure. 86 Solid 3-D aquifer models, Baswa-Bandikui watershed, Dausa district, Rajasthan

Volumetric analysis of the lithological layers indicate that the alluvium formation has about 24,000 cubic km of volume while the Weathered hard rock formation has about 6000 cubic km of volume. Hence, in case source water is available, the alluvium aquifer can be suitably recharged to mitigate the water crisis in the area. The details are given in Table 29 and Figure 87.

Table 32. Volumes of lithological formations in Baswa-Bandikui watershed area, Rajasthan

Sl. no.	Lithological formation	Volume (km^3)
1	Upper Sandy layer	9,126
2	Clay-Kankar layer	8,722
3	Lower Sandy layer	6,418
4	Weathered hard rock	6,480

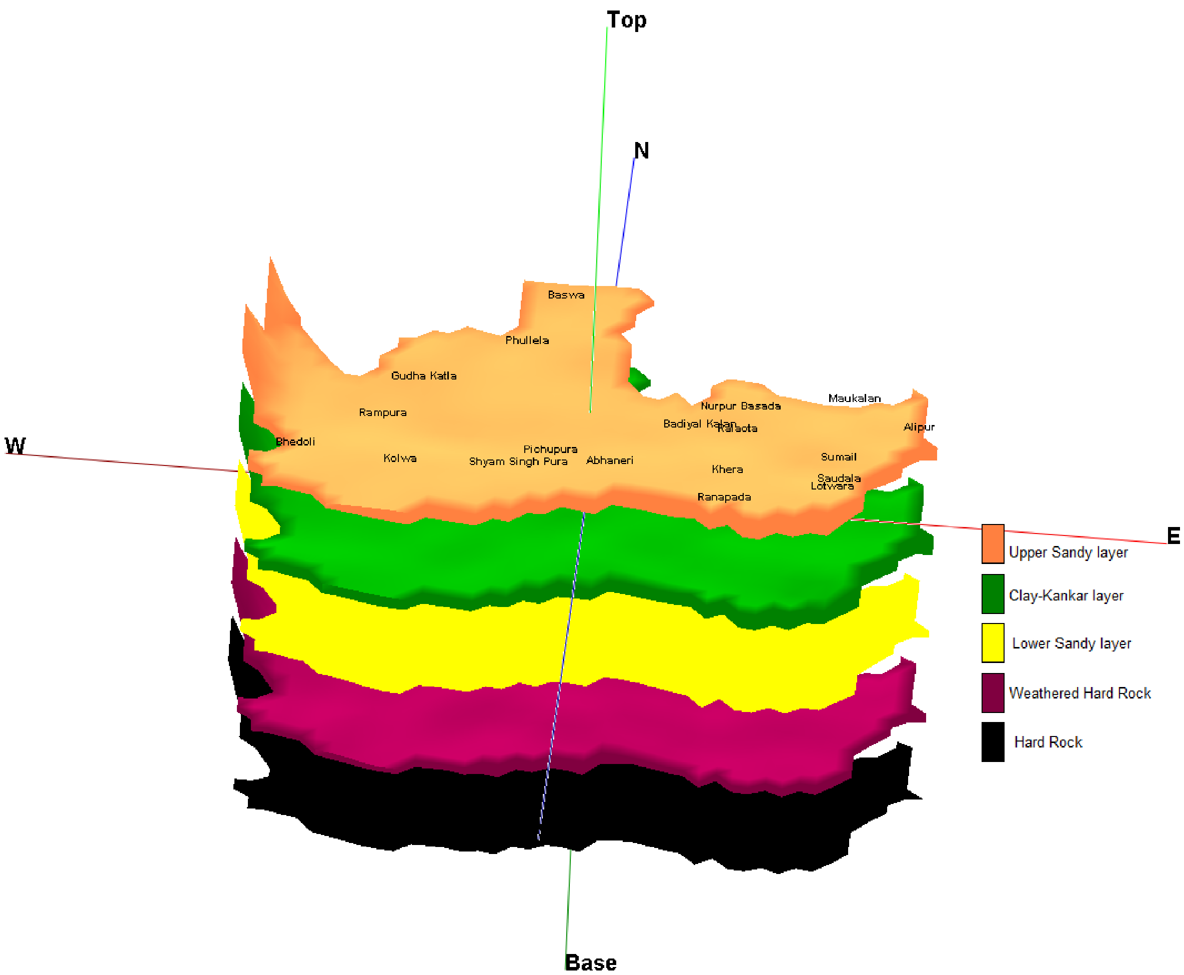


Figure 87.Lithological layers in Baswa-Bandikui watershed, Dausa district, Rajasthan

Principle aquifers in the study area have been demarcated based on the integrated lithological layers and post-monsoon water level data. The layer on depth of top of weathered rock is subtracted from depth to water level in GIS platform. Positive values of nodes indicate that on these points water level is in alluvium. Thus, two zones of saturated aquifers have been delineated - alluvium and hard rock (including weathered rock). Alluvium layers have further division into lower sand, clay and upper sand. However, these distinctions are not continuous throughout the study area. Clay is mostly associated with silt, kankar etc. At places, the clayey layer pinches out and found to be juxtaposed against sand layer. The alluvium aquifer has therefore been considered as a single principle aquifer in semi-unconfined condition. Similarly, hard rock aquifer has been considered to be the principle aquifer. In absence of detailed ground water exploration in hard rock areas, further sub-division of hard rock aquifer is not possible. The Figure 88 to Figure 90 presents the maps showing weathered rock elevation, water level and aquifer map of Baswa-Bandikui respectively. Two principle aquifers have been delineated in the area - Aquifer I, upper aquifer, Alluvium and Aquifer II, lower aquifer, Hard rock.

The 3-D aquifer disposition depicting the water table extent within aquifers is shown in Figure 91.

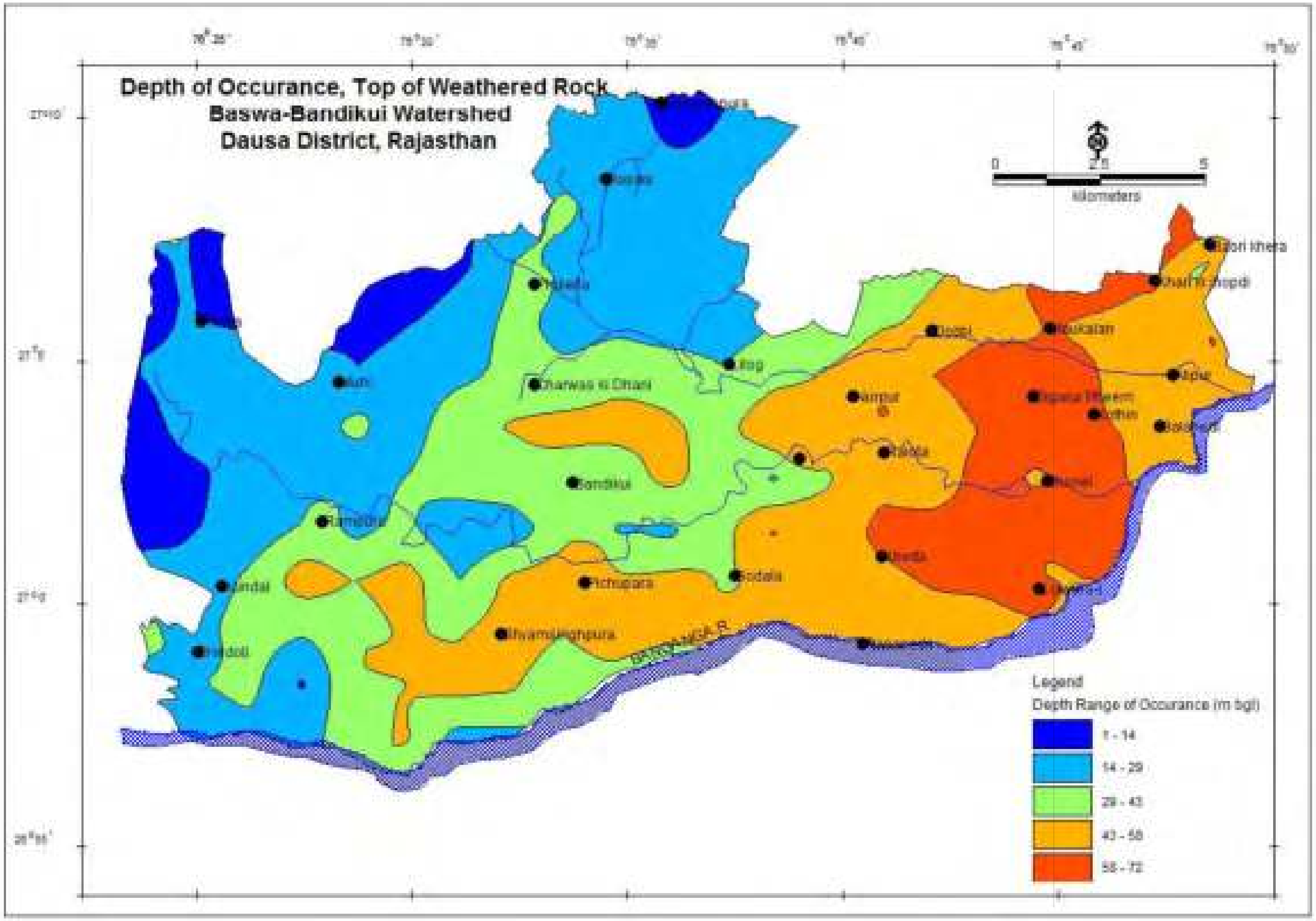


Figure 88. Map showing depth of top of weathered rock in Baswa-Bandikui watershed, Dausa district, Rajasthan

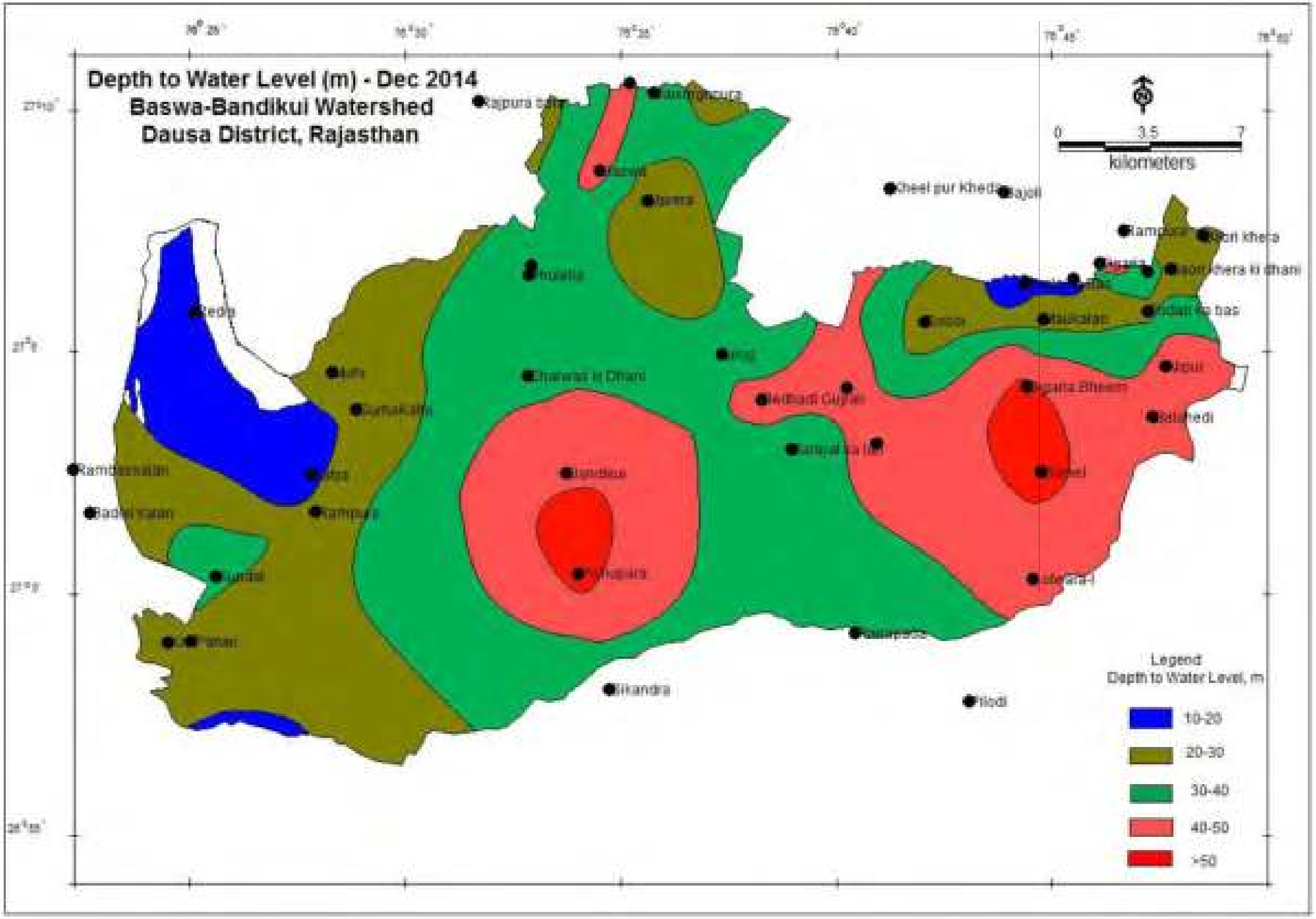


Figure 89. Map showing elevation of post-monsoon water level in Baswa-Bandikui watershed, Dausa district, Rajasthan

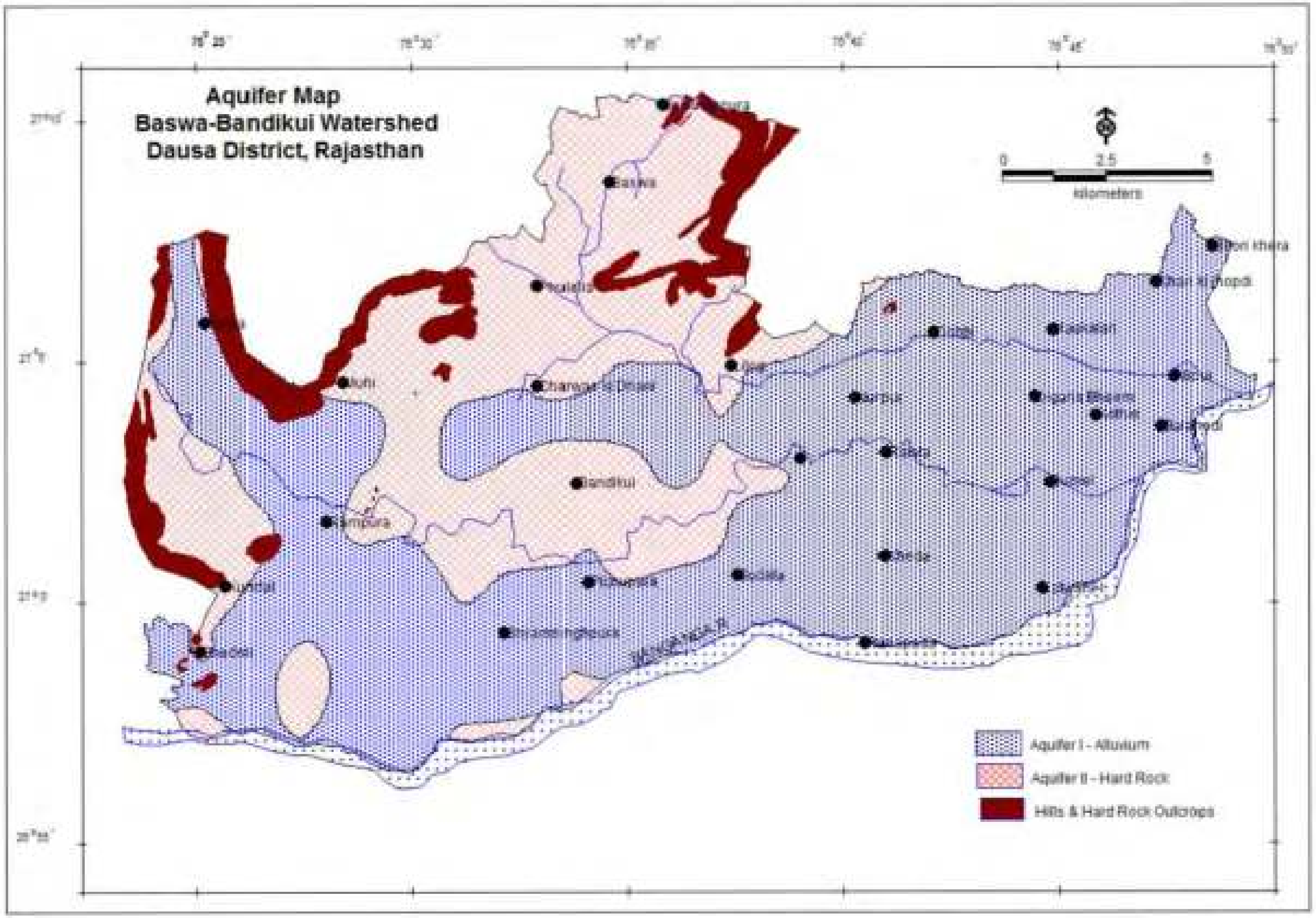


Figure 90. Aquifer disposition in Baswa-Bandikui waterhsed, Dausa district, Rajasthan

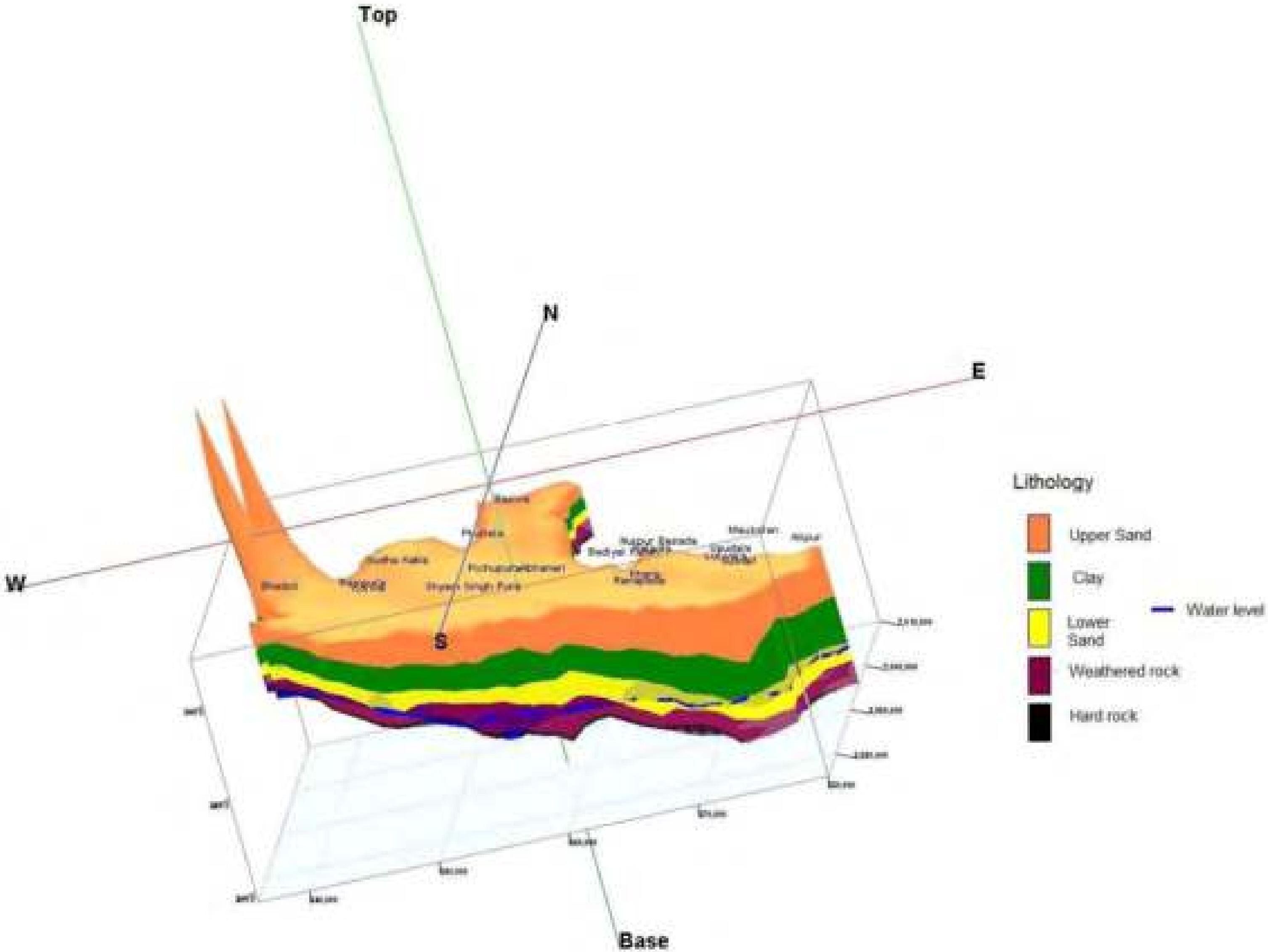


Figure 91. 3-D depiction of Water table within aquifer systems in Baswa-Bandikui watershed, Dausa district, Rajasthan

5.2 Aquifer Characterization

The various attributes of the two aquifers viz. aquifer I (alluvium) and aquifer II (hard rock) are described in the following paragraphs. The characteristics of the aquifers dealt in this section include – water level, water quality and hydraulic characteristics.

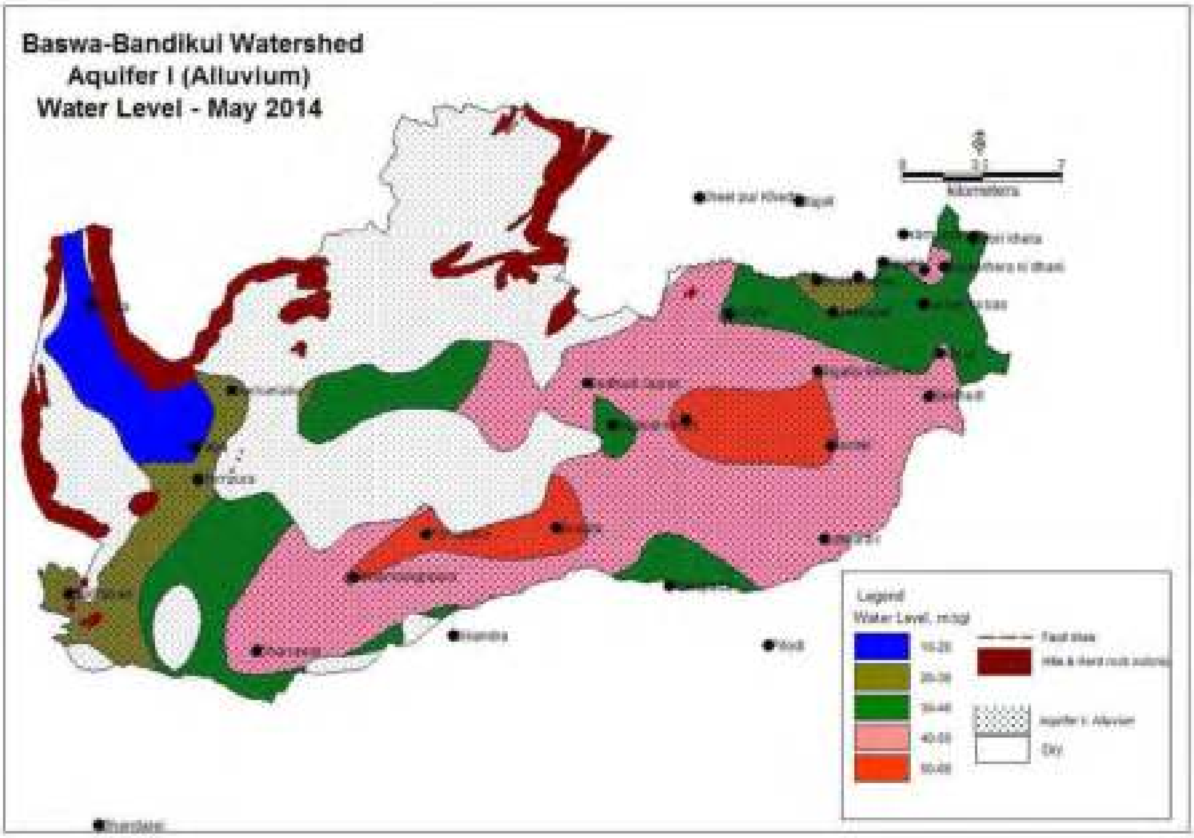
5.2.1 Water level

Ground water level monitoring was carried out in the project area using dug wells, piezometers and tubewells (private owner). Since dug wells and private tubewells are not dedicated monitoring stations, at many places, these structures have tapped both the alluvium and hard rock. In order to fill up the data gap, these ground water structures are also used for monitoring. The maps generated for water level and water table of aquifer I i.e. alluvium have thus considered both the wells tapping exclusively alluvium and wells tapping both alluvium and hard rock. Maps for aquifer II is similarly consisting of wells tapping hard rock aquifer and mixed type. The aquifer-wise details of monitoring stations are given in annexure.

Aquifer I (Alluvium)

The pre-monsoon and post-monsoon water level maps of aquifer I (alluvium) are shown in Figure 92.

A perusal of the figure indicate that in major part of the western portion of Baswa-Bandikui watershed, the water level has gone below the alluvium. Thus alluvium in the western part of the project area is de-saturated except at the downstream of Redia dam on the north-western corner of the project area, where the shallowest water level within 20 mbgl has been recorded both in pre-monsoon (May, 2014) and post-monsoon (December, 2014). Depth to water level is deep in the eastern portion of the project area, deepest water level is in the range of 50 mbgl to 60 mbgl. During pre-monsoon, major part of the alluvium aquifer is characterized with 40 mbgl to 50 mbgl water level while during post-monsoon, the major area of alluvium aquifer is covered with 30 mbgl to 40 mbgl water level.



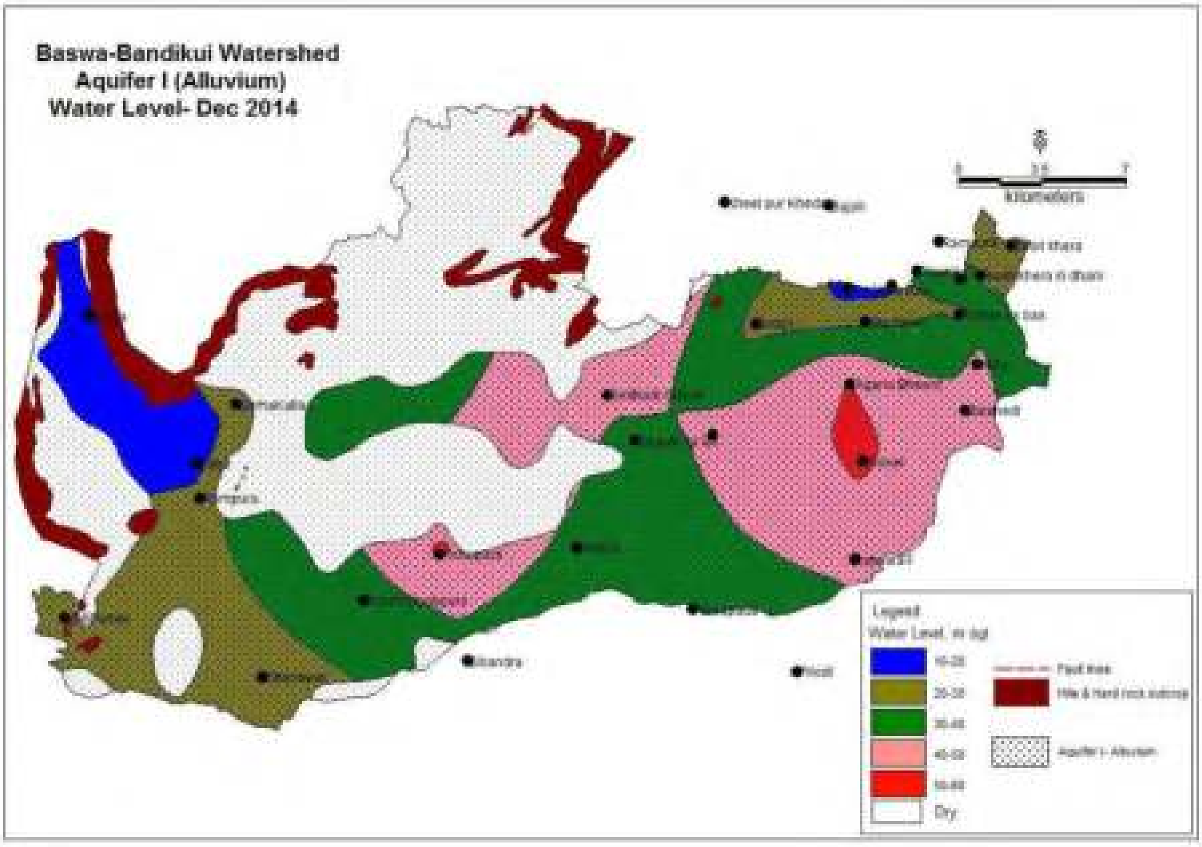


Figure 92. Pre-monsoon and post-monsoon water level in Aquifer I (Alluvium), Baswa-Bandikui watershed, Dausa district, Rajasthan

Aquifer II (Hard rock)

In Aquifer II i.e. hard rock, the major portion of the area is having water level between 40 mbgl to 60 mbgl during pre-monsoon season (May, 2014) (Figure 93). Hard rock aquifer in the southern part of the area is having deepest water level in the range of 50 to 60 mbgl. Water level is shallower in the western side corner as compared to eastern side. In western side, water level in hard rock is encountered at the depth range of 10 mbgl to 30 mbgl. During post-monsoon period (December, 2014), water level in hard rock aquifer is mostly in the range of 30 mbgl to 50 mbgl. Deeper water level in the range of 50 mbgl to 60 mbgl is found only in two small pockets. Western part of the area is having water level between 10 mbgl to 30 mbgl as was the case during pre-monsoon period.

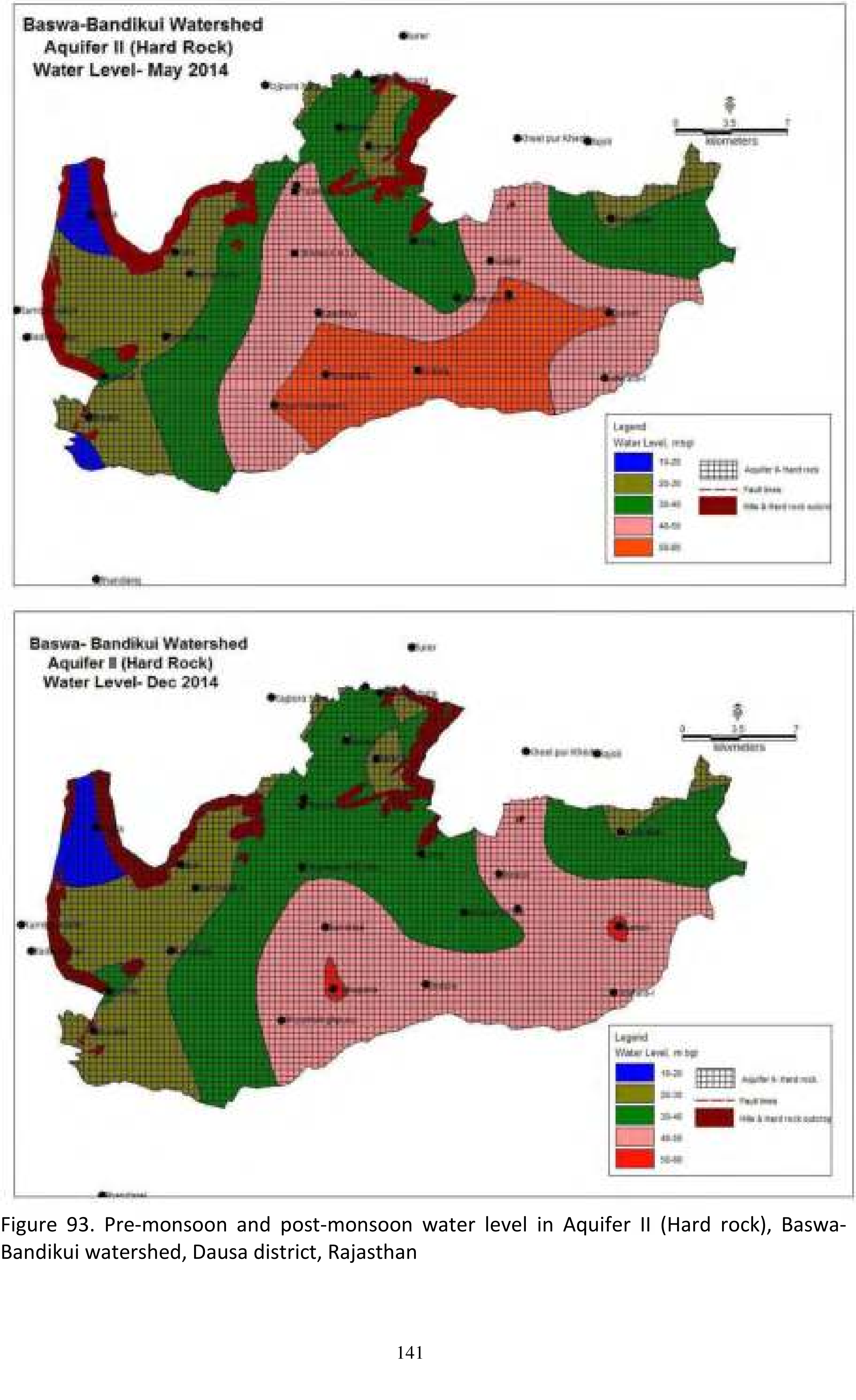


Figure 93. Pre-monsoon and post-monsoon water level in Aquifer II (Hard rock), Baswa-Bandikui watershed, Dausa district, Rajasthan

5.2.2 Water table

Aquifer I (Alluvium)

The pre-monsoon and post-monsoon water table maps of alluvium (aquifer I) are shown in Figure 94a & 94b.

The pre-monsoon water table map of alluvium aquifer shows that water table varies from around 260m above mean sea level (m amsl) to around 280 m amsl in western part of Baswa-Bandikui watershed. The ground water flow direction is from west to east at north western corner which means that the surface water at Redia dam is contributing to the ground water in the summer months. In the central and eastern part, the water table is from around 200 m amsl to around 240 m amsl. The ground water flow direction is from west to east.

The post-monsoon water table map of alluvium aquifer shows that water table varies from around 200m msl to around 260 m msl in western part of Baswa-Bandikui watershed. The ground water flow direction is towards Redia dam at north western corner, which means that ground water is contributing to the reservoir at Redia dam during post-monsoon period due to shallower ground water level. In the central and eastern part, the water table is from around 200 m msl to around 260 m msl. The ground water flow direction is from west to east, same as that in summer months. In the southern part of the project area, the ground water flow direction is towards south i.e. towards Banganga river.

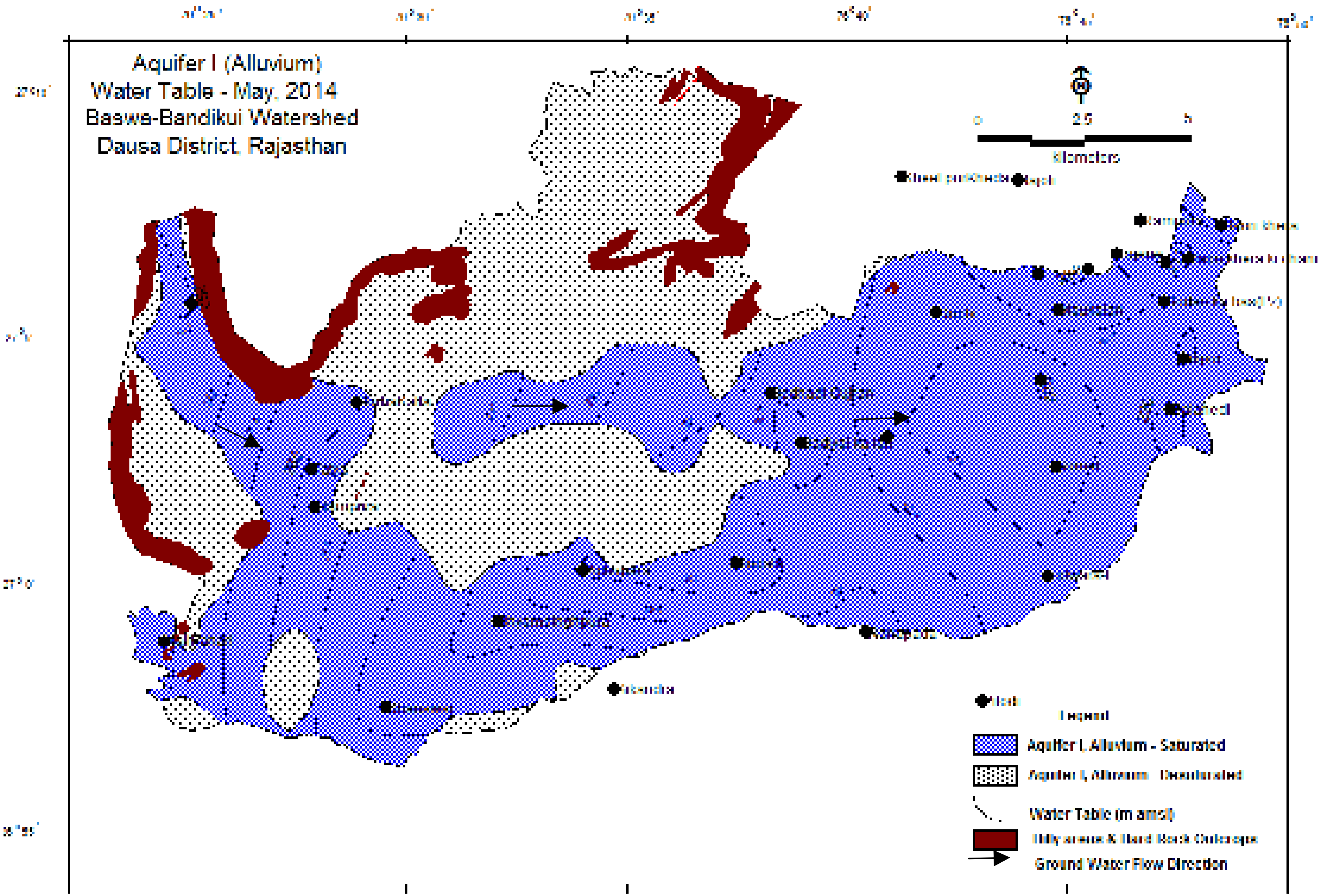


Figure 94a. Pre-monsoon water table in Aquifer I (Alluvium), Baswa-Bandikui watershed, Dausa district, Rajasthan

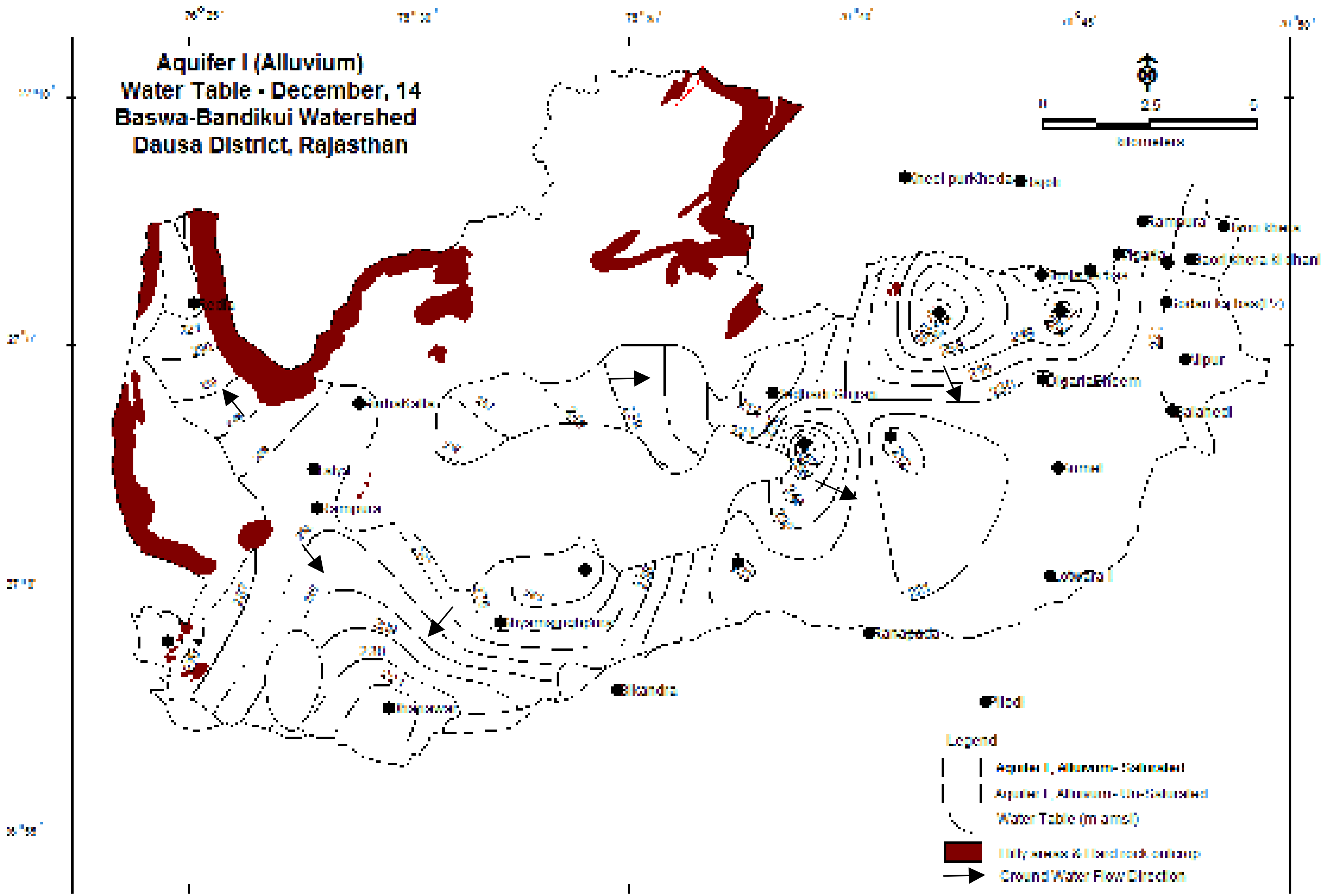


Figure 94b. Post-monsoon water table in Aquifer I (Alluvium), Baswa-Bandikui watershed, Dausa district, Rajasthan

Aquifer II (Hard rock)

The pre-monsoon water table map of hard rock aquifer (aquifer II) shows that water table varies from around 260m above mean sea level (m msl) to around 300 m msl in western part of Baswa-Bandikui watershed (Figure 95a and 95b). The ground water flow direction is from west to east at north western corner which means that like in alluvium aquifer, the surface water at Redia dam is contributing to the ground water in hard rock aquifer in the summer months. In the central and eastern part, the water table is from around 200 m msl to around 240 m msl. The ground water flow direction is from west to east.

The post-monsoon water table map of hard rock aquifer shows that water table varies from around 220m amsl to around 260 m amsl in western part of Baswa-Bandikui watershed. The ground water flow direction is towards Redia dam at north western corner, which means that ground water is contributing to the reservoir at Redia dam during post-monsoon period due to shallower ground water level. A ground water mound is formed in the north-south alignment along Muhi-Gurhakatla-Rampura belt. The ground water flow direction west of the belt is towards west and east of the belt is towards east. In the central and eastern part, the water table is from around 200 m amsl to around 260 m amsl. A ground water trough is formed along the north-south direction in the western part of the project area along Nurpur Basada-Ralaota belt. The ground water flow directions are converging along this belt. In general, the ground water flow direction in the eastern part of the area is towards east.

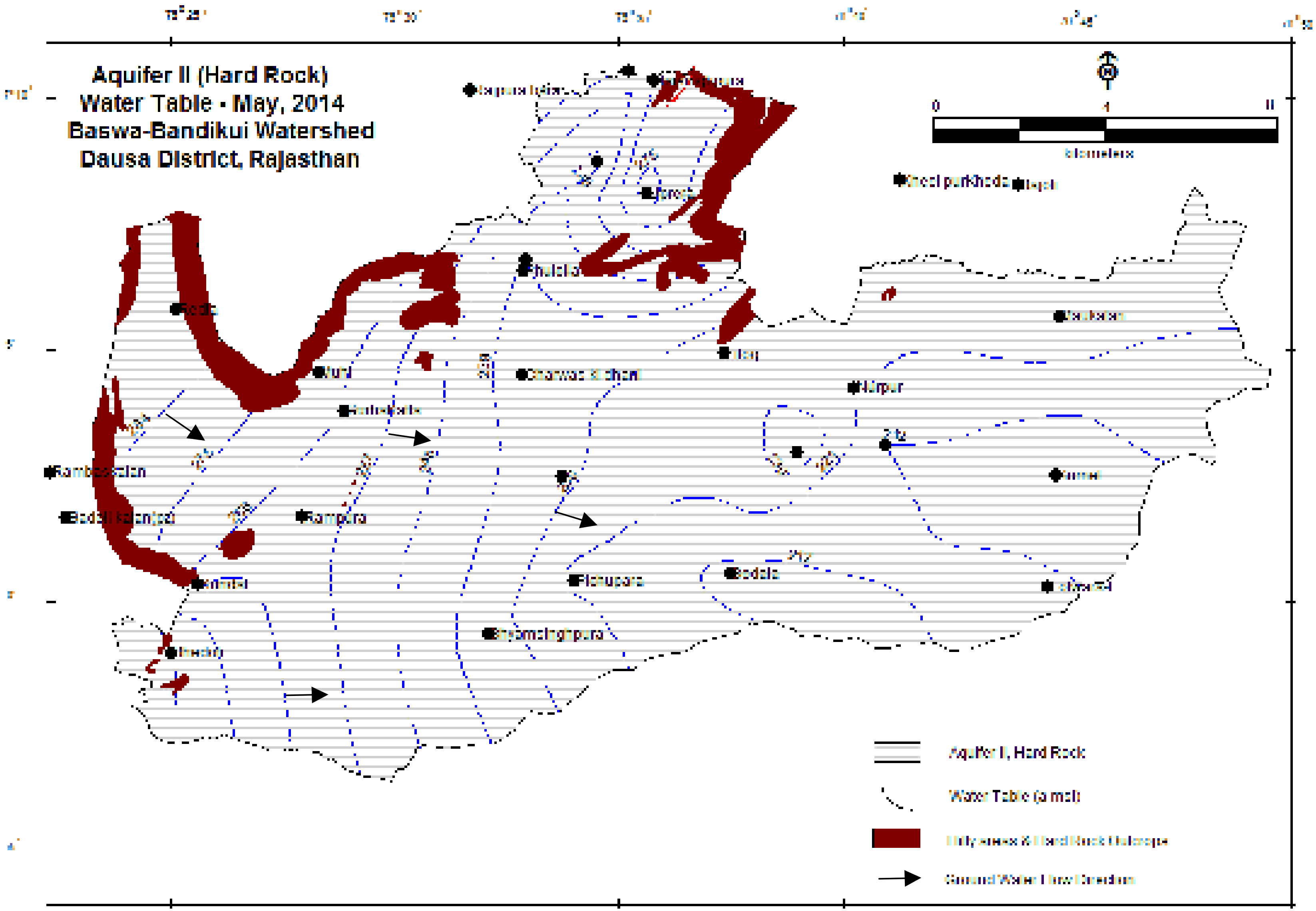


Figure 95a. Pre-monsoon Water Table in Aquifer II (Hard rock), Baswa-Bandikui watershed, Dausa district, Rajasthan

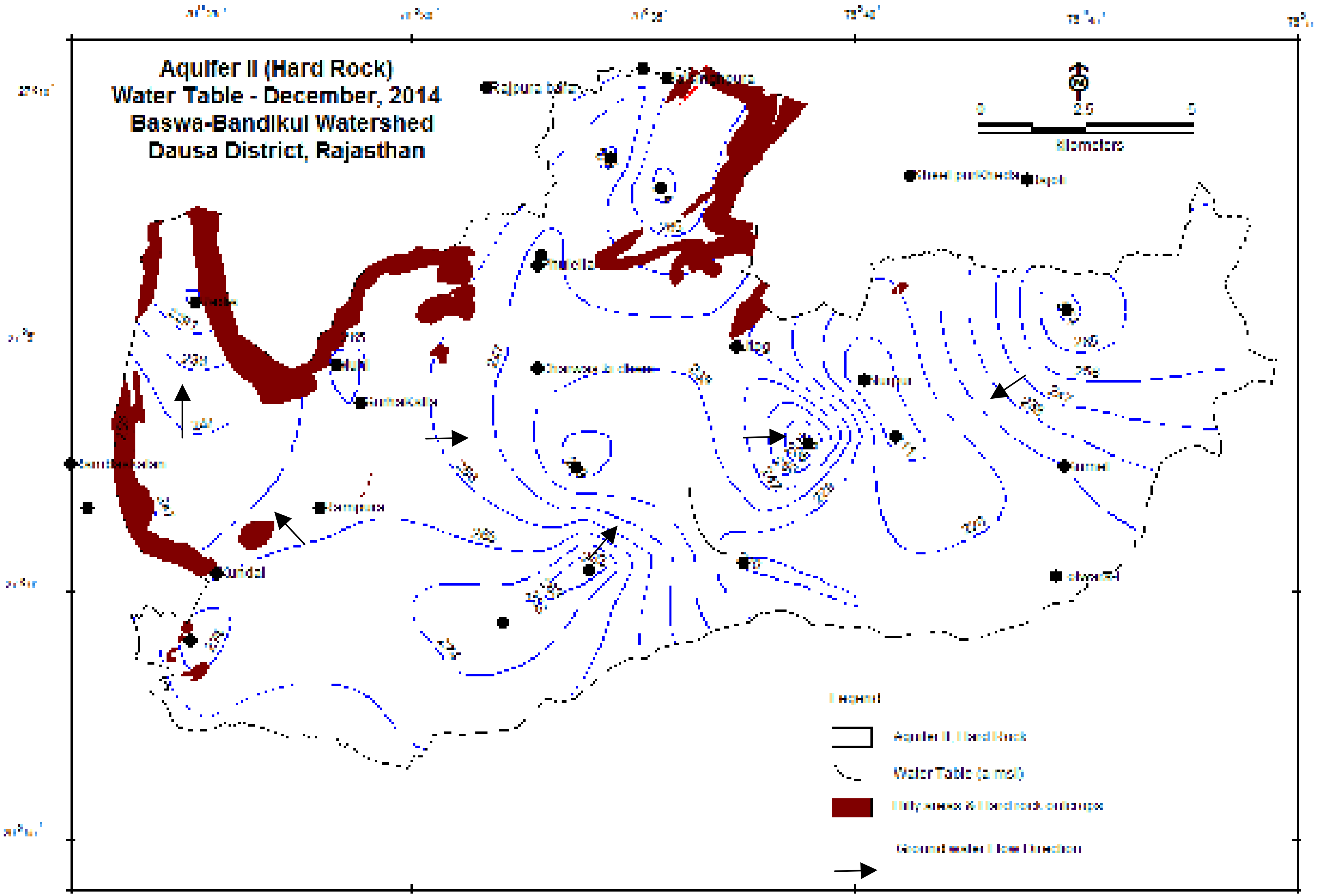


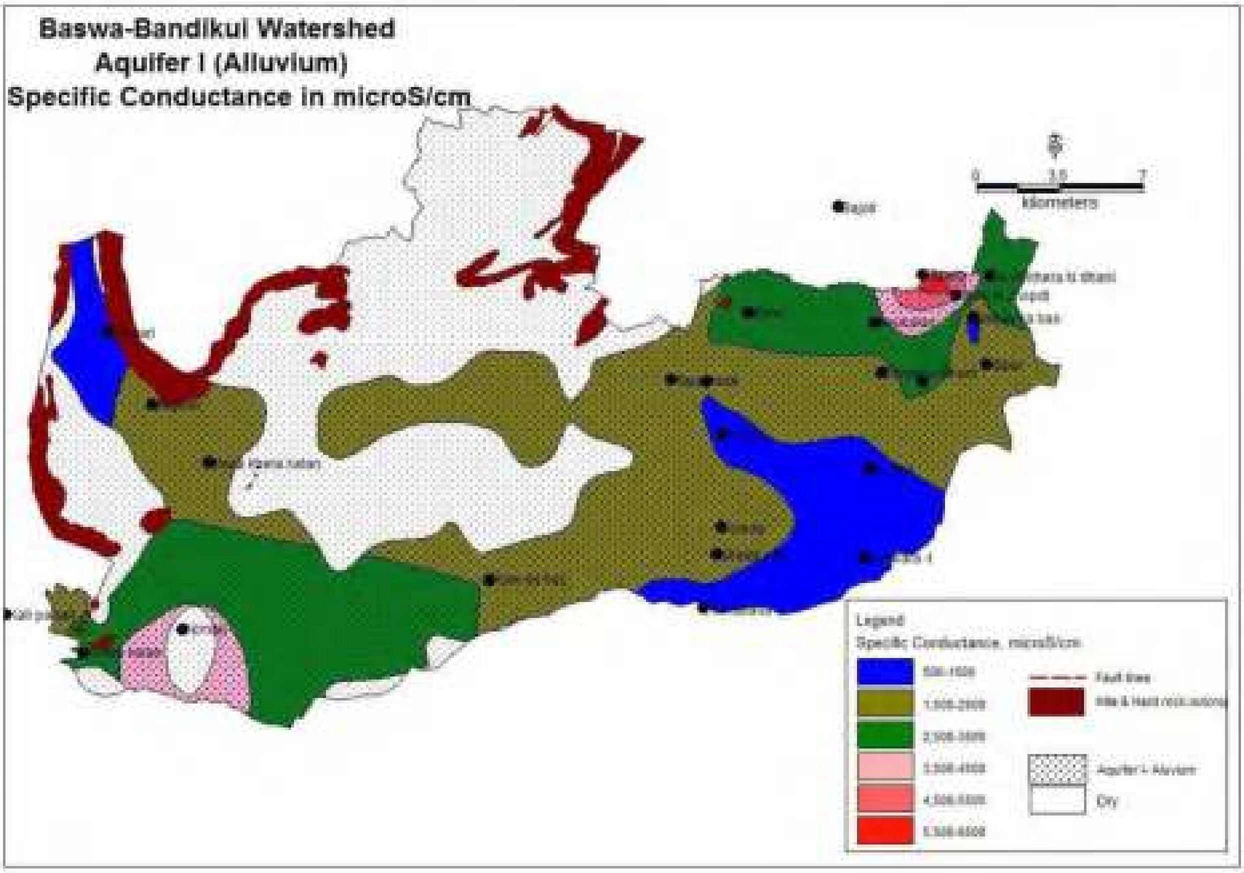
Figure 95b. Post-monsoon water table in Aquifer II (Hard rock), Baswa-Bandikui watershed, Dausa district, Rajasthan

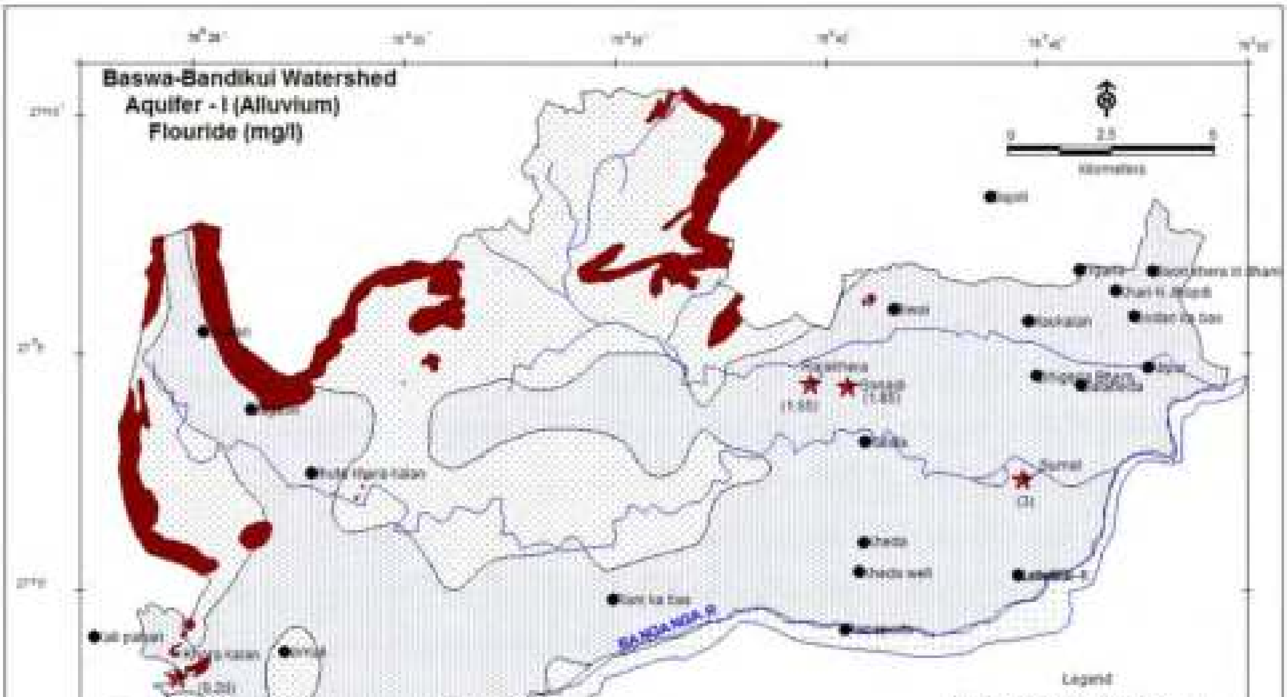
5.2.3 Water Quality

Aquifer-wise water quality information are compiled following the same approach as followed in case of ground water level monitoring described earlier in the section. The maps generated for ground water quality of aquifer I i.e. alluvium have thus considered both the wells tapping exclusively alluvium and wells tapping both alluvium and hard rock. Maps for aquifer II is similarly consisting of wells tapping hard rock aquifer and mixed type (Figure 96).

Aquifer I (Alluvium)

The perusal of the above maps indicate that the electrical conductivity is within 3500 micromhos/cm in the alluvium aquifer of the project area except for two very small patches in the south-west corner and north-east corner of the area, where it is more than 3500 micromhos/cm. The water quality of alluvium aquifer is therefore fresh to brackish in nature. The flouride content in ground water of alluvium aquifer is within the permissible limit of 1.5 mg/l in major part of the project area except for small patches around Rajahera and Sumel in the east and Khorakalan in south-west part of the area. The distribution of flouride contamination in alluvium aquifer thus indicates that it is of localised nature and not effected the major part of the aquifer. The nitrate content in ground water of alluvium aquifer is also within desirable limit of 45 mg/l except for north-east corner around Biwai-Maukalan belt. Irrigation water quality as par US salinity classification is C2S1 and C3S2 in major part of the area. A considerable part of eastern belt of alluvium aquifer is categorized as C4S4, which is not considered to be suitable for irrigation.


Baswa-Bandikui Watershed
Aquifer I (Alluvium)
Specific Conductance in microS/cm
Kilometers
Legend
Specific Conductance, microS/cm
Fault lines
Aquifer I- Alluvium
Dry


Baswa-Bandikui Watershed
Aquifer - I (Alluvium)
Flouride (mg/l)
Kilometers
Legend
Aquifer I (Alluvium) - Saturated
Aquifer I (Alluvium) - Un-saturated
Hilly areas & Hard rock outcrops

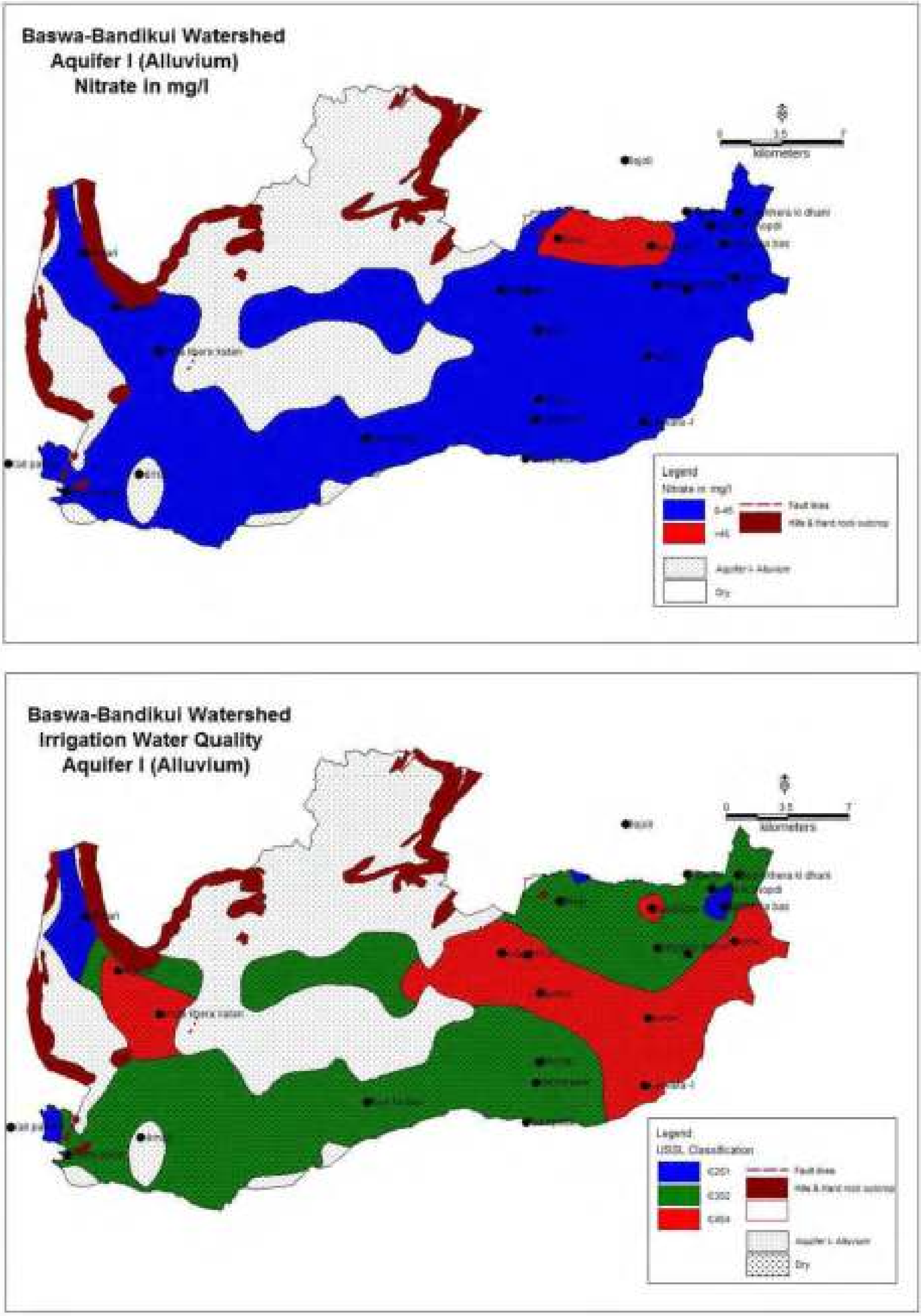
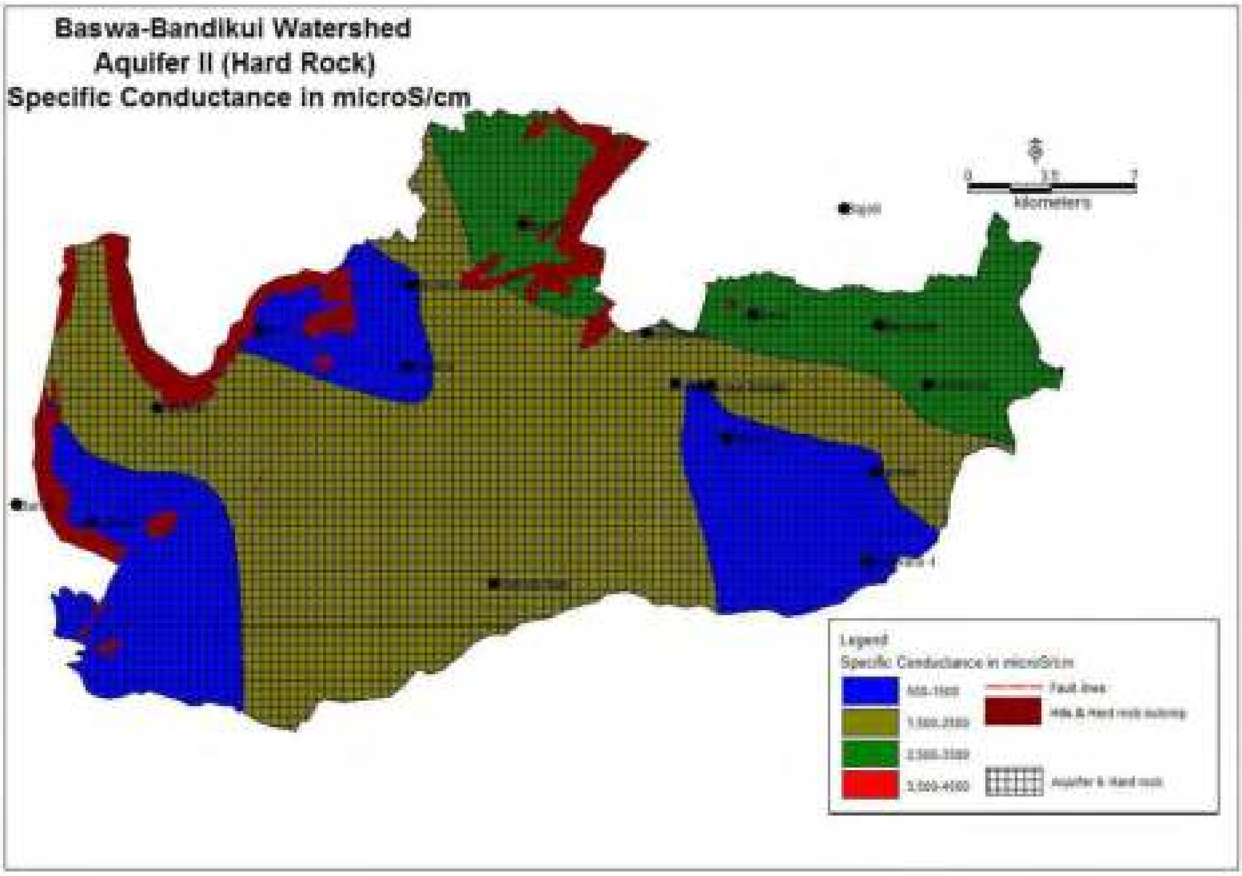
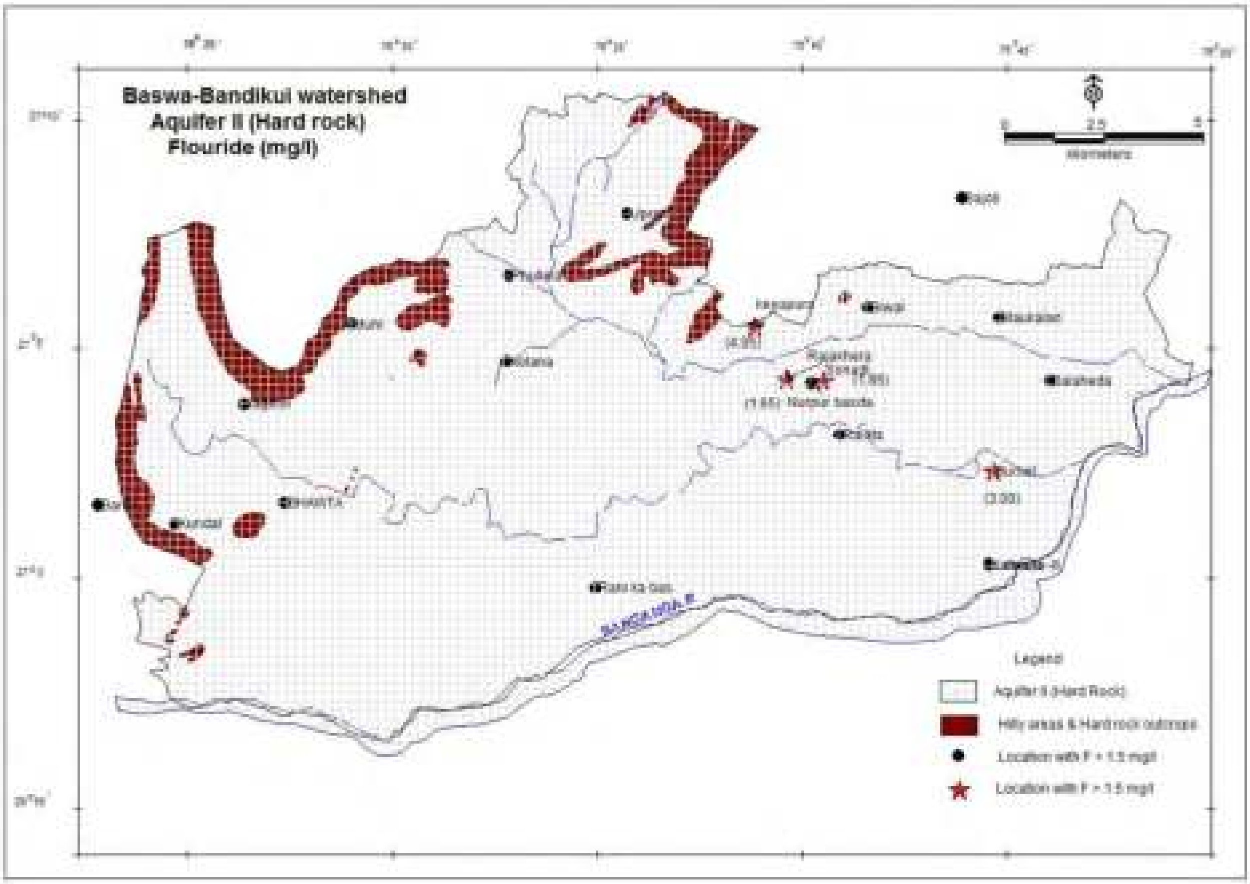


Figure 96. Ground water quality in alluvium aquifer

Aquifer II (Hard rock)

Specific conductance of the hard rock aquifer is within 3500 micromhos/cm, thus the water is potable to slightly brackish. The flouride in the hard rock aquifer is mostly within permissible limit of 1.5 mg/l, except for a small patch in north-east part in Keshupura-Nurpur Basada belt and in the east, around Sumel belt, where flouride content in ground water is higher than the permissible limit. The high flouride concentration could be due to the presence of flouride rich minerals in the aquifer. Nitrate content in ground water is within 45 mg/l (permissible limit) in the hard rock aquifers of the project area except for a patch in the north-east corner around Biwai-Maukalan (Figure 97). In this small pocket, nitrate content is more than 45 mg/l, indicating biogenic contamination. The irrigation water quality as per US classification is within C3S4 in the hard rock aquifer except few samples which comes under C4S4 classification. Overall, it can be concluded that the quality of water in hard rock aquifer is better than alluvium aquifer.


Baswa-Bandikui Watershed
Aquifer II (Hard Rock)
Specific Conductance in microS/cm
kilometers
Legend
Fault lines


Baswa-Bandikui watershed
Aquifer II (Hard rock)
Flouride (mg/l)
Legend
Rajpura
Kotana
Phulwara
Nangal Banjara
(4.00)
(1.65)
(1.90)
(3.00)
BHANTA
Kundal

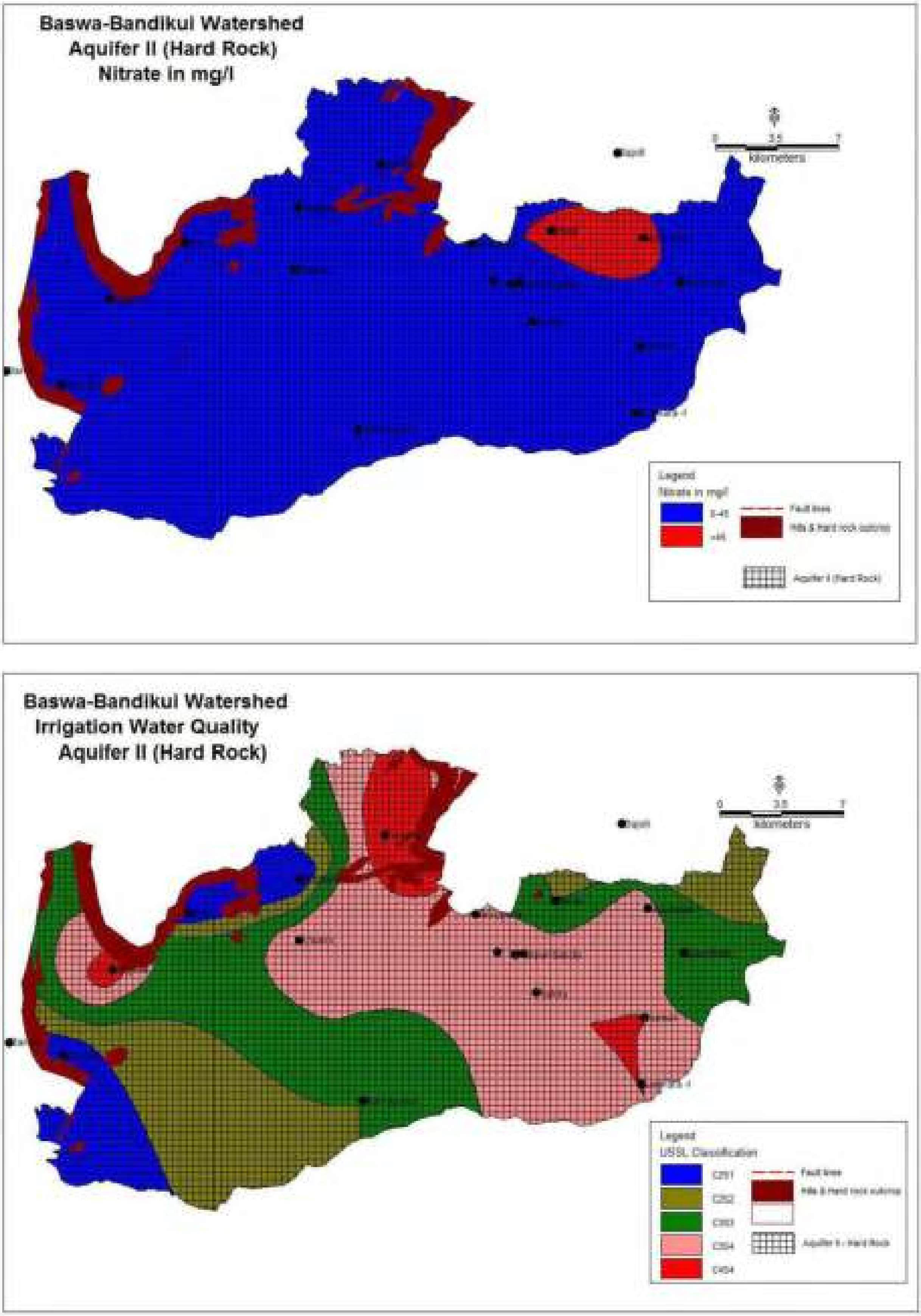


Figure 97. Ground water quality in hard rock aquifer

5.2.4 Hydraulic properties of aquifers

Hydraulic properties of aquifers are evaluated through aquifer test which involves abstraction of water from a well at a controlled rate and observing, with respect to time, the water level changes in the pumped well and/or in one or more observation wells (Karanth, 1987).

Aquifer Test

Two types of tests were conducted in the project. Pumping tests carried out in the wells where yield is sufficient. These are called 'Aquifer Performance Tests' (APT). Slug tests were carried out in the wells where yield is negligible. The yields of the wells are measured by bucket method. The hydraulic parameters found out through APT are - Specific Capacity, Transmissivity and Hydraulic Conductivity. The hydraulic characteristics found out through slug tests are - Transmissivity and Hydraulic Conductivity.

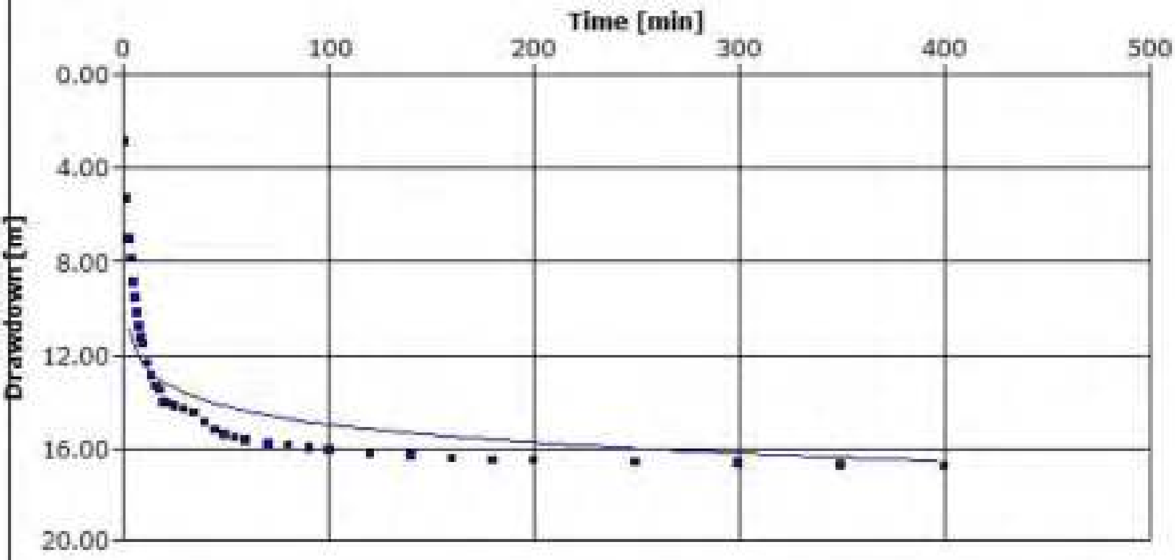
Aquifer Performance Test

Pumping test is one of the most useful tools for determining hydraulic properties of the aquifers, generally representative of larger area than other tests like slug test. APTs were carried out for 7 exploratory wells through outsourcing. In Aquifer Performance Test, the exploratory well was pumped for a certain time interval at a constant rate. The pumping tests in Baswa-Bandikui watershed project was conducted mostly using 2 to 3 HP submersible pump. The diameter of the delivery pipe and the main pipe were 2".

The effect of this pumping on the water level of the pumping well is measured. The hydraulic characteristics of the aquifer are then found by substituting the drawdown and the discharge in appropriate formulae.

The aquifer geometry constructed based on lithological details of the exploratory wells reveal that the predominant aquifer in the project area is in unconfined to semi-unconfined condition since layers of clay-kankar, silty clay and clay are present at various horizons. Hence, the data of pumping tests have been analysed using the Boulton's method (1963) and Theis Recovery method which are recommended methods for unconfined / semi-unconfined anisotropic aquifer of infinite extent. Certain representative plots of Aquifer Performance Tests are given in Figure 98 to Figure 101.

Contact Info Address Company Name City, State/Province		Pumping Test Analysis Report Project: AQRAJ Number: PT-7 Client: CGWB
Location: Bajoli	Pumping Test: Pumping Test 7	Pumping Well: Bajoli
Test Conducted by: Waseem Ahmed		Test Date: 12-03-2014
Analysis Performed by: Rana Chatterjee	Boulton	Analysis Date: 14-11-2014
Aquifer Thickness: 10.00 m	Discharge Rate: 1.5 [l/s]	



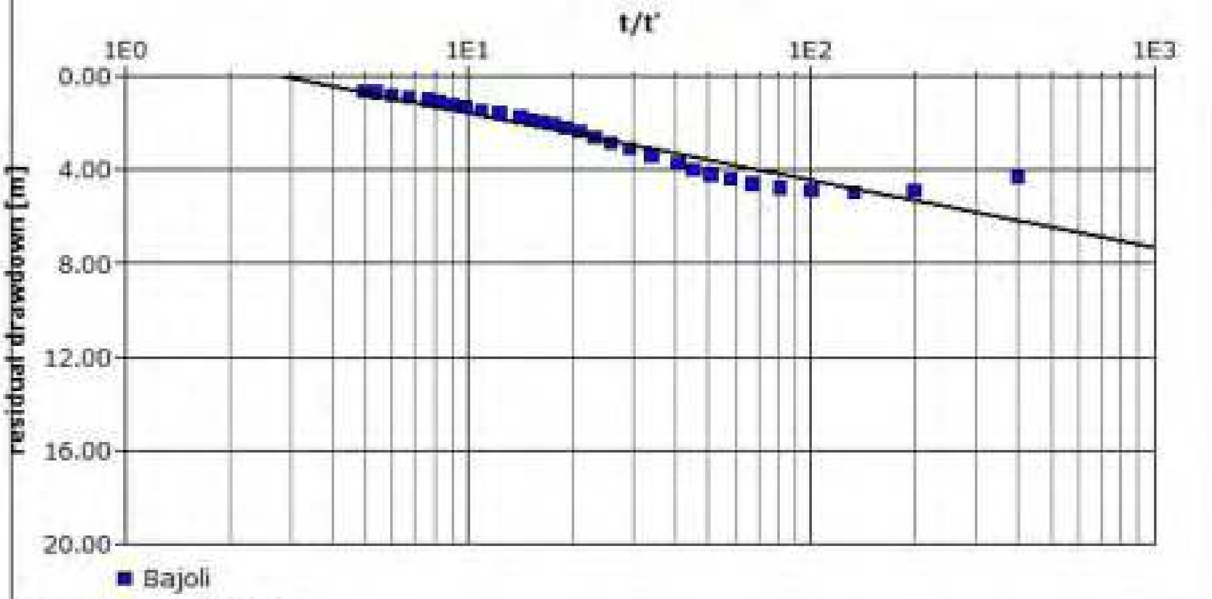
Calculation using Boulton

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific Yield	Drainage factor	Ratio Sy/S	Radial Distance to PW [m]
Bajoli	9.20×10^{0}	9.20×10^{-1}		3.34×10^{-8}	7.05×10^{1}	

Figure 98. Time-Drawdown plot, Boulton's method, Bajoli

	Contact Info Address Company Name City, State/Province	Pumping Test Analysis Report Project: AQRAJ Number: PT - 7 Client: Central Ground Water Board

Location: Bajoli	Pumping Test: Pumping Test -7	Pumping Well: Bajoli
Test Conducted by: Waseem Ahmed		Test Date: 12-03-2014
Analysis Performed by: Rana Chatterjee	Theis Recovery	Analysis Date: 15-11-2014
Aquifer Thickness: 10.00 m	Discharge: variable, average rate 1.5 [l/s]	

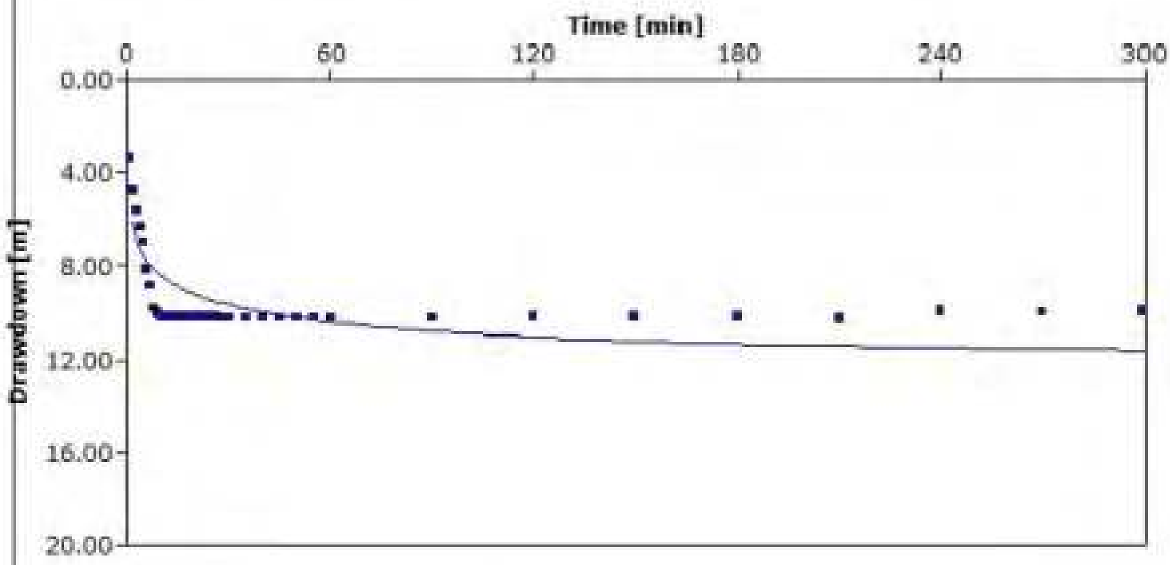


Calculation using THEIS & JACOB

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Radial Distance to PW [m]	
Bajoli	8.23×10^{0}	8.23×10^{-1}		

Figure 99. Theis recovery method, Bajoli

Contact Info Address Company Name City, State/Province		Pumping Test Analysis Report Project: AQRQAJ Number: PT-1 Client: CGWB
Location: Lotwara-1	Pumping Test: Pumping Test 1	Pumping Well: Lotwara-1
Test Conducted by: Waseem Ahmed, Rana Chatterjee, Vikas Tomar		Test Date: 13-02-2014
Analysis Performed by: Rana Chatterjee	Lotwara1_Boulton	Analysis Date: 17-11-2014
Aquifer Thickness: 69.00 m	Discharge Rate: 3.67 [l/s]	



Calculation using Boulton

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific Yield	Drainage factor	Ratio Sy/S	Radial Distance to PW [m]
Lotwara-1	2.03×10^{1}	2.56×10^{-1}		1.00×10^{-2}	1.00×10^{1}	

Figure 100. APT, Time-Drawdown plot, Boulton’s method, Lotwara

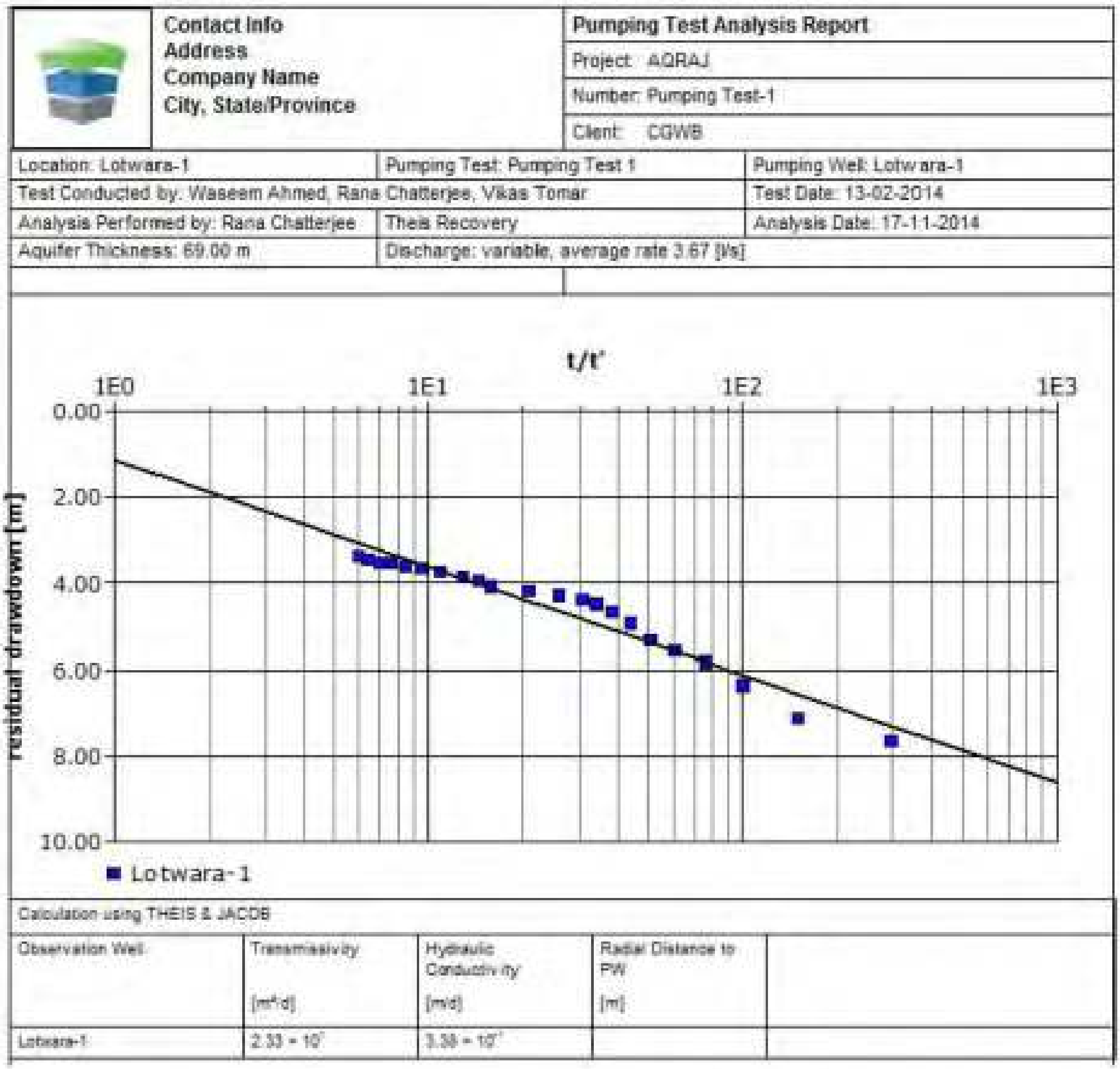


Figure 101. APT, Theis Recovery Method, Lotwara

Slug Test

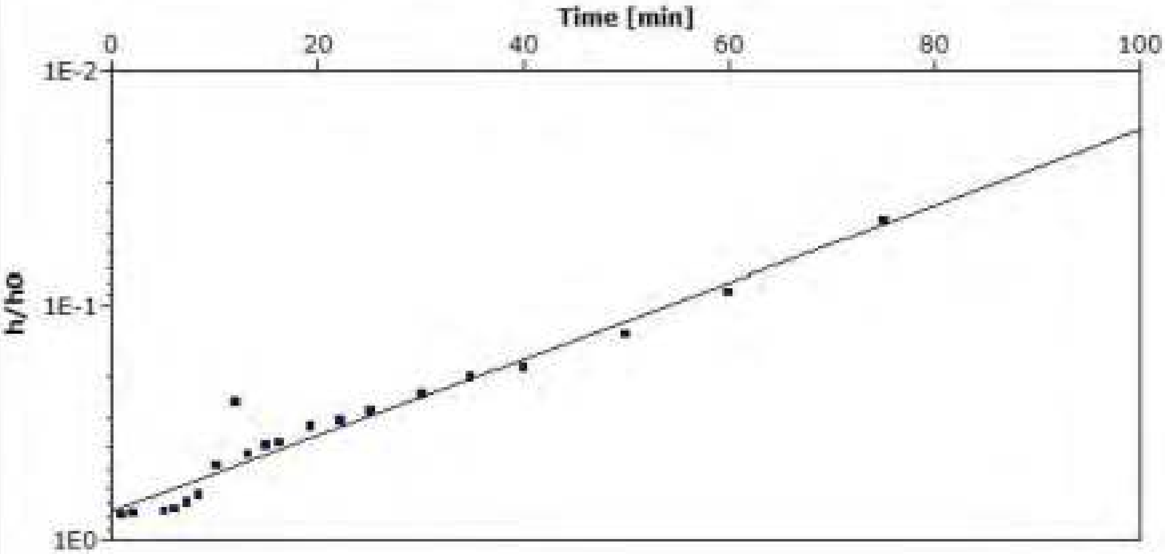
In exploratory wells where pumping tests could not be carried out either due to logistics problem or poor yield, Slug tests were conducted to obtain atleast an estimate of the transmissivity (T) of the aquifer. In this method, a known volume of slug water is suddenly injected into the well and the decline of water level is measured at close time intervals. In Baswa-Bandikui watershed project, slug tests were conducted in 7 exploratory wells.

In Baswa-Bandikui watershed project, slug tests were conducted through indigenous arrangements by using the logistics from the field itself. It was both cost effective as well as simple to fabricate. An Iron drum of 220 litre capacity which is generally used to store diesel was fitted with about 6” long steel pipe at the lower most end (Plate 5). The pipe is cut from the middle and the two segments are joined by a plastic valve of 2.5” diameter as shown in the photograph. The mouth of the pipe is fitted with a thin plastic tube, which is generally used as water conduit in tubewell irrigation. Inside the drum, three lines are drawn encircling the inner wall of the drum, representing the 50 litre, 100 litre and 200 litre volume of water respectively. This arrangement was fabricated to pour a measured quantity of water in the well. The source of water was a water tanker which was hired on daily basis and it moved from well to well alongwith other logistics. The tests were generally conducted for about 1 to 1.5 hour till the period when more than 80% of the water columns built during the test due to injection of water have dissipated.

Plate 5. Slug test in Baswa-Bandikui watershed project area, Dausa district, Rajasthan

The methods used for the analysis of the slug tests data are Bouwer-Rice method (1976) and Hvorslev method, since the aquifers are unconfined to semi-unconfined in nature. Some of the representative plots of both methods of slug test data analysis are given in the following Figure (102 & 103).

Contact Info Address Company Name City, State/Province		**Slug Test Analysis Report** Project: AQRAJ Number: 7 Client: CGWB
Location: Bhedoli	Slug Test: Slug Test 7	Test Well: Bhedoli
Test Conducted by: Rana Chatterjee & Vikas Tomar		Test Date: 17-10-2014
Analysis Performed by: Rana Chatterjee	Bhedoli_Bower&Rice	Analysis Date: 31-10-2014
Aquifer Thickness: 40.88 m		



Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/d]	
Bhedoli	2.33 × 10[illegible]	

Figure 102. Slug test analysis, Bouwer-Rice method, Bhedoli

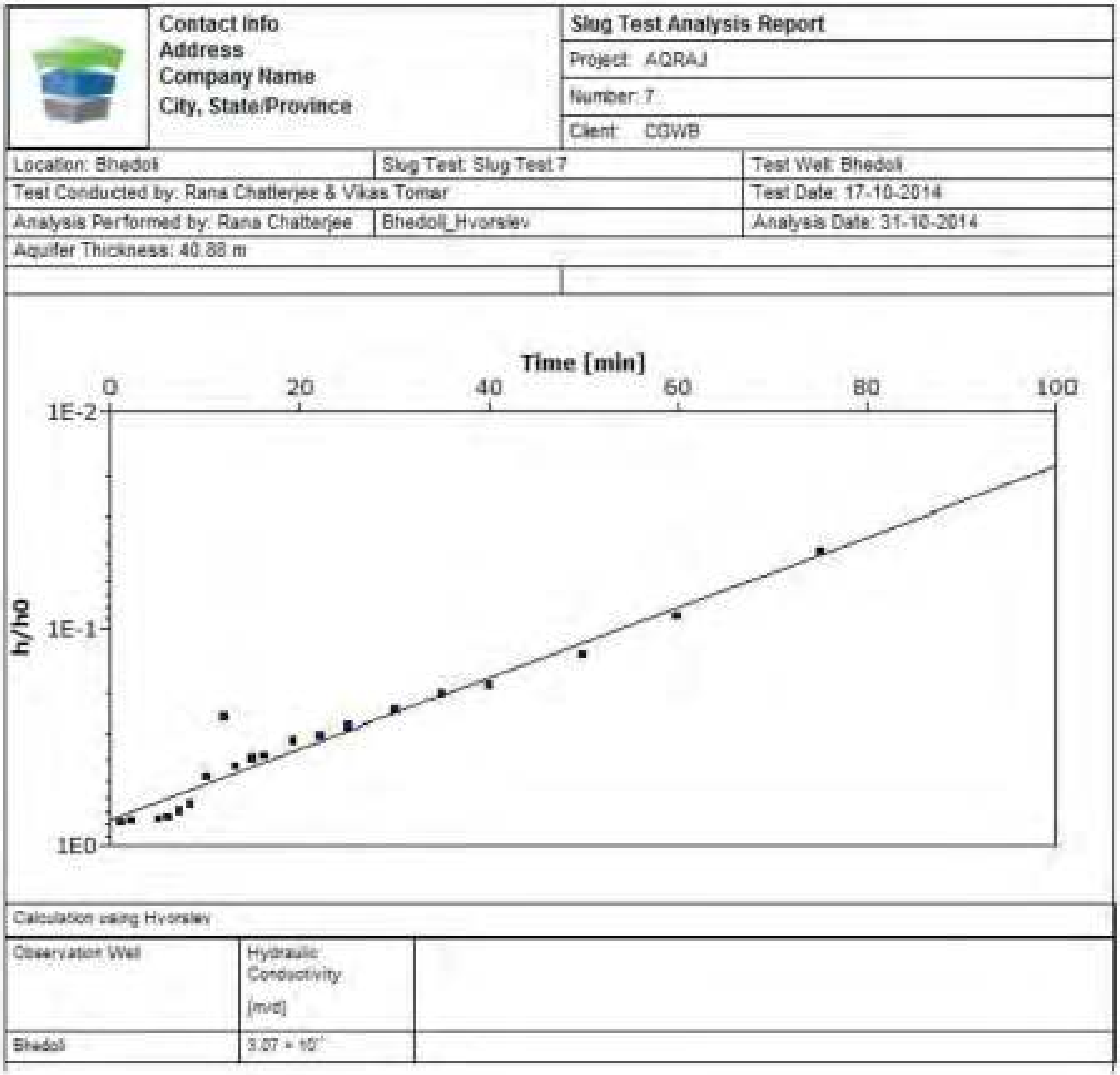


Figure 103. Slug test analysis, Hvorslev method, Bhedoli

Data Interpretation

The data of the exploratory drilling was interpreted to study the bed rock configuration and lithology, aquifer geometry and hydraulic properties of the aquifers and well characteristics.

Depth to bed rocks encountered in the exploratory borewells drilled in the project varies from 38 m to 80 m. The bedrock lithology is mainly schists, phyllites, quartzite and granite gneissic assemblage. The exploratory drilling reveals the presence of clayey horizon in discontinuous patches rendering the aquifers to be in unconfined to semi-confined condition. The yield of the wells varies from 30 to 330 m^3/day. The specific capacity of the wells varies from 3 to 22 lpm/m. The transmissivity of the formations varies from 1 to 22 m^2/day and the hydraulic conductivity of the aquifers ranges from 0.03 to 1.81 m/day.

The details of the Aquifer Characteristics of exploratory borewells drilled in Baswa-Bandikui watershed project is given in the following Table 30.

Table 33 Aquifer Charateristics of Exploratory Wells constructed in Baswa-Bandikui watershed project, Baswa-Bandikui watershed, Dausa district, Rajasthan

S.No.	Location	Coordinates		Disc	DD	Specific Capacity	T	K
		Long.	Lat.	(lpm)	(m)	(lpm/m)	(m^2 /day)	(m /day)
EW1	Lotwara-I	76.7425	27.0054	220	10	22.00	21.80[*]	0.98
EW2	Ranapada	76.6740	26.9863	60	17	3.53	1.07[*]	0.05
EW3	Kheda	76.6814	27.0164	30			17.01[+]	0.71
EW4	Nurpur	76.6703	27.0712	30			9.05[+]	1.81
EW5	Ralota	76.6820	27.0521	30			8.37[+]	0.76
EW6	Kothin	76.7636	27.0651				-	-
EW7	Alipur	76.7939	27.0785	47.4	12	3.95	2.41[*]	0.16
EW8	Sodala	76.7636	27.0651	30			7.02[+]	1.40
EW9	Sumel	76.7457	27.0421	90	5	18.00	11.75[*]	1.21
EW10	Shyamsinghpura	76.5344	26.9899	30			15.29[+]	1.21
EW11	Khare ki Jhopdi	76.7870	27.1110	30			1.79[+]	0.06
EW12	Maukalan	76.7466	27.0948	79	29	2.71	1.06[*]	0.03
EW13	Lotwara-II	76.7425	27.0052	228	14	16.29	13.50[*]	0.38
EW14	Bajoli	76.7314	27.1384	90	17	5.29	8.72[*]	0.48
EW15	Bhedoli	76.4169	26.9835	90			11.04[+]	1.10

*APT, +Slugtest

5.2.4.1 Permeability

The permeability of a rock is its capacity to transmit water under differential pressure and is measured by the rate at which it will transmit water through a unit cross section under unit pressure differential per unit distance (Karanth, 1987). It is also known as Hydraulic Conductivity or *K*. In field, *K* is evaluated through aquifer test, which provides information on transmissivity or T. The relation between *T* and *K* is as follows -

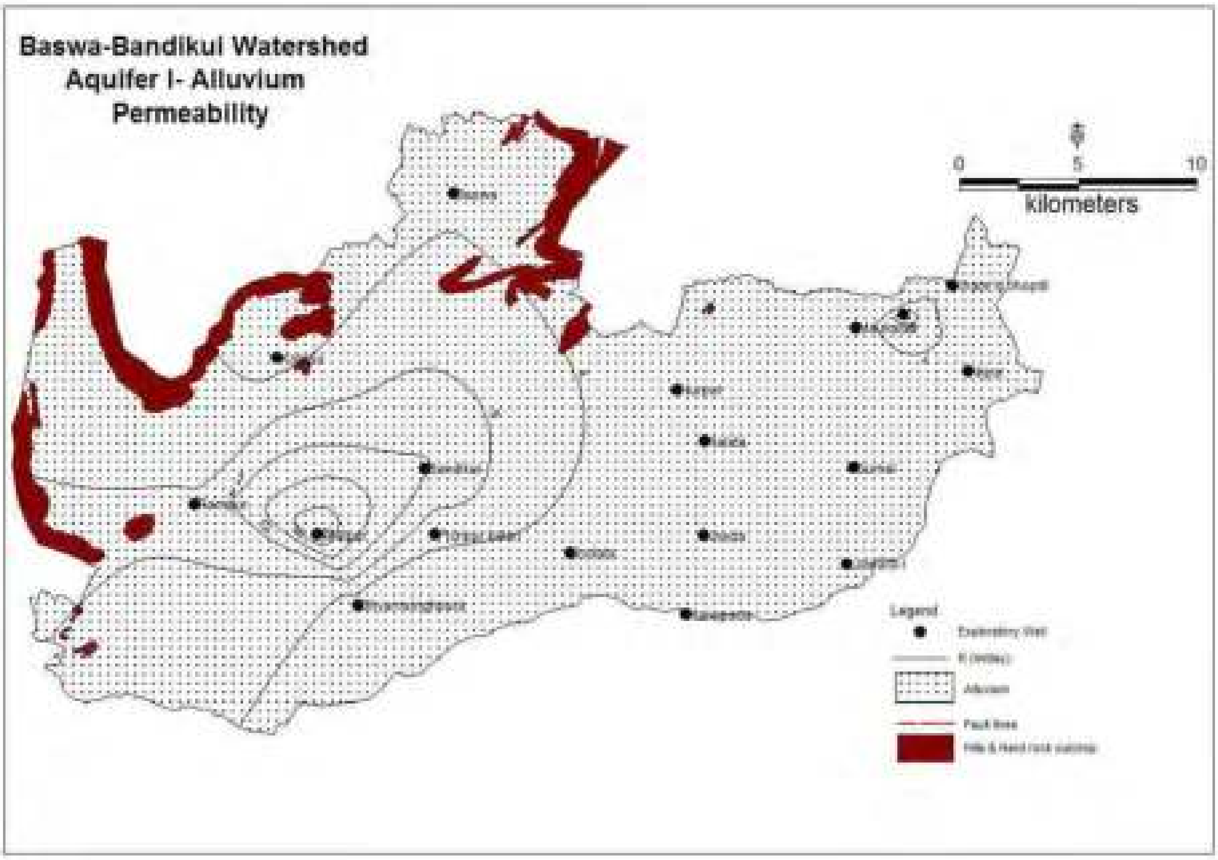
$$K = \frac{T}{b}$$

Where, b is the thickness of the aquifer.

The aquifer-wise maps on permeability are prepared using the data of all the exploratory wells existing in the area. Some of the exploratory wells have tapped both the aquifers i.e. Alluvium aquifer (aquifer I) and hard rock aquifer (aquifer II) while others have tapped single aquifer i.e. either alluvium or hard rock. Hence, as in case of water level and water quality, the permeability maps are prepared taking into consideration the wells tapping single aquifer and mixed aquifer.

Perusal of the above map (Figure 104) show that permeability of alluvium aquifer is more in the western part of the project area. It is in the range of 4 to 20 m/day. It may be noted that the aquifer tests in this portion of the watershed was conducted at earlier time when the aquifer was saturated. This also highlights the seriousness of the problem of ground water level decline in the area. The most potential aquifer zone in the study area has got desaturated due to excessive withdrawal of ground water.

The permeability map of the hard rock aquifer also shows higher permeability of the hard rock aquifer at the western part of the study area. This is because some of the wells have tapped both the aquifers and hence are common in both the maps. In general, the permeability of the hard rock aquifer in less than alluvium aquifer.



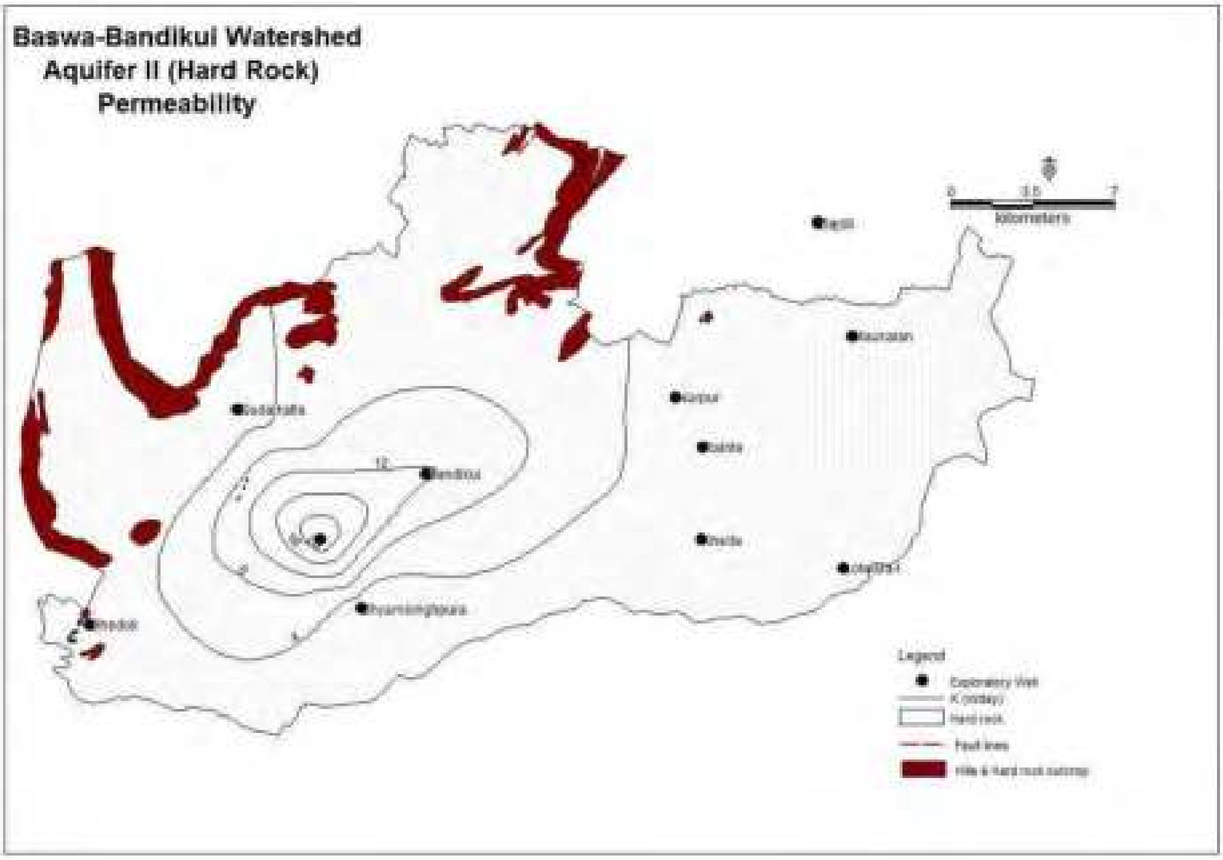


Figure 104. Permeability map of alluvium aquifer (Aquifer I) and hard rock aquifer (Aquifer II)

5.2.4.2 Specific Yield

Evaluation of specific yield by aquifer test involve one test well and one or more observation well. Since there were no such combination of exploratory well and observation well in the study area, specific yield studies are not carried out in the project area. Aquifer-wise maps on specific yield are drawn based on the figures provided by State Ground Water Department in the ground water resources assessment, 2013.

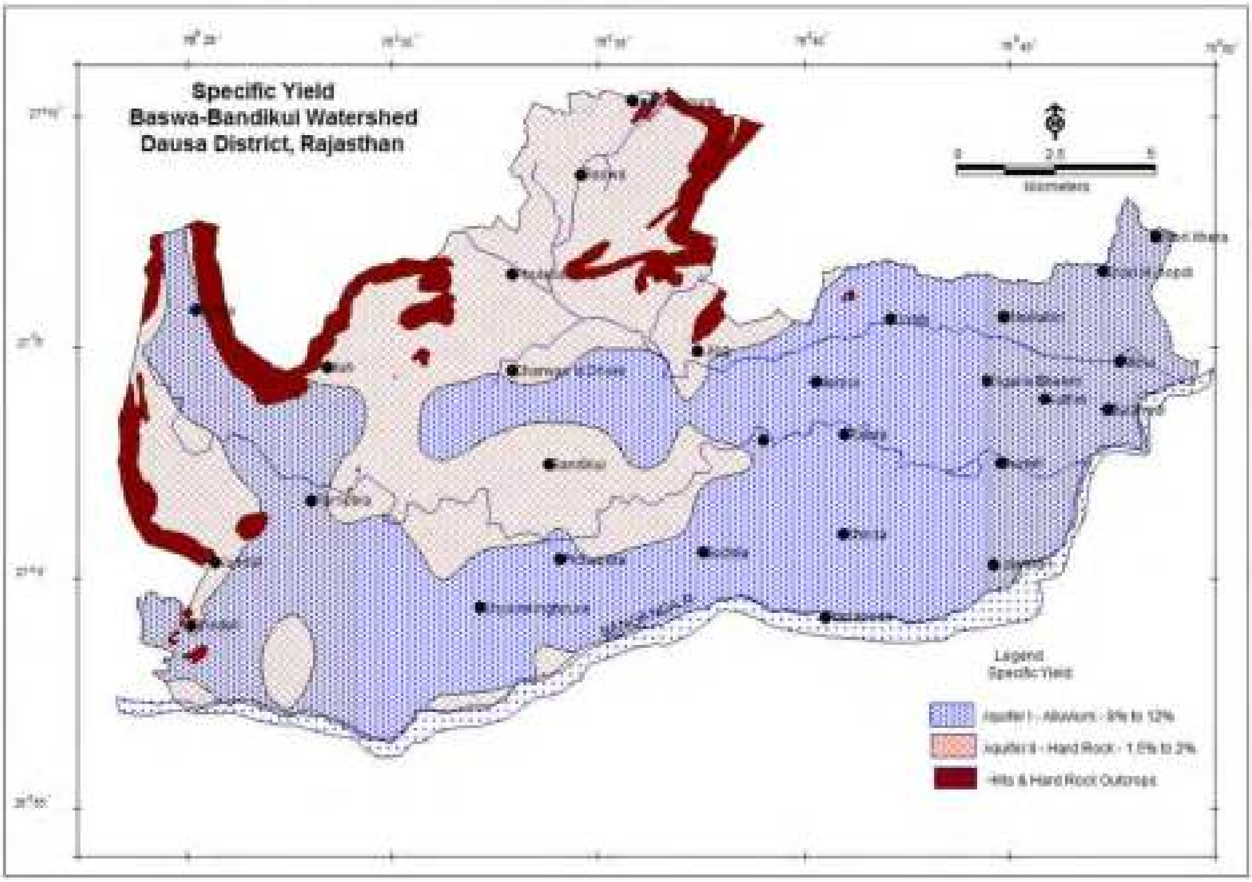


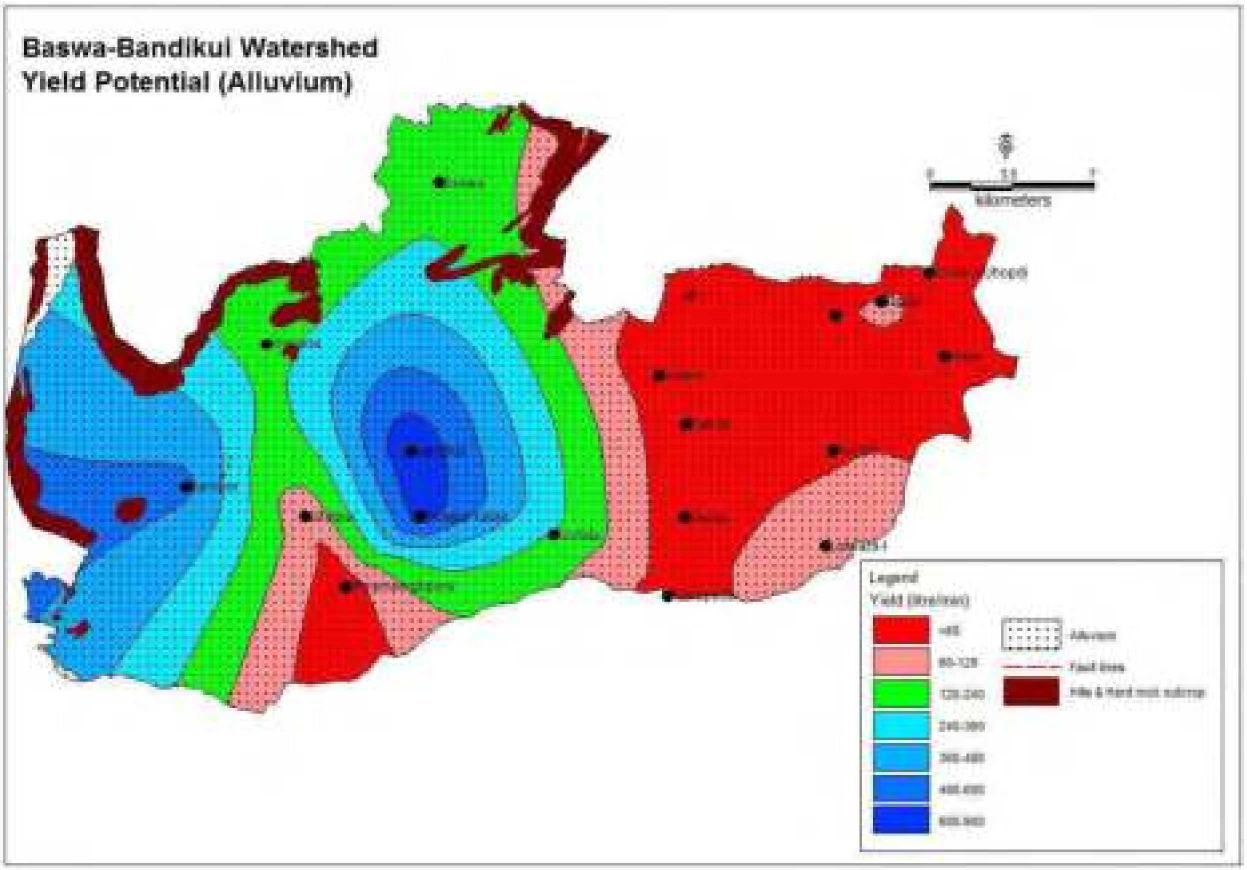
Figure 105.   Specific yield map of aquifers

The specific yield of the alluvium aquifer ranges from 0.08 to 0.12 whereas that of hard rock aquifers ranges from 0.015 to 0.02 (Figure 110). Thus storage capacity of alluvium aquifer is more than hard rock aquifer. This property is significant for the formulation of artificial recharge plan.

5.2.4.3 Yield Potential

The discharge of the wells are measured during well development and also at the time of pumping tests. Maps showing yield potential of the aquifers are presented below in Figure 106.

The yield potential map of alluvium aquifer indicate that the aquifer is good yielding at the western and central parts. Most of the wells in these parts were drilled earlier. The potentiality of the aquifer decreases towards east where fine-grained sediments are encountered in the aquifer zones. The yield potential in the eastern part is within 60 lpm. The yield potential map of the hard rock aquifer in contrast show that major part of the aquifer is poor yielding viz. Within 60 lpm. The high yield in the central portion is due to the wells tapping both aquifers. The poor yield of the hard rock aquifer is because of less thickness of weathered zone and lesser frequency of fractured zones tapped in the exploratory wells.



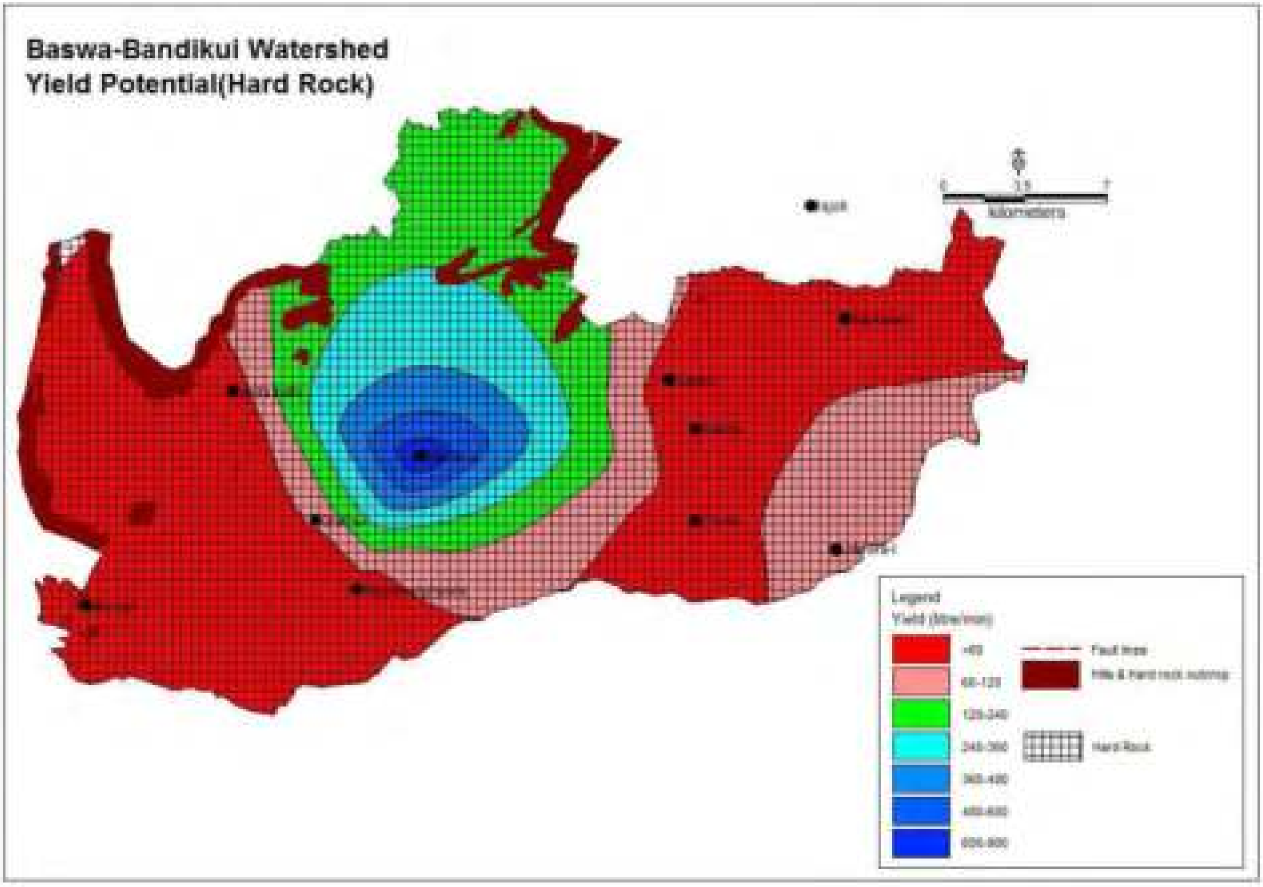


Figure 106. Yield potential map of alluvium aquifer and hard rock aquifer

6. AQUIFER RESPONSE MODEL AND AQUIFER MANAGEMENT PLAN FORMULATION

6.1 Aquifer Response Model

This chapter deals with the development and application of numerical ground-water-flow models of the Baswa-Bandikui micro-watershed. Steady-state and transient models are developed to evaluate regional effects of changes in the groundwater resources associated with increased water demands and development. The models is developed and calibrated on the basis of hydrogeologic data collected during pilot project on aquifer mapping and previous investigations. These data include lithologic information for aquifers, hydraulic properties of and recharge to aquifers, water levels measured in wells. The USGS modular three dimensional finite-difference ground-water flow modeling code, MODFLOW-2000 (McDonald and Harbaugh, 1988; Harbaugh and others, 2000), is used to simulate the aquifer system.

6.1.1 Objective

The objective of the study is to -

i. Design the predictive scenario of groundwater regime in case the present ground water budget pattern continues
ii. Optimization of ground water development
iii. To evolve the scenario of ground water regime in case artificial recharge programme is implemented in the area on a large scale

Results of several hypothetical scenarios that incorporate changes in the aquifer system, including pumping rates at existing withdrawals and increased recharge, are described. Zone budgeting done for different hydrogeological formation and estimated exchange of flow between them. This study is intended to scientifically inform the public and various stock holders and water resources authorities, the predictive ground water scenario of the area, who may use the result to formulate water resources management decisions.

6.1.2 Numerical Design

6.1.2.1 Methodology

The groundwater flow model for the alluvium and weathered rock formation is based upon MODFLOW, the USGS developed modular three-dimensional finite-difference computer code commonly used to simulate groundwater flow and determine hydrologic budgets in various physiographic regions (Mc Donald and Harbaugh, 1988). Many versions of this code have been created since 1983 and version MODFLOW 2000 is used in this modeling study. MODFLOW-2000 is release by U. S. Geological Survey in 2000, and introduced new process based approach to the MODFLOW Programme structure, together with built in parameter estimation capabilities. The computer program uses finite-difference technique and block centered formulation to solve the groundwater flow equation for three-dimensional, steady state flow in the anisotropic, heterogeneous, porous media of the Baswa-Bandikui micro watershed. In order to use a finite-difference approximation, a grid is superimposed over the study area, and aquifer parameters necessary to solve the flow equation are arranged over the area of cell of grid block and assigned a node at the center of the block. Finite difference computes the average head value for the cell at the node. In the block centered formulation, the nodes for which water levels are simulated are located at the Centre of the grid cells. The cells are the smallest volumetric units over which the hydraulic properties are assumed constant.

6.1.2.2 About Visual –Modflow

Visual MODFLOW is a modeling software provided with powerful preprocessor and post processor to USGS developed MOFLOW. MODFLOW is a three dimensional Modular finite – difference groundwater flow model, originally developed by the U.S. Geological Survey and release to public domain in 1983. The model input parameters and result can be visualized in 2d or 3D at any time during the development of the mode or displaying of the result. This Software provides most complete and user-friendly, modeling environment for practical application in three dimensional ground water flow and contaminant transport simulation. Visual MODFLOW support all of the most recent public domain and proprietary versions of MODFLOW and MT3D for simulating groundwater flow modeling and mass transport modeling respectively.

6.1.3 Conceptual model

After considering all the available data it is decided that one layer model can be developed in which the depth of the layer is considered up to the bottom of the weathered hard rock formations. One layer model has been developed in which the top elevation data has been imputed from the existing elevation data of the area and the bottom of top layer has been imputed from the lithogical log of the bore holes in the area. The single layer considered in this area includes alluvium as well as underlying weathered residuam and considered as single aquifer system in this area.

A conceptual model of the study area is applied to a numerical groundwater flow model to: 1) quantify the hydrologic parameters and hydrologic budget for area under steady-state conditions, 2) simulate the distribution of hydraulic head in the area, and 3) determine the overall water budget. The area is represented in a ground-water flow model subdivided into a grid system that incorporates the alluvium, weathered rock aquifers, rivers, the lineaments, estimated recharge, and discharge.

6.1.3.1 Grid Design

A finite-difference grid superimposed (Figure 108) over a 647 sq km area is designed and constructed based on the simplification of a conceptual model representing the physical properties of the groundwater system. The grid developed for the present study consist of 87 columns and 53 rows, forming 4611 squares grid with a constant spacing of 500m by 500m. Active node numbering 2662 are used to cover the study area. Remaining nodes about 1949 are exterior and are not considered for computation. Imposition of the flow boundaries and grid network on the study area leaves the area to be modeled as 665 sq Km.

Figure 108. Spatial Discretization of Model Grid

6.1.3.2 ASSUMPTION USED IN CONCEPTUAL MODEL

Following general simplified assumption are used in the development and calibration of model

1. The ground water system is homogeneous and isotropic
2. Only single aquifer system has been assumed
3. General ground water flow direction is from West to East

6.1.4 AQUIFER GEOMETRY AND BOUNDARY CONDITIONS

6.1.4.1 *AQUIFER GEOMETRY*

The physical parameters, that include aquifer top (Figure 109) and bottom (Figure 110) elevation, are assigned to the model. The aquifer geometry is mainly derived from the subsurface characterization using the bore-hole logs, dug well section and geological information collected during the field work. The model area comprising mainly alluvium formation and weathered and fracture thickness of quartzite, phyllite and gneiss farming single unconfined aquifer. The surface elevation ranges between 241 m and 339 m above mean sea level. The bottom elevation ranges between 167 m above mean sea level and 305 m below mean sea level.

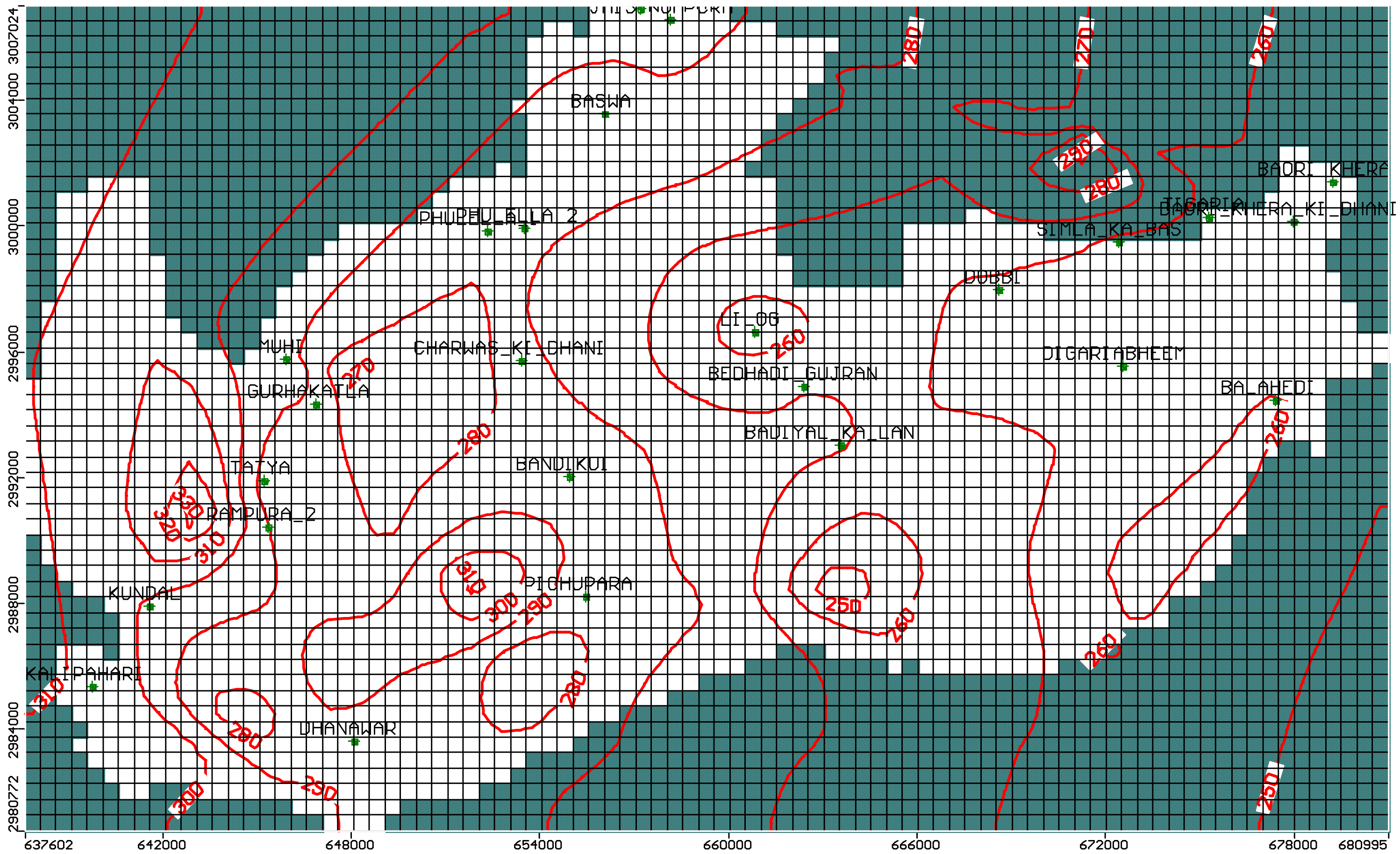


Figure 109. Surface elevation in m AMSL.

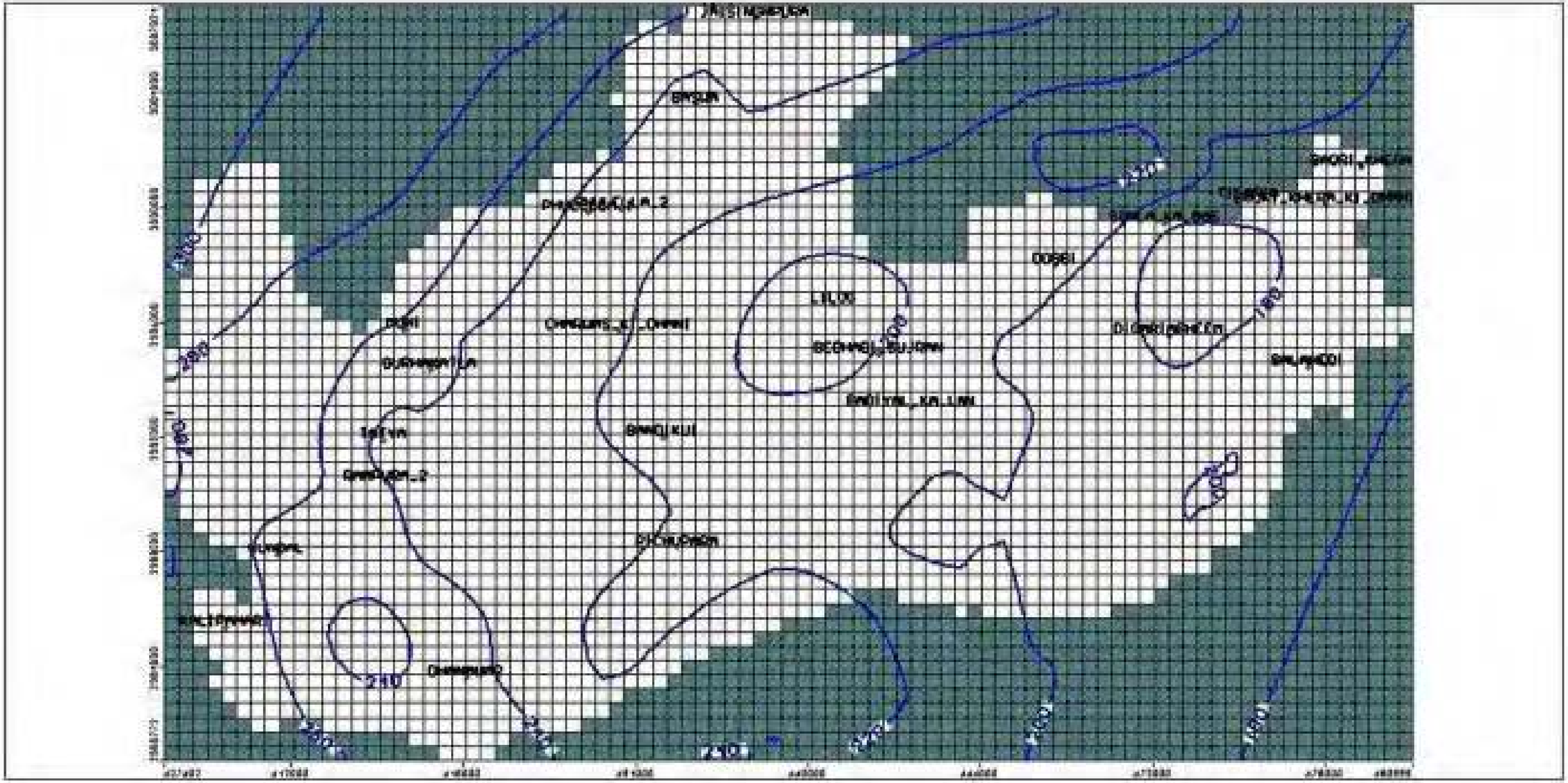
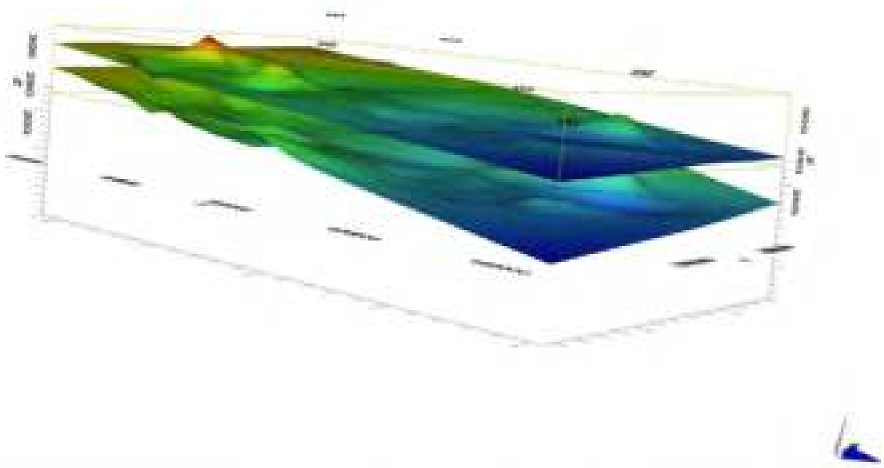


Figure 110. Bottom elevation in m AMSL.

Thickness of the model layer is maximum (>70m) in the central part of the watershed and shown in the Fig 111, 112 & 113.



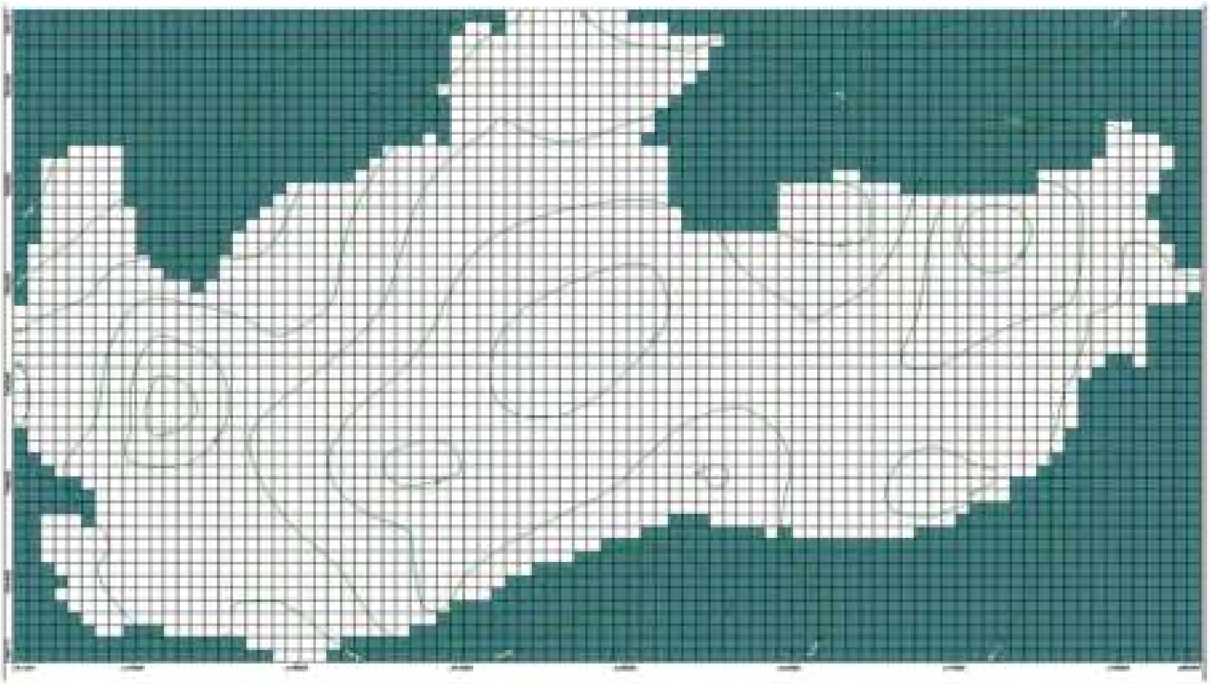


Figure 111. Thickness of layer in m

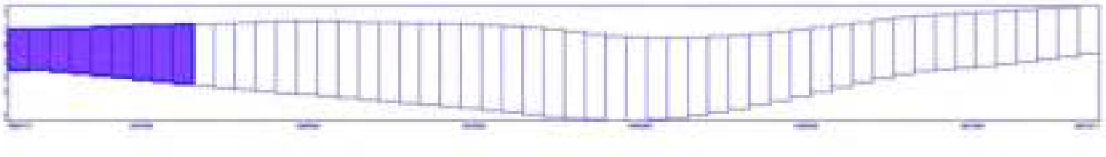


Figure 112. Thickness of layer along column 42 in m.

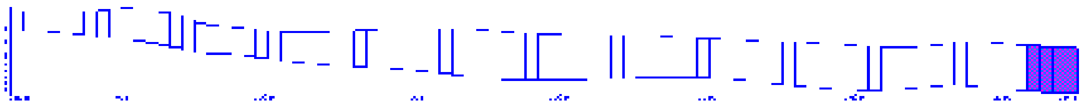


Figure 113. Thickness of layer along row 28 in m.

6.1.4.2 Boundary Conditions

The area represents a single layer of unconfined aquifer basin. The boundary conditions are specified for the upper surface, sides and bottom of the modeled area. The hydrogeologic boundaries of the basin include:

A topographic divide (hill ranges) to the western & north western part of the study area, which coincide with ground-water divides are represented by no-flow.

River boundary to the southern and part of eastern side of the area represented by a general head boundary.

Most of the ground-water flow in the basin occurs within the alluvium as well as in the underlying weathered hard rocks and also deeper fractures. Ground-water-flow in the quartzite, schist, phyllite and gneiss, weathered and fractured aquifers of the area is mostly restricted to the top weathered and fractured portion of formation. The fractures, joints act as permeable zones for ground-water movement and the dissemination of flow through the weathered rock formations.

General-Head Boundary

A general-head boundary is assigned along the southern and eastern boundary of the modeled area (Figure 114). Flow through the boundary (Qb) is calculated as the product of the conductance of the boundary (Cb) and the difference between the head at or beyond the boundary (hb) and in the aquifer (h):

$$Q_b = C_b (h_b - h)$$

Head values along the boundary are estimated from interpolation of the depth to water level in the area. The conductance term is representing the resistance to flow between the boundary and the aquifer. The values of conductance are determined from the product of the hydraulic conductivity (Kb) of the head-dependent boundary cells and the cross sectional area (MW) of the boundary through which flow is simulated divided by the length (L) of the flow path:

$$C_b = \frac{K_b MW}{L}$$

where

K_b is the conductance of the general-head boundary cells

M is the thickness of each layer

W is the width of the each general-head boundary source cells

L is the length of each general-head boundary source cells

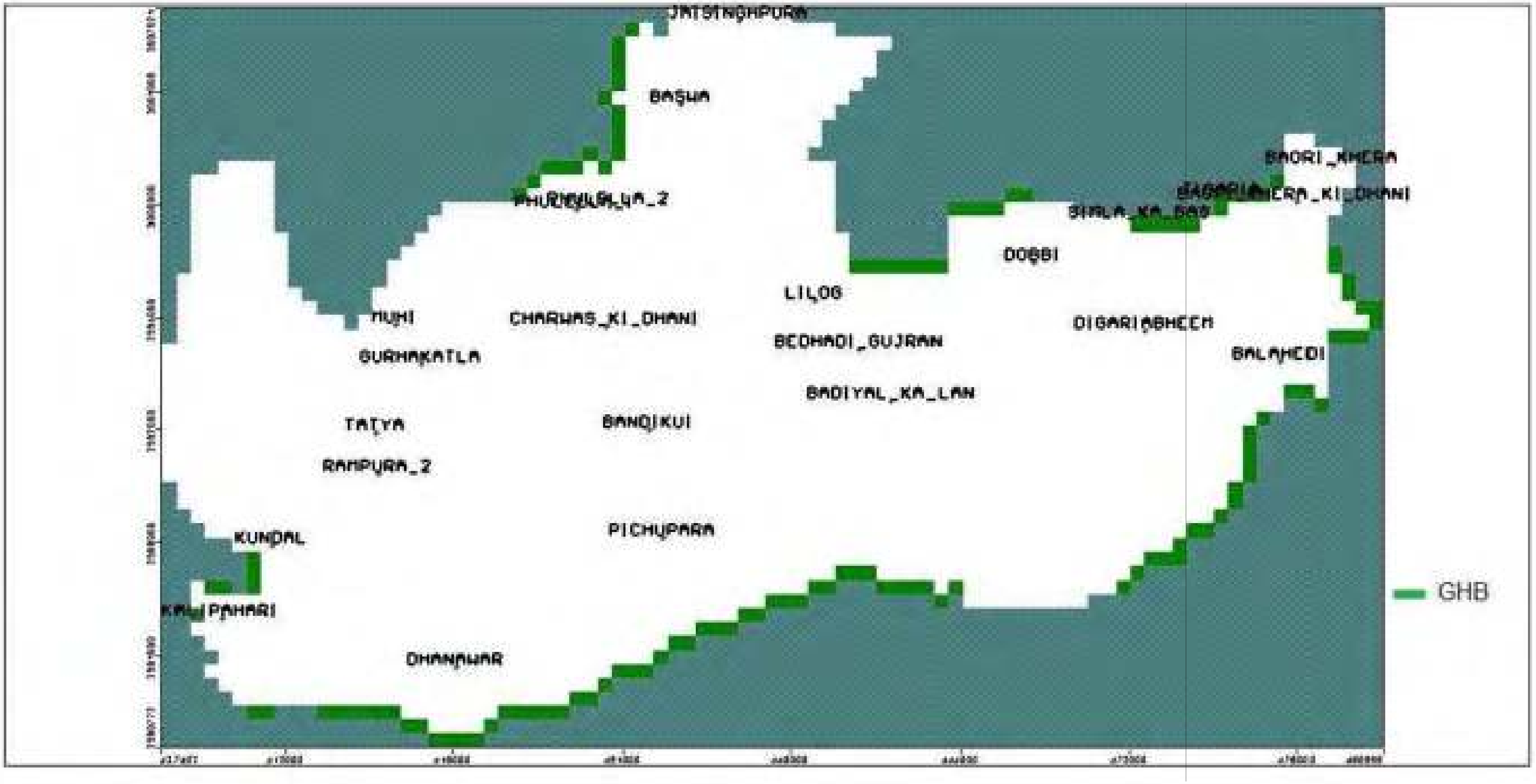


Figure 114. General Head Boundary in the model area.

6.1.5 *HYDROGEOLOLOGICAL ZONES*

Considering the Geology and geomorphologic characteristics, the area is mainly divided into three major zones of different hydro geologic characters i.e. Alluvium, Granite/gneiss and Quartzite/Phyllite. Alluvium is further sub divided into three sub-zones. Alluvium in river bed deposits consider younger alluvium whereas the alluvium in plain land is termed as older alluvium. Alluvium in plain land which yield the poor quality of groundwater is called Non-potential alluvium. Therefore five following hydrogeological zones are utilized to estimate zone budget in the model (Figure 115).

Zone-1 Alluvium Non –potential
Zone-2 Alluvium Older
Zone-3 Alluvium Younger
Zone 4 Gneiss.
Zone 5- Phyllite and Quartzite

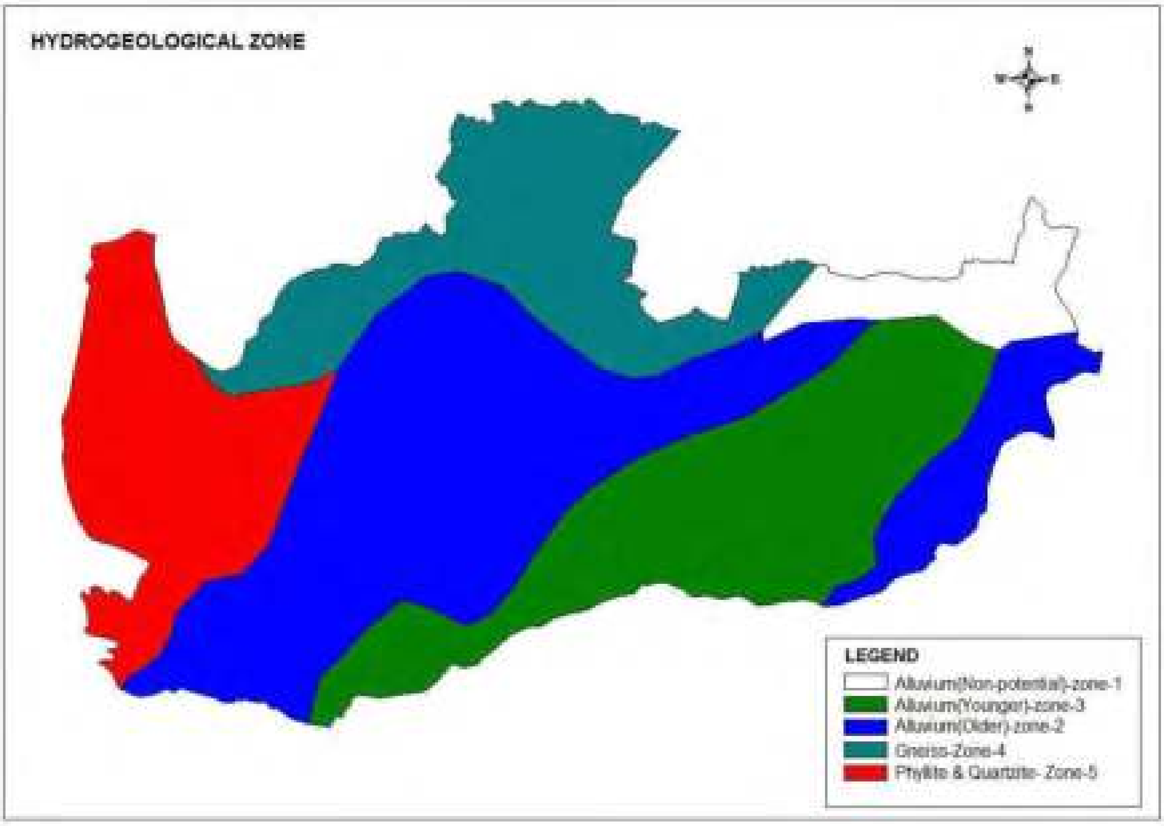


Figure 115. Distribution of hydrogeological zones

For imputing the aquifer properties in the model, the available data and the data generated during the fieldwork has been considered.

From the available data, the Hydraulic conductivity of Alluvium zone in river bed deposit (ravines) has been considered as 10 to 12 m/day (i.e Zone III with Kx 10 to 12 m/day, Ky 10 to 12 m/day & Kz 0.10 to 0.12 m/day), Alluvium of plain lands has been considered as 4 to 6m/day (i.e Zone I & II with Kx 4 to 6m/day, Ky 4 to 6 m/day & Kz 0.4 to 0.6 m/day) and Granite gneisses & Quartzies in hard rock areas as 1 to 2m/d (i.e Zone IV & V with Kx 1to 2 m/day, Ky 1 to 2 m/day & Kz 0.10 to 0.2 m/day).

Distribution of specific yield

Similarly for Storage Parameters similar zones have been considered and assigned suitable values as given below.

Zone I & II – Specific yield ranges 5 to 8%, effective porosity 5 to 8% & Total porosity 10 to 16%.

Zone III - Specific yield 10 to 15%, effective porosity 10 to 15% & Total porosity 20 to 30%.

Zone VI & V – Specific yield 1 to 3%, effective porosity 1 to 3% & Total porosity 2 to 6%

Recharge

Recharge to the models consisted of infiltration from precipitation. Recharge was applied to the active model area as a spatially varying, specified flux to the uppermost active layer. In general, precipitation recharge varies spatially with land-surface permeability, which is a function of soil characteristics and land use.

The recharge of the area has been imputed in the following five zones (Table 34).

Table 34. Zone wise recharge (m^3) in model area.

Potential Zone	Actual area (m^2)	Potential area (m^2)	Monsoon recharge (m^3)	Non-monsoon recharge (m^3)	Monsoon recharge(m)	Non-Monsoon recharge (m)
			June-Sept	Oct- May	June-Sept	Oct-May
Zone1to 3 Alluvium	394020000	367180000	13871351	2967341	0.035204688	0.00753094
Zone5- Quartzite	104600000	88070000	3264840	73800	0.03121262	0.000705545
Zone4- Gneiss	99490000	73650000	2725120	46300	0.027390894	0.000465373
Total	598110000	528900000	19861311	3087441	0.033206786	0.005161995

DISCHARGE

The ground Water Draft has been calculated for the area based on actual field data. The draft generated in the area has been distributed through pumping well in different zones as mentioned earlier and shown in the following table.

Table 35. Groundwater draft in the model area

Potential Zone	Actual area (m^2)	Potential area (m^2)	No. of wells	Draft monsoon (m^3)	Draft Non-monsoon (m^3)	Draft monsoon (m)	Draft Non-monsoon (m)
				June-Sept	Oct-May	June-Sept	oct-May
Alluvium	3.94E+08	3.67E+08	5428	14853500	44460900	0.037697	0.112839
Quartzite & Phyllite	1.05E+08	88070000	1640	497300	1486700	0.004754	0.014213
Gneiss	99490000	73650000	1234	318600	946200	0.003202	0.009511
Total	5.98E+08	5.29E+08	8302	15669400	46893800	0.026198	0.078403

In Zone I & II, the ground water draft has been imputed by pumping well discharge of 100 m^3/day during June to September (for 0 to 120 days), 400m^3/day during October to January (for 120to 240 days) and nil draft during February to May (for 240 to 365 days). In total 990 well have been created which ultimately created ground water draft of 59.40 MCM (Table 35). In Zone III, the ground water draft has been imputed by pumping well discharge of 30m^3/day during June to September (for 0 to 120 days), 120m^3/day during October to January (for 120 to 240 days) and nil draft during February to May (for 240 to 365 days). In total 170 well have been created (99 wells in Hard rock areas of Quartzitic terrain where draft has been computed as 1.78 MCM & 71 wells in Granite gneiss areas where draft have been computed as 1.3 MCM), which ultimately created ground water draft of nearly 3.08 MCM of ground water.

6.1.6 MODEL CALIBRATION -TRANSIENT STATE

The main purpose of this model is to predict changes in groundwater heads caused by changes in stresses on the system. Before the model is used for prediction, it must be calibrated, i.e. the groundwater head simulated by the model for the known stresses of the past must match the observed heads. The criteria used to determine an acceptable match between calculated and measured hydraulic heads are subjective, despite the goal of minimizing the difference between calculated and measured heads. The calibration criteria involved:

A fairly good visual comparison between the measured and simulated heads is observed. A root-mean square error between measured and simulating heads of less than 8.00 m

For the purpose of calibration, 2012 is chosen the base year and groundwater heads for June 2012 are used as the starting heads for steady state model calibration. The water level data of 36 observation wells (Figure 116) distributed over the area are used first in steady state calibration followed by transient calibration. Steady state conditions imply that the system is in equilibrium, such that total inflow is equal to total outflow. The model is calibrated using initial *trial and error* adjustments to selected input parameters followed by statistical linear regression analysis performed by the model. Adjustments are made to: 1) recharge, 2), conductance values at the general-head boundary and 3) the hydraulic conductivity field.

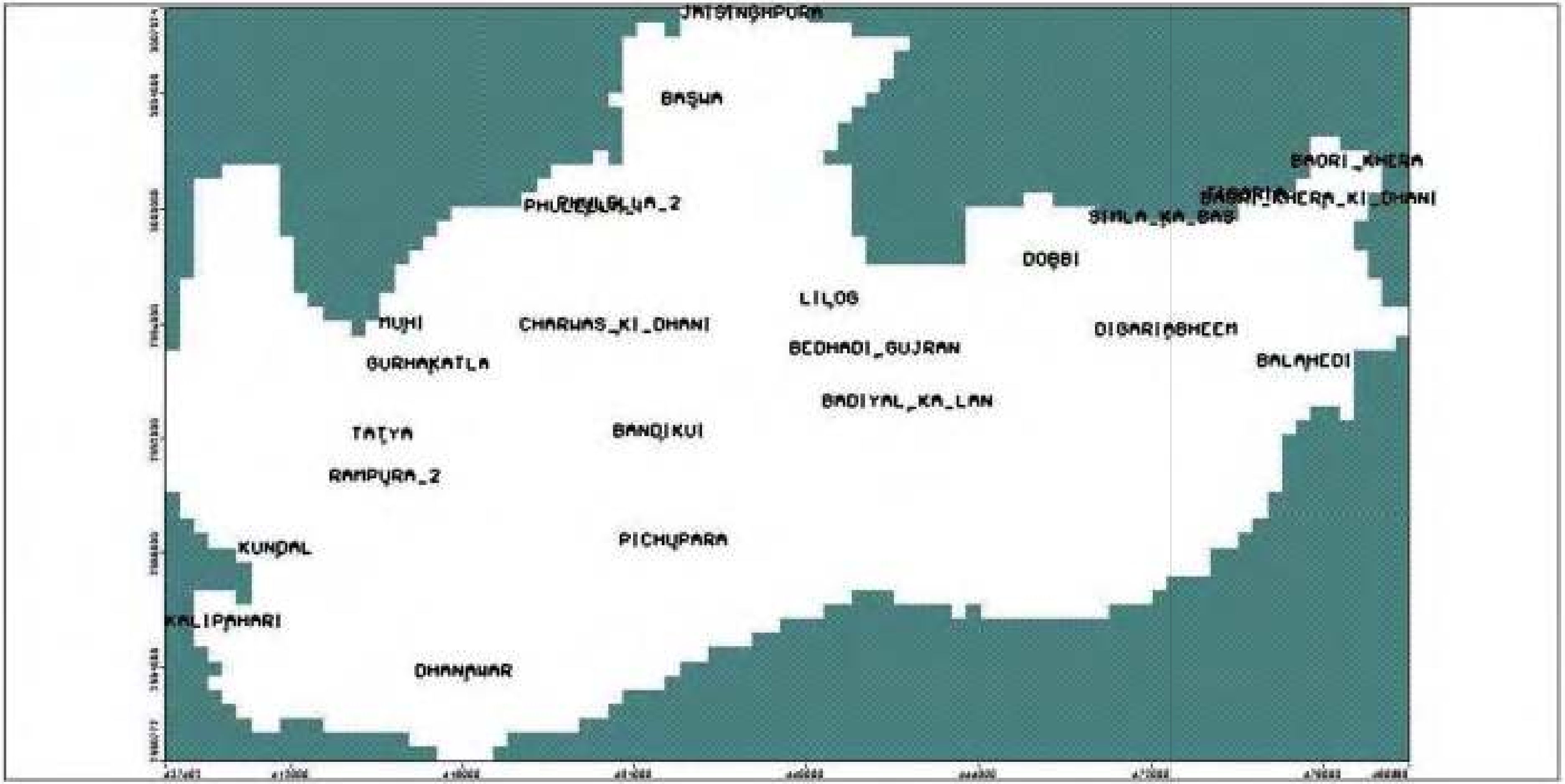


Figure 116. Disposition of observation wells in the model area

Initial simulations are conducted with no-flow conditions along the upper boundary and later changed to a general-head boundary. No-flow is initially used to determine the appropriate hydraulic conductivity and recharge values required to limit unrealistically large volumes of inflow across this boundary. The assignment of a general-head boundary is assumed appropriate to provide stability to the model allowing it to calculate the distribution of hydraulic heads in the basin and also provide a way to estimate the subsurface inflow that may be occurring through the boundary. Flow through the general-head boundary adjusted by varying the conductance value of aquifer at the boundary cells.

The statistical analysis is performed by VISUAL MODFLOW modeling Software by presenting the diagram (Figure 117) to judge the quality of calibration results. The observed values are plotted on one axis against the corresponding simulated value on the other. If there is exact agreement between measurement and simulation, all points lie on 45° line. The narrower the area of scatter around this line, the better is the match. It involves variance analysis. If the variance decreased, then the adjustment to the input data is retained. In addition to this percentage difference between measured and simulated heads are evaluated. Variance and root mean squire error are minimized through numerous trial runs and at last a fair and good match is obtained (Figure 117). The hydraulic conductivity values arrived from the steady state calibration the other parameters are then used as the initial condition in the transient model calibration.

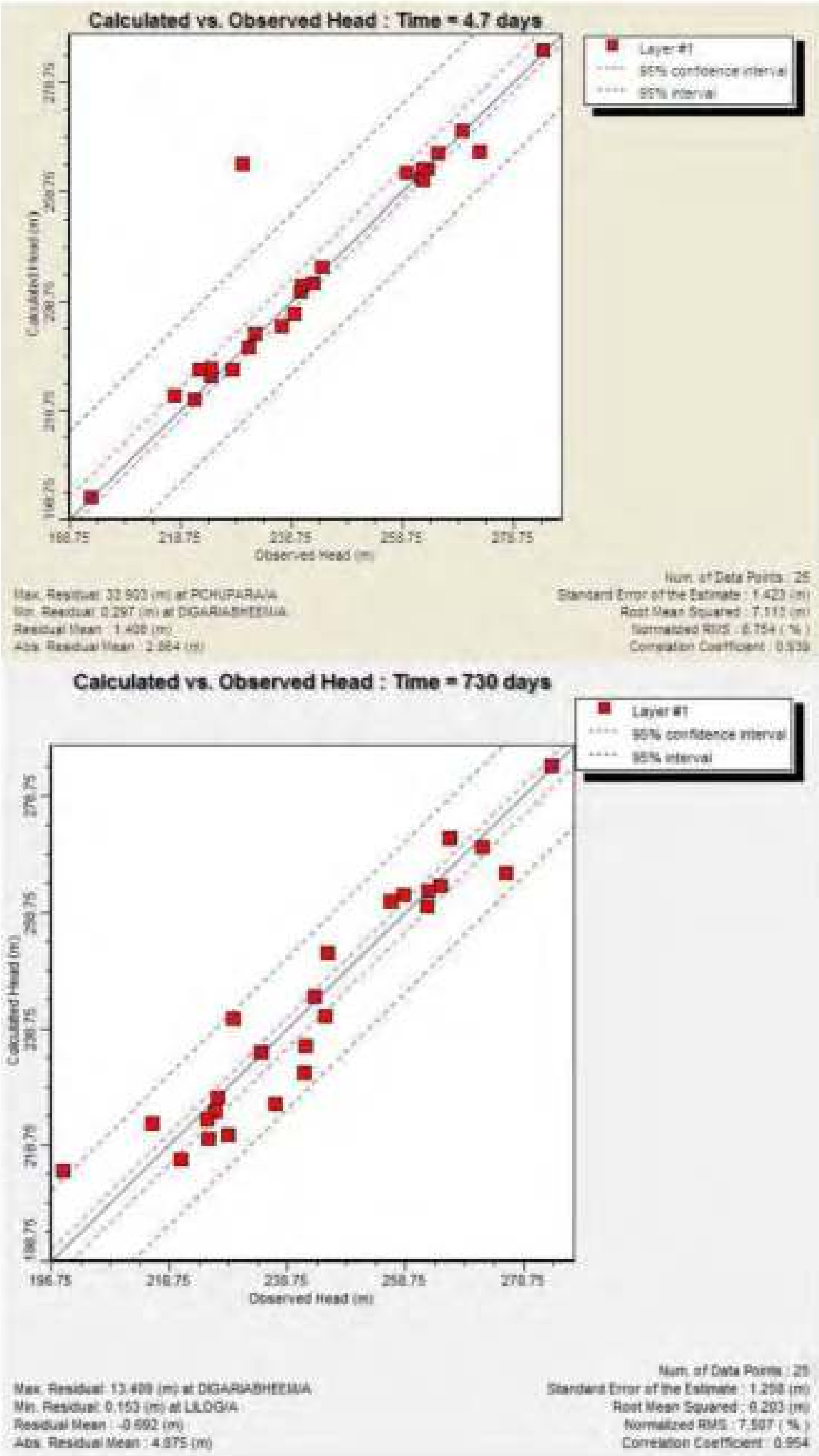


Figure 117. Comparison of observed and calculated head

Transient state simulation is carried for a period of 4 stress periods, i..e., 2 years (2012-13 to 2013-14). Each stress period is taken to be of first 4 months stating from June to September and second period for 8 months from October to May in each year. This scheme is chosen so that each stress periods approximately matched with monsoon and non-monsoon periods.:
Net recharge: Net recharge computed by subtracting recharge to the draft of the area and applied to the model in the transient calibration as given below in Table 36.

Table 36 Net Recharge applied in the transitional calibration

Potential Zone	Actual area (m3)	Potential area (m2)	NET_Monsoon recharge (m3)	NEET_Non-monsoon recharge(m3)	NET_Monsoon recharge (M)	NEET_Non-monsoon recharge(M)	NET_Monsoon recharge(m/day)	NEET_Non-monsoon recharge(m/day)
			June-Sept	oct-May				
Alluvium	3.94E+08	3.67E+08	-982149	-4.1E+07	-0.00249	-0.10531	-2.04E-05	-0.0004334
Quartzite & Phyllite	1.05E+08	88070000	2767540	-1412900	0.026458	-0.01351	0.0002169	-5.559E-05
Gneiss	99490000	73650000	2406520	-899900	0.024189	-0.00905	0.0001983	-3.722E-05

Stress period: Following stress period have been applied in the transient calibration.

CALIBRATION

Stess period	Time					
	From	To	Start	End	Duration	Season
1	01-Jun-12	30-Sep-12	0	122	122	Monsoon
2	01-Oct-12	31-May-13	122	365	243	Non-Monsoon
3	01-Jun-13	30-Sep-13	365	487	122	Monsoon
4	01-Oct-13	31-May-14	487	730	243	Non-Monsoon

6.1.6.1 TRANSIENT CALIBRATION RESULT:

Hydrographs:

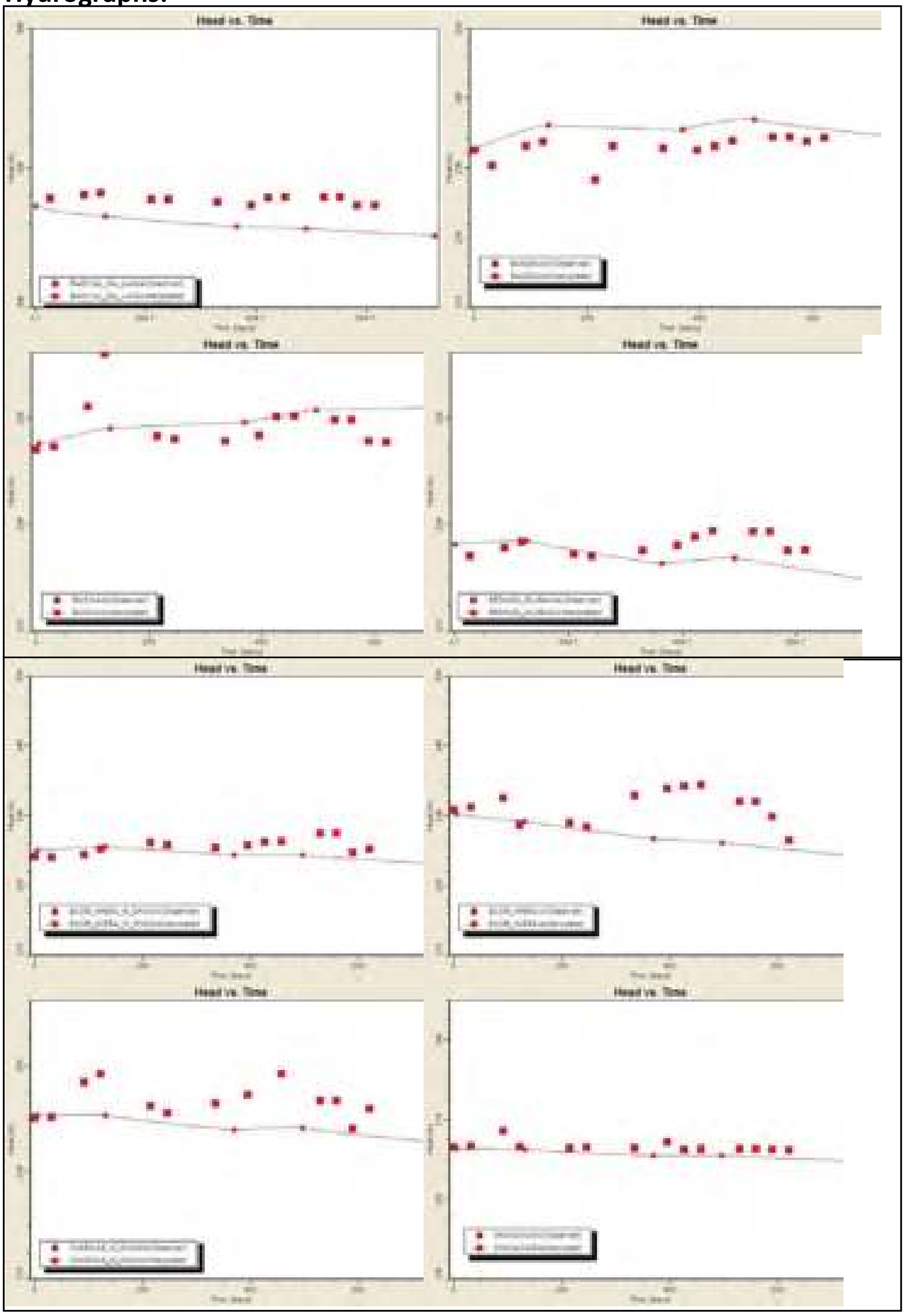


Figure 118. Hydrographs generated during Transient Calibration

WATER LEVEL HEAD

Generated water level head after transient calibration and shown in Figure 119 below for the period of May 2014.

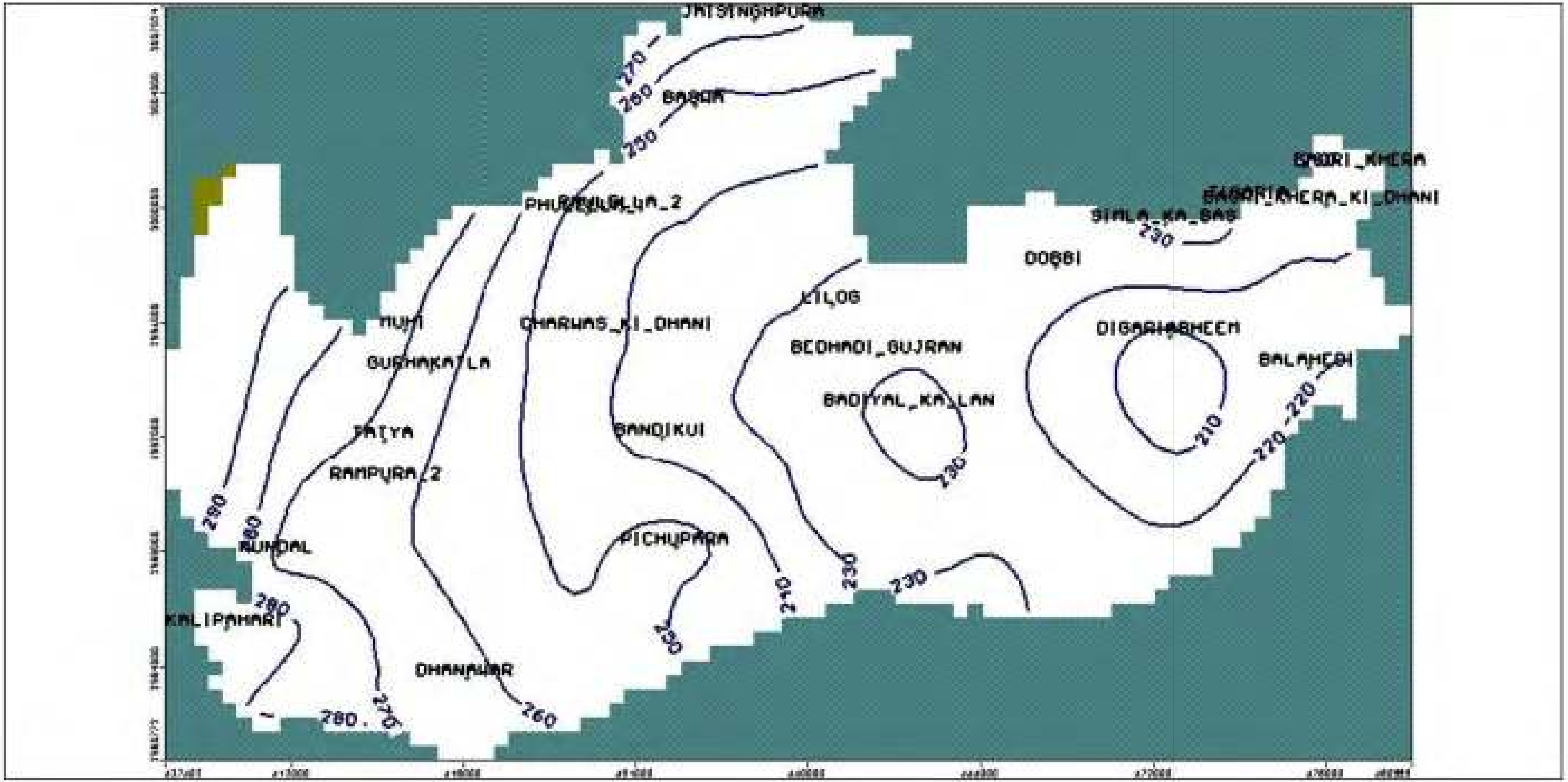


Figure 117. Water level head generated after Transient Calibration

Mass Balance

TABLE 37 CUMULATIVE MASS BALANCE IN M3

				FLOW IN			FLOW OUT			CHANGE IN STORAGE
Stress Period	From	To	Time	HDB	NET RECHARGE	TOTAL	HDB	NET RECHARGE	TOTAL	
1	01-Jun-12	30-Sep-12	122	6732013	5872736	12604749	4354009	1078257.625	5432266.625	7172482.38
2	01-Oct-12	31-May-13	365	19227542	5872736	25100278	6785087.5	49222448	56007535.5	-30907258
3	01-Jun-13	30-Sep-13	487	25268404	11745472	37013876	7883765.5	50300704	58184469.5	-21170594
4	01-Oct-13	31-May-14	730	39011496	11745472	50756968	9536495	98444888	107981383	-57224415

PERIOD WISE MASS BALANCE IN M3

				FLOW IN			FLOW OUT			CHANGE IN STORAGE
Stress Period	From	To	Time	HDB	NET RECHARGE	TOTAL	HDB	NET RECHARGE	TOTAL	
1	01-Jun-12	30-Sep-12	122	6732013	5872736	12604749	4354009	1078257.625	5432266.625	7172482.38
2	01-Oct-12	31-May-13	365	12495529	0	12495529	2431078.5	48144190.38	50575268.88	-38079740
3	01-Jun-13	30-Sep-13	487	6040862	5872736	11913598	1098678	1078256	2176934	9736664
4	01-Oct-13	31-May-14	730	13743092	0	13743092	1652729.5	48144184	49796913.5	-36053822
	TOTAL			39011496	11745472	50756968	9536495	98444888	107981383	-57224415

Zone Budget

Formation wise Zone budget has been computed for the 4th stress period (730 days) and presented below in Figure120.

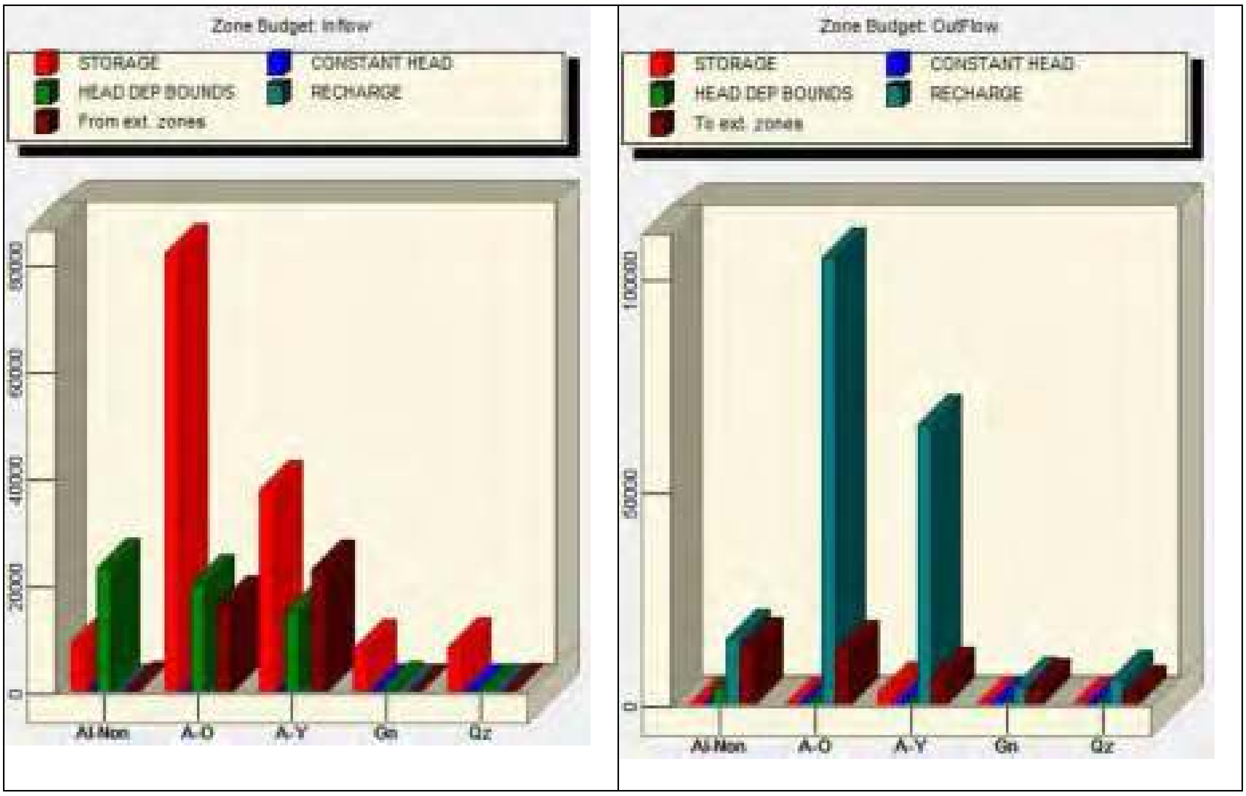


Figure 120. Formation-wise Zone Budget

Table 38. Zone Budget in m^3/day

Zone 1	Time	In Flow in m3/day						Out Flow in m3/day					
Stress Period		HDB	NET RECHARGE	Zone 2 to 1	Zone 3 to 1	Zone 4 to 1		HDB	NET RECHARGE	Zone 1 to 2	Zone 1 to 3	Zone 1 to 4	
1	122	18958	0	347.2	347.66	364.9		6814.9	741.98	5576	14631	0	
2	365	22597	0	0	260.82	293.92		4687.5	15738	4405	11516	0	
3	487	21494	0	0	295.15	506.08		5342	741.98	4186	10986	0	
4	730	23619	0	0	372.87	330.47		4368.9	15738	3595	10166	0	
Zone 2	Time												
Stress Period		HDB	NET RECHARGE	Zone 1 to 2	Zone 3 to 2	Zone 4 to 2	Zone 5 to 2	HDB	NET RECHARGE	Zone 2 to 1	Zone 2 to 3	Zone 2 to 4	Zone 2 to 5
1	122	14580	0	5576	8568	1621.6	2457.8	7622.1	4976.8	347.2	22443	76.423	174.6
2	365	19266	0	4405	6522.7	3082.1	2445.8	1739.7	1.06E+05	0	16811	0	33.42
3	487	15828	0	4186	6459.2	3055.4	2972.4	2143.5	4976.8	0	15724	0	9.151
4	730	20559	0	3595	6600.3	3721.4	2759.7	1054.1	1.06E+05	0	13043	0	0
Zone 3													
Stress Period	Time	HDB	NET RECHARGE	Zone 1 to 3	Zone 2 to 3			HDB	NET RECHARGE	Zone 3 to 1	Zone 3 to 2		
1	122	8698.4	0	14631	22443			2851.7	3119.4	347.7	8568		
2	365	13117	0	11516	16811			601.4	66166	260.8	6522.7		
3	487	9738.5	0	10986	15724			1023.1	3119.4	295.2	6459.2		
4	730	15481	0	10166	13043			300.15	66166	372.9	6600.3		

Zone 4 Stress Period	Time	HDB	NET RECHARGE	Zone 1 to 4	In: Zone 2 to 4	In: Zone 5 to 4		HDB	NET RECHARGE	Zone 4 to 1	Zone 4 to 2	Zone 4 to 5	
1	122	508.38	24495	0	76.423	62.243		803.1	0	364.9	1621.6	290.29	
2	365	624.18	0	0	0	63.757		71.445	4598	293.9	3082.1	297.34	
3	487	317.85	24495	0	0	65.155		655.27	0	506.1	3055.4	350.87	
4	730	620.56	0	0	0	66.6		53.285	4598	330.5	3721.4	330.72	
Zone 5 Stress Period	Time	HDB	NET RECHARGE	Zone 2 to 5	In: Zone 4 to 5			HDB	NET RECHARGE		Zone 5 to 2	Zone 5 to 4	
1	122	0	23642	174.6	290.29			706.25	0		2457.8	62.243	
2	365	0.94839	0	33.42	297.34			220.54	6056.2		2445.8	63.757	
3	487	0	23642	9.151	350.87			487.97	0		2972.4	65.155	
4	730	22.496	0	0	330.72			194.19	6056.2		2759.7	66.6	

6.1.7 *EVOLVING MANAGEMENT STRATEGIES AS PREDICTIVE SCENARIO*

The ultimate purpose of a model study is to predict the response of the aquifer system to the anticipated changes in hydrogeological stresses. In the study area the parameters determined during calibration has been used for predicting future scenarios.

Three approaches are used to investigate alternate ground water management practices. In the first approach, the flow model is used to determine the effect of withdrawal and recharge hypothetically to be continued upto next 10 years at the same rate as exist in the present date. The scenario is selected to represent possible future changes in water used in the basin or to investigate the effect of water management and practices that could mitigate potential adverse effect of increased water withdrawals.

In the Second scenario, the flow model is used in conjunction with the availability of more recharge. Monsoon recharge is increased by three times and applied to the model. The scenario is selected to see the possible changes in future in case artificial recharge plan is implemented in the study area to mitigate the declining water level.

The model forecast is carried out for the period of 10 years commencing from June 2014 to May 2024 (Table 39). The annual hydrologic cycle is divided into two periods consisting 122 days (June to September) during pre-monsoon period and 243 days (October to May) in non-monsoon period. Within each period, boundary flows are uniform whereas stress varies according to recharge and discharge. Multiple model stress period with the same stress and boundary flow are used to simulate the model.

Table 39. Multiple Model Stress period used for Model forecast

Stress period	Date		Time in days			Season
	From	To	Start	End	Duration	
1	01-Jun-14	30-Sep-14	0	122	122	Monsoon
2	01-Oct-14	31-May-15	122	365	243	Non-Monsoon
3	01-Jun-15	30-Sep-15	365	487	122	Monsoon
4	01-Oct-15	31-May-16	487	731	244	Non-Monsoon
5	01-Jun-16	30-Sep-16	731	853	122	Monsoon
6	01-Oct-16	31-May-17	853	1096	243	Non-Monsoon
7	01-Jun-17	30-Sep-17	1096	1218	122	Monsoon
8	01-Oct-17	31-May-18	1218	1461	243	Non-Monsoon
9	01-Jun-18	30-Sep-18	1461	1583	122	Monsoon
10	01-Oct-18	31-May-19	1583	1826	243	Non-Monsoon
11	01-Jun-19	30-Sep-19	1826	1948	122	Monsoon
12	01-Oct-19	31-May-20	1948	2192	244	Non-Monsoon
13	01-Jun-20	30-Sep-20	2192	2314	122	Monsoon
14	01-Oct-20	31-May-21	2314	2557	243	Non-Monsoon
15	01-Jun-21	30-Sep-21	2557	2679	122	Monsoon
16	01-Oct-21	31-May-22	2679	2922	243	Non-Monsoon
17	01-Jun-22	30-Sep-22	2922	3044	122	Monsoon
18	01-Oct-22	31-May-23	3044	3287	243	Non-Monsoon
19	01-Jun-24	30-Sep-23	3287	3409	122	Monsoon
20	01-Oct-23	31-May-24	3409	3652	243	Non-Monsoon

DATA REQUIREMENT

Input data require is primarily of two types, the aquifer parameters which remain same for all the scenarios and the stress applied vary according to the scenario being simulated. The groundwater head obtained for June 2014 as generated during calibration is used as starting head for generating the scenarios.

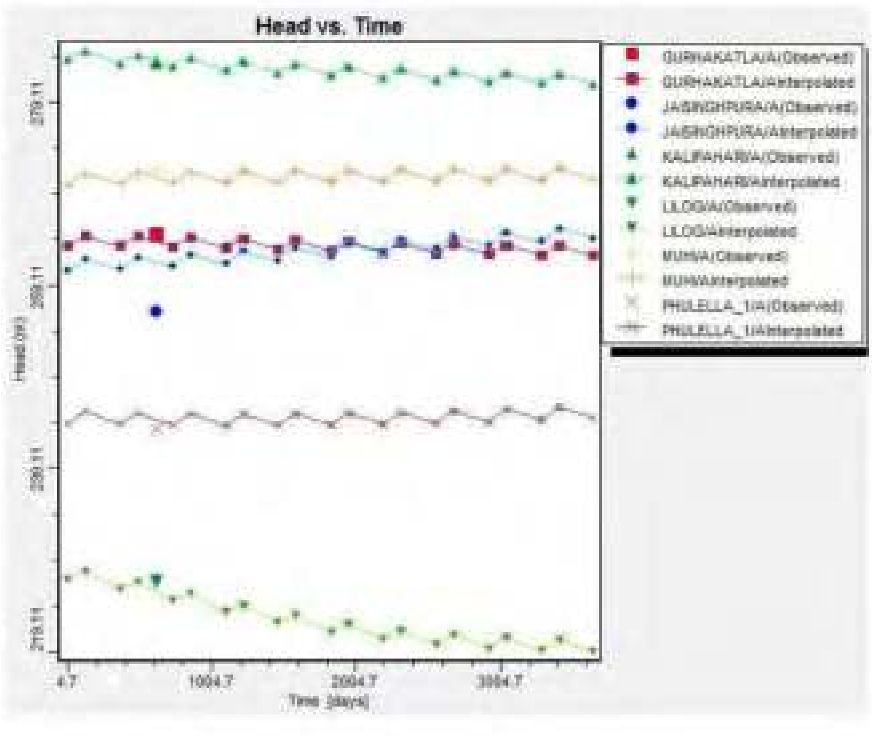
6.1.7.1 PREDICTIVE MODEL RESULTS OF PROPOSED MANAGEMENT STRATEGIES

6.1.7.1.1 SCENARIO: 1 - PRESENT HYDROGEOLOGICAL STRESS

In this scenario model is run to predict the regional groundwater head for 10 years that is till the year 2024. The simulated groundwater head at the end of the May 2014 is taken as initial head condition at the start of June 2014. The net rainfall recharge rate for the projected years are taken corresponds to calibration level and applied to the model throughout the 10 years.

RESULTS

Hydrographs: Generated hydrographs for selected observation points and presented below in Figure 119.



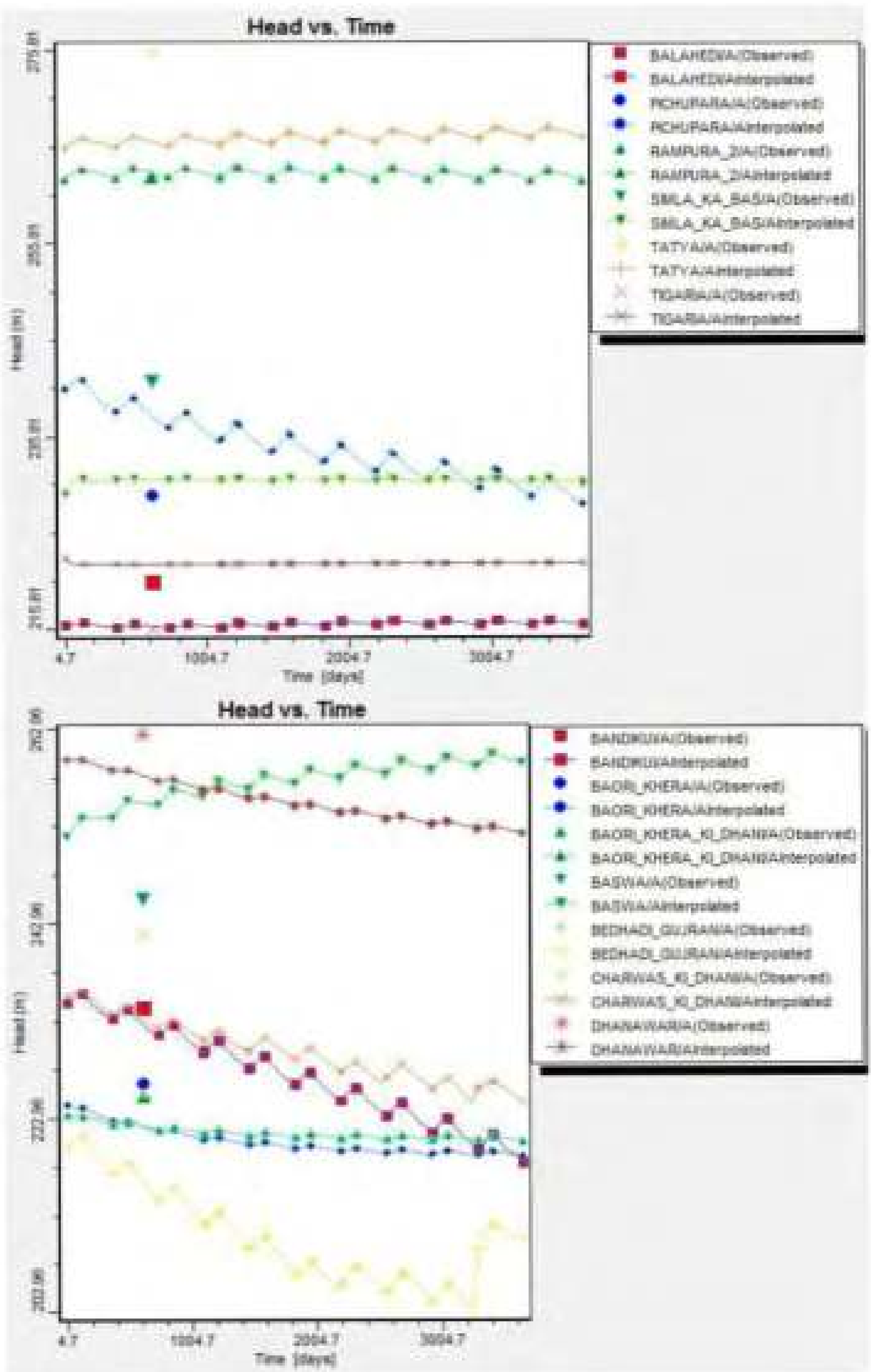


Figure 121. Representative Hydrographs generated in Predictive Model Scenario – I

WATER LEVEL HEAD

Generated water level head at the end of this scenario and shown in Figure 122 for the period of May 2024. Certain part of the area as shown in figure has started dried up from the second stress period and progressively occupy the area till the end of this scenario.

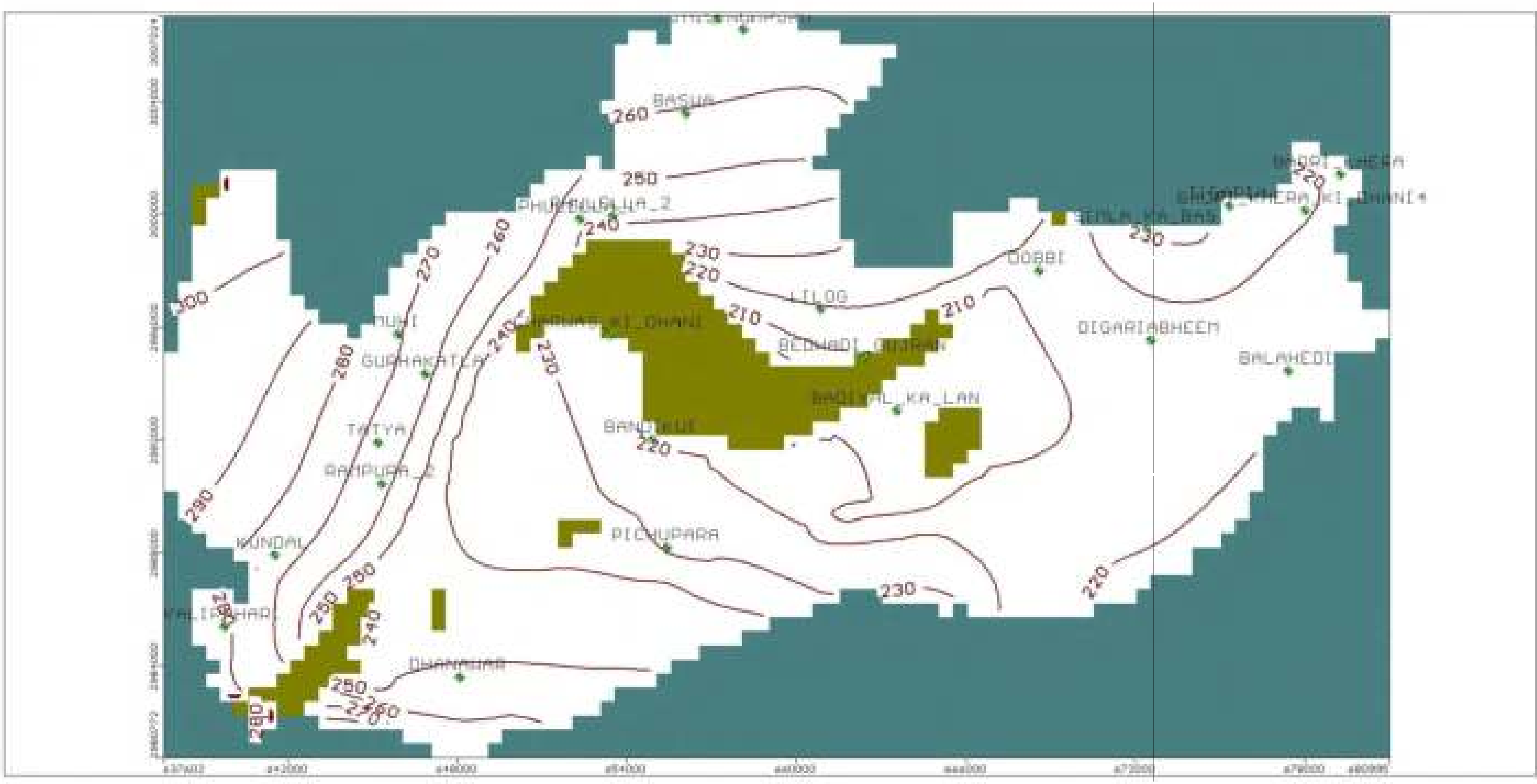


Figure 122. Water Level Map generated in Predictive Model Scenario – I

MASS BALANCE

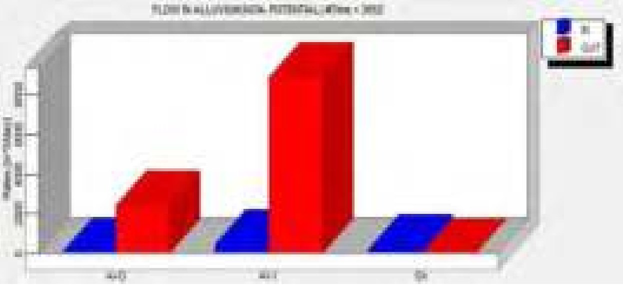
Cumulative and period-wise Volumetric water budget is given in the table below. Perusal of the Table 40 & 41 indicates that in the last stress period during October, 2023 and May, 2024, 216 mcm Cumulative Volume of water is added to the system through the general head boundary and 184 mcm is water is dewatered from the Storage in the domain.

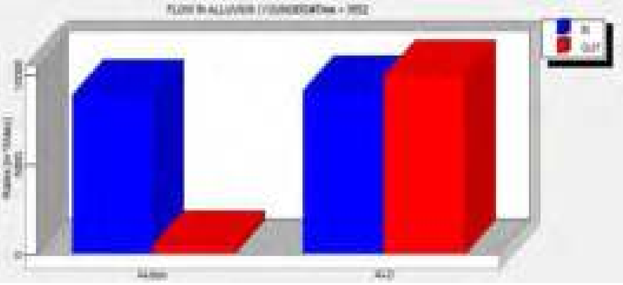
ZONE BUDGET

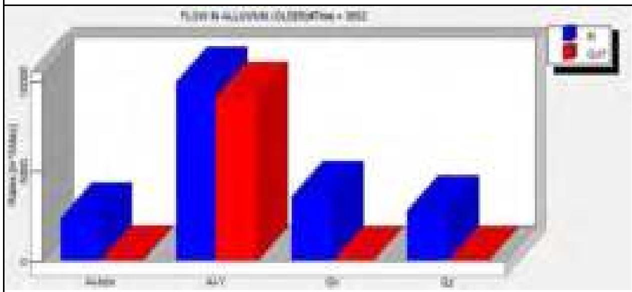
The ground water budget for transient state simulation in Baswa-Bandikui watershed gives an accounting of recharge to basin, discharge from the watershed and flow between hydrogeologic units in the watershed (Modflow-Zonebudget-2000). The main objective of the study were the estimates of groundwater flow budget and determination of aquifer flow direction. Five budget zones were assigned throughout the basin using zone-budget to determine the overall hydraulic budget for the region.

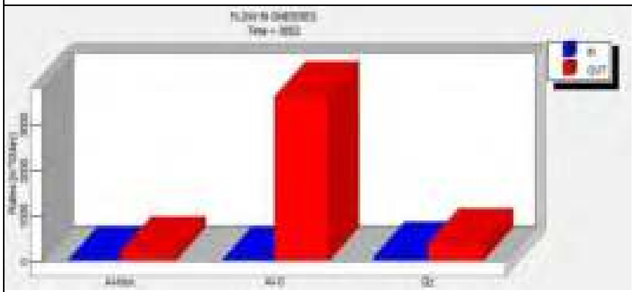
The groundwater zone budget has been estimated for all the stress period and summarised in Annexure 6 and histogram of zone budget for the period of May 2024 is shown in the Fig. 123. Water budget inflow include recharge from Net Recharge and Recharge through General Head Boundary (GHB). Perusal of the table given in Annexure 6 and figure 121 depicts that exchange of horizontal flow is exist between Non-potential Alluvium(zone -1) and adjoining Older Alluvium (zone-2) and Younger Alluvium (zone-3). Older Alluvium and Younger Alluvium is getting recharge from Non-potential Alluvium @ 2425 m^3/day and 8912 m^3/day respectively (Annexure 6, zone-1) during last stress period May 2024. Therefore there are chances of quality deterioration in both Older and Younger Alluvium. Younger Alluvium is transmitting 10015 m^3/day and receiving 9179.9 m^3/day flow from Older Alluvium. Similarly, Older Alluvium is getting recharged from Gneisses and Quartzite/ Phyllites @ 3622 m^3/day and 2858 m^3/day respectively during last stress period May 2024.

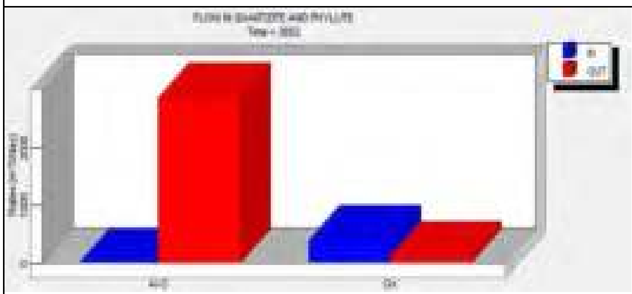
Zone budget:











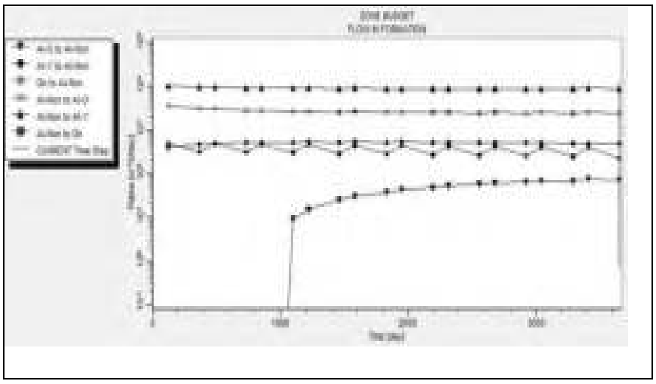


Figure 123. Zone Budget in Predictive Model Scenario - I

Dry Cell

The above result indicated a reasonable ground for experimenting with increase pumpage in weathered hard rock area. Drying of cells covering an area of 59.50 sq.km. in northern part of alluvium area close to Gneisses formation resulted due to over-drafting of ground water that should be reduced for optimum utilization of ground water.

6.1.7.1.2 SCENARIO: 2 - THREE TIMES MONSOON RECHARGE:

In this scenario model is run to predict the regional groundwater head for 10 years, that is till the year 2024. The simulated groundwater head at the end of the May 2014 is taken as initial head condition at the start of June 2014. In the scenario the recharge for the monsoon period is taken 3 times to the monsoon recharge computed during the year 2012-13. Recharge and draft for the other period remained same as in the stress applied in the calibration period. Net recharge computed is by subtracting recharge to draft and applied to the model for all the stress period in recharge module in Visual –Modflow as given below in Table 42.

Table 42 Groundwater Recharge computed for scenario 2.

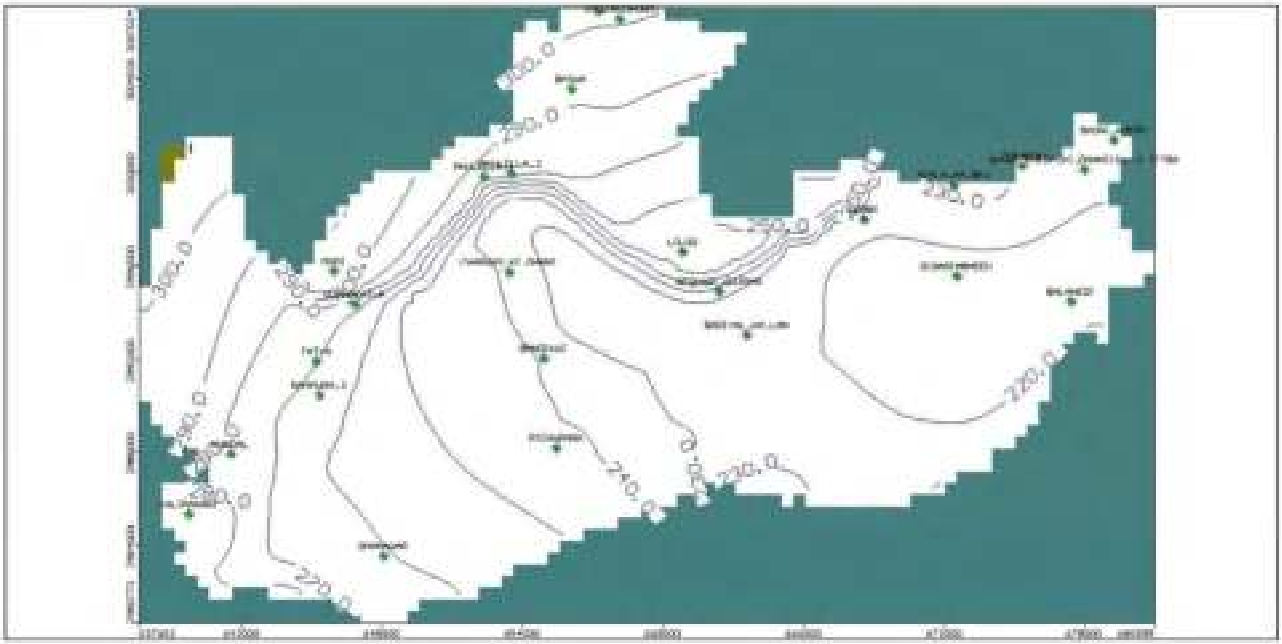
Potential Zone	Area (m3)	Monsoon recharge (m3)	3Time_monsoon_recharge	Non-monsoon recharge (m3)	Net_Monsoon recharge (m3)	Net_Non-monsoon recharge (m3)	Net_Monsoon recharge (M)	Net_Non-monsoon recharge(M)	NET_Monsoon recharge(m/day)	Net_Non-monsoon recharge (m/day)
		June-Sept		oct-May	June-Sept	oct-May				
Alluvium	394020000	13871351	41614053	2967341	26760553	-41493559	0.067917	-0.105308	0.000557	-0.0004334
Quqrtzite & phyllite	104600000	3264840	9794520	73800	9297220	-1412900	0.088884	-0.013508	0.000729	-5.559E-05
Gneiss	99490000	2725120	8175360	46300	7856760	-899900	0.07897	-0.009045	0.000647	-3.722E-05

RESULT

WATER LEVEL HEAD

Generated water level head at the end of this scenario and shown in Figure 124 for the period of September 2014 and May 2024.

Groundwater Head September 2014



Groundwater Head May 2024

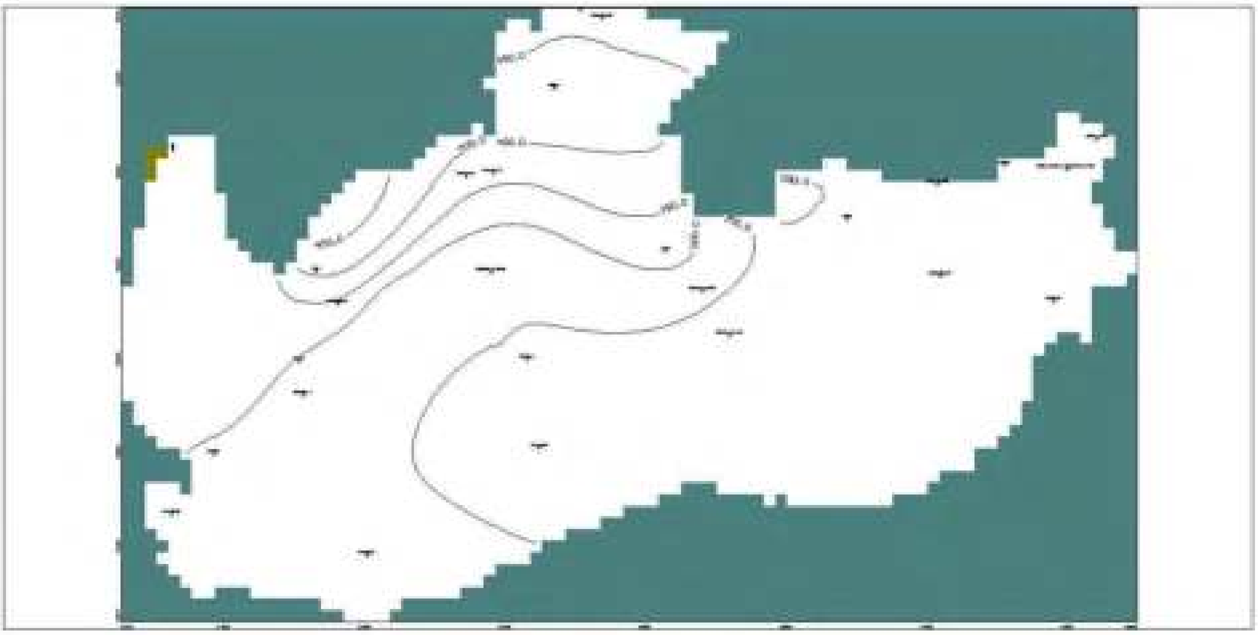


Figure 124. Groundwater head generated in Scenario 2 i.e. three time recharge.

Mass Balance

Table 43

Table: Scenario-2 Cummulative Mass balance in m3										
Stress Period	Period		Time_ Days	Flow In			Flow Out			
	From	To		GHB	Recharge	Total in	GHB	Recharge	Total	CHANGE IN STORAGE
1	01-Jun-14	30-Sep-14	122	5609754	136678176	142287930	3031017.5	0	3031017.5	139256913
2	01-Oct-14	31-May-15	365	18210042	136678176	154888218	7280540	48153856	55434396	99453822
3	01-Jun-15	30-Sep-15	487	23178686	273356352	296535038	10716691	48153856	58870547	237664491
4	01-Oct-15	31-May-16	731	35412488	273356352	308768840	15675979	96505872	112181851	196586989
5	01-Jun-16	30-Sep-16	853	40203932	410034528	450238460	19343758	96505872	115849630	334388830
6	01-Oct-16	31-May-17	1096	52049224	410034528	462083752	24658686	144659712	169318398	292765354
7	01-Jun-17	30-Sep-17	1218	56693532	546712704	603406236	28469022	144659712	173128734	430277502
8	01-Oct-17	31-May-18	1461	68242400	546712704	614955104	34067224	192813584	226880808	388074296
9	01-Jun-18	30-Sep-18	1583	72753824	683390848	756144672	38001972	192813584	230815556	525329116
10	01-Oct-18	31-May-19	1826	84049664	683390848	767440512	43837280	240967424	284804704	482635808
11	01-Jun-19	30-Sep-19	1948	88449216	820069056	908518272	47885204	240967424	288852628	619665644
12	01-Oct-19	31-May-20	2192	99567984	820069056	919637040	53966372	289319424	343285796	576351244
13	01-Jun-20	30-Sep-20	2314	103868872	956747264	1060616136	58115664	289319424	347435088	713181048
14	01-Oct-20	31-May-21	2557	114738608	956747264	1071485872	64373792	337473280	401847072	669638800
15	01-Jun-21	30-Sep-21	2679	118945696	1093425408	1212371104	68628032	337473280	406101312	806269792
16	01-Oct-21	31-May-22	2922	129620288	1093425408	1223045696	75085120	385627136	460712256	762333440
17	01-Jun-22	30-Sep-22	3044	133741584	1230103808	1363845392	79434312	385627136	465061448	898783944
18	01-Oct-22	31-May-23	3287	144235056	1230103808	1374338864	86074528	433780992	519855520	854483344
19	01-Jun-24	30-Sep-23	3409	148274432	1366782080	1515056512	90519640	433780992	524300632	990755880
20	01-Oct-23	31-May-24	3652	158492416	1366782080	1525274496	97296232	481934848	579231080	946043416

Table 44

Table: Scenario-2 Stress period wise Mass balance in m3											
Stress Period	Period		Time_ Days	Flow In			Flow Out			CHANGE IN STORAGE	Cummulative change in storage
	From	To		Head Dependent Boundary	Net Rechagre	Total in	Head Dependent Boundary	Net Recharge	Total		
1	01-Jun-14	30-Sep-14	122	5609754	136678176	142287930	3031017.5	0	3031017.5	139256913	139256913
2	01-Oct-14	31-May-15	365	12600288	0	12600288	4249522.5	48153856	52403378.5	-39803091	99453822
3	01-Jun-15	30-Sep-15	487	4968644	136678176	141646820	3436151	0	3436151	138210669	237664491
4	01-Oct-15	31-May-16	731	12233802	0	12233802	4959288	48352016	53311304	-41077502	196586989
5	01-Jun-16	30-Sep-16	853	4791444	136678176	141469620	3667779	0	3667779	137801841	334388830
6	01-Oct-16	31-May-17	1096	11845292	0	11845292	5314928	48153840	53468768	-41623476	292765354
7	01-Jun-17	30-Sep-17	1218	4644308	136678176	141322484	3810336	0	3810336	137512148	430277502
8	01-Oct-17	31-May-18	1461	11548868	0	11548868	5598202	48153872	53752074	-42203206	388074296
9	01-Jun-18	30-Sep-18	1583	4511424	136678144	141189568	3934748	0	3934748	137254820	525329116
10	01-Oct-18	31-May-19	1826	11295840	0	11295840	5835308	48153840	53989148	-42693308	482635808
11	01-Jun-19	30-Sep-19	1948	4399552	136678208	141077760	4047924	0	4047924	137029836	619665644
12	01-Oct-19	31-May-20	2192	11118768	0	11118768	6081168	48352000	54433168	-43314400	576351244
13	01-Jun-20	30-Sep-20	2314	4300888	136678208	140979096	4149292	0	4149292	136829804	713181048
14	01-Oct-20	31-May-21	2557	10869736	0	10869736	6258128	48153856	54411984	-43542248	669638800
15	01-Jun-21	30-Sep-21	2679	4207088	136678144	140885232	4254240	0	4254240	136630992	806269792
16	01-Oct-21	31-May-22	2922	10674592	0	10674592	6457088	48153856	54610944	-43936352	762333440
17	01-Jun-22	30-Sep-22	3044	4121296	136678400	140799696	4349192	0	4349192	136450504	898783944
18	01-Oct-22	31-May-23	3287	10493472	0	10493472	6640216	48153856	54794072	-44300600	854483344
19	01-Jun-24	30-Sep-23	3409	4039376	136678272	140717648	4445112	0	4445112	136272536	990755880
20	01-Oct-23	31-May-24	3652	10217984	0	10217984	6776592	48153856	54930448	-44712464	946043416

Zone Budget

Formation wise Zone budget has been computed for the 10th stress period (3652 days) and presented below in Table 45.

Table 45 Formation wise Zone Budget

Alluvium formation potential aquifer:

Older Alluvium Output Time: 10 Stress Period: 35 Time (days): 3652 Input Report Storage = 60316 [m^3/day] Recharge = 0 [m^3/day] General-Head = 0 [m^3/day] Zone 1 to 2 = 5891.5 m^3/day Zone 3 to 2 = 6876.5 m^3/day Zone 4 to 2 = 45884 m^3/day Zone 5 to 2 = 14030 m^3/day Total IN = 133000 m^3/day	Output Report Storage = 10926 [m^3/day] Recharge = 105570 [m^3/day] General Head = 0 [m^3/day] Zone 2 to 1 = 0 m^3/day Zone 2 to 3 = 16562 m^3/day Zone 2 to 4 = 0 m^3/day Zone 2 to 5 = 0 m^3/day Total OUT = 133050 m^3/day Difference: IN - OUT = -56.542 [m^3/day] Percent Discrepancy = -0.04%
Younger Alluvium Output Time: 10 Stress Period: 35 Time (days): 3652.0007 Input Report Storage = 51541 [m^3/day] Recharge = 0 [m^3/day] General-Head = 0 [m^3/day] Zone 1 to 3 = 6131.7 m^3/day Zone 2 to 3 = 16562 m^3/day Total IN = 74234 m^3/day	Output Report Storage = 363.5 [m^3/day] Recharge = 66166 [m^3/day] General Head = 0 [m^3/day] Zone 3 to 1 = 861.27 m^3/day Zone 3 to 2 = 6876.5 m^3/day Total OUT = 74267 m^3/day Difference: IN - OUT = -32.731 [m^3/day] Percent Discrepancy = -0.04%

Gneiss Formation

Zone 4 [Zone8] [Zone8] ---------- Output Time: 10 Stress Period: 35Time (days): 3652 Input Report Storage = 76034 [m^3/day] General-Head = 0 [m^3/day] Zone 1 to 4 = 0 m^3/day Zone 2 to 4 = 0 m^3/day Zone 5 to 4 = 0 m^3/day Total IN = 76034 m^3/day	Output Report Storage = 10617 [m^3/day] Recharge = 4595.2 [m^3/day] ET = 0 [m^3/day] General-Head = 0 [m^3/day] Zone 4 to 1 = 3083.2 m^3/day Zone 4 to 2 = 45884 m^3/day Zone 4 to 5 = 11944 m^3/day Total OUT = 76123 m^3/day Difference: IN - OUT = -88.705 [m^3/day] Percent Discrepancy = -0.12%

QUARTZITE AND PHYLITE FORMATION

Output Time: 10 Stress Period: 35 Time (days): 3652 Input Report Storage = 11133 [m^3/day] Recharge = 0 [m^3/day] General Head = 0 [m^3/day] Zone 2 to 5 = 0 m^3/day Zone 4 to 5 = 11944 m^3/day Total IN = 23077 m^3/day	Output Report Storage = 2980.1 [m^3/day] Recharge = 6098.8 [m^3/day] General Head = 0 [m^3/day] Zone 5 to 2 = 14030 m^3/day Zone 5 to 4 = 0 m^3/day Total OUT = 23109 m^3/day Difference: IN - OUT = -32.248 [m^3/day] Percent Discrepancy = -0.14%

6.1.7.1.3 Salient outcome of Ground water Management Strategy Models

On the basis of simulated behavior of water table in future years corresponding to different scenarios, the following general observations are made.

- In case the area is continued to be developed for several years at the present rate, it will result in desaturation of alluvium aquifer in the central part of the area. It is observed that desaturation (drying of cell) of area reached to cover an area 82 sq. km. from June 2014 to May, 2024 in the first scenario.
- Inferior quality flow from non-potential alluvium aquifer to the adjoining area may be hazardous for quality deterioration.
- Three times recharge in monsoon period as envisaged in the Scenario II is not feasible for hard rock area resulting in water logging condition.
- Area adjoining to the potential alluvium aquifer (Older and Younger) to non-potential aquifer formation should be recharged (if source water available) and over-pumping should be restricted at and around the area to maintain the Head in potential aquifer to restrict the inflow of poor quality water from adjoining non-potential aquifer.

6.1.8 Model limitations

- Alluvium formation underlain by the weathered / fractured rock formations are considered in continuation and forming a single aquifer system. Hydraulic head observed in the area represent both alluvium and weathered rock formations. Therefore the hydraulic parameters are averaged to represent both the formation to represent the approximate natural property of the formation and utilized in the model. The model is not intended to be used to simulate changes that occur separately in alluvium and weathered rock formation. Recharge and Discharge values are not separately simulated in the model. Net Recharge termed Recharge minus Discharge and value of it is applied to the model in the Recharge Module of the model. Net Recharge is approximated and applied to the Model cell (500 m X 500 m grid).
- Reflection in rise of water level in the hard rock area may be due to poor transmissivity of the aquifer or absence of drainage in the model. Therefore Model

could be refined in case additional data is available for drains passing through the area.

- Present model is required for further refinement, therefore future investigation need to include broad database. Future modeling study requires additional hydraulic Head around the boundary to establish the precise flow along the boundary.
- Additional Hydraulic properties of the aquifer are required for further refinement of the model.

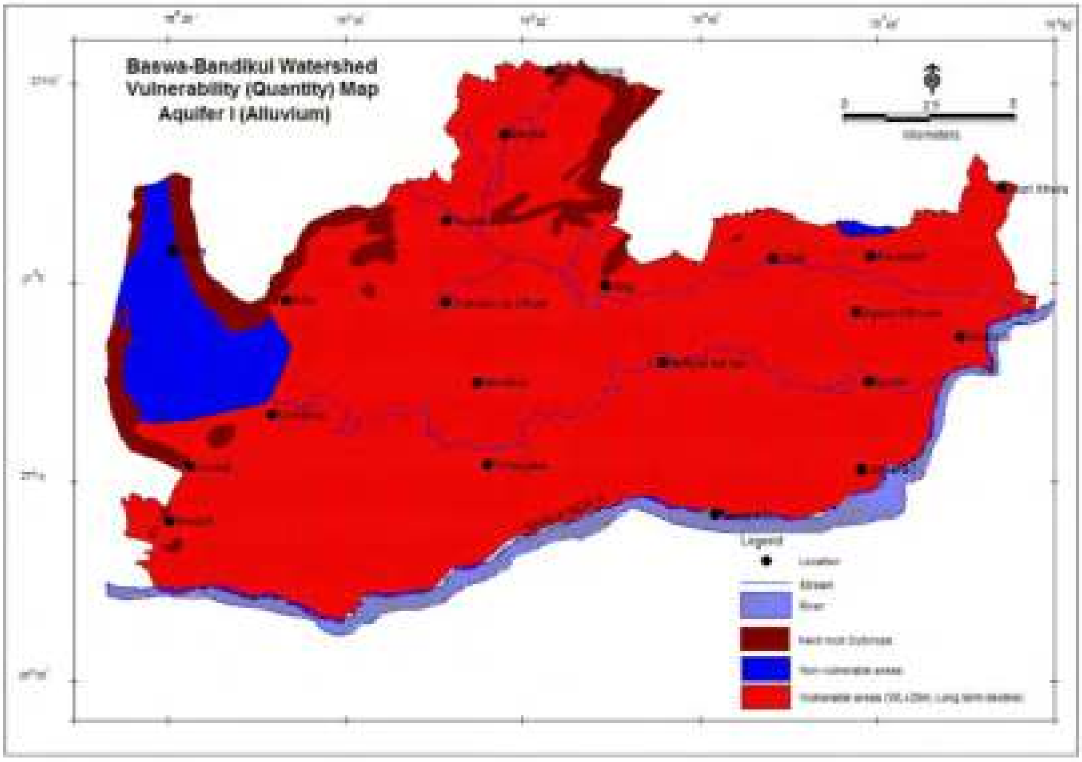
6.2 Aquifer Management Plan Formulation

The predictive ground water flow model scenarios generated in the previous section indicate that one of the key aquifer management option is artificial recharge to ground water. This section discusses aquifer-wise vulnerability in terms of water availability and quality) and formulation of artificial recharge plan in the Baswa-Bandikui watershed as a mitigation measure in response to the ground water stress condition. The artificial recharge plan is tested in the ground water flow model to find out the efficacy of the management strategy.

6.2.1 Aquifer-wise vulnerability

Ground water availability

The entire Baswa-Bandikui watershed is over-exploited. Continuous decline of water levels have been observed in both the aquifers. The assessment of ground water resources for the base-year 2013 as carried out by State Ground Water Department in consultation with Central Ground Water Board indicates that Stage of Ground Water Development in Alluvium aquifer is 220% and that of hard rock aquifer is 214%. The vulnerable areas of both the aquifers in the area are shown in Figure 125.



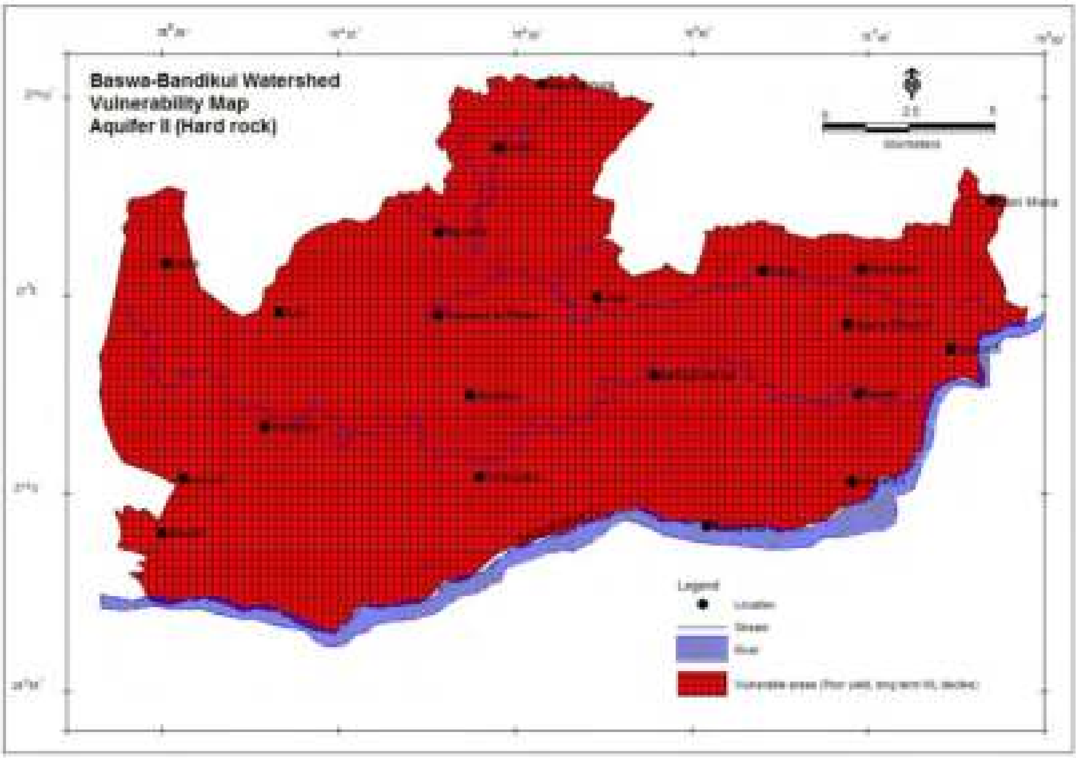
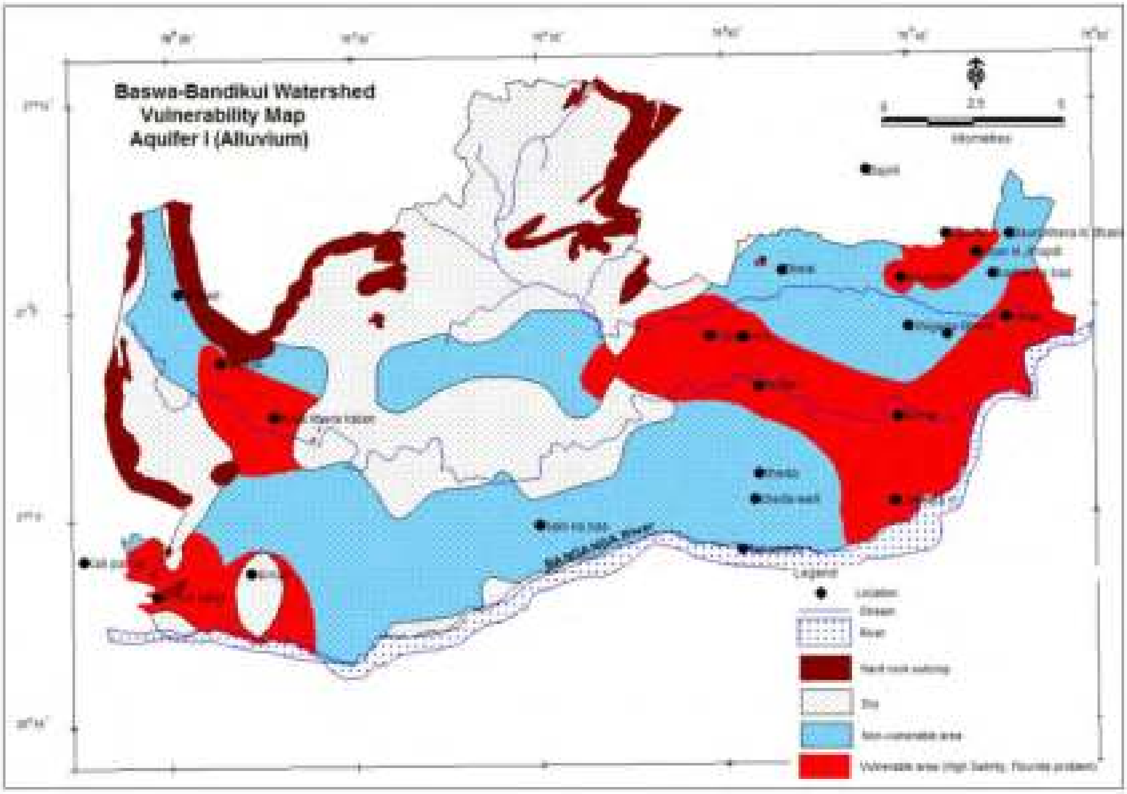


Figure 125. Aquifer-wise vulnerability maps in terms of quantity

Perusal of the above map indicates that the alluvium aquifer at the downstream of Redia dam has water level of less than 20m bgl. Thus this portion can be considered to be non-vulnerable. Rest of the Alluvium aquifer is vulnerable from quantity aspect, since it is ‘over-exploited’, water level is more than 20 mbgl and long term water level trend show decline. The entire Hard rock aquifer is vulnerable because of deep water level (more than 20 m bgl), long term decline in water level and poor yield and hydraulic characteristics of the aquifer.

Ground water Quality

Ground water quality in major part of the project area is within permissible limit. However, high salinity and fluoride have been recorded at certain pockets (figure 126).



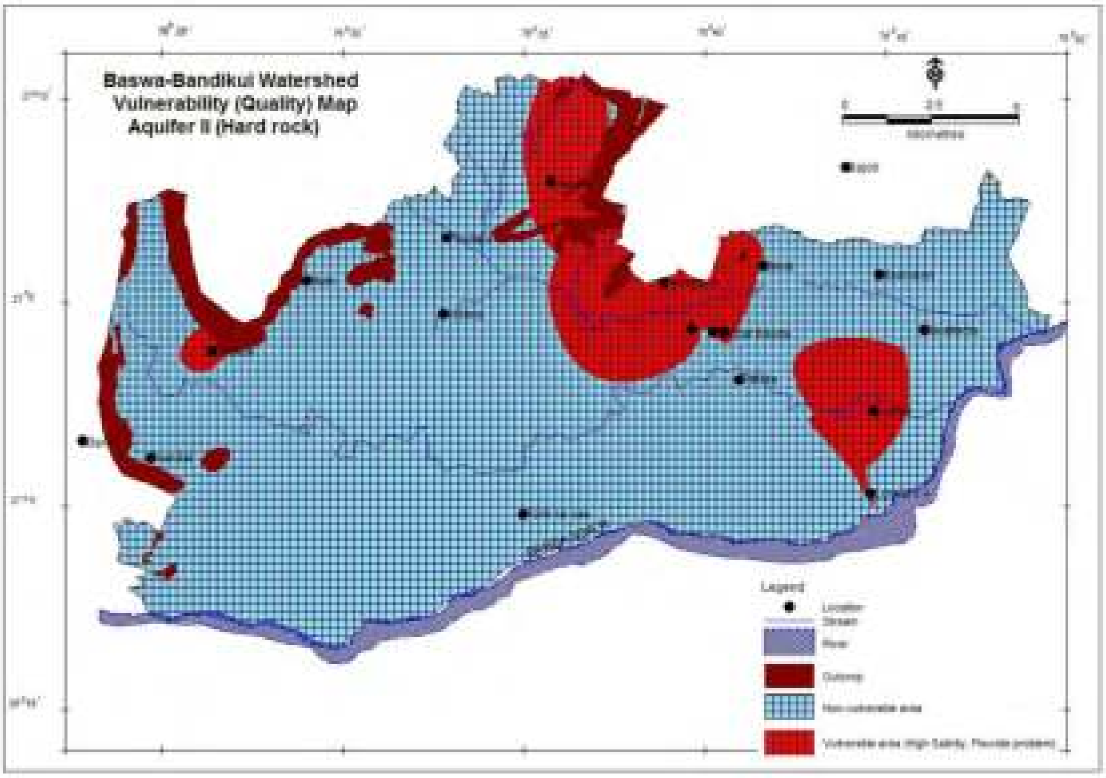


Figure 126. Aquifer-wise vulnerability maps in terms of quality

The alluvium aquifer is marked with high salinity C4S4 category as per US Salinity Classification) at several parts within project area. The alluvium aquifer in the area around Kora Kalan at the south-west corner of the project area is vulnerable in term of quality. Similarly, the alluvium aquifer around Jagsoli in the western part of the project area also has high salinity, fluoride content (Figure 124). The long belt of alluvium aquifer in the eastern part of the project area is vulnerable from ground water quality point of view. The alluvium aquifer in the pocket around Maukalan-Khare Ki Jhopdi is also vulnerable as far as quality is concern. The hard rock aquifer is less vulnerable from quality concern. A considerable portion of the hard rock aquifer in the northern part of the project area around Uprera-Nurpur Basada-Biwai is vulnerable due to high salinity, fluoride. Another pocket around Sumel is also vulnerable for similar reasons.

6.2.2 Concept of Artificial Recharge

The artificial recharge to ground water aims at augmentation of ground water reservoir by modifying the natural movement of surface water utilizing suitable civil construction techniques. Artificial recharge techniques normally address to the following issues:

- To enhance the sustainability in areas where over-development has depleted the aquifer.
- Conservation and storage of excess surface water for future requirements, since these requirements often change within a season or a period
- To improve the quality of existing ground water through dilution.

6.2.3 Need for Artificial Recharge

Ground water flow modeling studies carried out in Baswa-Bandikui watershed generated predictive scenarios involving two alternate ground water management practices. In the first scenario, the flow model is used to determine the effect of withdrawal and recharge hypothetically to be continued upto next 10 years at the same rate as exist in the present date. The scenario is selected to represent possible future changes in water used in the basin or to investigate the effect of water management and practices that could mitigate potential adverse effect of increased water withdrawals.

Second, the flow model is used in conjunction with the availability of more recharge. Monsoon recharge is increased by three times and applied to the model. The scenario is selected to see the possible changes in future in case artificial recharge plan is implemented in the study area to mitigate the declining water level. The model forecast is carried out for the period of 10 years commencing from June 2014 to May 2024.

The studies concluded that –

- *Scenario I*

Certain part of the area as shown in Figure 120 has started dried up from the second stress period and progressively occupy the area till the end of this scenario. Drying of cells covering an area of 59 sq.km. in northern part of alluvium area close to

Gneisses formation resulted due to over-drafting of ground water that should be reduced for optimum utilization of ground water.

- *Scenario II*

In this scenario, the recharge for the monsoon period is taken 3 times to the monsoon recharge computed during the year 2012-13. The water level scenario generated at year 2024 is shown in Figure 122. It is concluded that

➢ Three times recharge in monsoon period as envisaged in the Scenario II is not feasible for hard rock area resulting in water logging condition.

➢ Area adjoining to the potential alluvium aquifer (Older and Younger) to non-potential aquifer formation should be recharged (if source water available) and over-pumping should be restricted at and around the area to maintain the Head in potential aquifer to restrict the inflow of poor quality water from adjoining non-potential aquifer.

The additional recharge to be generated as per the scenario II is as follows –

Table 46. Additional recharge required to be generated as per Model Scenario

Potential zone	**Existing monsoon Recharge**	**3 Times Recharge**	**Additional Recharge**
	cub m	**cub m**	**cub m**
Alluvium	13871351	41614053	27742702
Quartizite	3264840	9794520	6529680
Gneiss	2725120	8175360	5450240
Total (cub m)	**19861311**	**59583933**	**39722622**
Total (mcm)	**19.86**	**59.58**	**39.72**

6.2.3 Prioritization of Areas for artificial recharge identified

The area identified for artificial recharge in the watershed *by the GW Flow Model* is the alluvium areas adjoining the hard rock and poor quality aquifers as shown in Figure 127.

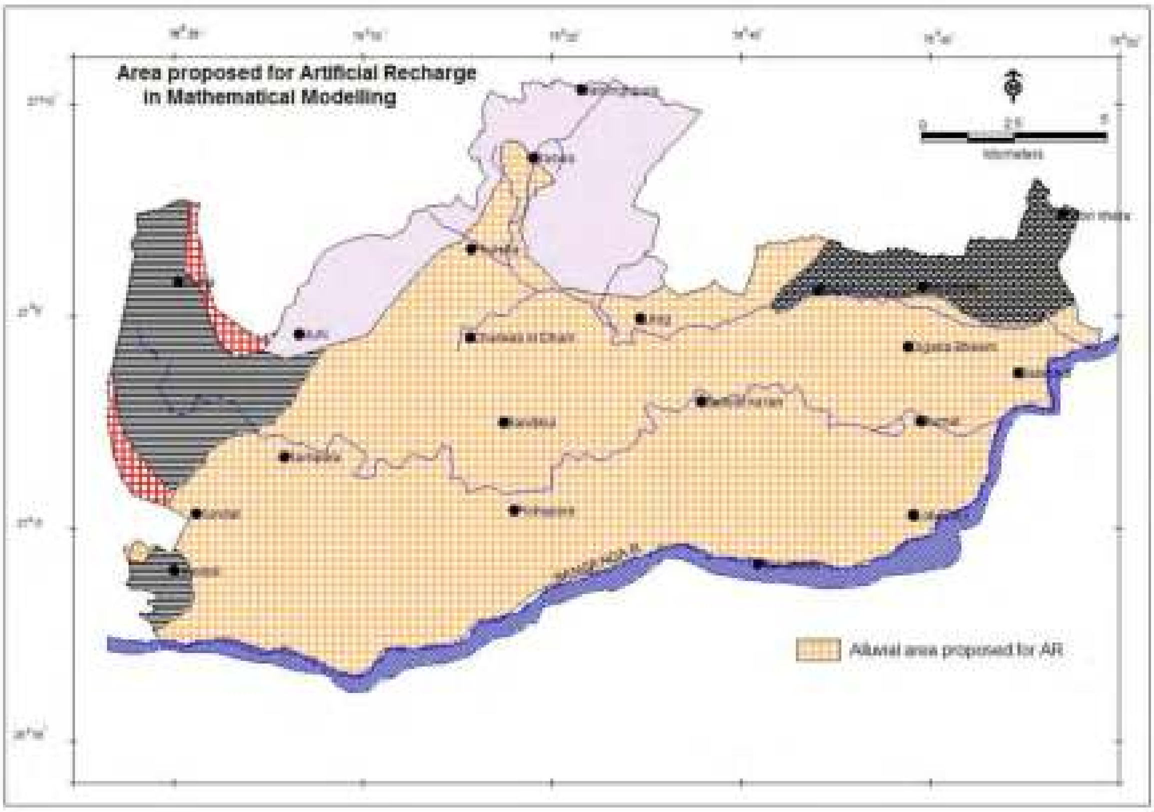


Figure 127. Area proposed for Artificial Recharge in Mathematical Modeling Studies

6.2.4 Estimation of sub-surface storage capacity

The scope for artificial recharge in an area is basically governed by the thickness of unsaturated material available above the water table in the unconfined aquifer. Depth to water level, therefore, provides the reference level to calculate the volume of unsaturated material available for recharge. The assessment of available storage space has been computed based on the contour maps prepared from the post-monsoon water level data of November, 2013 with contour intervals of 5m in the alluvial areas only (excluding hard rock and poor quality areas) as recommended in the modeling studies (Figure 128). The inter-contour areas between successive contours are determined and the total area below the cut-off level of 8 mbgl (Master Plan, Central Ground Water Board, 2013) is multiplied by the specific yield of the aquifer material to obtain the volume of subsurface storage space available for recharge (Table 47). Considering the limited source water i.e. rainfall availability, only the areas with deeper water level (>35 m bgl) have been considered for artificial recharge.

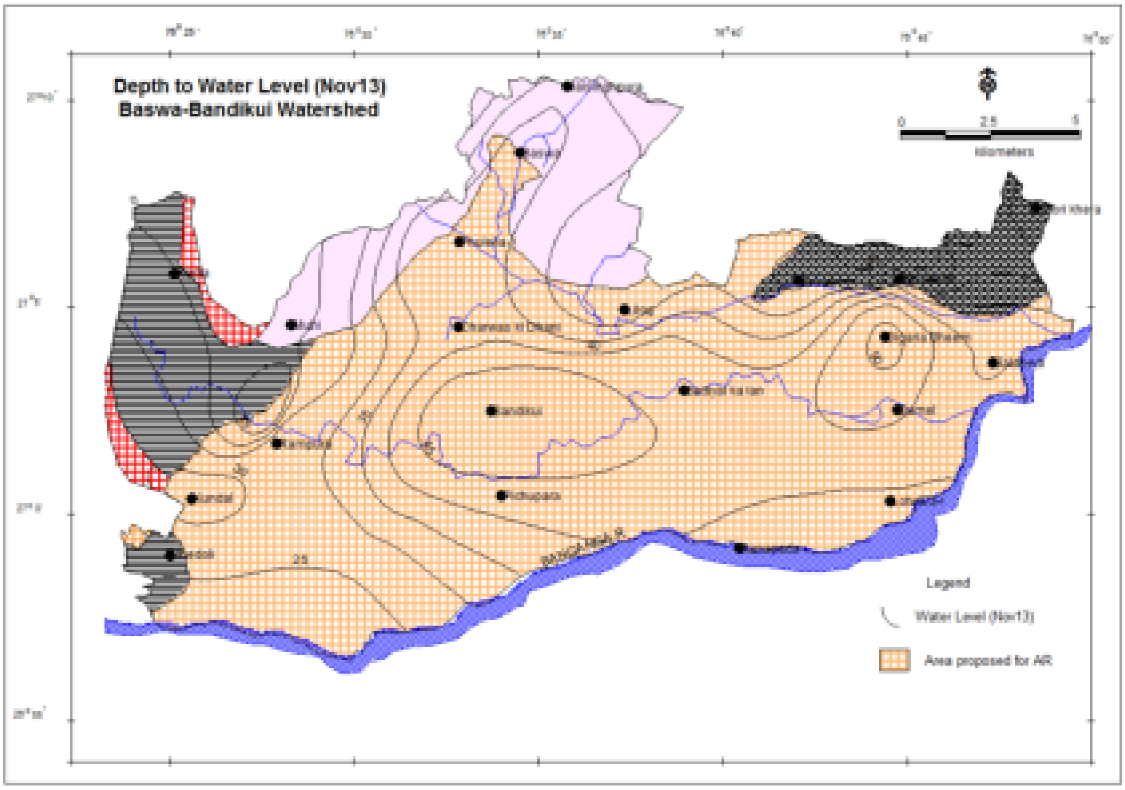


Figure 128. Water level (Nov, 13) contour map, Baswa-Bandikui watershed, Dausa district, Rajasthan

Table 47. Calculation of Sub-surface Storage Potential

WL Range	**Area identified for artificial recharge**	**Depth to water level (Postmonsoon) below cut-off level (8m)**	**Volume of unsaturated zone**	**Average specific yield**	**Total subsurface storage potential as volume of water**
mbgl	(sq.km)	(m)	(M Cu m)	(%)	(M Cum)
1	2	3	4= (2x3)	5	6=(4x5)
50-55	2.64	42	110.88	0.08	8.87
45-50	58.43	39.5	2307.99	0.08	184.64
40-45	69.63	34.5	2402.24	0.08	192.18
35-40	101.26	29.5	2987.17	0.08	238.97
TOTAL	**231.96**		**7808.27**		**624.66**

6.2.5 Quantification of Water Required for Recharge

After assessing the subsurface storage space, the actual requirement of source water is to be estimated. The volume of water required for artificial recharge is calculated by multiplying the volume of subsurface storage space with the reciprocal of recharge efficiency of the structure proposed (Table 48).

Table 48. Quantification of Water Required for Recharge

Area Identified for Artificial Recharge (Col 2 of table 45)	**Sub surface Storage Potential (col6 of table 45)**	**Recharge Efficiency**	**Surface Water Requirement**
(Sq.km)	(M Cu m)	(%)	(M Cu m)
1	2	3	4=2x 100/3
231.96	**624.66**	75*	**832.88**

* Source: Master Plan for Artificial Recharge (Central Ground Water Board, 2013)

6.2.6 Source water Availability

The source water in Baswa-Bandikui watershed is rainfall. The project area on an average (1992-2013) received about 650 mm of rainfall annually. The monsoon, contributes about 90 percent of the total annual rainfall in the basin, which is about 585 mm.

The runoff has been estimated using Strange Table Showing Depth of Runoff as Percentage of Total Monsoon Rainfall and Yield of Runoff (Central Ground Water Board, 2007). The quantification of local monsoon run off availability as source water for artificial recharge is given in the following Table 49.

Table 49. Source water availability for artificial recharge in Baswa-Bandikui watershed, Dausa district, Rajasthan

Total Monsoon Rainfall	***Bad Catchment****					**Catch-ment Area**	**Total Runoff**
	Percentage of Run-off to Rainfall	**Depth of Runoff due to Rainfall**	**Yield of Run-off**				
inches	%	inches	square mile in Mcft	square mile in Mcm	square km in Mcm	sq.m	Mcm
							8= (6*7)
23	9.2	2.116	4.916	0.139	0.22	253.00**	56.68

* Bad catchment : flat and cultivated sandy soils (Strange Table, Source: Manual on Artificial Recharge, Central Ground Water Board, 2007)

** Area feasible for recharge

6.2.7 Suitability of Area for recharge

The climatic, topographic, soil, land-use and hydrogeologic conditions are important factors controlling the suitability of an area for artificial recharge. The climatic conditions broadly determine the spatial and temporal availability of water for recharge, whereas the topography controls the extent of run-off and retention. The prevalent soil and land use conditions determine the extent of infiltration, whereas the hydrogeologic conditions govern the occurrence of potential aquifer systems and their suitability for artificial recharge.

The above criteria are imposed in Baswa-Bandikui watershed to further demarcate the specific area suitable for recharge. The conditions considered are -

i. semi-arid climate (~585 mm monsoon rainfall),
ii. topography with moderate to gentle slope,
iii. loamy soil with high infiltration rate (avg. 39 mm/hr.)(Figure 129)
iv. unconsolidated alluvium, water level > 35 mbgl (post-monsoon) (Figure 128) and
v. ground water quality – EC<3000µmhos/cm (Figure 129).

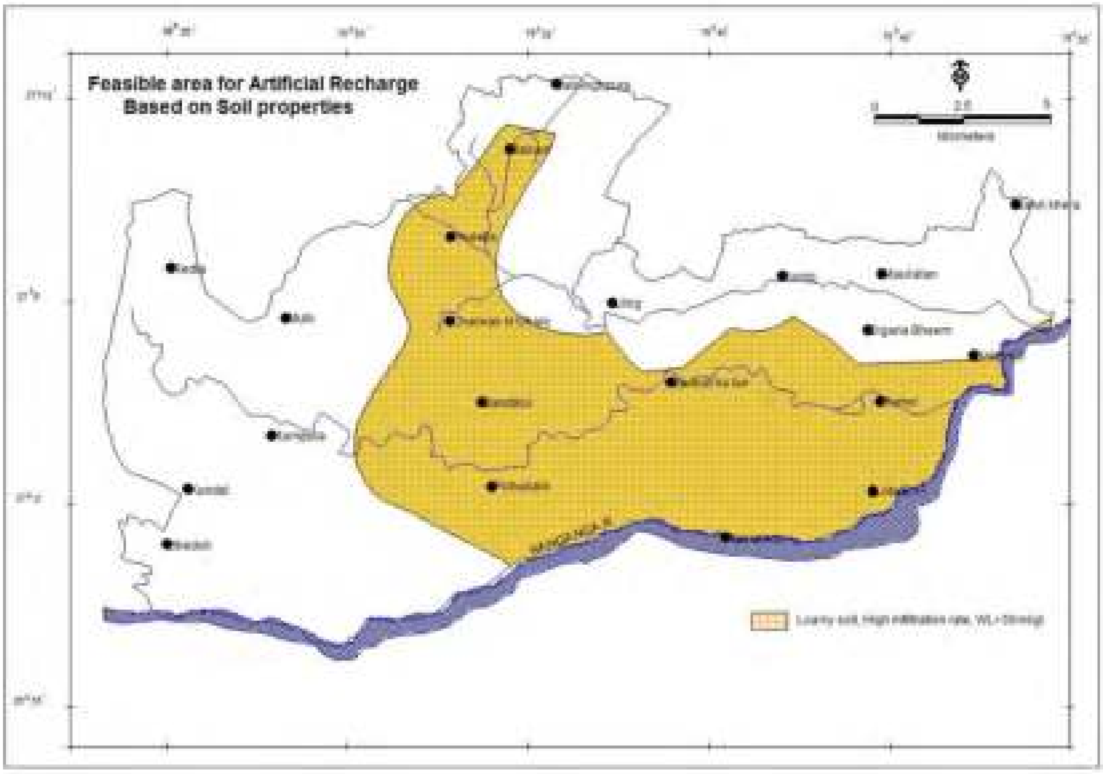


Figure 129. Feasible area for Artificial Recharge – based on soil type

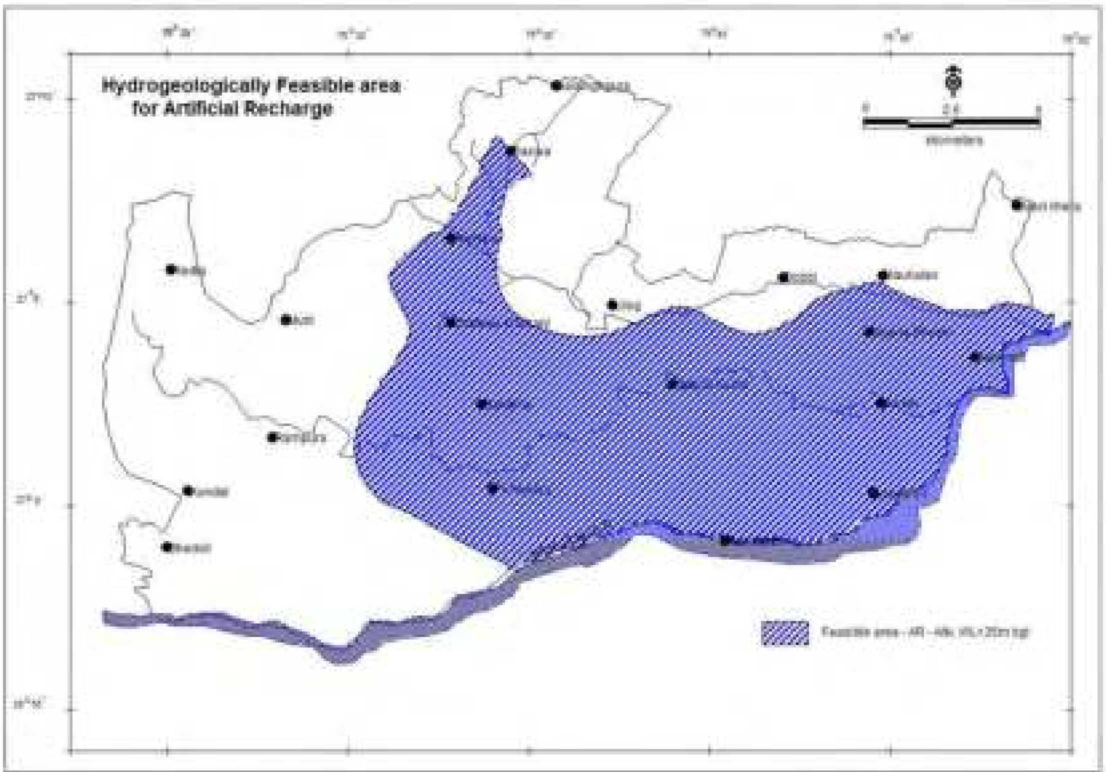


Figure 130. Feasible area for Artificial Recharge – based on Hydrogeological conditions

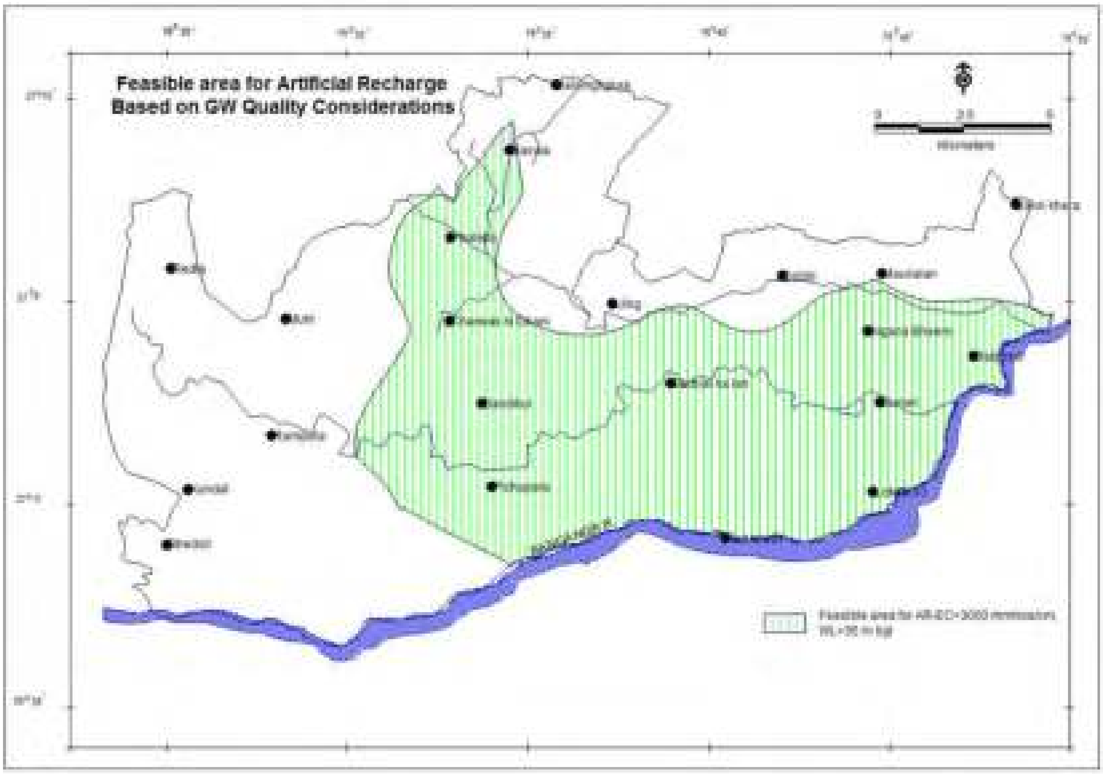


Figure 131. Feasible area for Artificial Recharge – based on GW quality

All these parameters are superimposed on GIS platform to delineate the area feasible for artificial recharge by Percolation Tanks and Recharge Shafts (Figure 130). The total area is about 253 sq.km. In addition to these structures, Roof top rainwater harvesting structures is also proposed for the entire project area.

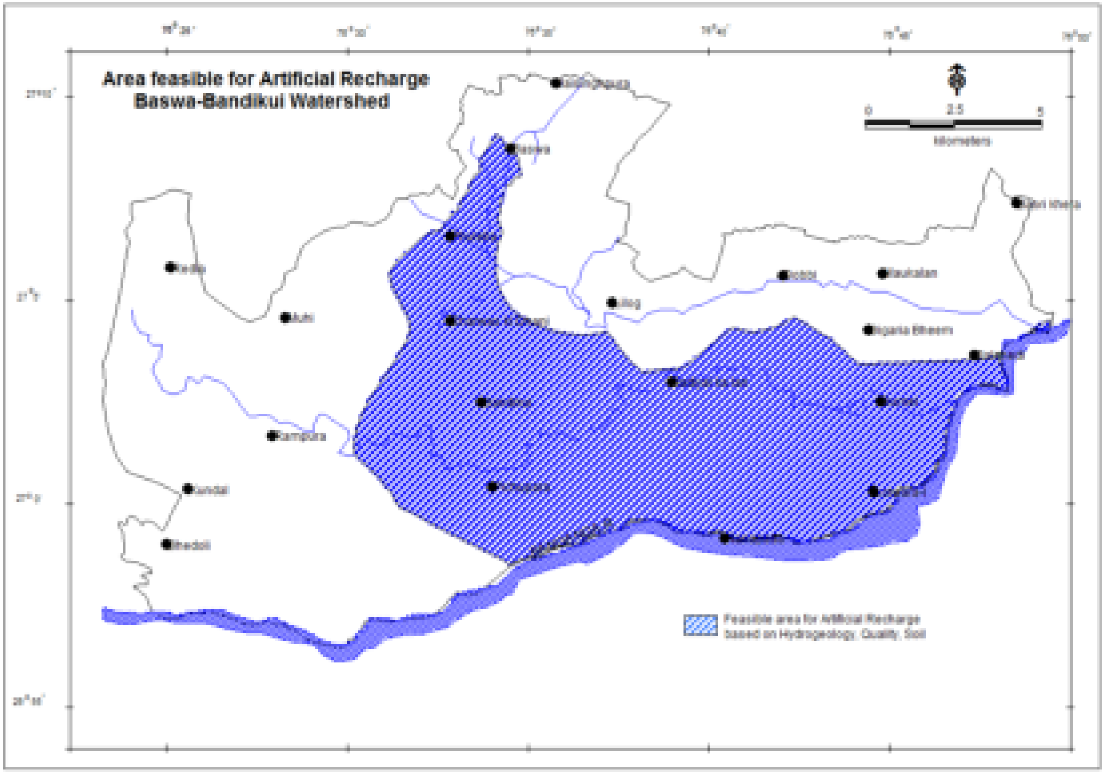


Figure 132. Area feasible for Artificial recharge based on soil type, hydrogeology and ground water quality

6.2.6 Ground water recharge expected to be generated through proposed Artificial Recharge

The additional Ground water recharge expected to be generated through proposed Artificial Recharge is given in Table 50. The details of artificial recharge plan is discussed in Chapter 7.

Table 50. Ground water recharge through proposed AR structures

Sl. No.	Type of AR Structure	Ground water Recharge (mcm)
1	Percolation Tank	2.64
2	Recharge Shaft	0.95
3	RT Rainwater Harvesting	0.02
	TOTAL	**3.62**

6.2.7 Mathematical model scenario

In this scenario, model is run to predict the regional groundwater head for 10 years that is till the year 2024. The simulated groundwater head at the end of the May 2014 is taken as initial head condition at the start of June 2014. The net rainfall recharge rate for the projected years are taken corresponds to calibration level and applied to the model throughout the 10 years. Imputed additional recharge 3.62

mcm per year generated through proposed artificial recharge structures as mentioned above in monsoon period. Recharge and draft for the other period remained same as in the stress applied in the calibration period. Net recharge computed is by subtracting recharge to draft and applied to the model for all the stress period in recharge module in Visual Modflow.

6.2.7.1 RESULTS

Hydrographs: Generated hydrographs for selected observation points and presented below.

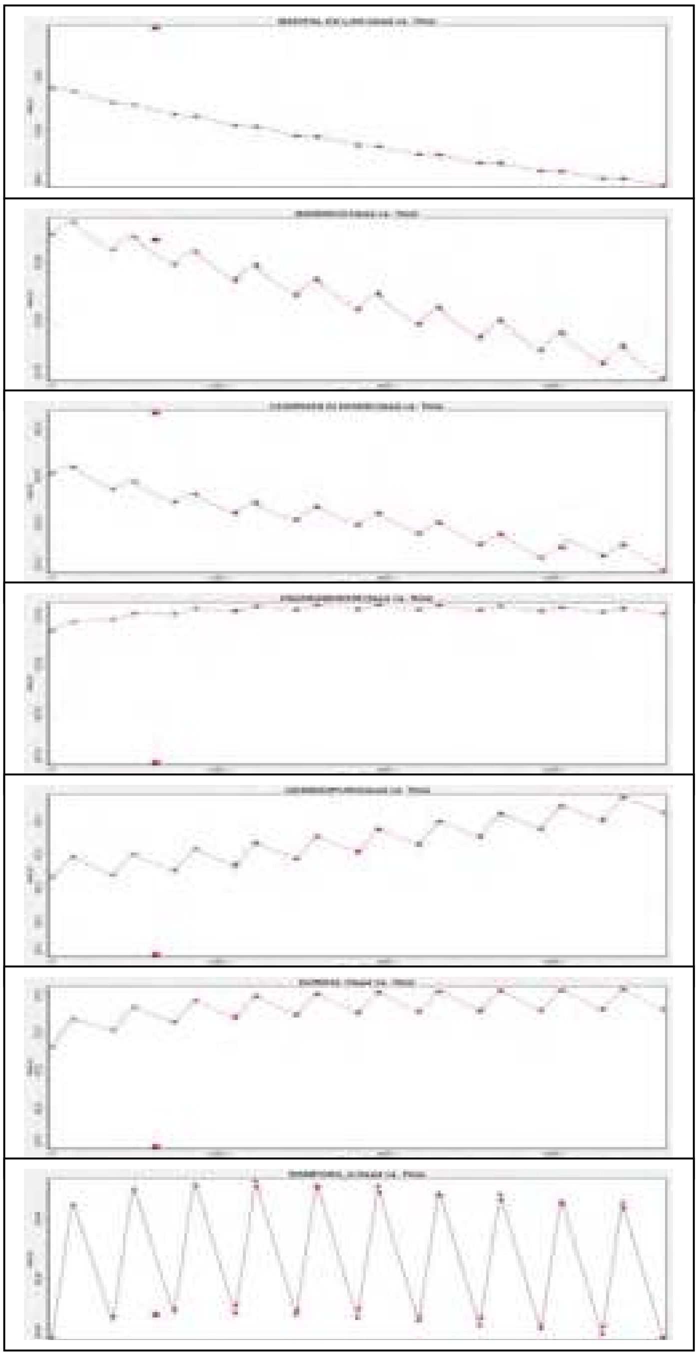


Figure. 133. Hydrographs generated from the period of May 2014 to May 2024 in scenario 3.

Water Level Head:

The water level head generated in scenario 3 is given in Figure 134 & 135.

Figure 134. Water level head in the first scenario September 2014

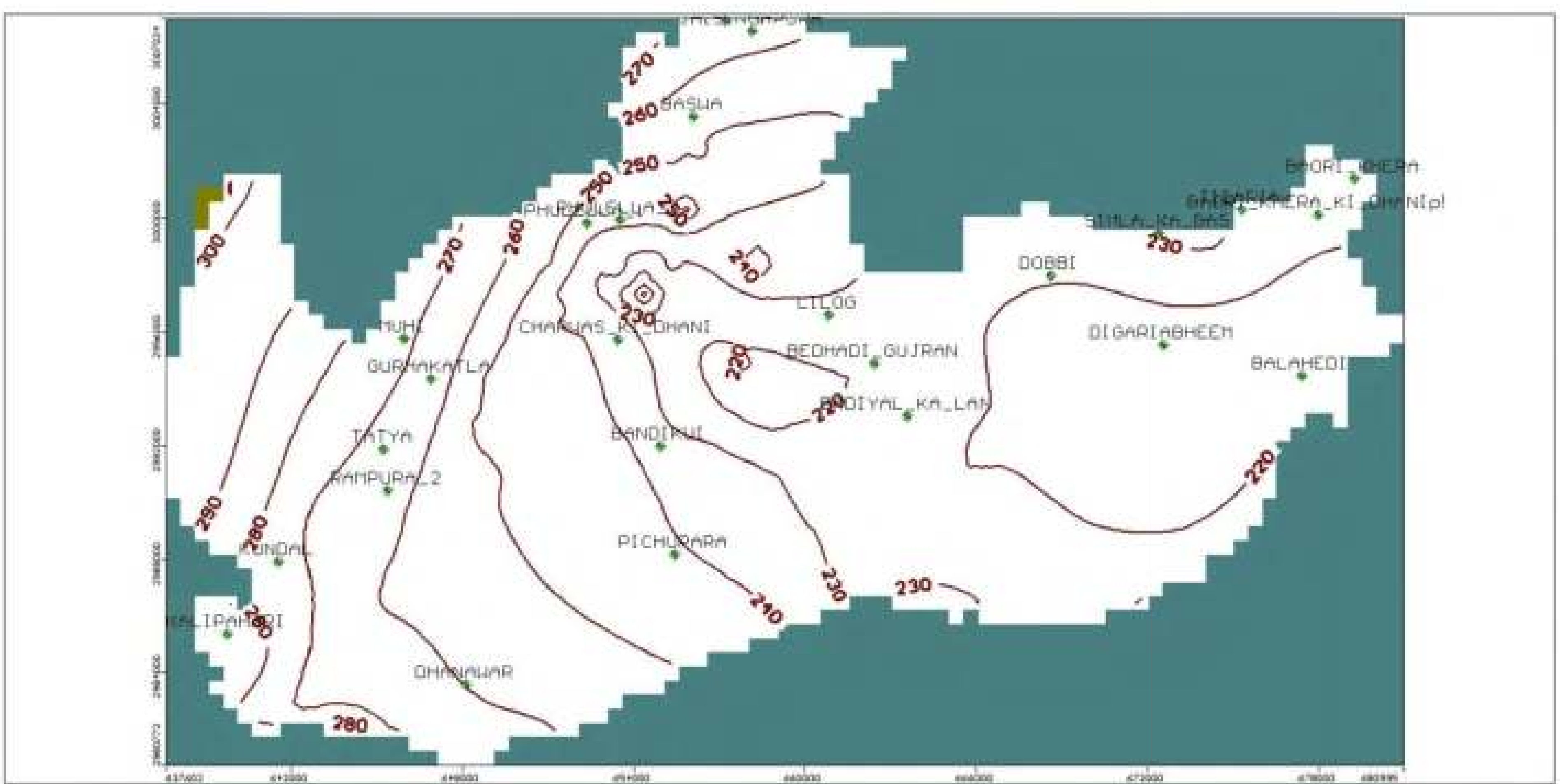
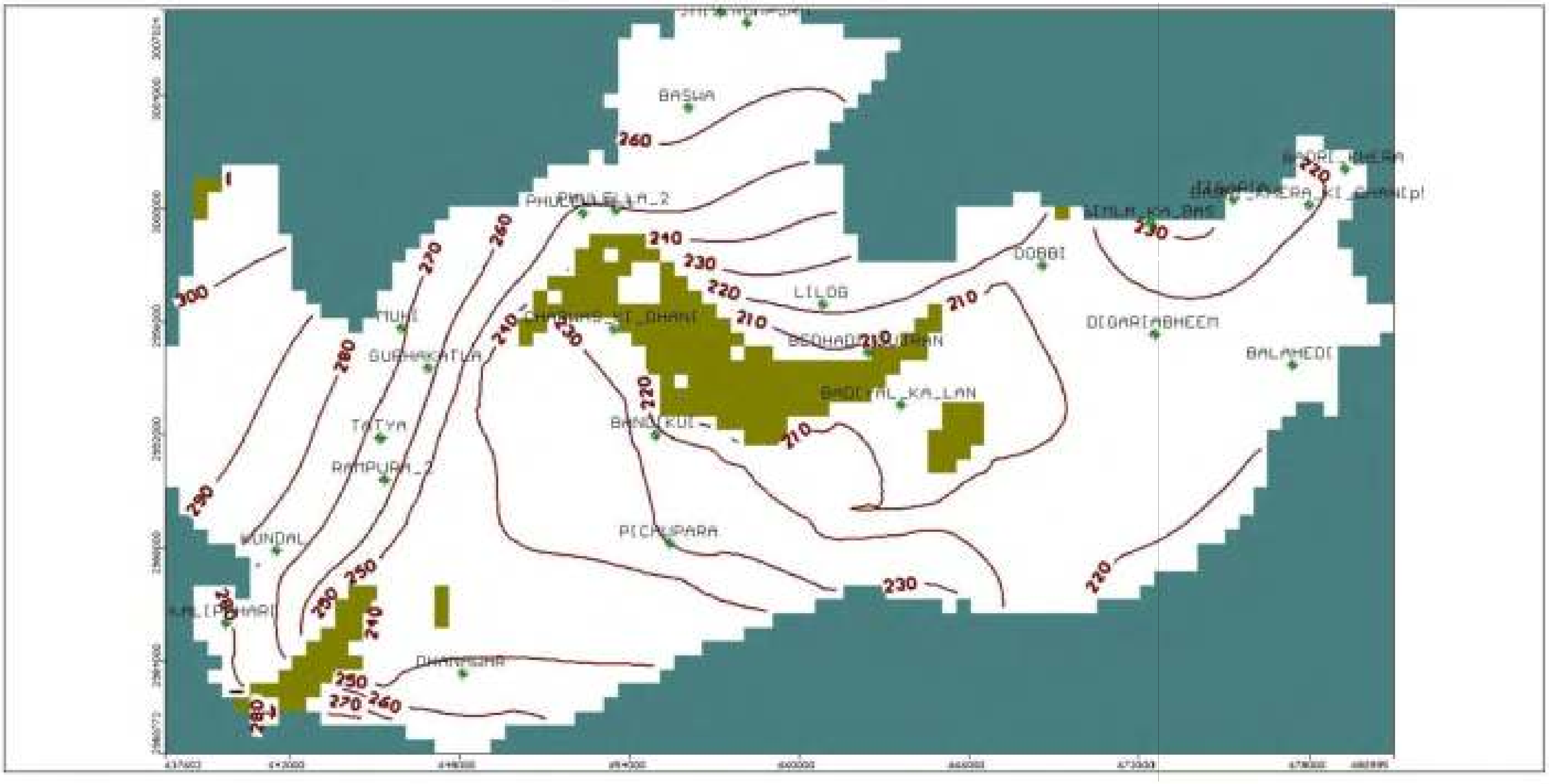


Figure 135 Water level head in the last scenario (May 2024)



Mass Balance:

The mass balance generated in scenario 3 is given in Table 51 & 52.

TABLE: 51 SCENARIO- 3 CUMMULATIVE MASS BALANCE IN m3

Stress Period	Period			Flow In				Flow Out			Change in storage
	From	To	Time in days	WELLS	GHB	RECHARGE	TOTAL IN	GHB	RECHARGE	TOTAL OUT	
1	01-Jun-14	30-Sep-14	122	3345952	6804484	5892356	16042792	1103958	1078258	2182216	13860576
2	01-Oct-14	31-May-15	365	3345952	21234318	5892356	30472626	2614522	49137184	51751706	-21279080
3	01-Jun-15	30-Sep-15	487	6691904	28016190	11784714	46492808	3460519	50209284	53669803	-7176995
4	01-Oct-15	31-May-16	731	6691904	43107272	11784714	61583890	4897275	98121936	103019211	-41435322
5	01-Jun-16	30-Sep-16	853	10037727	50149060	17677070	77863857	5710732	99184800	104895532	-27031675
6	01-Oct-16	31-May-17	1096	10037727	65643044	17677070	93357841	7102132	146306208	153408340	-60050499
8	01-Jun-17	30-Sep-17	1218	13383299	72891688	23569424	109844411	7894917	147351232	155246149	-45401738
11	01-Oct-17	31-May-18	1461	13383299	88764632	23569424	125717355	9263013	193685616	202948629	-77231274
13	01-Jun-18	30-Sep-18	1583	16728530	96185080	29461784	142375394	10041860	194710080	204751940	-62376546
14	01-Oct-18	31-May-19	1826	16728530	112386632	29461784	158576946	11393750	240398608	251792358	-93215412
16	01-Jun-19	30-Sep-19	1948	20073672	119957808	35354136	175385616	12162906	241414032	253576938	-78191322
19	01-Oct-19	31-May-20	2192	20073672	136516064	35354136	191943872	13509309	286838464	300347773	-108403901
21	01-Jun-20	30-Sep-20	2314	23418646	144224272	41246496	208889414	14271537	287839104	302110641	-93221227
22	01-Oct-20	31-May-21	2557	23418646	160975856	41246496	225640998	15605545	332340000	347945545	-122304547
24	01-Jun-21	30-Sep-21	2679	26763496	168804176	47138848	242706520	16363439	333325280	349688719	-106982199
27	01-Oct-21	31-May-22	2922	26763496	185787088	47138848	259689432	17693612	377409056	395102668	-135413236
29	01-Jun-22	30-Sep-22	3044	30108302	193725504	53031208	276865014	18447636	378387552	396835188	-119970174
30	01-Oct-22	31-May-23	3287	30108302	210920512	53031208	294060022	19774772	422088544	441863316	-147803294
32	01-Jun-24	30-Sep-23	3409	33452978	218957088	58923560	311333626	20526120	423055936	443582056	-132248430
35	01-Oct-23	31-May-24	3652	33452978	236192512	58923560	328569050	21840698	466343936	488184634	-159615584

TABLE: 52 SCENARIO- 3 STRESS PERIOD WISE MASS BALANCE IN m3

Stress Period	Period			Flow In				Flow Out			Change in storage	Cummulative Change in storage
	From	To	Time in days	WELLS	GHB	RECHARGE	TOTAL IN	GHB	RECHARGE	TOTAL OUT		
1	01-Jun-14	30-Sep-14	122	3345952	6804484	5892356	16042792	1103958	1078258	2182216	13860576	13860576
2	01-Oct-14	31-May-15	365	0	14429834	0	14429834	1510563	48058926	49569490	-35139656	-21279080
3	01-Jun-15	30-Sep-15	487	3345952	6781872	5892358	16020182	845997	1072100	1918097	14102085	-7176995
4	01-Oct-15	31-May-16	731	0	15091082	0	15091082	1436756	47912652	49349408	-34258326	-41435322
5	01-Jun-16	30-Sep-16	853	3345824	7041788	5892356	16279968	813457	1062864	1876321	14403647	-27031675
6	01-Oct-16	31-May-17	1096	0	15493984	0	15493984	1391401	47121408	48512809	-33018825	-60050499
8	01-Jun-17	30-Sep-17	1218	3345572	7248644	5892354	16486570	792785	1045024	1837809	14648762	-45401738
11	01-Oct-17	31-May-18	1461	0	15872944	0	15872944	1368097	46334384	47702481	-31829537	-77231274
13	01-Jun-18	30-Sep-18	1583	3345231	7420448	5892360	16658039	778847	1024464	1803311	14854728	-62376546
14	01-Oct-18	31-May-19	1826	0	16201552	0	16201552	1351890	45688528	47040418	-30838866	-93215412
16	01-Jun-19	30-Sep-19	1948	3345142	7571176	5892352	16808670	769156	1015424	1784580	15024090	-78191322
19	01-Oct-19	31-May-20	2192	0	16558256	0	16558256	1346403	45424432	46770835	-30212579	-108403901
21	01-Jun-20	30-Sep-20	2314	3344974	7708208	5892360	16945542	762228	1000640	1762868	15182674	-93221227
22	01-Oct-20	31-May-21	2557	0	16751584	0	16751584	1334008	44500896	45834904	-29083320	-122304547
24	01-Jun-21	30-Sep-21	2679	3344850	7828320	5892352	17065522	757894	985280	1743174	15322348	-106982199
27	01-Oct-21	31-May-22	2922	0	16982912	0	16982912	1330173	44083776	45413949	-28431037	-135413236
29	01-Jun-22	30-Sep-22	3044	3344806	7938416	5892360	17175582	754024	978496	1732520	15443062	-119970174
30	01-Oct-22	31-May-23	3287	0	17195008	0	17195008	1327136	43700992	45028128	-27833120	-147803294
32	01-Jun-24	30-Sep-23	3409	3344676	8036576	5892352	17273604	751348	967392	1718740	15554864	-132248430
35	01-Oct-23	31-May-24	3652	0	17235424	0	17235424	1314578	43288000	44602578	-27367154	-159615584

Zone Budget:

The zone budget in scenario 3 is given in Figure 136. Tabulated information is presented in the annexure.

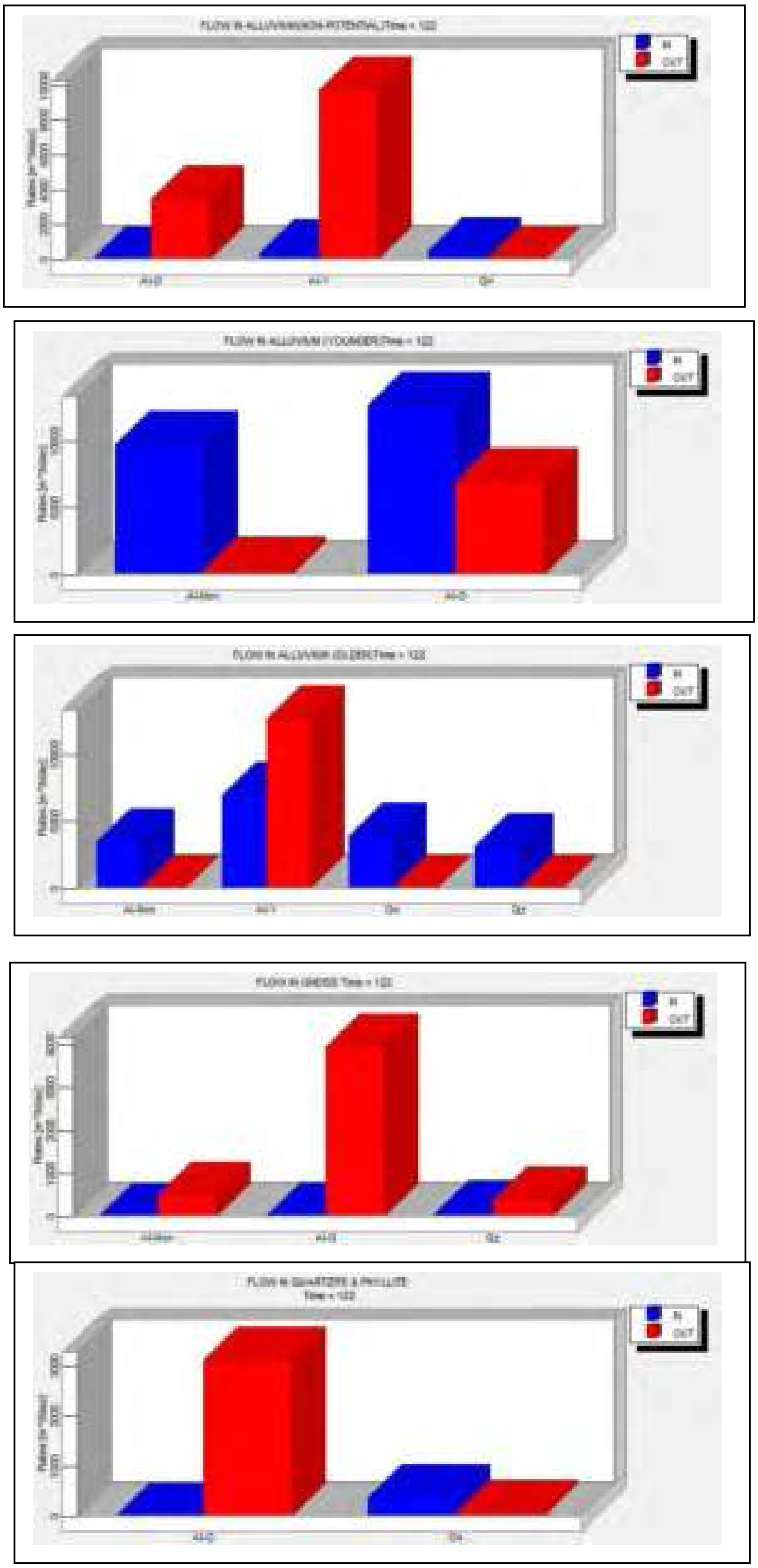


Figure 136. Zone Budget of Scenario 3

Drawdown

The drawdown generated in scenario 3 is given in Table 53.

Table 53. Area covering in rise and fall in different hydrogeological formations in the last stress period (May 2024)

Type	Range in m		Alluvium_non potential	Gneiss	Alluvium_older	Phyllite	Alluvium_younger	Grand Total
	From	To	Area in sq km					
Fall	-14	-12		6.83	0.1			6.93
Fall	-12	-10		15.3	0.9			16.2
Fall	-10	-8		12.03	0.55			12.58
Fall	-8	-6		10.83	0.4	6.78		18.01
Fall	-6	-4		9.98	0.5	27.4		37.88
Fall	-4	-2		7.23	1.1	21.45	9.33	39.11
Fall	-2	0	7.11	10.52	17.02	17.01	18.13	69.79
Fall	**Total**		**7.11**	**72.72**	**20.57**	**72.64**	**27.46**	**200.5**
Rise	0	2	12.87	18.64	15.78	8.06	20.45	75.8
Rise	2	4	3.92	8.55	6.43	7.86	22.57	49.33
Rise	4	6	3.9	5.19	9.66	5.29	19.97	44.01
Rise	6	8	2.38	2.96	23.23	3.87	17.93	50.37
Rise	8	10	1.1	1.56	40	1.92	12.09	56.67
Rise	10	12	0.34	0.23	28.38	0.92	8.05	37.92
Rise	12	14			21.32	0.27	4.57	26.16
Rise	14	16			9.32	0	3.42	12.74
Rise	16	18			4.38		4.1	8.48
Rise	18	20			0.43		0.5	0.93
Rise	20	22			0.39		0.07	0.46
Rise	22	24			0.05			0.05
Rise	24	26			0.02			0.02
Rise	26	28			0.02			0.02
Rise	**Total**		**24.51**	**37.13**	**159.41**	**28.19**	**113.72**	**362.96**
	Grand Total		**31.62**	**109.9**	**179.98**	**100.83**	**141.18**	**563.46**

Compression of scenario-1 and scenario-2

The comparison of the results of scenario 3 wherein artificial recharge is envisaged has been drawn with the results of scenario 1 in which no additional recharge is proposed. The same is presented in Table 54 and Figure 135.

Table 54. Result of scenario-3 (artificial recharge) vis-à-vis scenario-1 (without recharge)

Scenario	Type	**Alluvium_non potential**	**Gneiss**	**Alluvium_older**	**Phyllite**	**Alluvium_younger**
Scenario_3	Fall	7.11	72.72	20.57	72.64	27.46
Scenario_1	Fall	12.37	25.79	135.77	20.92	94.27
	Area diffrence	**-5.26**	**46.93**	**-115.2**	**51.72**	**-66.81**
Scenario_3	Rise	24.51	37.13	159.41	28.19	113.72
Scenario_1	Rise	20.28	86.9	34.98	82.01	47.56
	Area diffrence	**4.23**	**-49.77**	**124.43**	**-53.82**	**66.16**

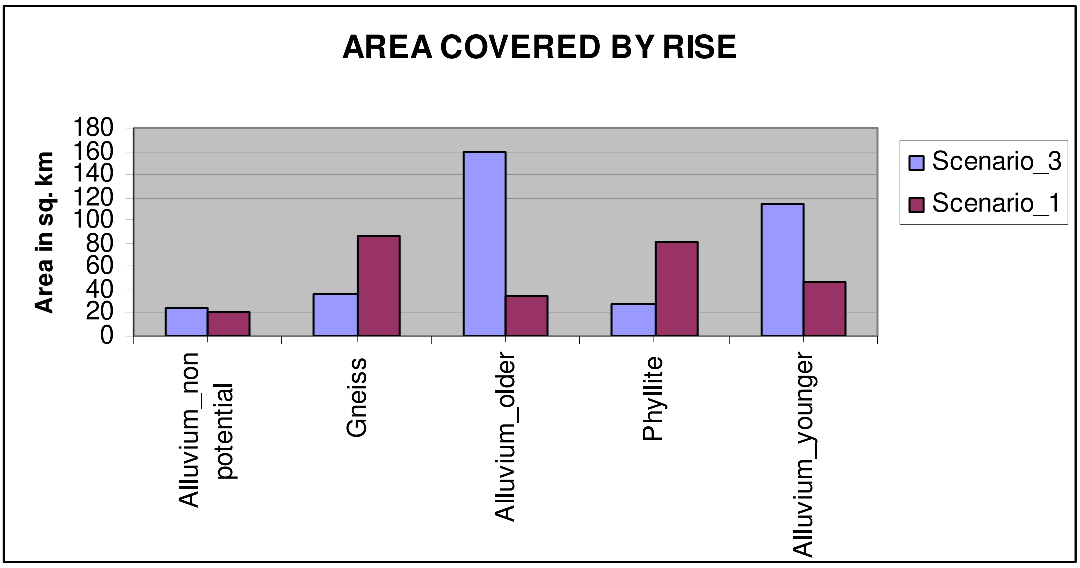


Figure 137. Comparative analysis of area covered by rise and fall in water level in scenario 1 vis-à-vis scenario 3

7. IMPLEMENTATION PLAN & RECOMMENDATIONS

The discussions in the previous chapters have amply reflected the precarious condition of ground water resources in the Baswa-Bandikui watershed. The top aquifer viz. alluvium is gradually getting dried up due to over-exploitation of the ground water resources. The bottom aquifer is poor yielding. Thus immediate and urgent steps are required to be taken to arrest the further decline of ground water in the area and restore the dried up aquifers. The management intervention envisaged in the project area are - artificial recharge to ground water, on-farm micro-irrigation practices and Notification of the area for regulated ground water withdrawal.

7.1. Artificial Recharge to Ground water

Artificial recharge to ground water is one of the key management intervention envisaged for the area. It will benefit the overlying alluvium aquifer and also the underlying hard rock aquifer.

7.1.1 Planning for Artificial Recharge Structures

The planning for artificial recharge structures is proposed based on - Quantum of non-committed surface run-off available, Rainfall pattern, Land use and vegetation, Topography and terrain profile, Soil type and soil depth, Thickness of weathered / granular zones, Hydrological and hydrogeological characteristics, Socio-economic conditions and infrastructural facilities available and Environmental and ecological impacts of artificial recharge scheme propose. The structures proposed are – surface spreading technique using Percolation Tank and sub-surface technique using Recharge Shaft, and combination of both these techniques. In addition, Roof Top Rainwater Harvesting technique is also suggested.

Percolation Tank

Percolation tanks are among the most common runoff harvesting structures in India. A percolation tank can be defined as an artificially created surface water body submerging a highly permeable land area so that the surface runoff is made to percolate and recharge the ground water storage.

The important site selection criteria for percolation ponds include -

i) The hydrogeology of the area should be such that the litho-units occurring in the area of submergence of the tank should have high permeability. The soils in the catchment area of the tank should be sandy to avoid silting up of the tank bed.

ii) The percolation tank should be located downstream of runoff zone, preferably toward the edge of piedmont zone or in the upper part of the transition zone. Land slope between 3 and 5 percent is ideal for construction of percolation tanks.

iii) There should be adequate area suitable for irrigation and sufficient number of ground water abstraction structures within the command of the percolation tank to fully utilise the additional recharge. The area benefited should have a productive phreatic aquifer with lateral continuity up to the percolation tank. The depth to water level in the area should remain more than 3 m below ground level during post- monsoon period.

Based on the above criteria, the upper catchment area as shown in Figure 138 has been identified for construction of Percolation Tank. The total area is about 74 sq.km. The Percolation Tanks would be constructed on second order and third order streams.

The capacity of Percolation Tank is determined based on the guidelines given in Manual on Artificial Recharge to Ground Water, Central Ground Water Board, 2007. Step-wise calculation is given in Table 55. The values of average Catchment area of the Percolation Tank and Catchment yield have been adopted from the Manual (Central Ground Water Board, 2007). A lower value of Storage Capacity of individual structure have been adopted in the plan proposal considering the low rainfall in the area.

Table 55 Capacity of Percolation Tank proposed in Baswa-Bandikui watershed

Catchment area	2.5 sq.km	Based on the specifications and Case Studies given in Manual on Artificial Recharge to Ground Water, Central Ground Water Board,2007
Catchment yield	0.56 mcm	Based on Strange Table (Manual on Artificial Recharge to Ground Water, Central Ground Water Board,2007)
Submergence area	160000 sq.m	Considering around 225 m radius
Full Tank Level (FTL)	5 m	
Storage Capacity	264000 cu.m	Submergence area X 1/3rd of FTL, source: Manual on Artificial Recharge to Ground Water, Central Ground Water Board,2007
	0.26 mcm	
Gross Storage Capacity	528000 cu.m	Twice of Storage Capacity considering repeated filling (based on case study, Icchkedha, Maharashtra)

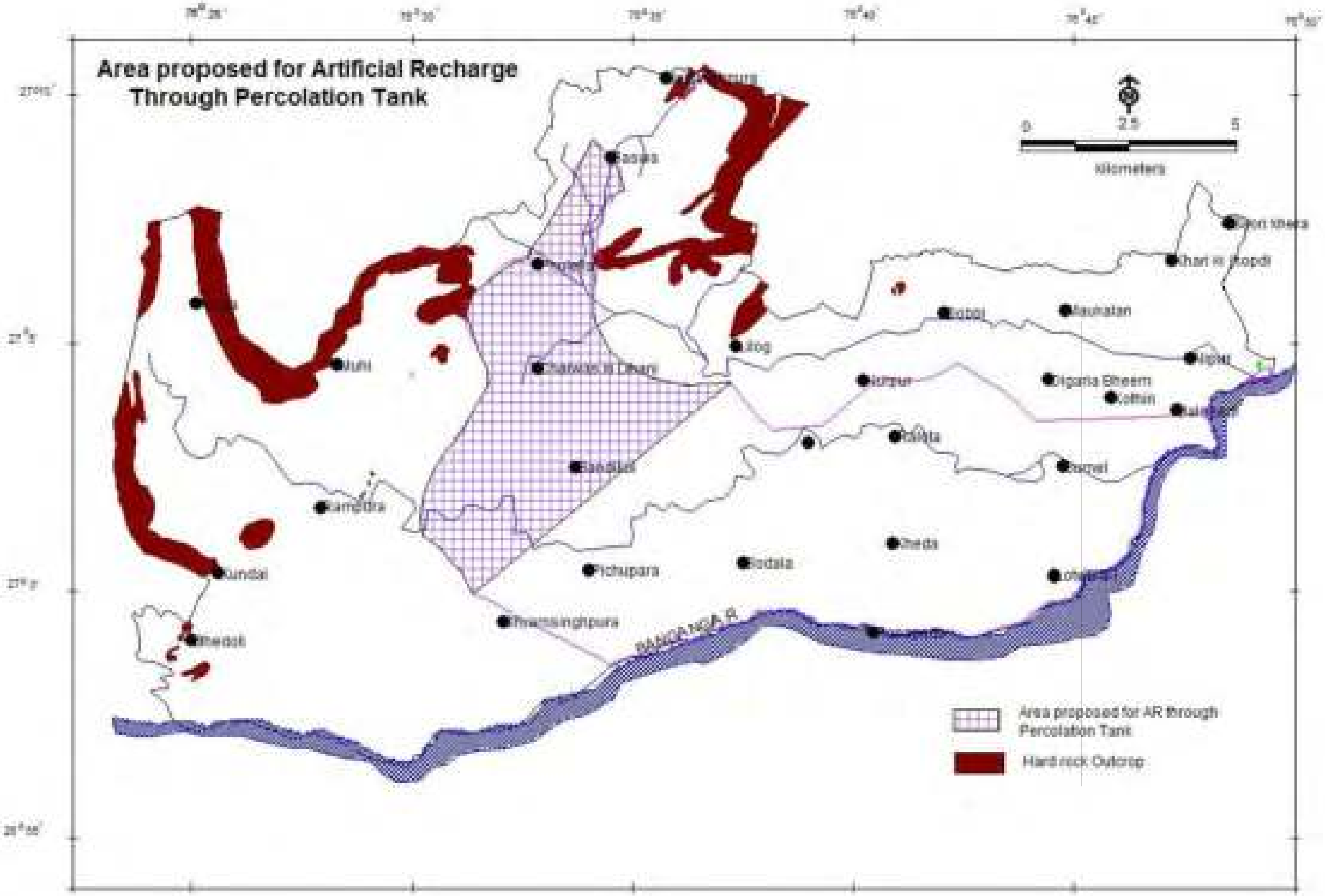


Figure 138. Area identified for Artificial Recharge through Percolation Tank

RECHARGE SHAFT

Recharge shafts are artificial recharge structures commonly used for recharging shallow phreatic aquifers, which are not in hydraulic connection with surface water due to the presence of impermeable layers. General guidelines for design of Recharge shafts are as follows -

i) Recharge shafts may be dug manually in non-caving strata. For construction of deeper shafts, drilling by direct rotary or reverse circulation may be required.
ii) The shafts may be about 2m in diameter at the bottom if manually dug. In case of drilled shafts, the diameter may not exceed 1m.

iii) The shaft should reach the permeable strata by penetrating the overlying low permeable layer, but need not necessarily touch the water table.

iv) Unlined shafts may be back-filled with an inverse filter, comprising boulders/cobbles at the bottom, followed by gravel and sand. The upper sand layer may be replaced periodically. Shafts getting clogged due to biotic growth are difficult to be revitalized and may have to be abandoned.

The Recharge Shafts in the project area are proposed to be constructed in combination with Percolation Tank, village ponds and also individual structures. Recharge Shafts with Injection wells are also proposed to enhance its capacities. The area demarkated for Recharge Shaft is the entire feasible area of 253 sq.km. (Figure 139). The capacity of Recharge Shaft has been computed as follows (Table 56).

Table 56. Capacity of Recharge Shaft

Radius of catchment	30 m	
Area of catchment	0.09 sq.km.	
Yield of runoff from Catchment per sq.km. in mcm	0.45 sq. km in mcm	Adopted from Strange Table (Manual on Artificial Recharge to Ground Water, Central Ground Water Board,2007)
Total Runoff Generated	0.04 mcm	Area of Catchment X Yield of runoff from Catchment

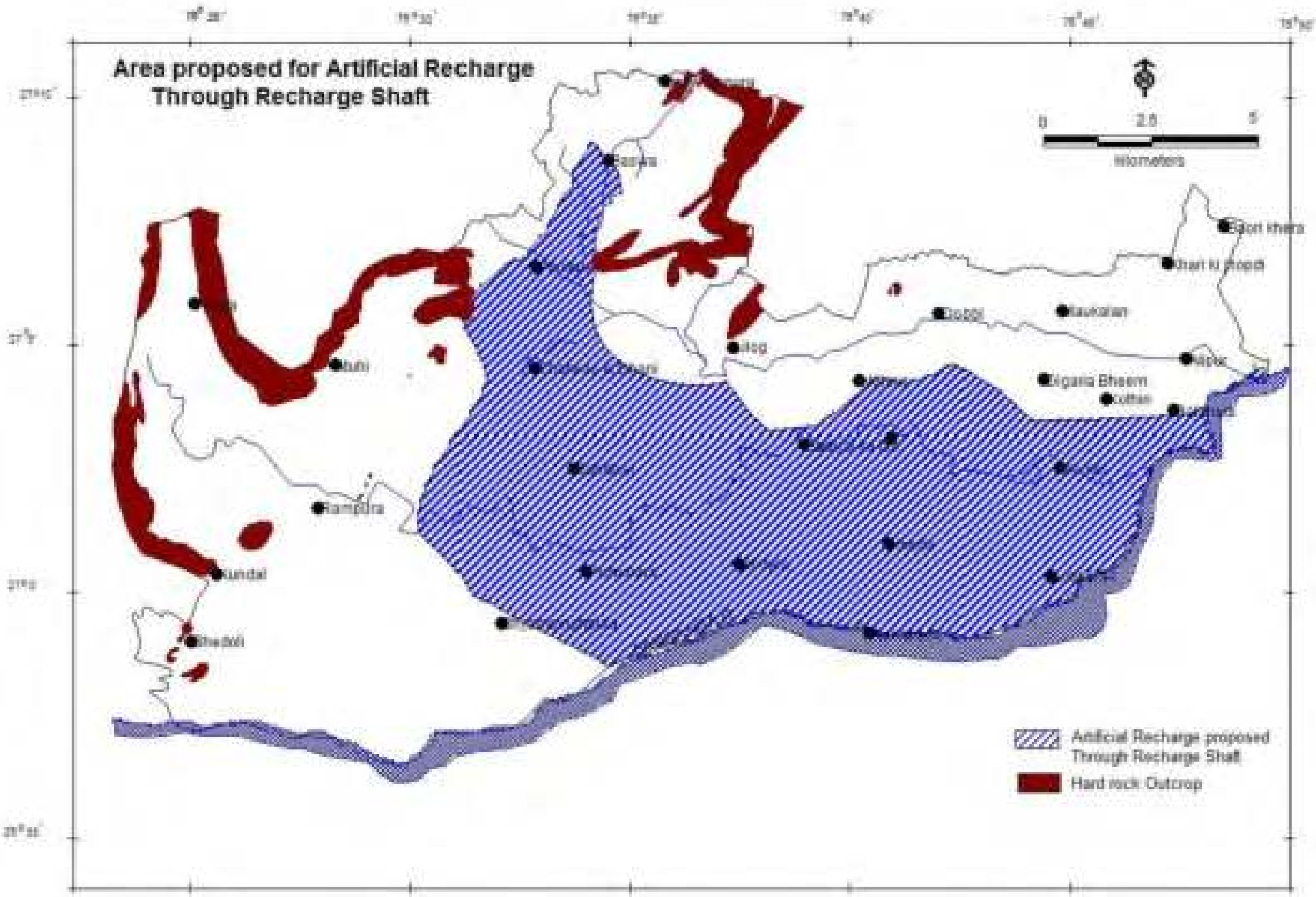


Figure 139. Area identified for Artificial Recharge through Recharge Shaft

ROOF TOP RAINWATER HARVESTING

The concept of rainwater harvesting involves 'tapping the rainwater where it falls'. The technique of rainwater harvesting involves collecting the rain from localized catchment surfaces such as roofs, plain / sloping surfaces etc., either for direct use or to augment the ground water resources depending on local conditions. Among various techniques of water harvesting, Roof top rainwater harvesting is one of the appropriate options for augmenting ground water recharge/ storage. Roof top rainwater harvesting can supplement the domestic requirements.

The Roof Top Rainwater Harvesting is proposed in the Government buildings existing in the entire project area. The details of the Govt Buildings are as follows (Table 57).

Table 57. Details of the Government buildings in Bandikui block, Dausa district, Rajasthan

Govt. buildings suitable for RTRWH	**No.**	**Unit roof area**	**Total Roof Area**
		(sq.m.)	**(sq.m.)**
Primary School	148	100	14800
Upper Primary School	86	200	17200
Secondary & Higher School	64	350	22400
Gram Panchayat – Atal Sewa Kendra	64	50	3200
College	1	1500	1500
Panchayat Samity Office	3	200	600
Railway School	1	600	600
Other Buildings	50	300	15000
Grand Total	**417**		**75300**

The capacity of Roof Top Rainwater Harvesting in the area is given in Table 58. The roof top rainwater harvesting structures are envisaged to harvest only the monsoon rainfall. It is advisable to leave one shower for cleaning of the roof-top of the building and only the subsequent showers be used for ground water recharge. Since the non-monsoon rainfall in the area is quite sporadic and consequent showers during non-monsoon period is not a common phenomenon, the non-monsoon rainfall has not been considered for Roof Top Rainwater harvesting.

Table 58. Rainwater available for Roof Top Rainwater Harvesting

Number of Govt. Buildings	**Rainfall (monsoon)**	**Total Roof Area**	**Runoff Coefficient**	**Water Available for recharge**	
	m	sq.m.		cu. m	mcm
1	2	3	4	5 =2*3*4	6
417 buildings	0.585	73850	0.7	30835.35	**0.03**

Thus the total runoff utilization for the purpose of Artificial Recharge in the project area is as follows (Table 59).

Table 59. Utilization of surface runoff

Area Identified for Recharge	253 sq.km.
Monsoon Runoff Generated in the area	56.68 mcm
Utilization	
Percolation Tank (10 nos.)	5.28 mcm
Recharge Shafts (30 nos.)	1.27 mcm
RTRWH (417 nos.)	0.03 mcm
Total Utilization	6.90 mcm
Percentage Utilization	12%

7.1.2 Ground water recharge expected to be generated through proposed Artificial Recharge

The additional Ground water recharge expected to be generated through proposed Artificial Recharge is given in Table 60.

Table 60. Ground water recharge through proposed AR structures

Sl. No.	Type of AR Structure	Number of Structures proposed	Total Water available from All Structures (mcm)	Efficiency(%)	Ground water Recharge (mcm)	Remarks
1	Percolation Tank	10	5.28*	50#	2.64	* table 57 # GEC'97
2	Recharge Shaft	30	1.27*	75##	0.95	* table 57 ## Manual of AR (Central Ground Water Board, 2007)
3	RT Rainwater Harvesting	417	0.03*	80###	0.02	* table 57 ### Master Plan for AR to GW (Central Ground Water Board, 2013)
	TOTAL				**3.62**	

Thus only about 3.62 mcm additional recharge would be generated through the proposed artificial recharge structures against the recommendation of Mathematical Modeling Studies of about 40 mcm.

7.1.3 Financial outlay

The cost of construction of proposed Artificial Recharge structures have been worked out based on Master Plan on Artificial Recharge to Ground Water (Central Ground Water Board, 2013). The average unit cost of Percolation Tank has been taken as Rs. 41 lakh and that of Recharge Shaft has been assumed to be Rs. 5 lakh only. Thus the total cost of construction of 10 Percolation Tank and 30 Recharge Shaft comes out to be Rs. 5.70 crore only. The cost of roof top rainwater harvesting of a building having roof and paved area of ~ 200 sq.m. has been assessed to be Rs. 12,000 and for bigger buildings having more than 1000 sq.m. will be Rs. 1.0 lakh. The total cost for roof top rain water harvesting is Rs. 47 lakh only. The total cost of construction of Artificial Recharge and Rainwater harvesting Structures is Rs. 6.17 crore. The detail of computation is given in Table 61.

Table 61. Cost of Construction of Artificial Recharge and Rain Water Harvesting structures

Sl No	Structure	Unit Cost (Rs.)	Number of Structures	Total Cost (Rs. In crore)
1	Percolation Tank	4100000	10	4.10
2	Recharge Shaft	500000	30	1.60
3	RTRWH			
3a	Avg. roof area – 200 sq.m.	12000	387	0.46
3b	Avg. roof area > 1000 sq.m.	100000	1	0.01
GRAND TOTAL				**6.17**

Roof top rainwater harvesting - Case study

Roof top rainwater harvesting programme has been implemented in the area prior to the project period through the initiatives of a civil society namely, Sujalam Day-To-Day Development Society, Alwar, Rajasthan. The Sujalam has constructed roof top rainwater harvesting structures in several government school buildings in the Bandikui Panchayat Samity. They were constructed using little investment cost, around Rs. 13000/- to Rs. 21000/- per structure. The design of structures involve collection of rain water falling in roof through pvc pipes, into a settling pit, which is then either diverted to a collection chamber or to an abandoned dug well. The water is used during non-rainy days by the help of hand pumps installed over the collection chamber. A survey of these structures during project period revealed that regular maintenance is required in order to make these structures effective for more than one rainy season, otherwise the structures will become defunct after few initial rains.

7.2. Adopting On-Farm Water Management practices including Micro-irrigation in agriculture sector

In traditional surface irrigation methods, the losses in water conveyance and application are large. These losses can be considerably reduced by adopting Micro Irrigation systems. About 30 to 60 % of water can be saved depending upon the type of MI system chosen. Micro irrigation system is a relatively new method, which applies water slowly, almost matching with the consumptive water use of the plant, to keep the soil moisture within the desired range of available moisture for plant growth. This system minimizes the water losses in the conventional irrigation methods such as deep percolation, runoff and evaporation. There are several types of micro-irrigation systems in practice like Drip Irrigation System, Mini Sprinkler, Micro Sprinkler, Sprinkler, Rain Gun etc.

Micro-irrigation practices like drip irrigation system and mini-sprinkler are suitable for the soil condition (loamy and alluvial soil) and cropping pattern (wheat, mustards etc.) of Baswa-Bandikui watershed area. Adopting water saving micro-irrigation techniques will reduce demand for ground water by 35 % (adopted from Master Plan for Artificial Recharge to Ground Water, Central Ground Water Board, 2013). Thus considering the Rabi ground water draft for irrigation purpose in the area as around 70 mcm (as per GWD estimate of 2011), about 25 mcm of ground water is envisaged to be saved in case proper on-farm water management practices are adopted. This will result in lowering the ground water development considerably. However, return flow from applied irrigation will also stand reduce. Moreover, successful implementation of farmers participatory approach and R&D activities in improvising irrigation efficiency can further ease pressure on demand side. Hence, the second recommendation is adoption of micro-irrigation practices in agriculture sector in Baswa-Bandikui tehsil. The area proposed for micro-irrigation practices is given in the following figure 140.

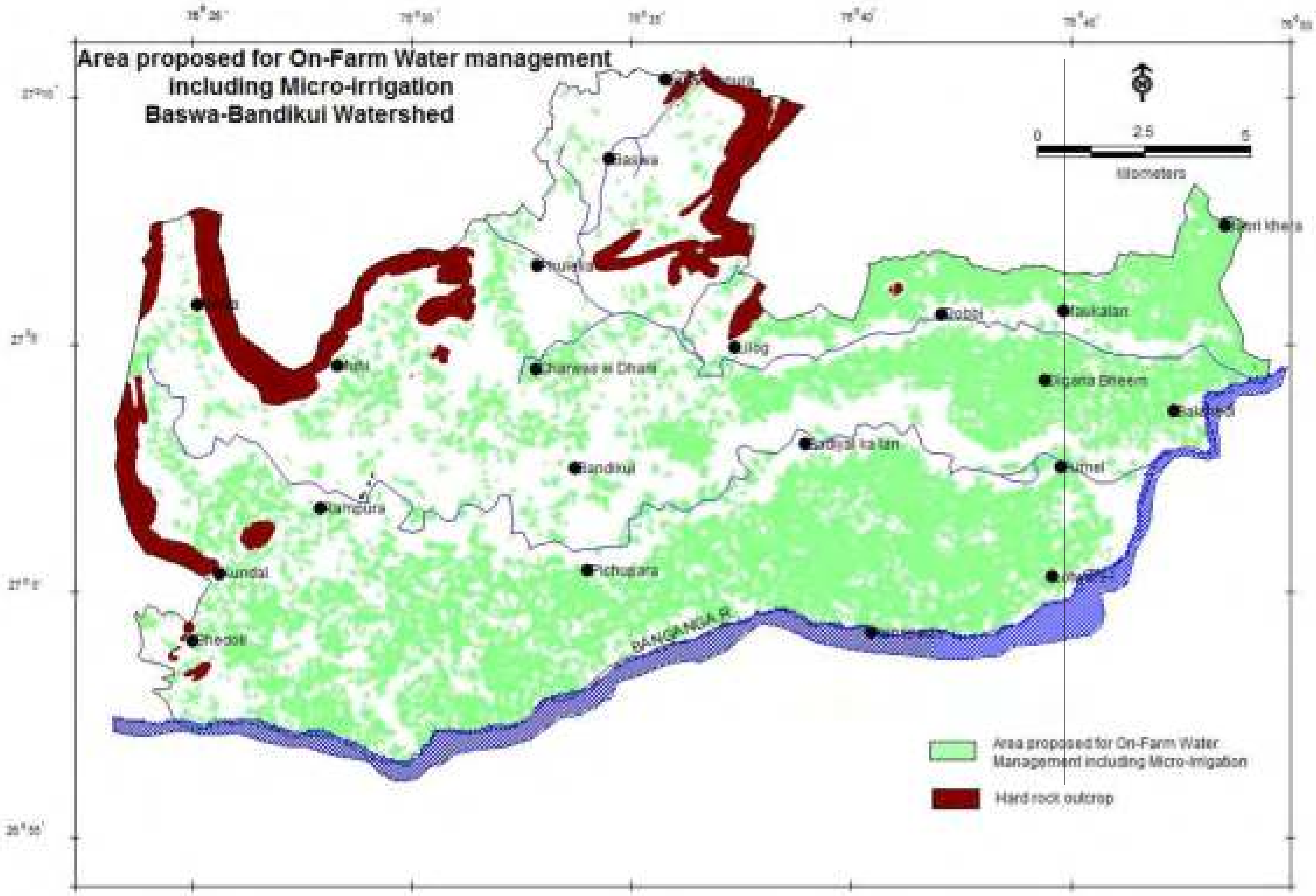


Figure 140. Area proposed for On-Farm Water Management practices including micro-irrigation

7.3 Notification of the Bandikui block

The Mathematical Models on Ground Water Flow simulation discussed in the previous chapter have generated few predictive scenarios for the period of ten years from 2014 to 2024. In the 1st scenario, the present recharge and discharge (withdrawal) of ground water resources was kept at the present level. At 2024, it was found that the alluvium aquifer becomes dry in about 59.50 sq. km. area. In another scenario, the Artificial Recharge Plan proposed for the study area was tested. In this case the recharge was enhanced and the ground water withdrawal was kept at the present level i.e. there is no progressive increase in ground water discharge during the Model study period of 2014-2024. However, inspite of the proposed Artificial Recharge, still about 48 sq.km. area remained dry at the end of the study period i.e. 2024. Thus it is imperative that ground water withdrawal should not be allowed to be increased further. Hence it is recommended that the Bandikui block be Notified by Central Ground Water Authority to restrict further enhancement in ground water withdrawal in the study area.

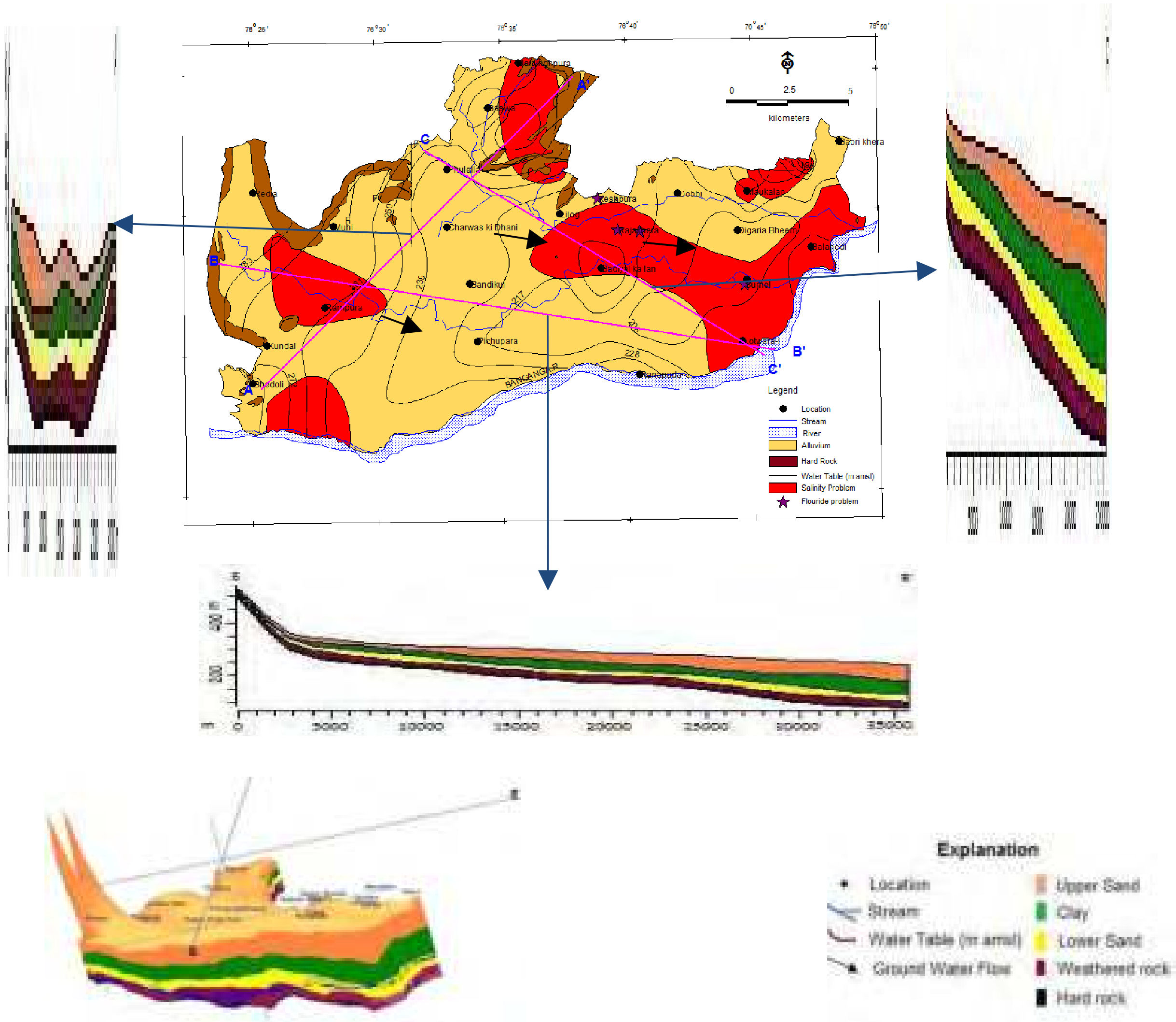
7.4 Conclusion

Baswa-Bandikui watershed in Dausa district of eastern Rajasthan is a typical representative area of North-western India having semi-arid climate with limited water resources. Geologically the area is having alluvium underlain by hard rocks of Achean/ Proterozoic age. The pilot project on aquifer mapping studies in this watershed revealed that the thickness of alluvium aquifer, with aquifer characteristics more promising than the underlying hard rock, is in the range of 5 m to 72 m. The over-dependence on ground water is gradually lowering the water table in the area. At many places, particularly in the western part of the study area, the water level has gone below the alluvium layer, wherever the thickness of alluvium is less. The consecutive ground water resources assessment carried out for the Bandikui block for the year 2009, 2011 and 2013 (provisional) has categorized the area as 'Over-exploited'. The Numerical Ground water Flow Model simulated for the study area to generate predicative scenarios indicate that even if the ground water withdrawal is kept as present level, the alluvium aquifer will get dried up in about 60 sq.km. by 2024. In case, Artificial Recharge plan is adopted, about 11 sq.km. of the dry area would be recovered as per Ground Water Modelling studies. Thus it is recommended that the Artificial Recharge plan be implemented through construction of Percolation Tank, Recharge Shaft and Roof Top Rain Water Harvesting. The Bandikui block may be Notified to restrict ground water withdrawal and On-Farm Water Management Practices including Micro-Irrigation may be adopted for the Baswa-Baswa Bandikui watershed as additional ground water management intervention. The aquifer disposition and the ground water management plan of the Baswa-Bandikui watershed are presented in figure 141 to 143.

In addition to the above, it is highly recommended that the local people residing in the Baswa-Bandikui watershed may be sensitised about the depleting ground water resources situation in the area. Radical changes in the water utilization pattern is required with general consensus of the people of the area to stop further depletion of this pristine resource.

Pilot Aquifer Mapping Studies
Baswa-Bandikui Watershed, Dausa district, Rajasthan

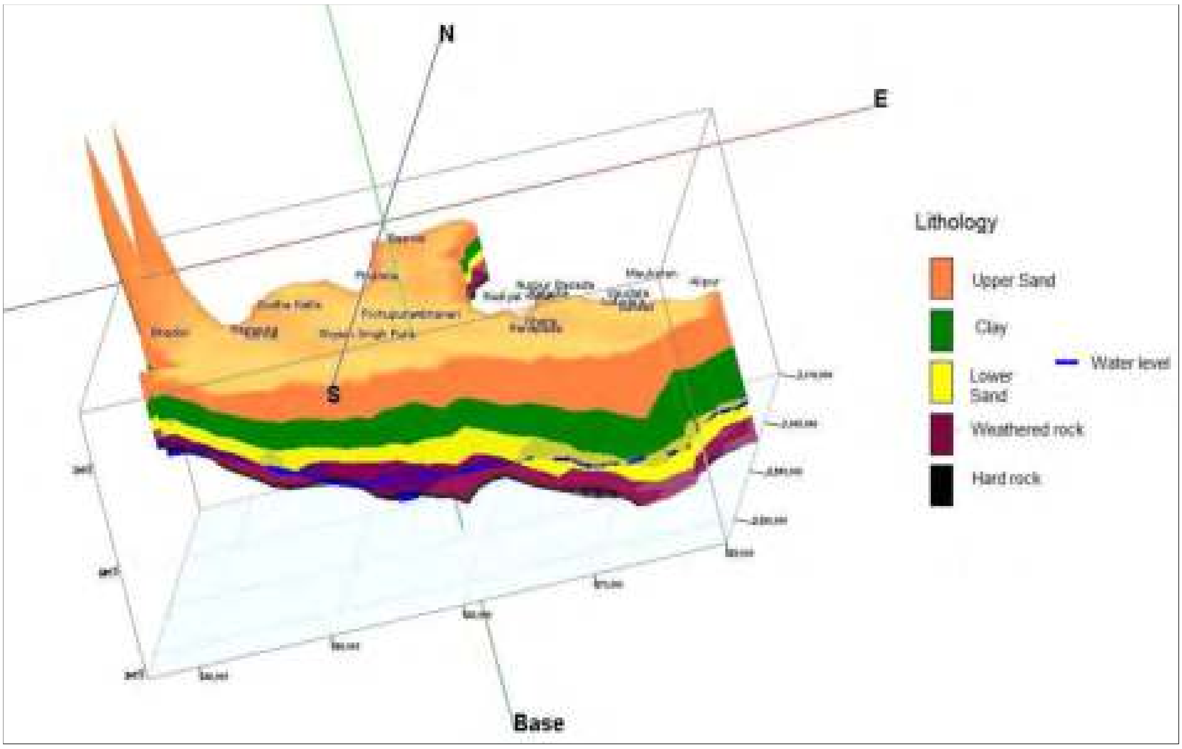
AQUIFER MAP



Aquifer	Prominent Lithology	Depth Range of Occurrence (m bgl)	Thickness Range (m)	Range of Yield Potential (cu.m/day)	Storage Characteristics	Range of Hydraulic Conductivity (m/day)	Suitability for Irrigation	Suitability for Drinking purpose	Remarks
Aquifer I	Alluvium	Ground level	5 - 72	90 - 1200	8% - 12%	0.06 - 24	Yes	Yes	Over-exploited aquifer; Salinity, Flouride problems in pockets
Aquifer II	Weathered & Hard rock	5 - 72	1 - 33	40 - 130	0.015 – 0.02	0.50 - 2	Yes	Yes	Declining GW level; Salinity, Flouride problems in pockets

Figure 141. Aquifer Map, Baswa-Bandikui Watershed, Dausa district, Rajasthan

3D Aquifer Disposition



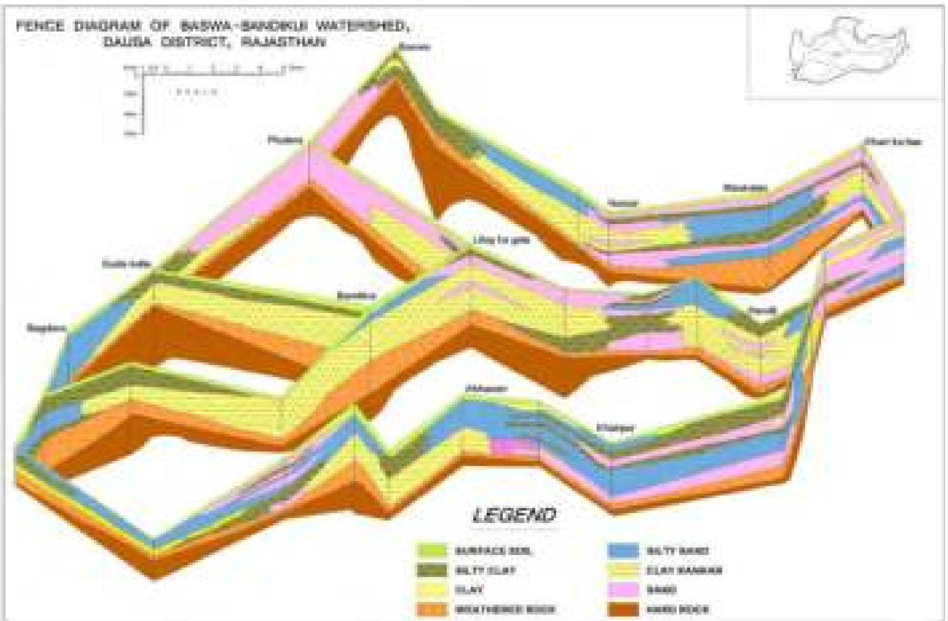
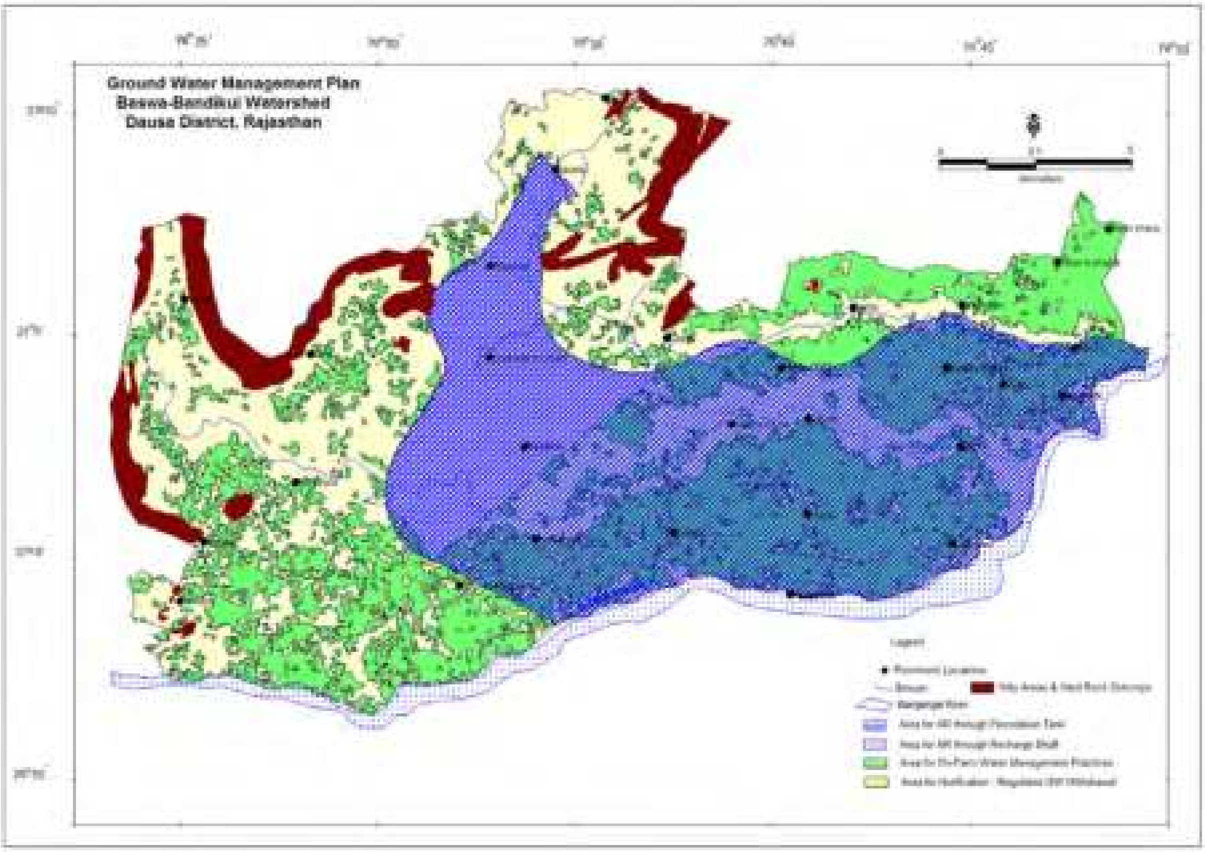


Figure 142. 3-D Aquifer Disposition, Baswa-Bandikui watershed, Dausa district, Rajasthan

Aquifer Management Plan



<table>
<tr><th>Aquifer</th><th>Depth of Occurrence (m bgl)</th><th>Current Use</th><th colspan="5">Aquifer Management Plan</th></tr>
<tr><td rowspan="7">Aquifer I</td><td rowspan="7">Ground level</td><td rowspan="7">Irrigation; Domestic</td><td colspan="5">1. Artificial Recharge</td></tr>
<tr><td>Structure</td><td>Number</td><td>Total water available for recharge (mcm)</td><td>Ground water recharge (mcm)</td><td>Rise in Water Level (m)</td></tr>
<tr><td>Percolation Tank</td><td>10</td><td>5.28</td><td>2.64</td><td>0.40 - 9.00</td></tr>
<tr><td>Recharge Shaft</td><td>30</td><td>1.27</td><td>0.95</td><td>0.01 -9.00</td></tr>
<tr><td>Roof Top Rain water Harvesting</td><td>417</td><td>0.03</td><td>0.02</td><td>0.01 - 10.00</td></tr>
<tr><td colspan="5">2. On-Farm Water Management Practices</td></tr>
<tr><td colspan="5">3. Notification to regulate Ground Water Withdrawal</td></tr>
<tr><td rowspan="2">Aquifer II</td><td rowspan="2">5 - 72</td><td rowspan="2">Irrigation; Domestic</td><td colspan="5">1. On-Farm Water Management Practices</td></tr>
<tr><td colspan="5">2. Notification to regulate Ground Water Withdrawal</td></tr>
</table>

Figure 143. Aquifer Management Plan, Baswa-Bandikui Watershed, Dausa district, Rajasthan

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GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVINATION

CENTRAL GROUND WATER BOARD

REPORT ON PILOT PROJECT ON AQUIFER MAPPING IN BASWA-BANDIQUI AREA, DAUSA DISTRICT, RAJASTHAN

SUPPLEMENTARY VOLUME (ANNEXURES & APPENDICES)

WESTERN REGION, JAIPUR

December-2015

CONTENTS

LIST OF ANNEXURES

LIST OF APPENDIX

Annexure I

Details of Exploratory Borewells drilled during Study period in Baswa-Bandikui Watershed, Dausa District, Rajasthan

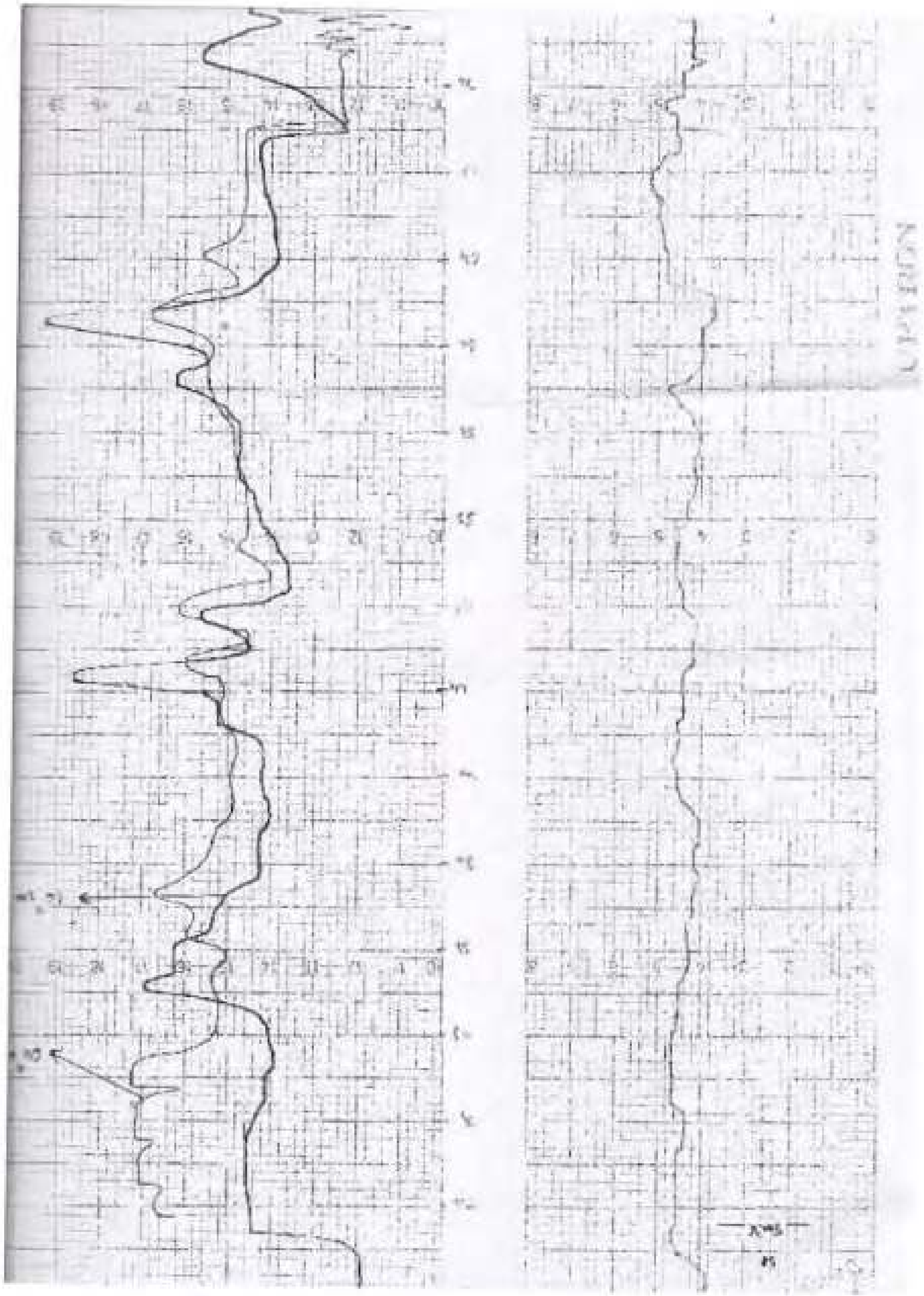
1. Village: Lotwara (East) Block: Bandikui District: Dausa
   Lat: 27.00536 Long: 76.7425

DRILL TIME LOG

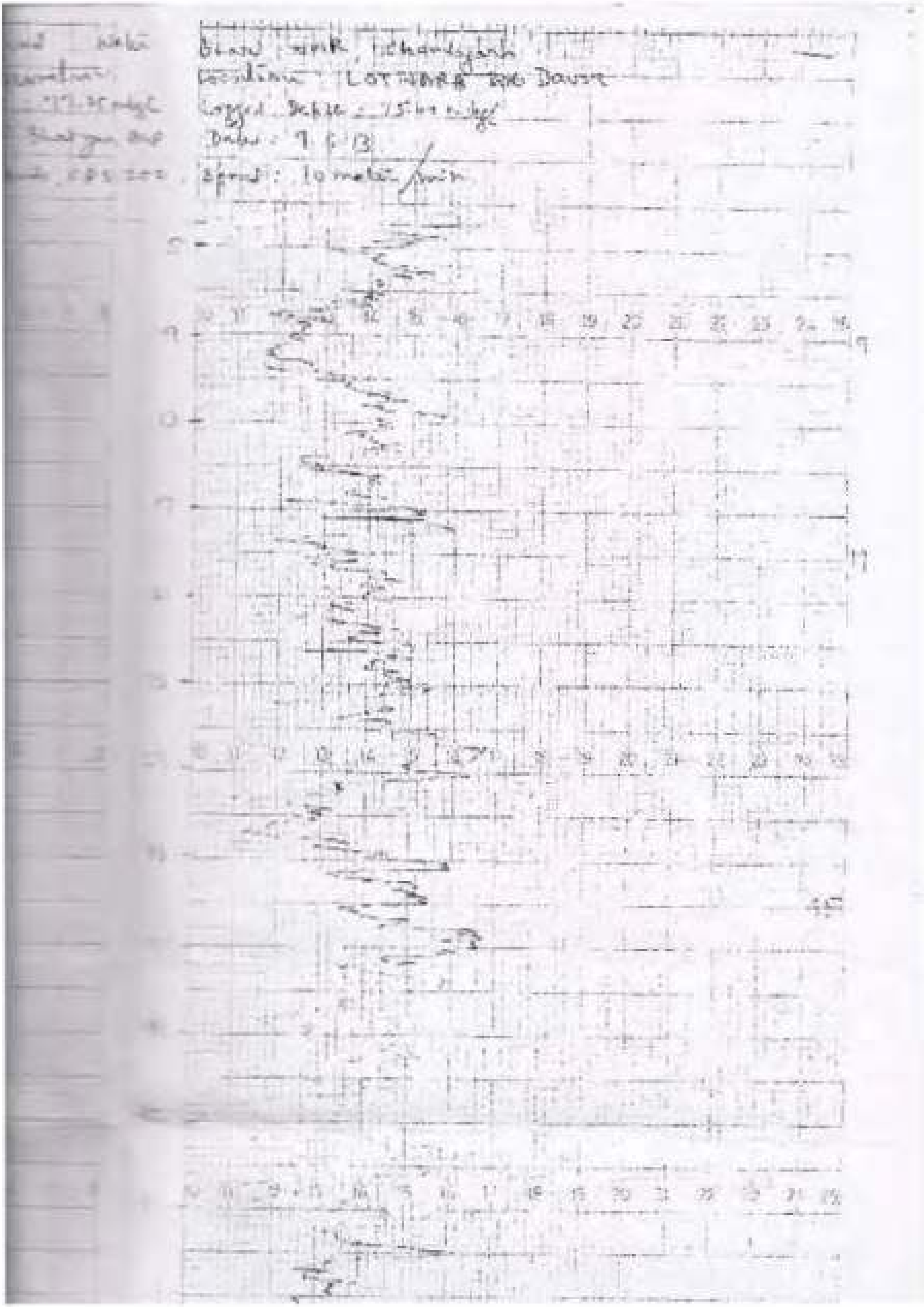
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
4/6/13	4.42	4.42	8	0.55	Drager
	8.92	4.50	18	0.25	
	13.58	4.66	22	0.21	
	18.00	4.42	26	0.17	
5/6/13	22.59	4.59	28	0.16	
	27.18	4.59	19	0.24	
	31.76	4.58	09	0.51	
	36.42	4.66	25	0.18	
6/6/13	41.08	4.66	35	0.13	
	45.71	4.63	391.2	0.01	
7/6/13	50.28	4.57	100.8	0.045	
	54.82	4.54	102	0.04	
	59.47	4.65	37	0.125	
	64.07	4.60	50	0.09	
8/6/13	68.26	4.19	339	0.012	
	72.56	4.30	271	0.015	
	75.61	3.05	25	0.122	
9/6/13	79.03	3.42	590	0.0058	

COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	29	24	Silty sand with clay
29	33	4	Sand
33	41	8	silty sand with clay
41	46	5	Silty sand
46	54	8	Silty sand with clay
54	56	2	Silty sand
56	58	2	Sand
58	61	3	Clay
61	68	7	silty sand
68	72	4	Weathered
72	77	5	Hard rock



Electrical Resistivity and Self Potential Logs, Lotwara – I



Gamma Log, Lotwara - I

2. Village: Ranapada Block: Bandikui District: Dausa

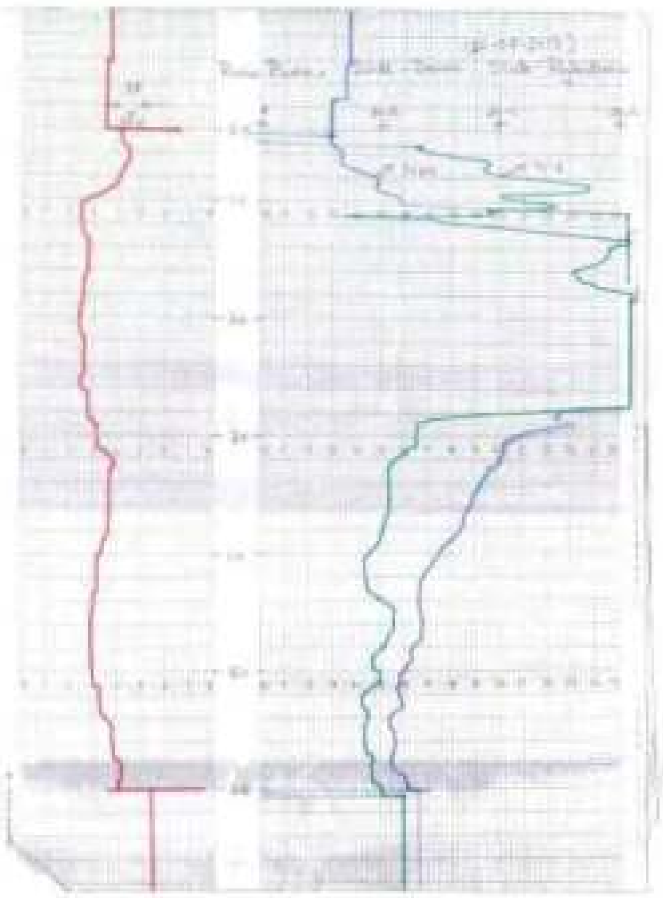
Lat: 26.98629 Long: 76.67401

DRILL TIME LOG

Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
7/7/13	4.42	4.42	9	0.49	RR
	8.93	4.51	18	0.250	
	13.56	4.63	13	0.356	
	18.16	4.60	17	0.27	
	22.76	4.60	11	0.418	
	27.39	4.63	23	0.201	
	32.05	4.66	61	0.076	
8/07/13	36.65	4.60	140	0.032	
	41.15	4.50	93	0.048	
	45.73	4.58	87	0.052	
	50.39	4.66	71	0.065	
9/07/13	54.67	4.28	71	0.06	
	59.27	4.60	167	0.027	
	63.68	4.41	90	0.049	

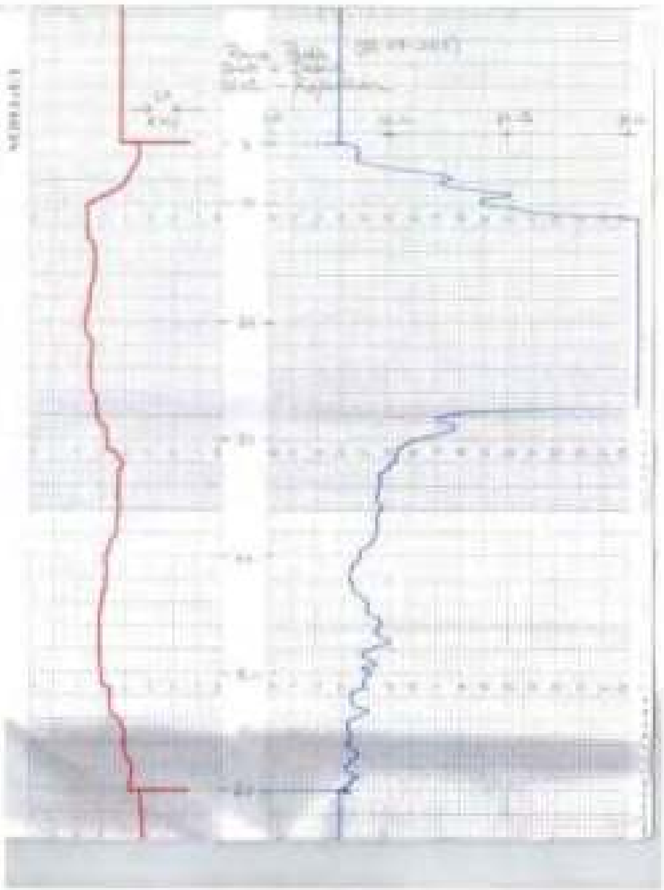
COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	11	6	Silty sand with clay
11	18	7	Clay with kankar and silt
18	21	3	Sand with kankar
21	24	3	Sand with kankar
24	26	2	Clay with kankar and silt
26	32	6	Silty sand with sand
32	52	20	Silty sand with clay
52	60	8	Sand
60	63	3	Weathered Hard Rock
63	64	1	Hard rock

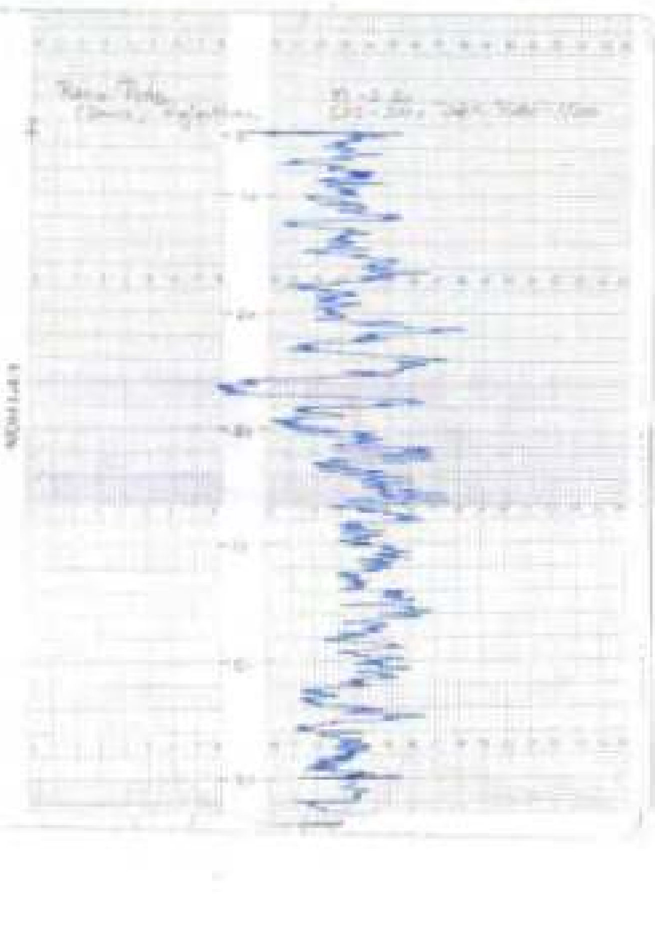


Rana Pada, AQRAJ

Short Normal and Long Normal E-Logs



Rana Pada, AQRAJ
Lateral Log



Rana Pada, AQRAJ
Gamma Log

3. Village: Kheda Block: Bandikui District: Dausa
Lat: 27.01641 Long: 76.68141

DRILL TIME LOG

Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
17/7/13	5	5	8	0.625	RR
	8	3	30	0.1	
	11	3	22	0.132	
	14	3	30	0.1	
	17	3	25	0.12	
	20	3	33	0.090	
18/07/13	23	3	28	0.107	
	26	3	30	0.1	
	29	3	30	0.1	
	32	3	38	0.078	
	35	3	36	0.083	
	38	3	43	0.069	
	41	3	43	0.069	
	44	3	45	0.066	
	47	3	55	0.054	
	50	3	45	0.066	
	53	3	73	0.041	
	56	3	65	0.046	
19/07/13	59	3	72	0.041	
	62	3	65	0.046	
	63	1	93	0.032	

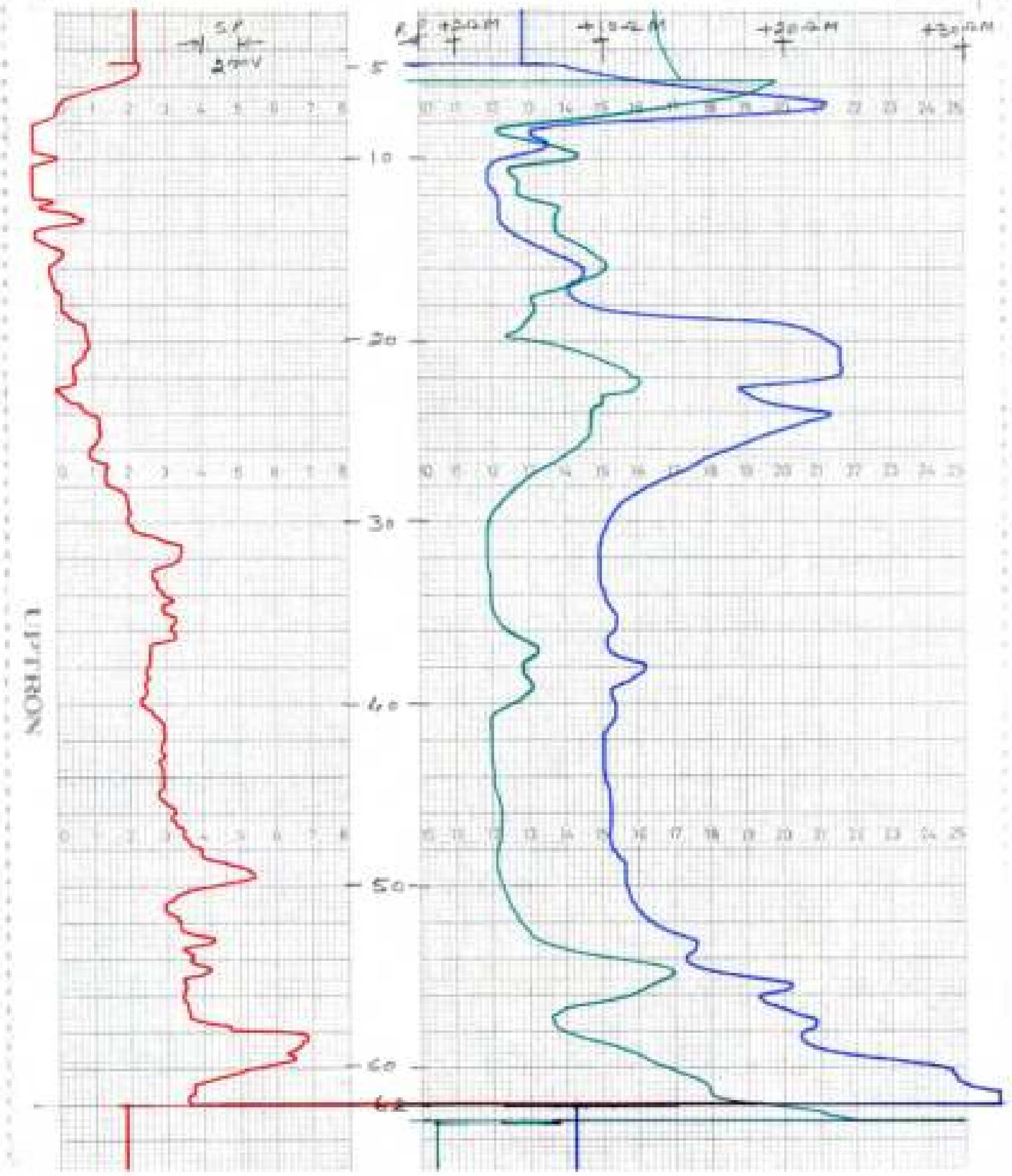
COMPOSITE LITHOLOG

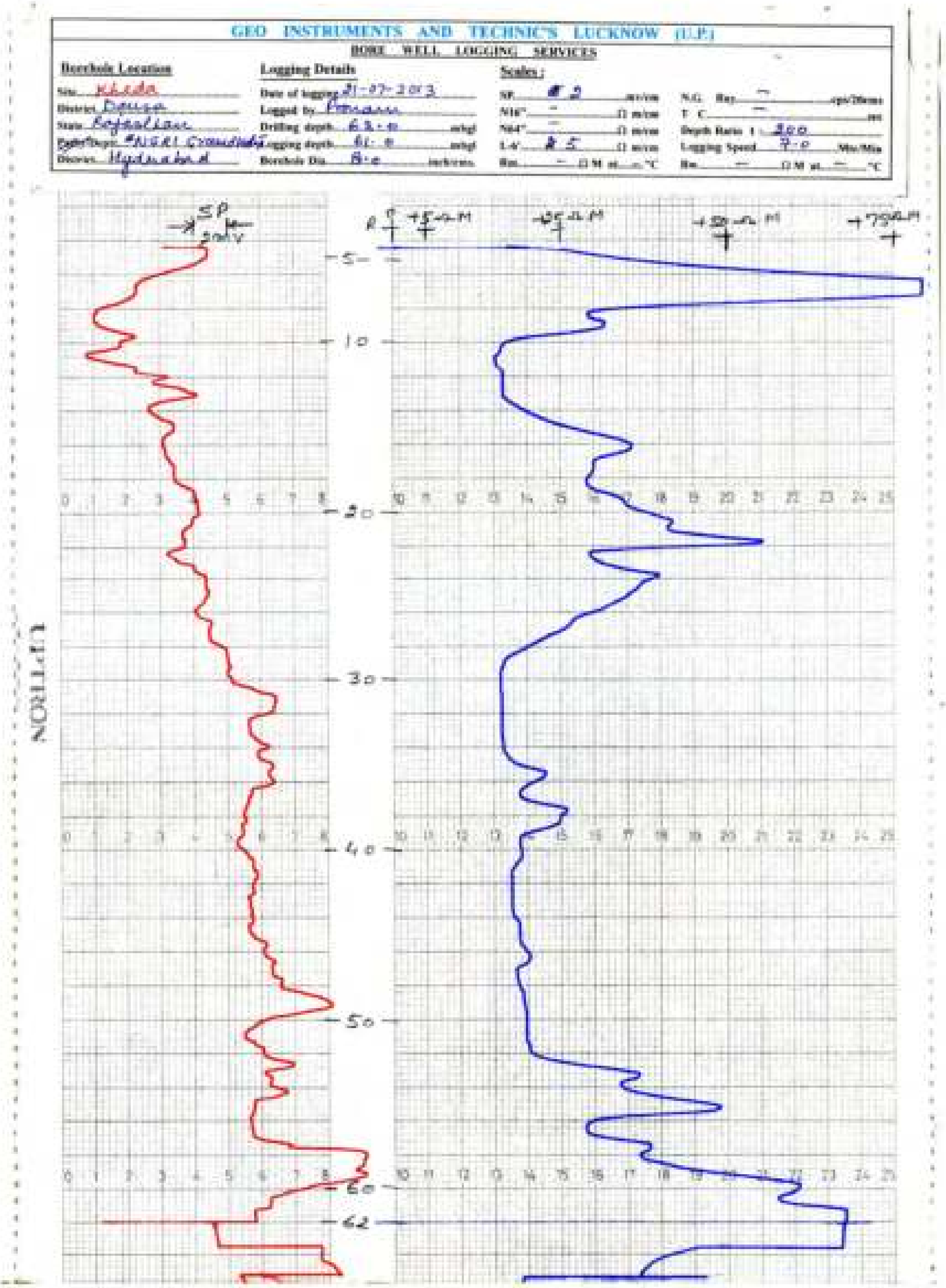
Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	10	5	Sand
10	16	6	Silty sand with clay
16	20	4	Clay
20	24	4	Sand
24	38	14	Clay kankar and silt
38	50	12	Silt
50	56	6	Sand
56	60	4	Weathered
60	63	3	Hard rock

GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)

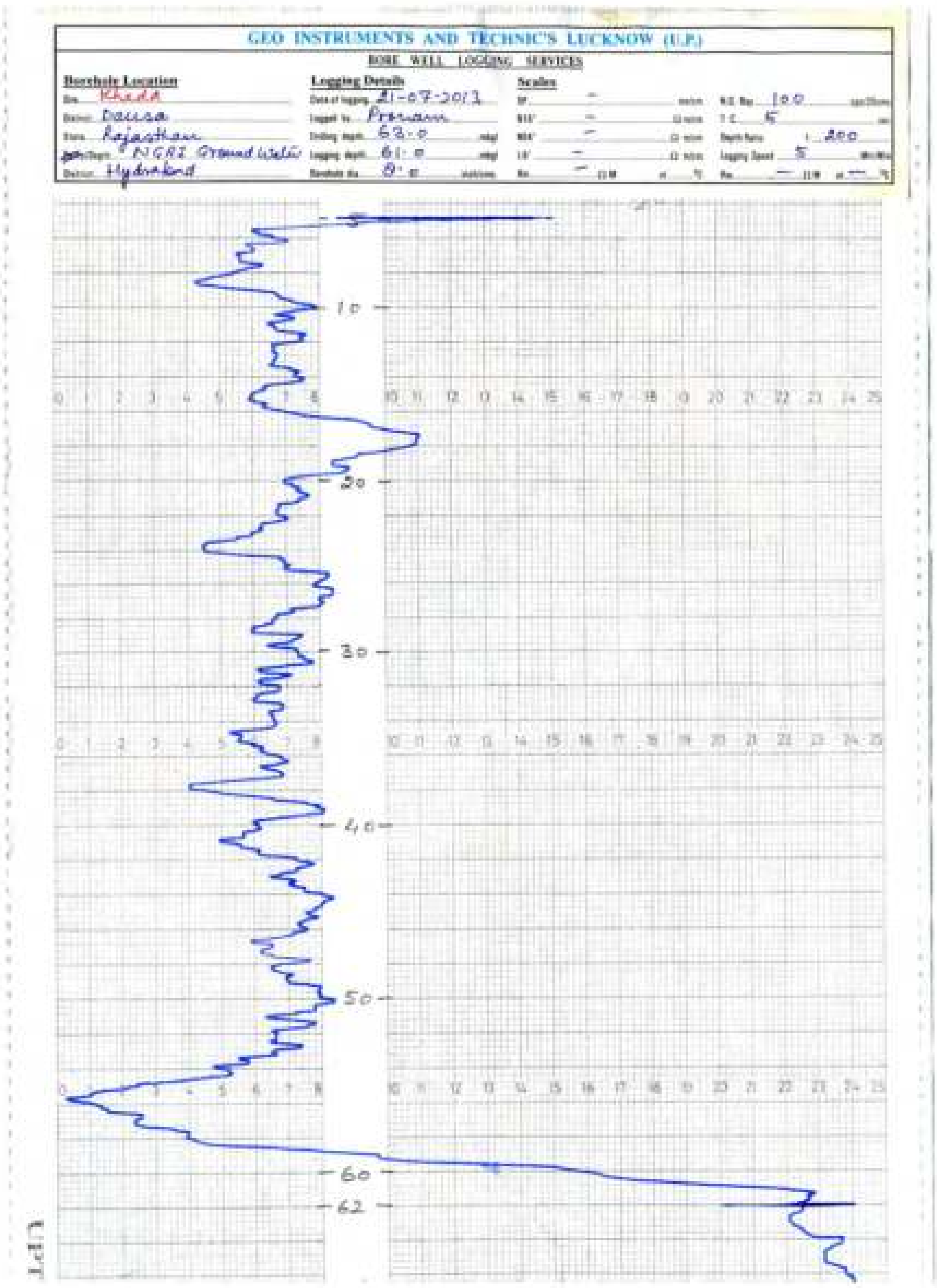
BORE WELL LOGGING SERVICES

Borehole Location	Logging Details	Scales:	
Site: Khera	Date of logging: 21-07-2013	SP: 2 mv/cm	N.G. Ray: – cps/20cm
District: Dausa	Logged by: Pravan	N16": 2 Ω m/cm	T. C.: – sec
State: Rajasthan	Drilling depth: 62.0 mbgl	N64": 2 Ω m/cm	Depth Ratio 1: 200
Deptt/Org: NGRI Groundwater	Logging depth: 61.0 mbgl	L.6': – Ω m/cm	Logging Speed: 7.0 Mtr/Min
District: Hyderabad	Borehole Dia.: 8.0 inch/cms	Rm: 7.5 Ω M at N °C	Rw: 4.5 Ω M at N °C





GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales :
Date of logging 21-07-2013
Drilling depth 63.0 mbgl
Logging depth 61.0 mbgl
Depth Ratio 1 : 200
Logging Speed 7.0 Mts/Min
Hyderabad
SP
UPTRON


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Kheda
Dausa
Rajasthan
NGRI Ground Water
Hyderabad
Logging Details
21-07-2013
Pramam
62.0
61.0
Scales
100
5
1:200
10
20
30
40
50
60
62

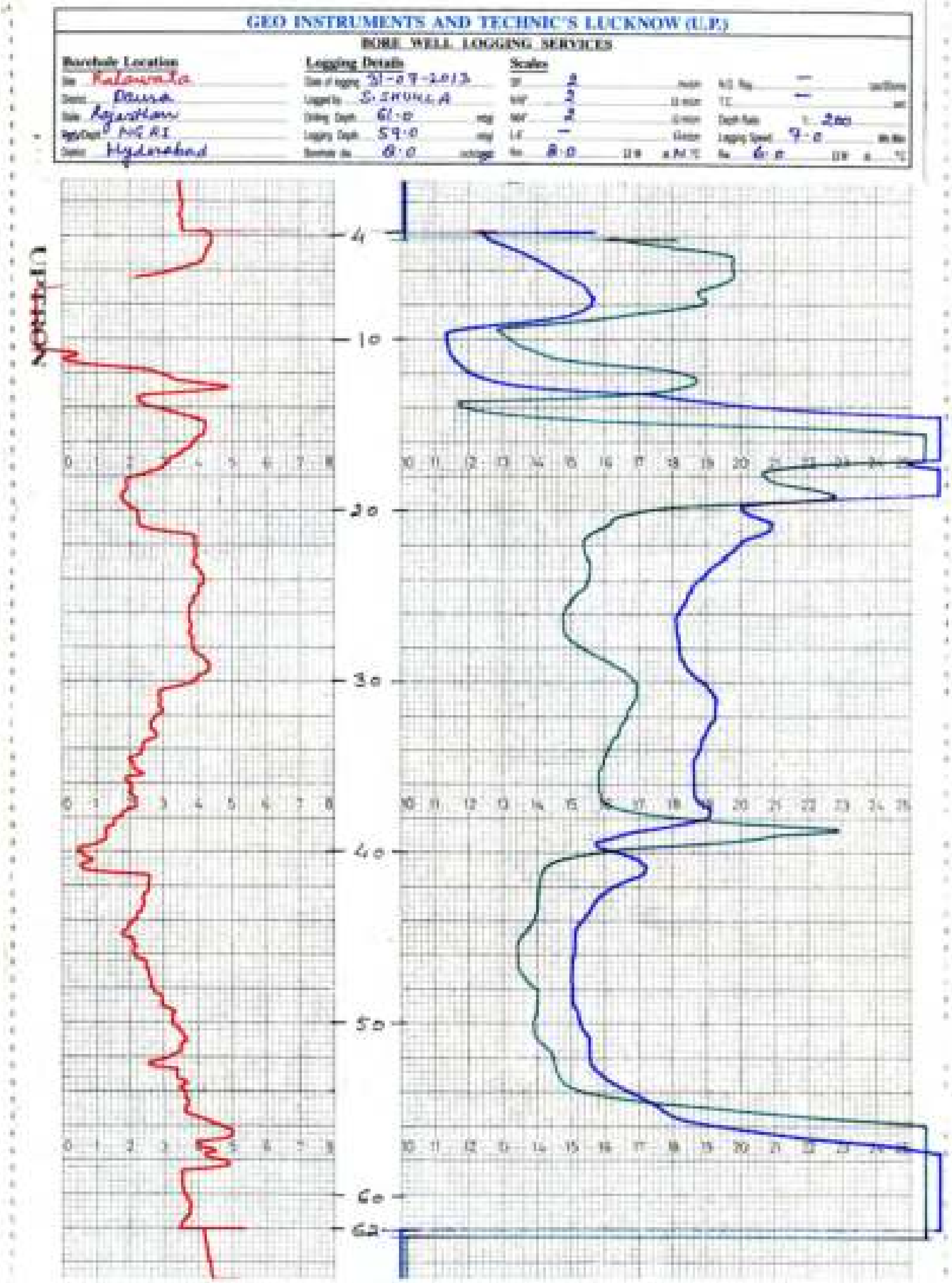
4. Village: Ralaota Block: Bandikui District: Dausa
Lat: 27.05214 Long: 76.68207

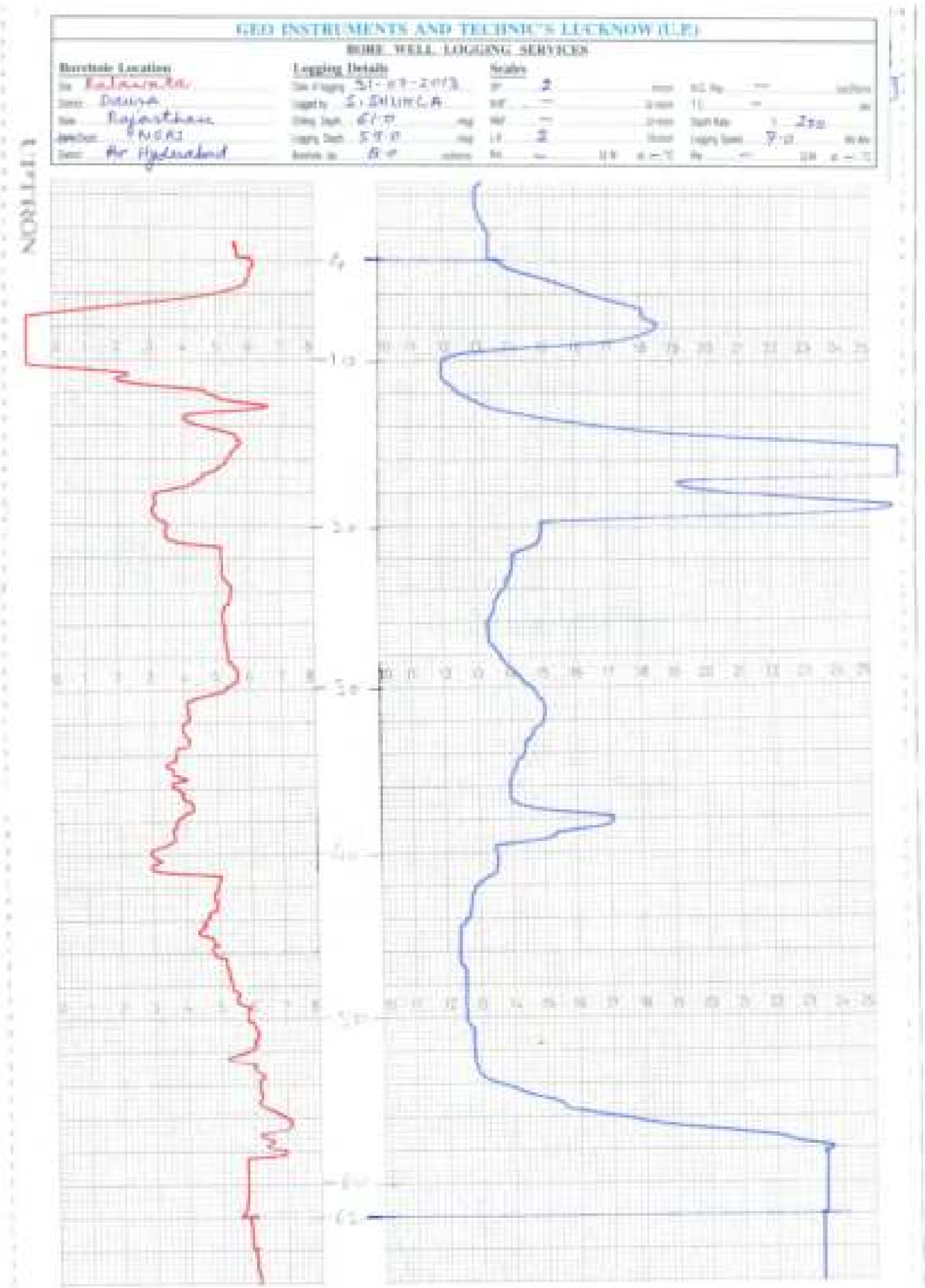
DRILL TIME LOG

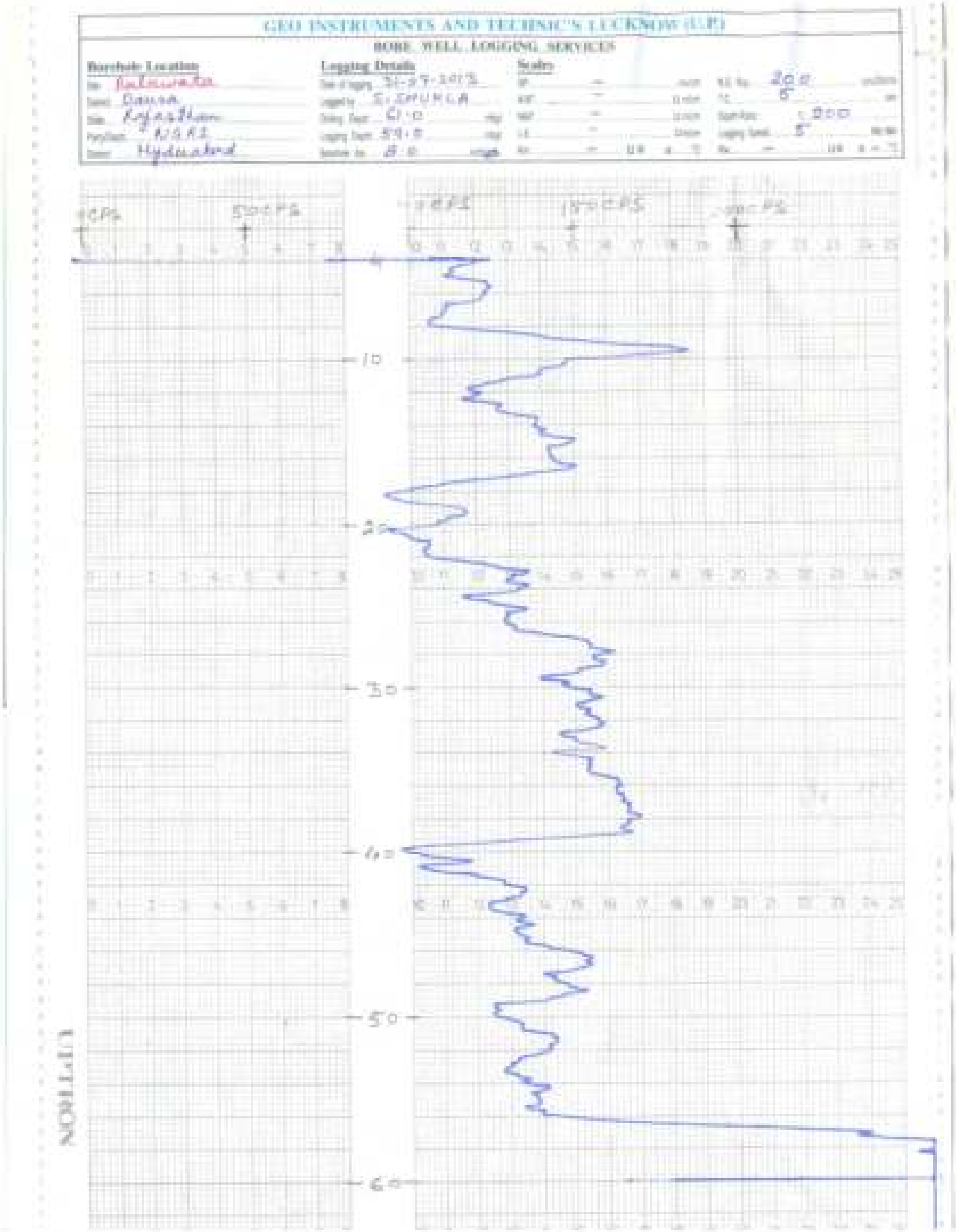
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
29/07/13	4.42	4.42	20	0.221	RR
	8.92	4.50	37	0.121	
	13.55	4.63	56	0.082	
	18.15	4.60	103	0.044	
	22.75	4.60	48	0.095	
	27.27	4.52	47	0.096	
	31.87	4.60	42	0.109	
	36.53	4.66	163	0.028	
30/07/13	41.20	4.67	175	0.026	
	45.82	4.62	190	0.024	
	50.41	4.59	205	0.022	
	55.02	4.61	188	0.024	
31/07/13	59.32	4.30	185	0.023	
	61.32	2.0	260	0.007	

COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	7	2	Clay
7	8	1	Sand
8	11	3	Clay
11	18	7	Silty sand with clay
18	22	4	Sand
22	39	17	Clay kankar with silt
39	42	3	Sand
42	55	13	Silty sand with clay
55	56	1	Weathered
56	61	5	Hard rock


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
4
10
20
30
40
50
60
62


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
10
20
30
40
50
60

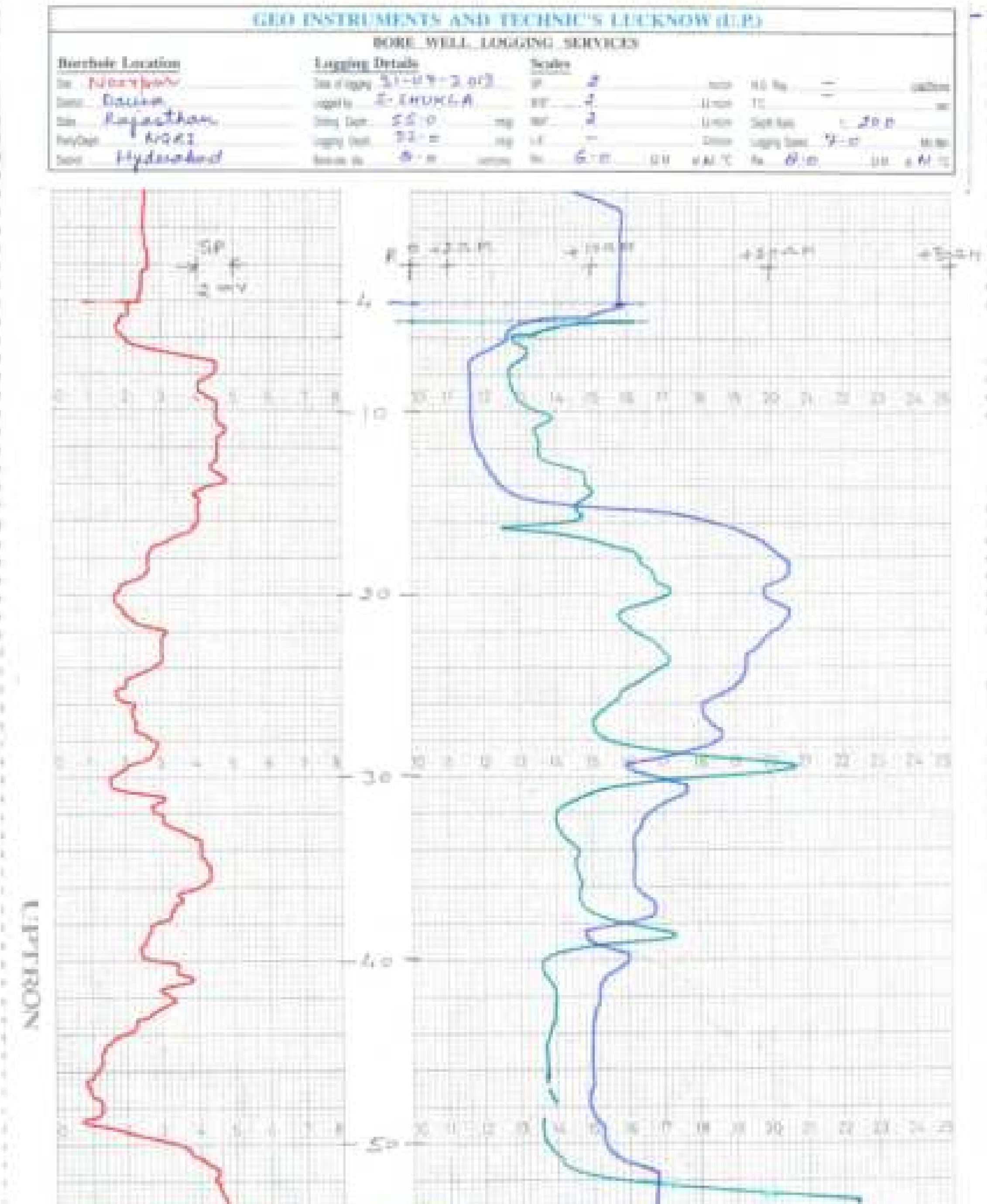
5. Village: Nurpur Basda Block: Bandikui District: Dausa
Lat: 27.07121 Long: 76.67037

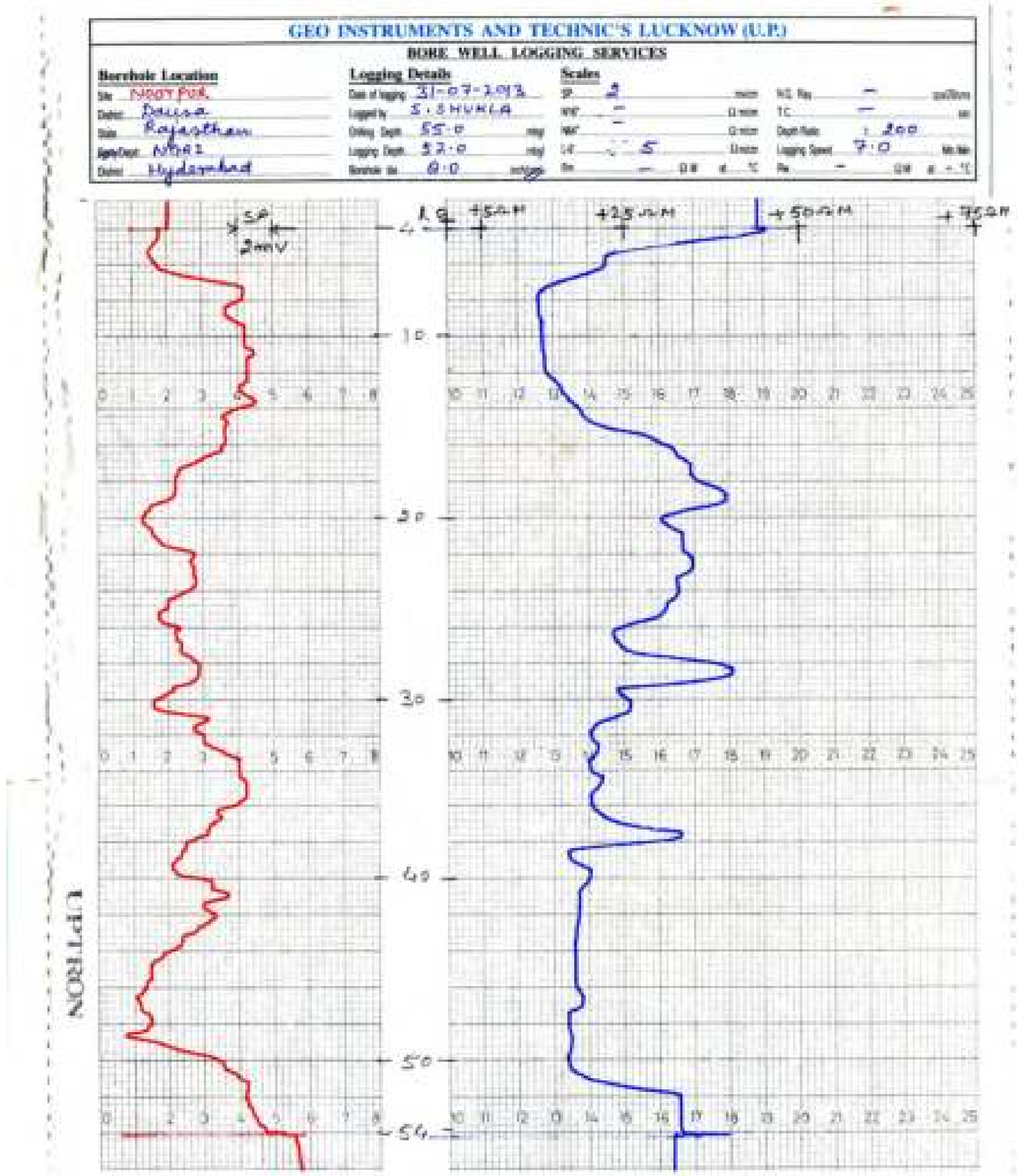
DRILL TIME LOG

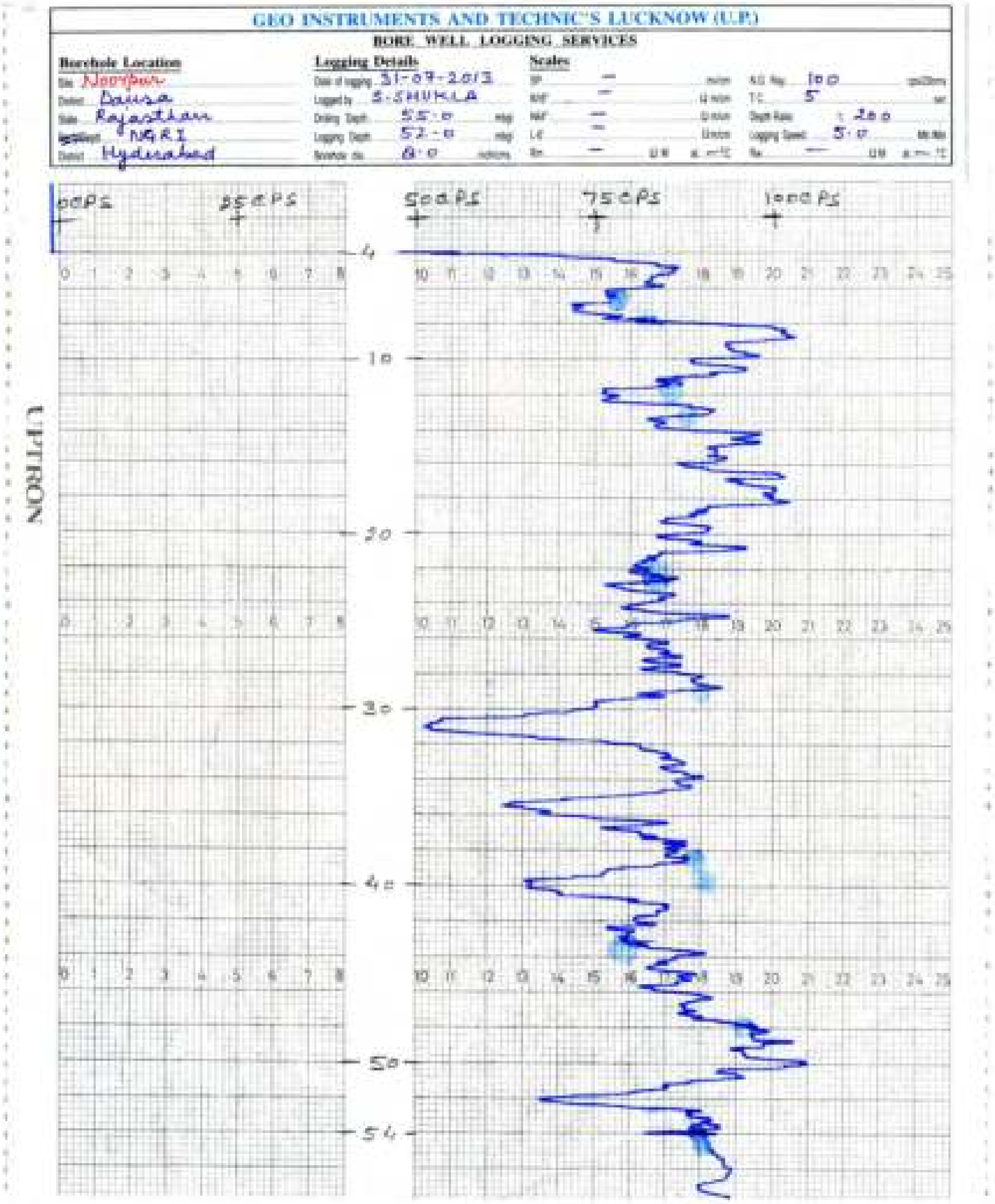
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
27/07/13	4	4	15	0.267	RR
	8	4	15	0.267	
	12	4	13	0.308	
	17	5	20	0.250	
	21	4	18	0.222	
	25	4	19	0.211	
	29	4	21	0.190	
	33	4	19	0.211	
	37	4	25	0.160	
	42	5	33	0.152	
	46	4	25	0.160	
	50	4	29	0.138	
27/07/13	55	5	82	0.061	

Composite Litholog

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	8	3	Sand
8	11	3	Clay
11	16	5	Sand
16	18	2	Clay Kankar and silt
18	28	10	Sand with Kankar
28	32	4	Sand
32	35	3	Silty sand with clay
35	36	1	Sand
36	40	4	Clay Kankar and silt
40	42	2	Sand with Kankar
42	52	10	Silty sand with clay
52	55	3	Weathered
55	56	1	Hard rock


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Rajasthan
NGRI
Hyderabad
SP
UPTRON


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
NOOTPUR
Dausa
Rajasthan
Hyderabad
31-07-2013
S. SHUKLA
55.0
52.0
8.0
1 : 200
7.0
SP
2mV
+5ΩM
+25ΩM
+50ΩM
+75ΩM
10
20
30
40
50
54
UPTRON


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Noorpur
Dausa
Rajasthan
NGRI
Hyderabad
31-07-2013
S.SHUKLA
55.0
52.0
8.0
100
5
1:200
5.0
0CPS
25CPS
50CPS
75CPS
100CPS
10
20
30
40
50
54
UPTRON

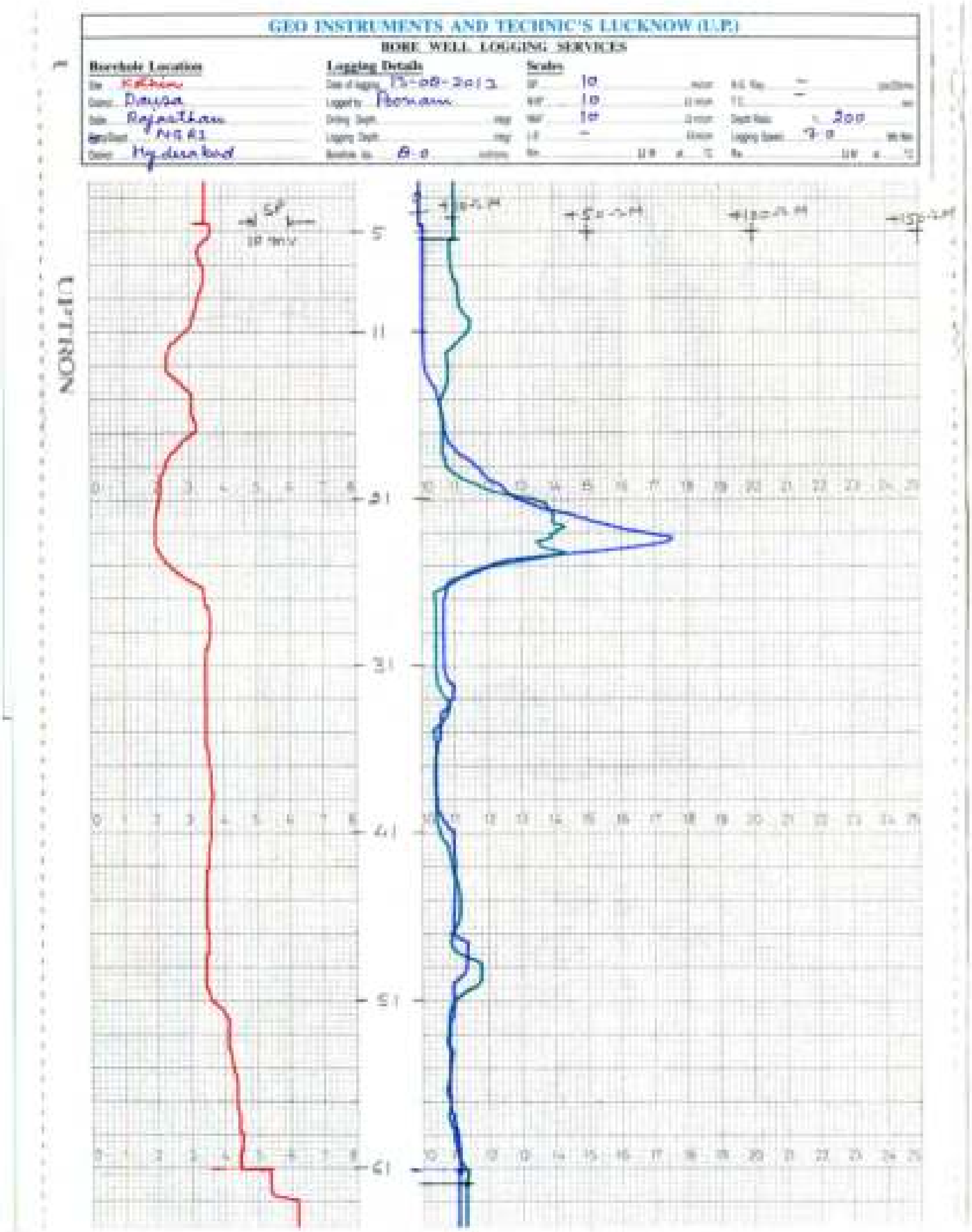
6. Village: Kothin Block: Bandikui District: Dausa
Lat: 27.06514 Long: 76.7636

DRILL TIME LOG

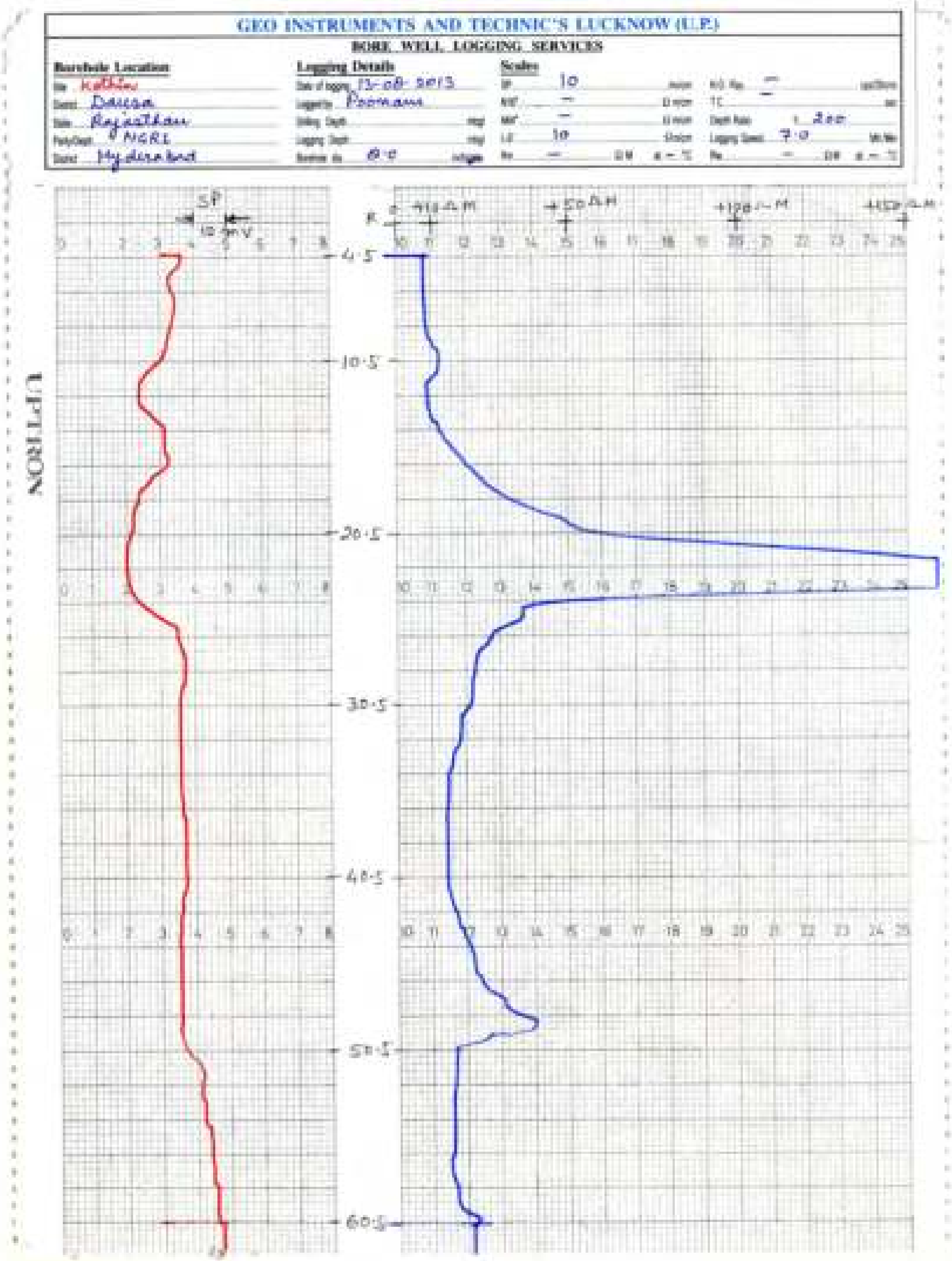
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
7/8/13	3	3	20	0.15	RR
	6	3	15	0.2	
	9	3	10	0.3	
	12	3	15	0.2	
	15	3	15	0.2	
	18	3	15	0.2	
	21	3	12	0.25	
	24	3	20	0.15	
	27	3	30	0.1	
	30	3	20	0.15	
8/8/13	33	3	20	0.15	
	36	3	25	0.12	
	39	3	20	0.15	
	42	3	15	0.2	
	45	3	30	0.1	
	48	3	10	0.3	
	51	3	45	0.066667	
	54	3	45	0.066667	
	57	3	80	0.0375	
	60	3	70	0.042857	
	61	1	160	0.00625	

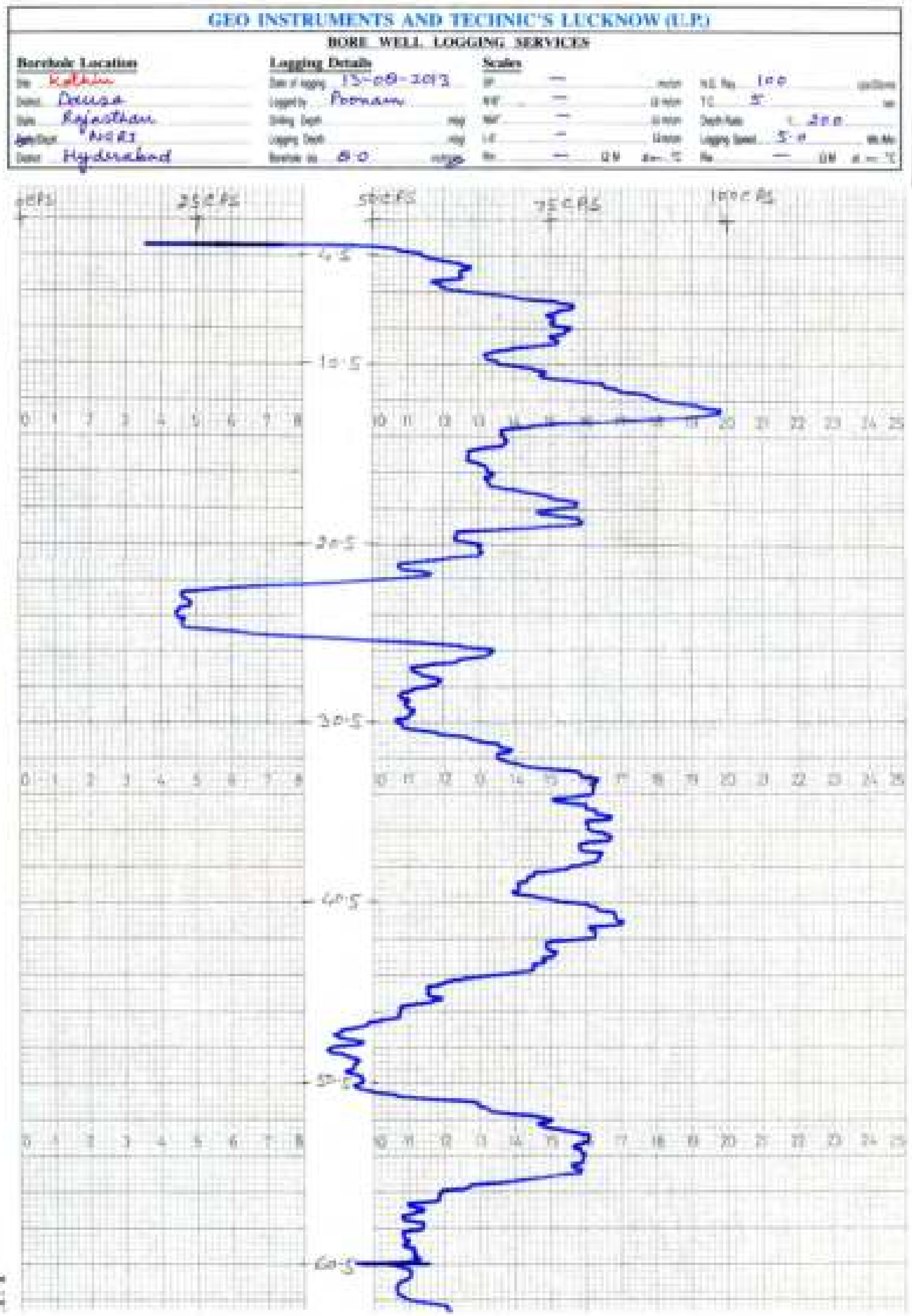
COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	9	4	Silty sand with clay
9	11	2	Silty sand
11	14	3	Clay
14	19	5	Silty sand
19	26	7	Sand
26	33	7	Silty sand with clay
33	42	9	Clay Kankar and silt
42	51	9	Sand
51	54	3	Clay kankar and gravel
54	60	6	Weathered
60	61	1	Hard rock



GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Kithan
Dausa
Rajasthan
NGRI
Hyderabad
15-08-2012
Poonam
NORTRON


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
SP
4.5
10.5
20.5
30.5
40.5
50.5
60.5
UPTRON


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Dausa
Rajasthan
NGRI
Hyderabad
13-08-2013
Poonam
0 CPS
25 CPS
50 CPS
75 CPS
100 CPS
4.5
10.5
20.5
30.5
40.5
50.5
60.5

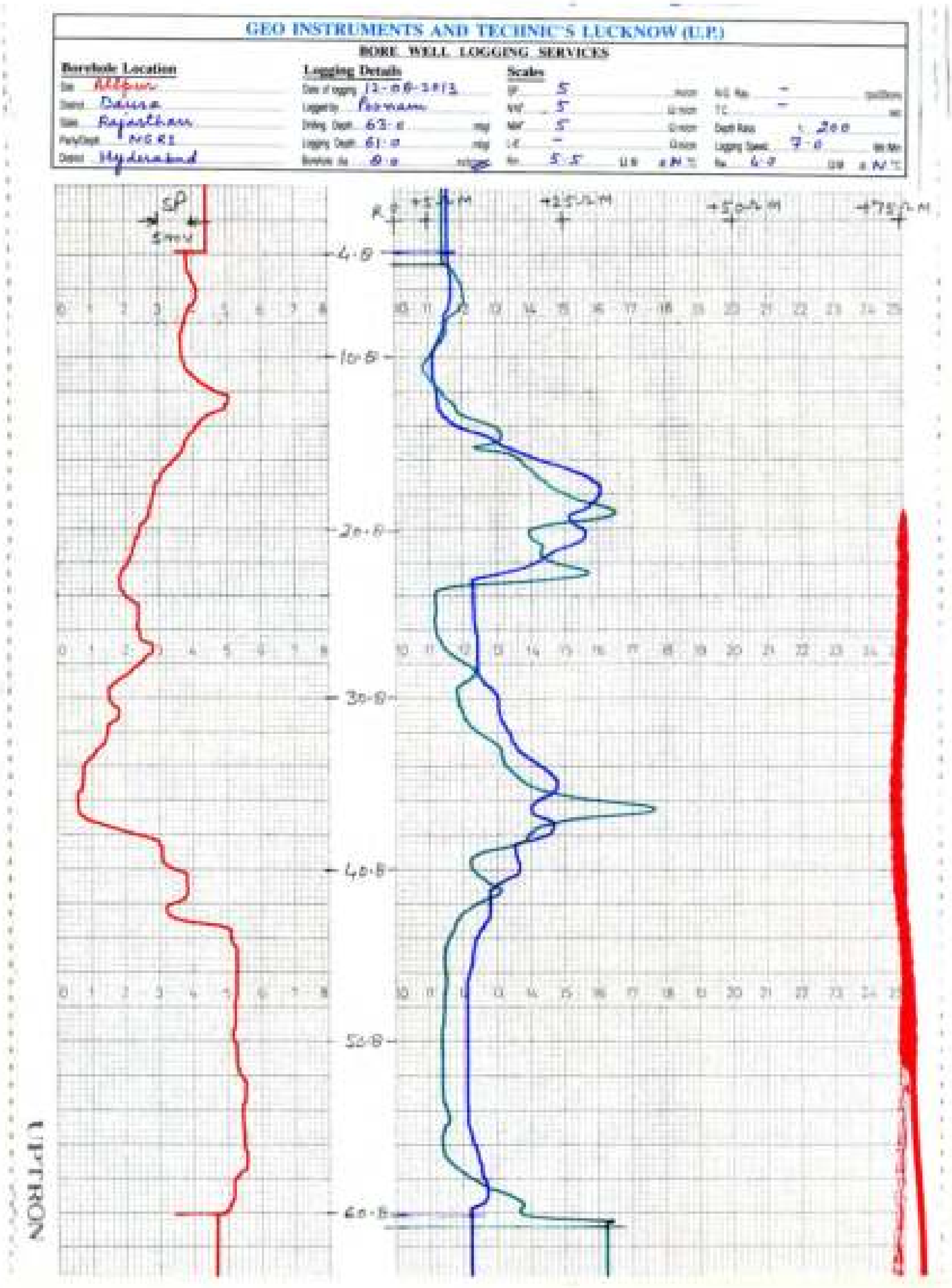
7. Village: Alipur Block: Bandikui District: Dausa
Lat: 27.07851 Long: 76.79393

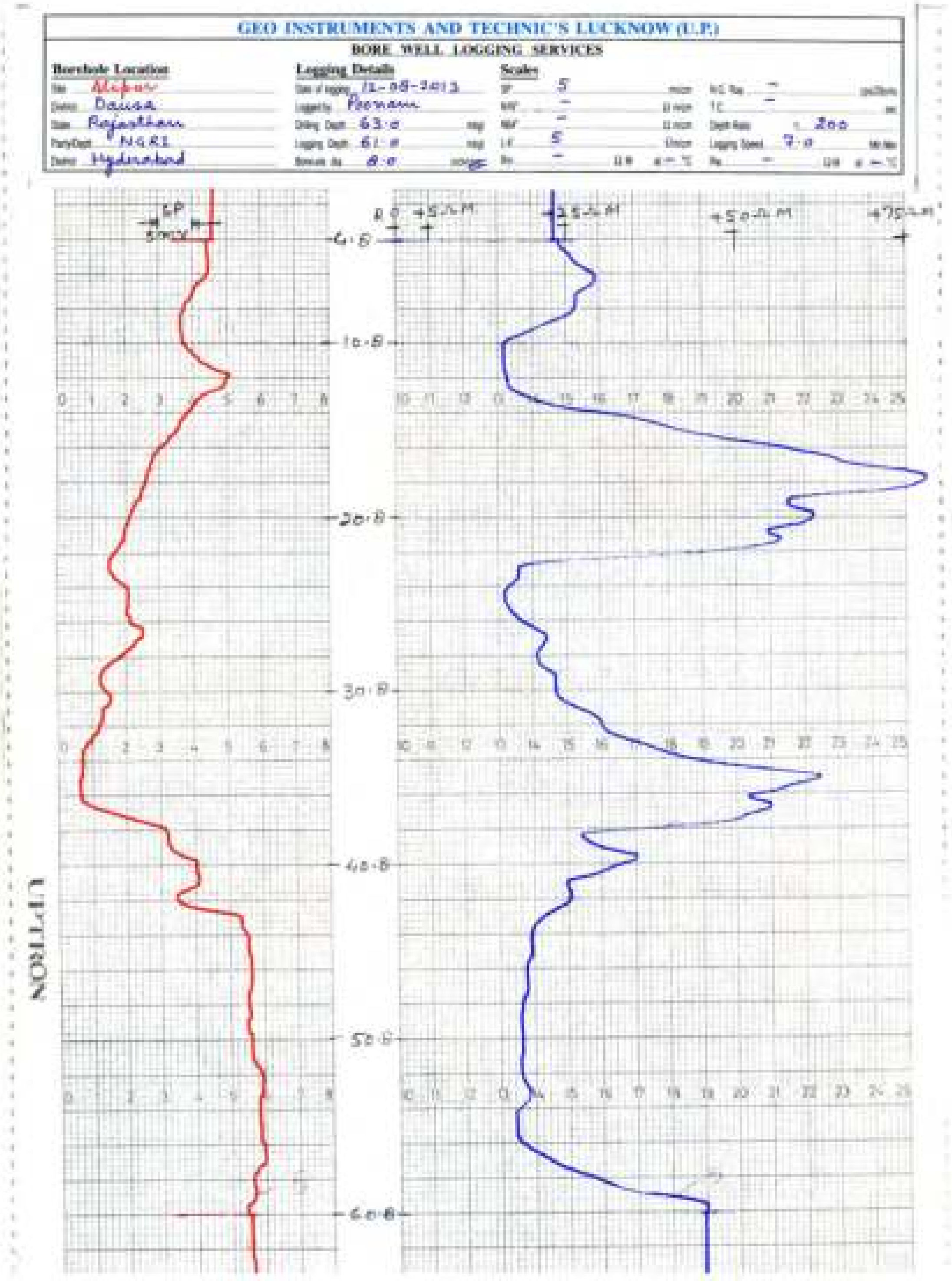
DRILL TIME LOG

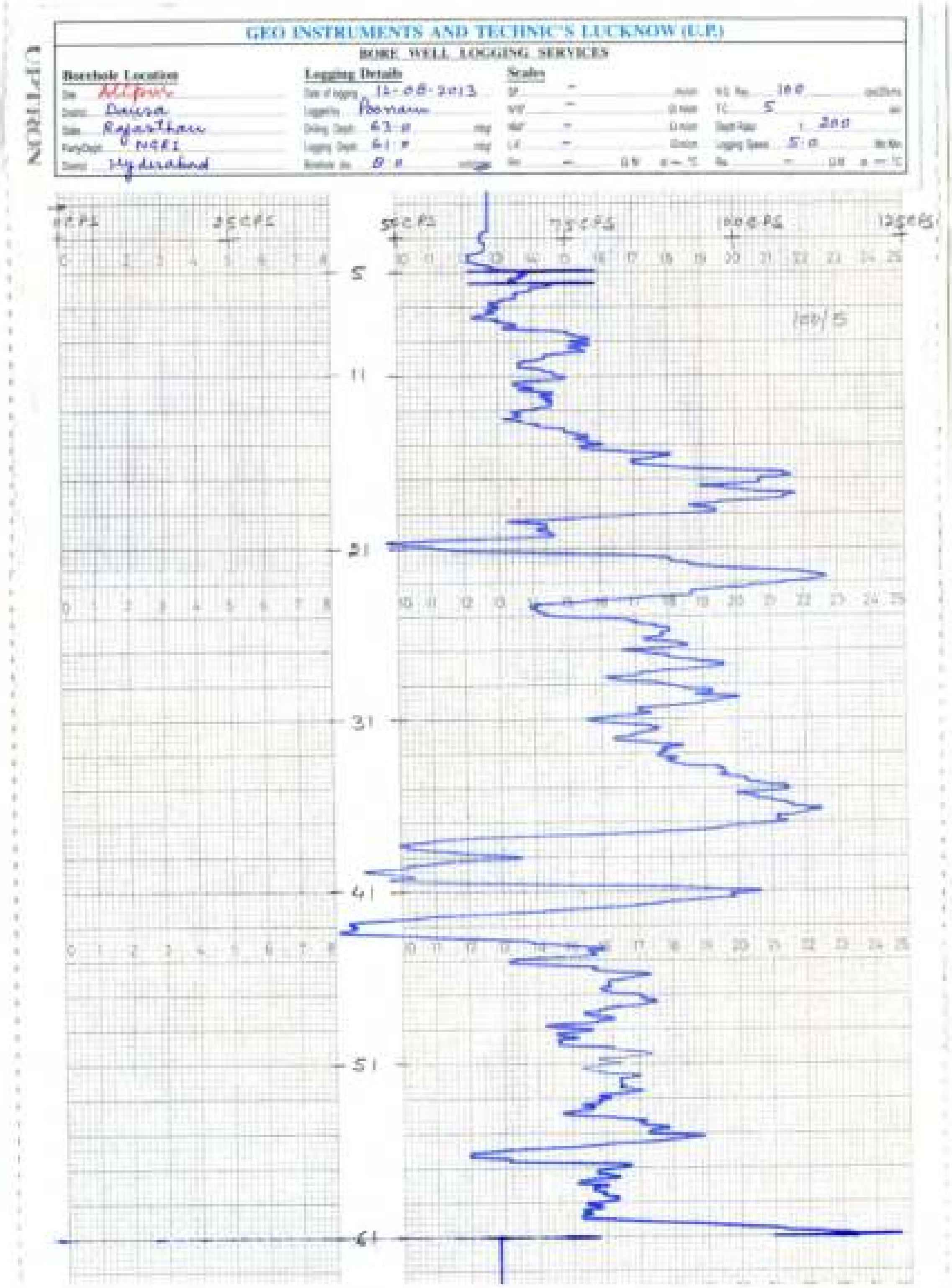
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
07/08/13	4.42	4.42	17	0.26	RR
	8.92	4.5	20	0.225	
	13.54	4.62	28	0.165	
	18.06	4.52	23	0.196522	
	22.66	4.6	30	0.153333	
08/08/13	27.25	4.59	30	0.153	
	31.85	4.6	48	0.095833	
	36.49	4.64	289	0.016055	
	41.1	4.61	275	0.016764	
09/08/13	45.7	4.6	116	0.039655	
	50.28	4.58	149	0.030738	
	54.93	4.65	162	0.028704	
	59.35	4.42	256	0.017266	
10/08/13	63.63	4.28	265	0.016151	

COMPOSITE LOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	8	3	Sand with clay
8	10	2	Clay
10	13	3	Silty sand with clay
13	19	6	Clay
19	21	2	Sand
21	24	3	Clay
24	25	1	Sand
25	37	12	Silty sand with clay
37	41	4	Sand
41	42	1	Clay
42	44	2	Sand
44	55	11	Sand with clay
55	57	2	Sand
57	59.5	2.5	Weathered
59.5	63	3.5	Hard rock


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Dausa
Rajasthan
NGRI
Hyderabad
SP
4.0
10.0
20.0
30.0
40.0
50.0
60.0
UPTRON


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Alipur
Dausa
Rajasthan
NGRI
Hyderabad
12-08-2013
Poonam
63.0
61.0
8.0
5
200
SP
10.0
20.0
30.0
40.0
50.0
60.0


UPTRON
GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Dausa
Rajasthan
NGRI
Hyderabad
12-08-2013
Poonam
63.0
61.0
8.0
100
5
1:200
5.0
5
11
21
31
41
51
61

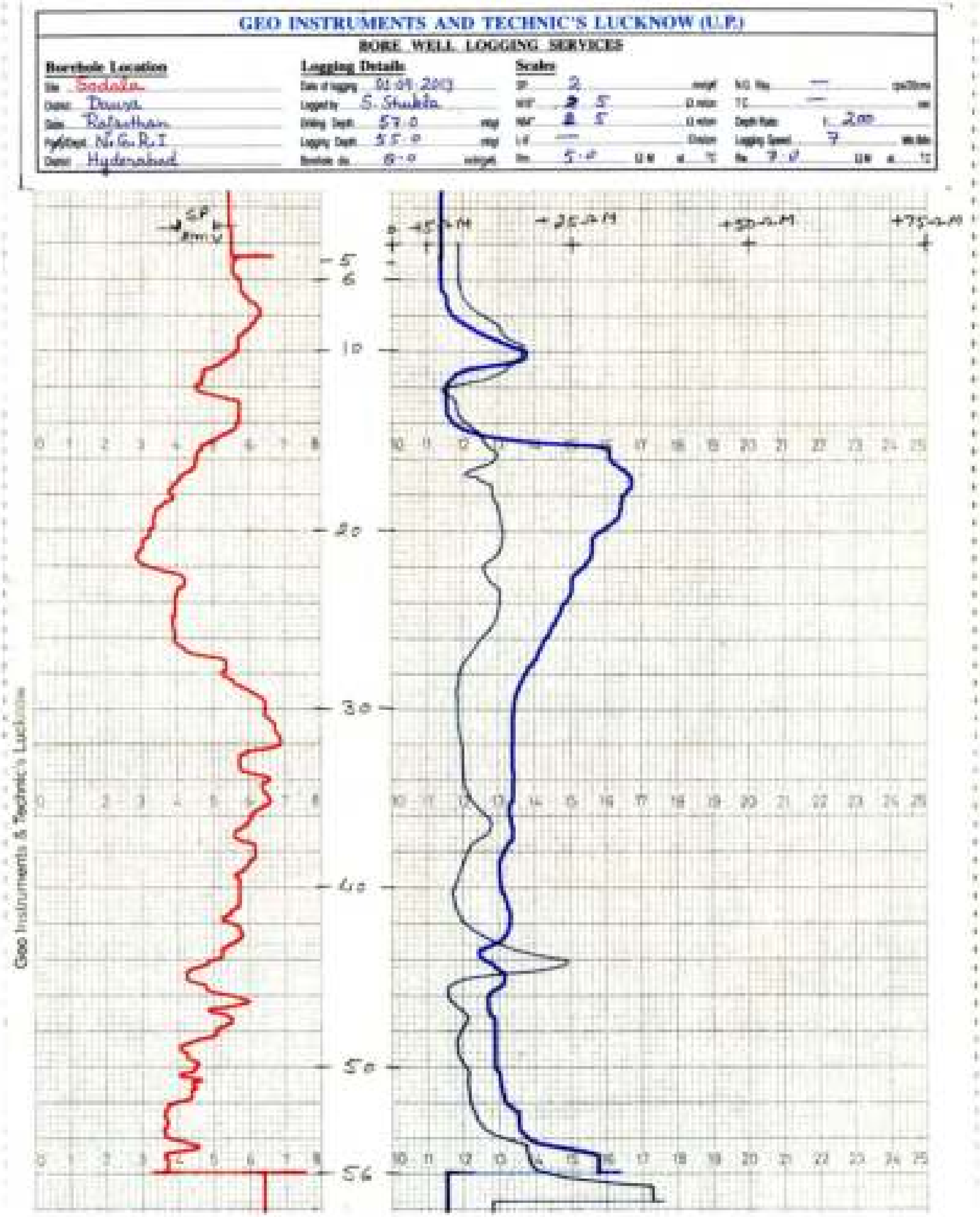
8. Village: Saudala Block: Bandikui District: Dausa
Lat: 27.00972 Long: 76.62468

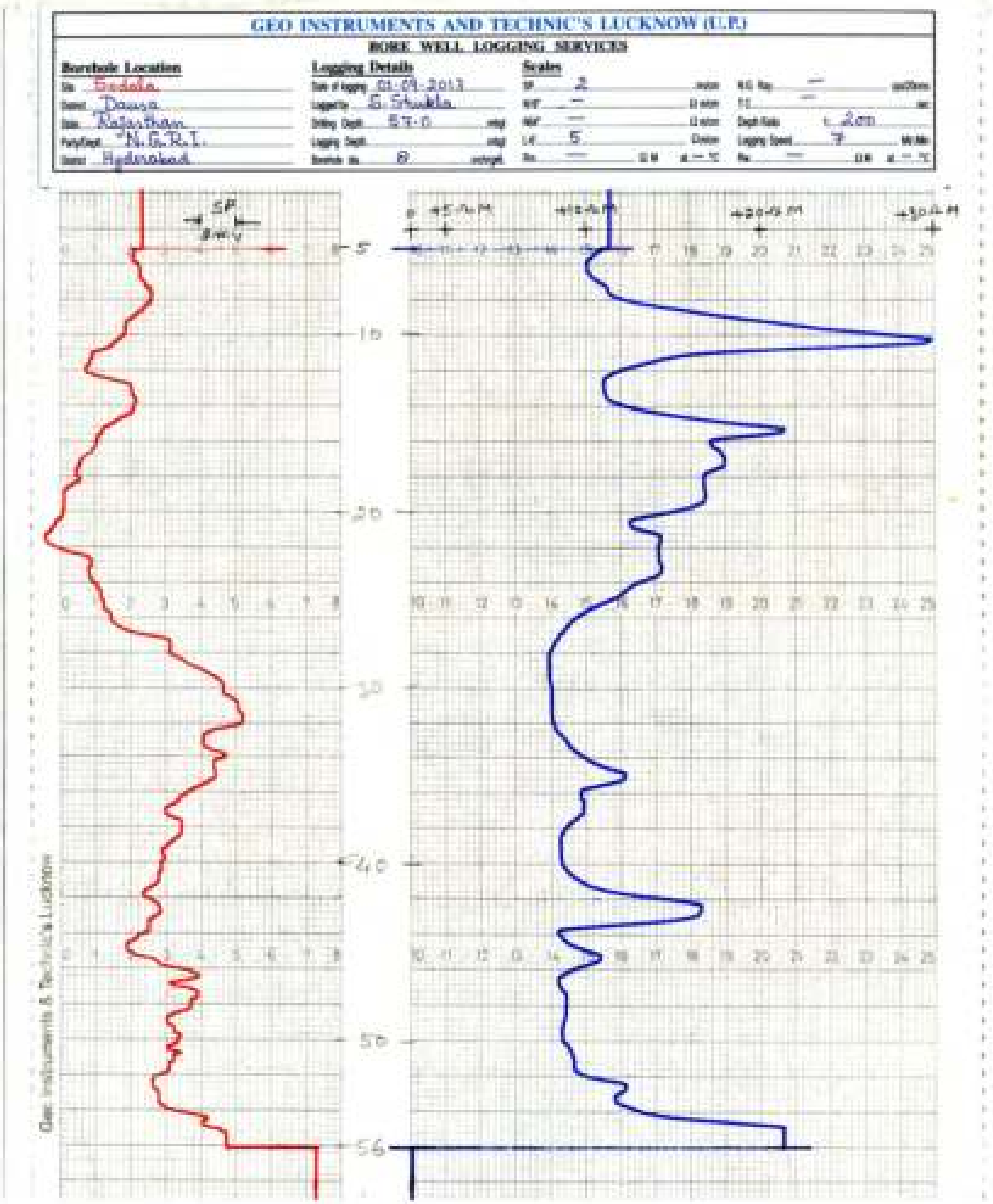
DRILL TIME LOG

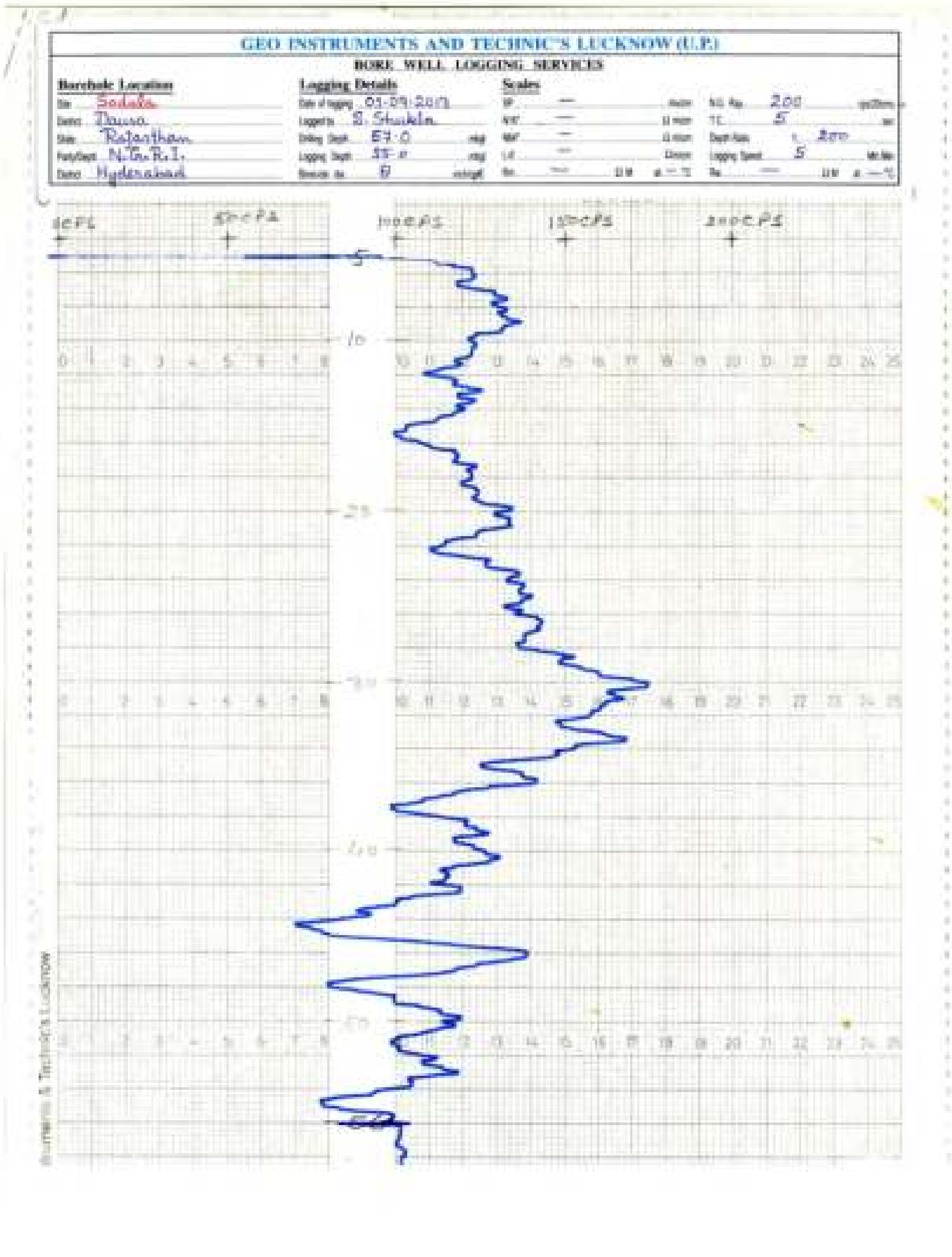
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
24/08/13	6	6	33	0.181818	RR
	10	4	85	0.047059	
25/08/13	14.3	4.3	95	0.045263	
	18.95	4.65	88	0.052841	
	23.52	4.57	142	0.032183	
	28.18	4.66	85	0.054824	
	32.45	4.27	103	0.041456	
	37.07	4.62	129	0.035814	
28/08/13	41.74	4.67	120	0.038917	
	45.94	4.2	152	0.027632	
	50.36	4.42	158	0.027975	
29/08/13	54.89	4.53	178	0.025449	
	59.51	2.09	390	0.011846	

COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface Soil
5	10	5	Clay
10	14	4	Silty Clay with sand
14	16	2	Sand
16	22	6	Silty clay with sand
22	24	2	Sand
24	36	12	Silty clay with sand
36	38	2	Sand
38	43	5	Silty sand/clay
43	46	3	Sand
46	48	2	Clay
48	54	6	Silty sand/clay
54	57	3	Weathered
57	58	1	Hard rock


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Sodala
Dausa
Rajasthan
N.G.R.I
Hyderabad
S. Shukla
SP
+25 Ω M
+50 Ω M
+75 Ω M
5
6
10
20
30
40
50
56
Geo Instruments & Technic's Lucknow


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Dausa
Rajasthan
N.G.R.I.
Hyderabad
01-09-2013
S. Shukla
SP
Geo Instruments & Technic's Lucknow


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Sodala
Dausa
Rajasthan
N.G.R.I.
Hyderabad
03-09-2013
S. Shukla
57.0
55.0
200
5
200
5
0CPS
50CPS
100CPS
150CPS
200CPS

9. Village: Shyamsinghpura Block: Bandikui District: Dausa

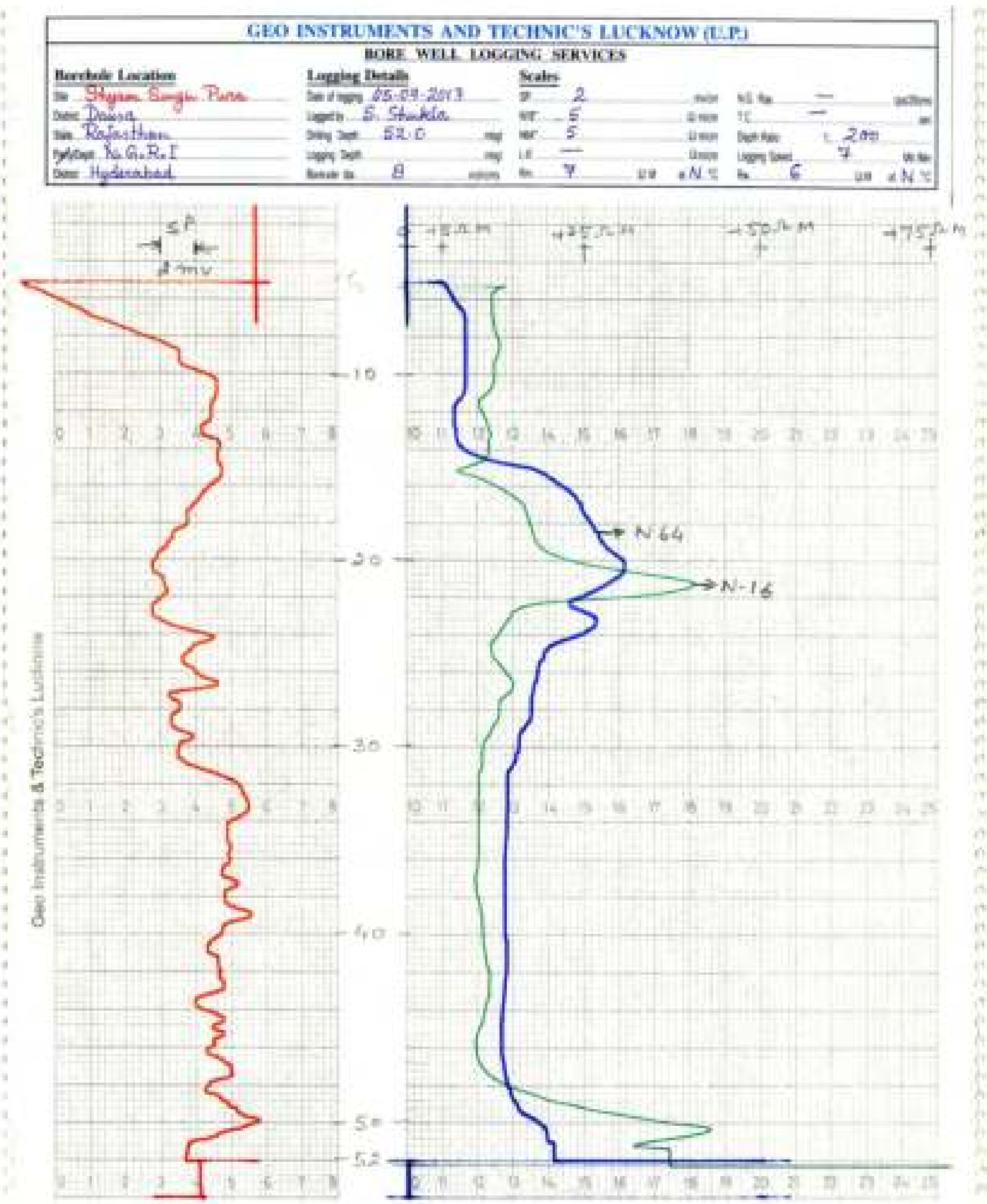
Lat: 26.98986 Long: 76.53439

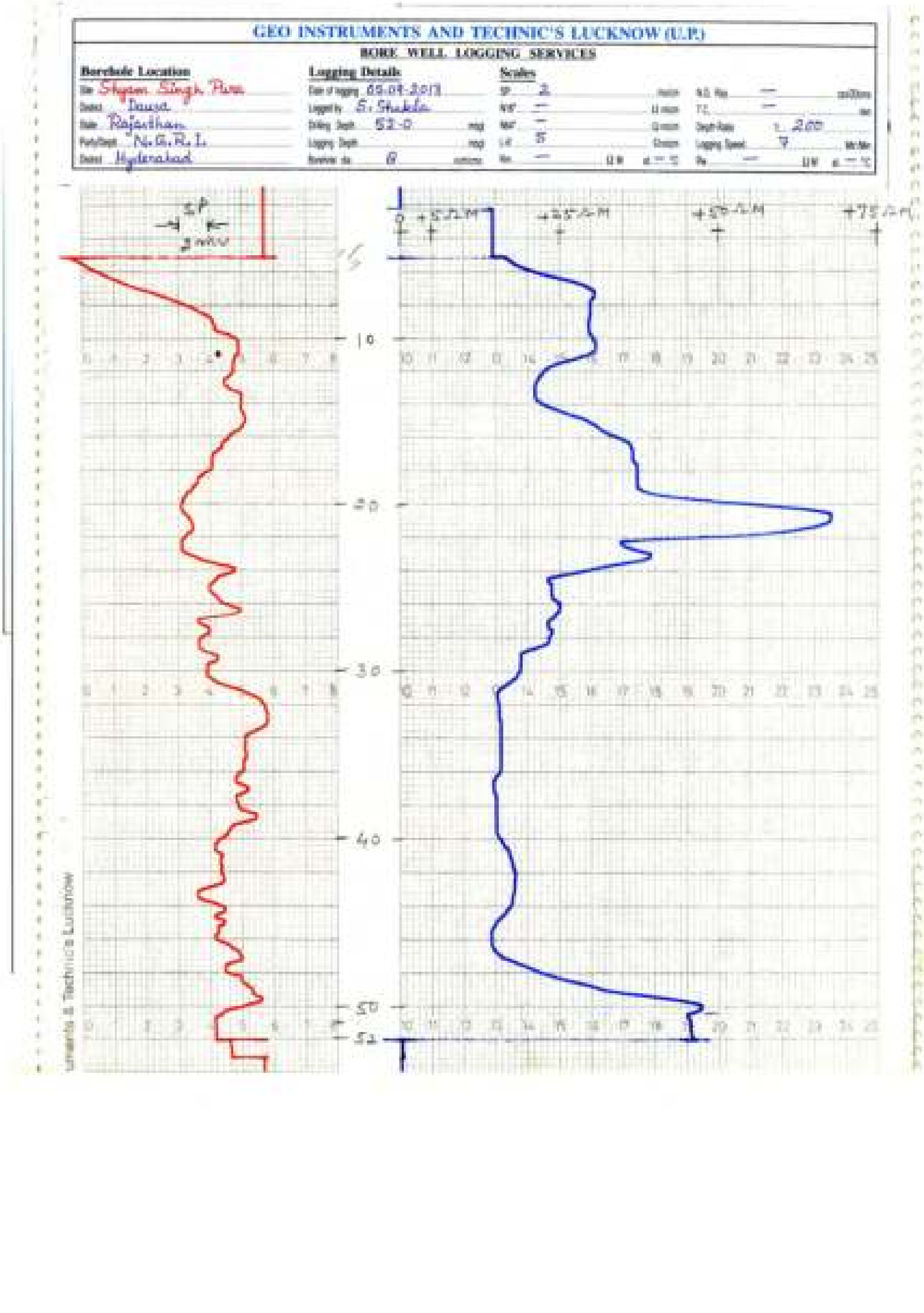
DRILL TIME LOG

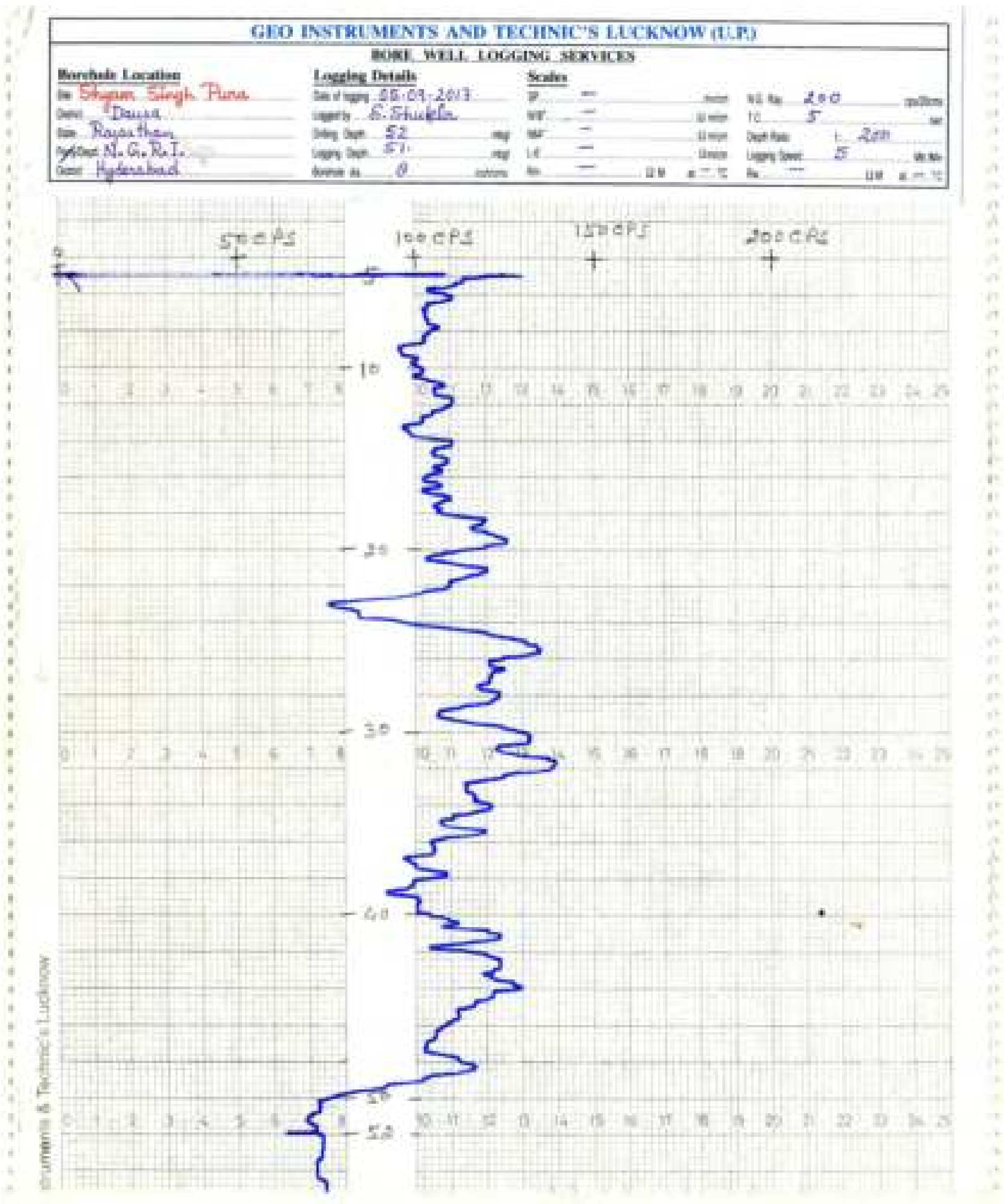
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	BIT TYPE & SIZE
29/8/13	4	4	15	0.267	RR
	8	4	15	0.267	
	12	4	13	0.308	
	17	5	20	0.250	
	21	4	18	0.222	
	25	4	19	0.211	
	29	4	21	0.190	
	33	4	19	0.211	
	37	4	25	0.160	
	42	5	33	0.152	
	46	4	25	0.160	
	50	4	29	0.138	
	51	1	90	0.011	
3/9/13 to 4/9/13	52	1	780	0.001	

COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	9	4	Silt sand and clay
9	14	5	Clay
14	16	2	Sand
16	18	2	Silty sand with clay
18	20	2	Clay
20	26	6	Sand
26	32	6	Silty sand with clay
32	42	10	Clay kankar and silt
42	48	6	Sand
48	52	4	Weathered
52	53	1	Hard rock


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Shyam Singh Pura
Dausa
Rajasthan
N.G.R.I
Hyderabad
05-09-2013
S. Shukla
52.0
8
N 64
N-16
SP
Geo Instruments & Technic's Lucknow


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Shyam Singh Pura
Dausa
Rajasthan
N.G.R.I.
Hyderabad
Logging Details
05.09.2013
S. Shukla
52.0
6
Scales
SP 2
5
1 : 200
7
SP
2 mV
0 +5 Ω.M
+25 Ω.M
+50 Ω.M
+75 Ω.M
10
20
30
40
50
52


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Shyam Singh Pura
Dausa
Rajasthan
N.G.R.I.
Hyderabad
E. Shukla
50 CPS
100 CPS
150 CPS
200 CPS
10
20
30
40
50

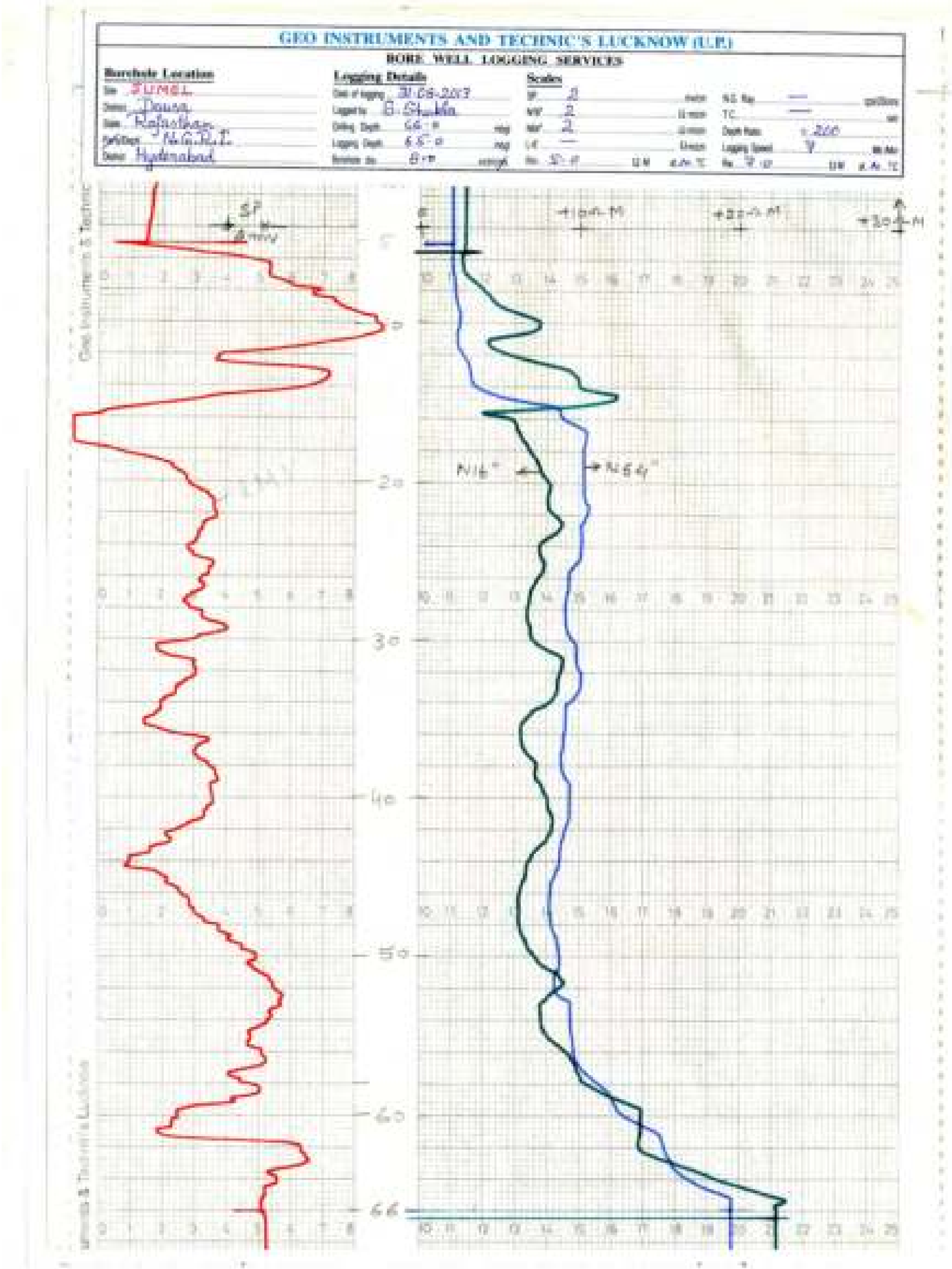
10. Village: Sumail Block: Bandikui District: Dausa
Lat: 27.04206 Long: 76.74565

DRILL TIME LOG

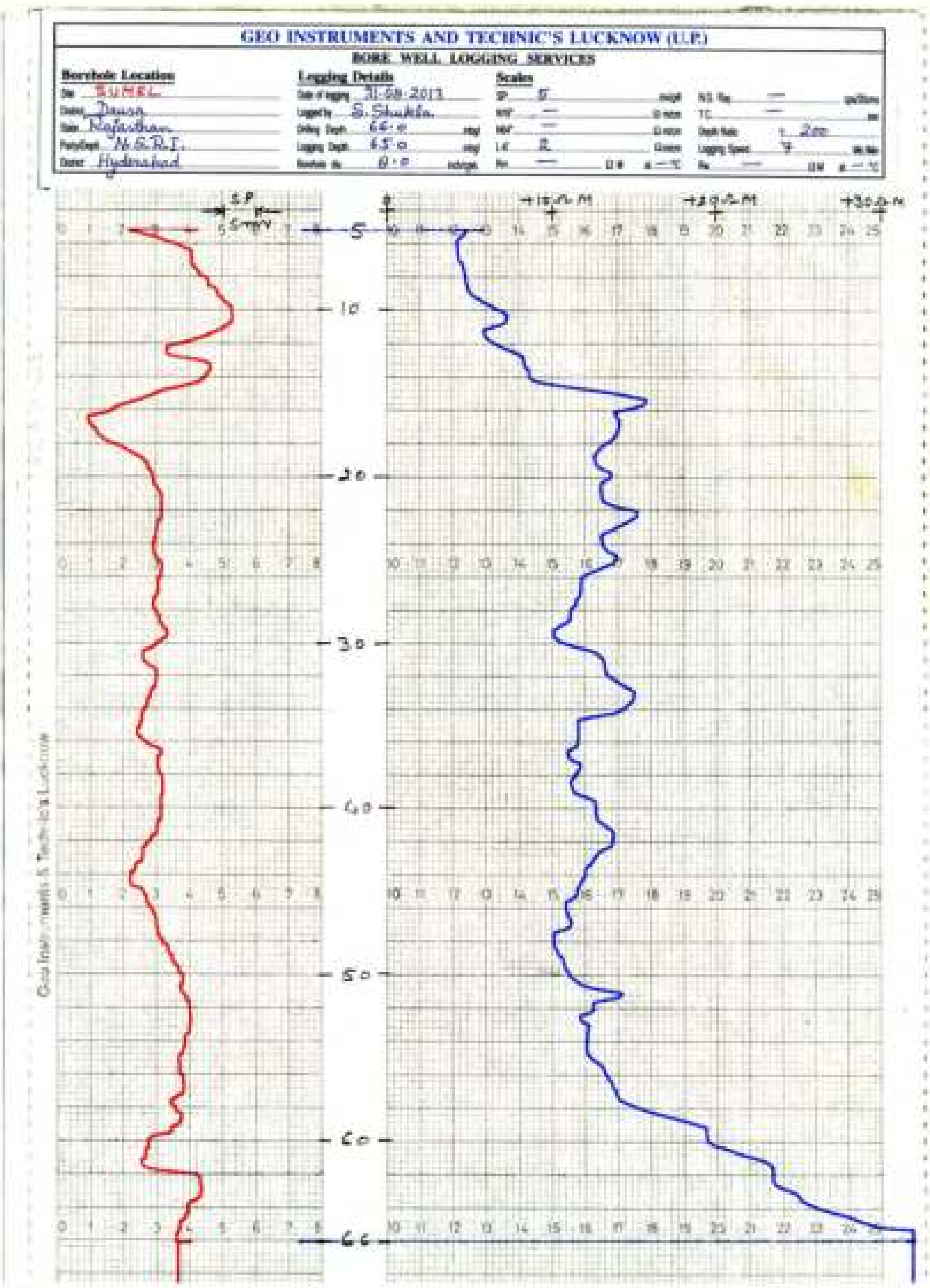
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
	4.42	4.42	29	0.152414	RR
	8.98	4.56	51	0.089412	
	13.56	4.58	70	0.065429	
	18.07	4.51	84	0.05369	
	22.68	4.61	81	0.056914	
	27.28	4.6	84	0.054762	
	31.86	4.58	85	0.053882	
	36.46	4.6	94	0.048936	
	39.53	3.07	50	0.0614	
	42.96	3.43	50	0.0686	
	45.76	2.8	47	0.059574	
	48.47	2.71	53	0.051132	
	52.28	3.81	85	0.044824	
	55.33	3.05	120	0.025417	
	58.38	3.05	150	0.020333	
	61.45	3.07	113	0.027168	
	64.51	3.06	148	0.020676	
	67.56	3.05	180	0.016944	

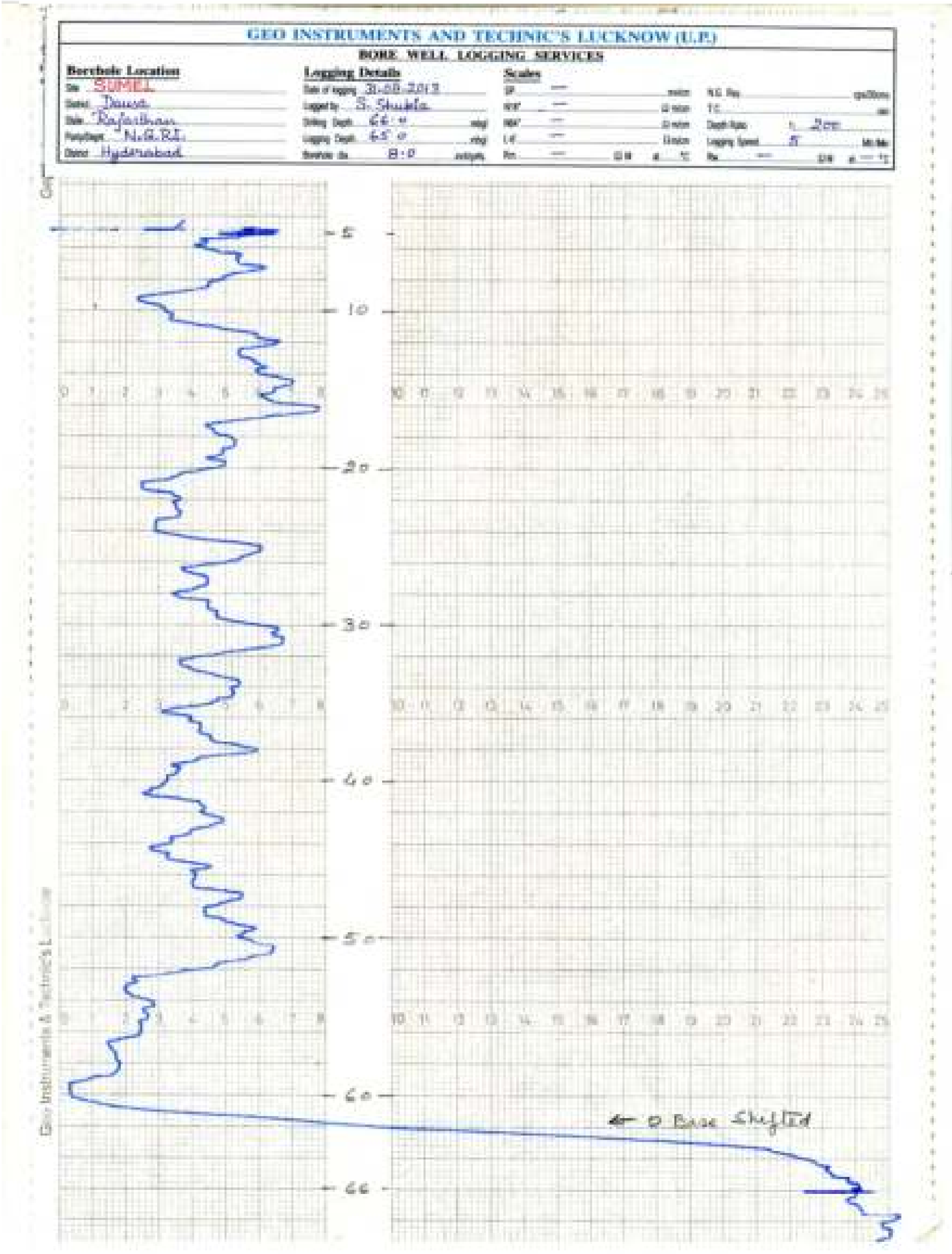
COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface Soil
5	12	7	Silty Clay
12	16	4	Silty Clay
16	24	8	Clay and kankar
24	26	2	Fine grained sand
26	30	4	Clay kankar and gravel
30	32	2	Fine grained sand
32	38	6	Clay kankar and gravel
38	42	4	Clay
42	52	10	Clay kankar and gravel
52	61	9	Coarse Sand
61	66	5	Weathered
66	67	1	Hard rock



GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
JUMEL
Dausa
Rajasthan
Hyderabad
B. Shukla
SP
10
20
30
40
50
60
66
N16"
N64"


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
SUMEL
Dausa
Rajasthan
N.G.R.I.
Hyderabad
Logging Details
31-08-2013
S. Shukla
66.0
65.0
8.0
Scales
2cm
5
5
10
20
30
40
50
60
66
← 0 Base Shifted
Geo Instruments & Technic's Lucknow

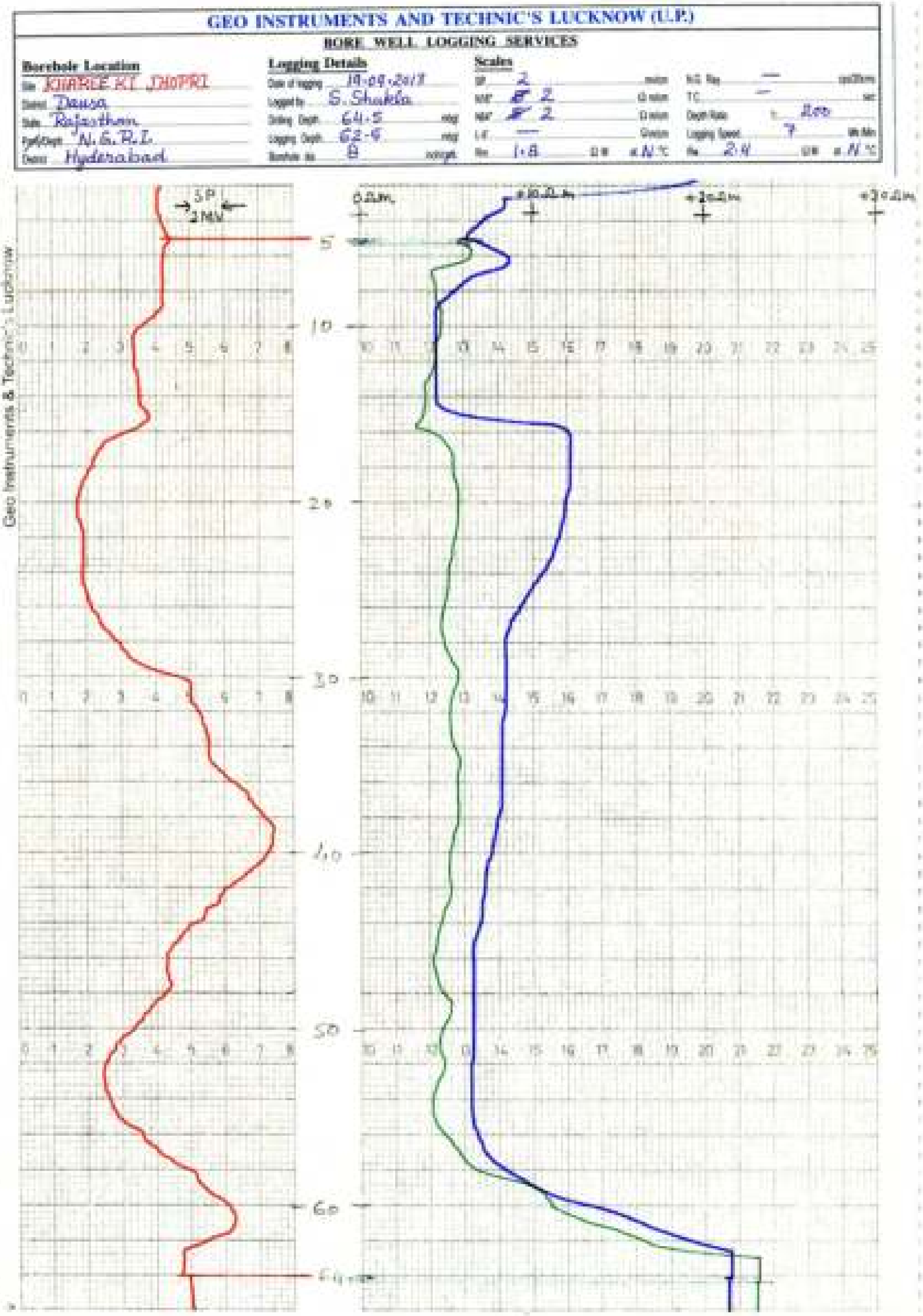
11. Village - Khari Ki Jhopdi Block: Bandikui District: Dausa
Lat: 27.11098 Long: 76.78696

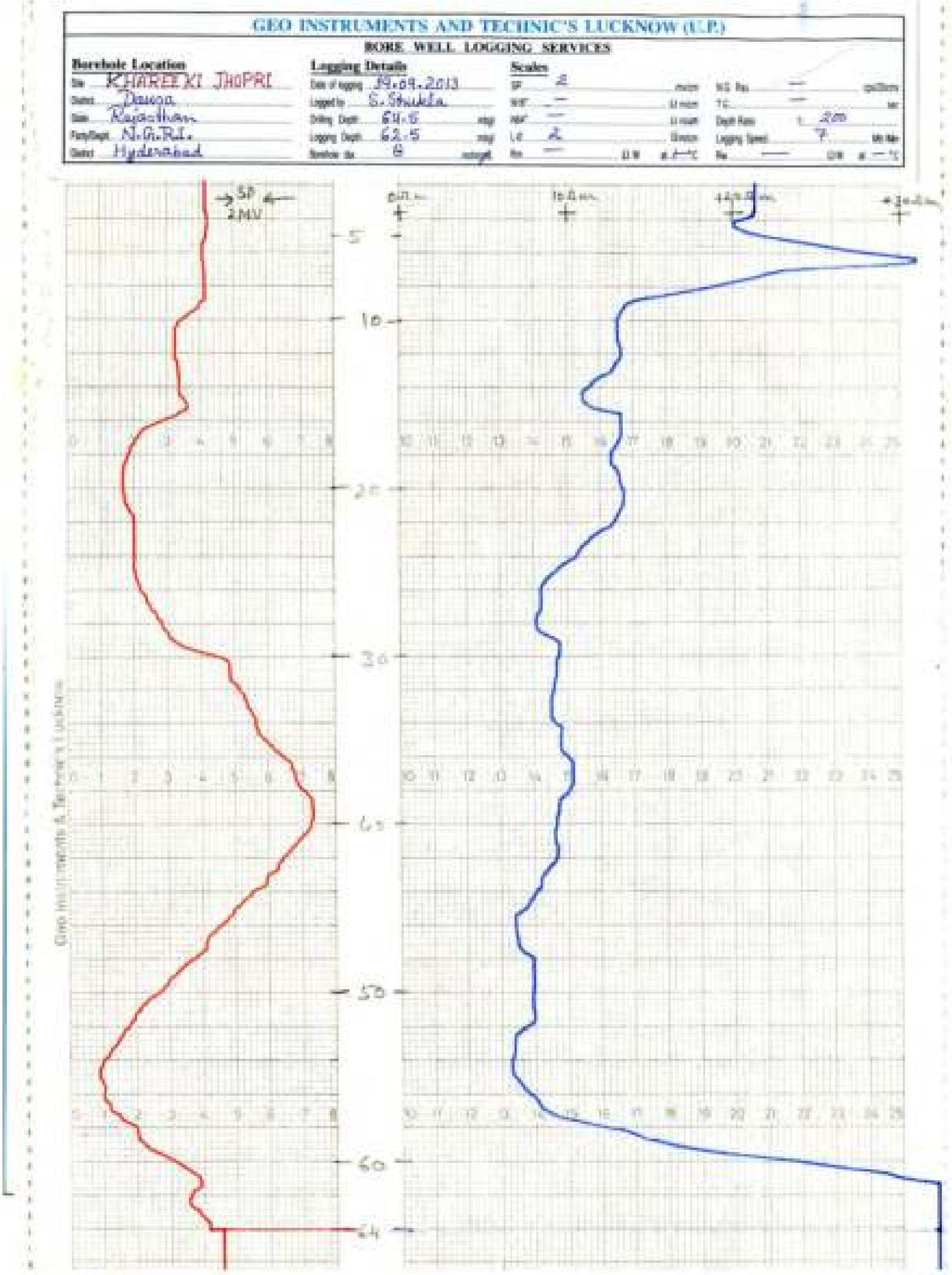
DRILL TIME LOG

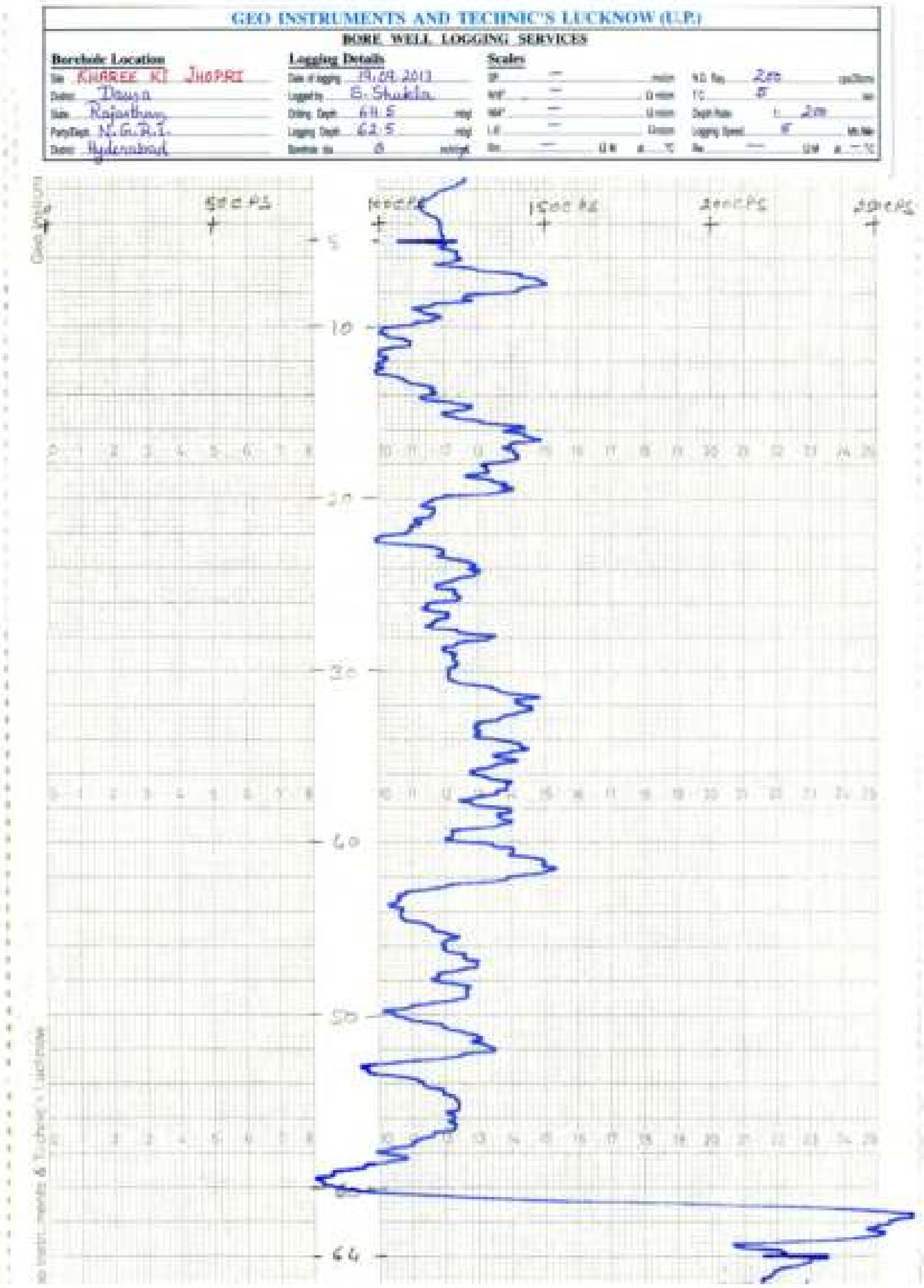
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
14/09/13	4	4	45	0.088889	RR
	8.1	4.1	21	0.195238	
	12.76	4.66	39	0.119487	
	17.27	4.51	30	0.150333	
	21.9	4.63	44	0.105227	
	26.4	4.5	23	0.195652	
15/09/13	30.98	4.58	15	0.305333	
	35.38	4.4	25	0.176	
	39.98	4.6	51	0.090196	
	44.28	4.3	49	0.087755	
	48.93	4.65	73	0.063699	
	53.54	4.61	131	0.035191	
	58.16	4.62	200	0.0231	
16/09/13	61.96	3.8	183	0.020765	
	67	5	300	0.01667	

COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	16	11	Sand
16	20	4	Clay
20	24	4	Sand
24	40	16	Sand and kankar
40	43	3	Clay
43	46	3	Sand
46	50	4	Silty sand/clay
50	52	2	Clay
52	54	2	Sand
54	57	3	Clay
57	60	3	Sand
60	62	2	Weathered
62	67	5	Hard rock


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Site KHARLE KI JHOPRI
District Dausa
State Rajasthan
N.G.R.I.
Hyderabad
Logging Details
19-09-2017
S. Shukla
64.5
62.5
8
Scales
SP 2
2
2
200
7
1.8
2.4
SP
2 MV
0.Ω.m.
Geo Instruments & Technic's Lucknow


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
KHAREE KI JHOPRI
Dausa
Rajasthan
N.G.R.I.
Hyderabad
Logging Details
19.09.2013
S. Shukla
64.5
62.5
Scales
SP
2MV
5
10
20
30
50
60
64


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
KHAREE KI JHOPRI
Dausa
Rajasthan
N.G.R.I.
Hyderabad
Logging Details
19.09.2013
B. Shukla
64.5
62.5
Scales
2m
2m
5
10
20
40
50
64

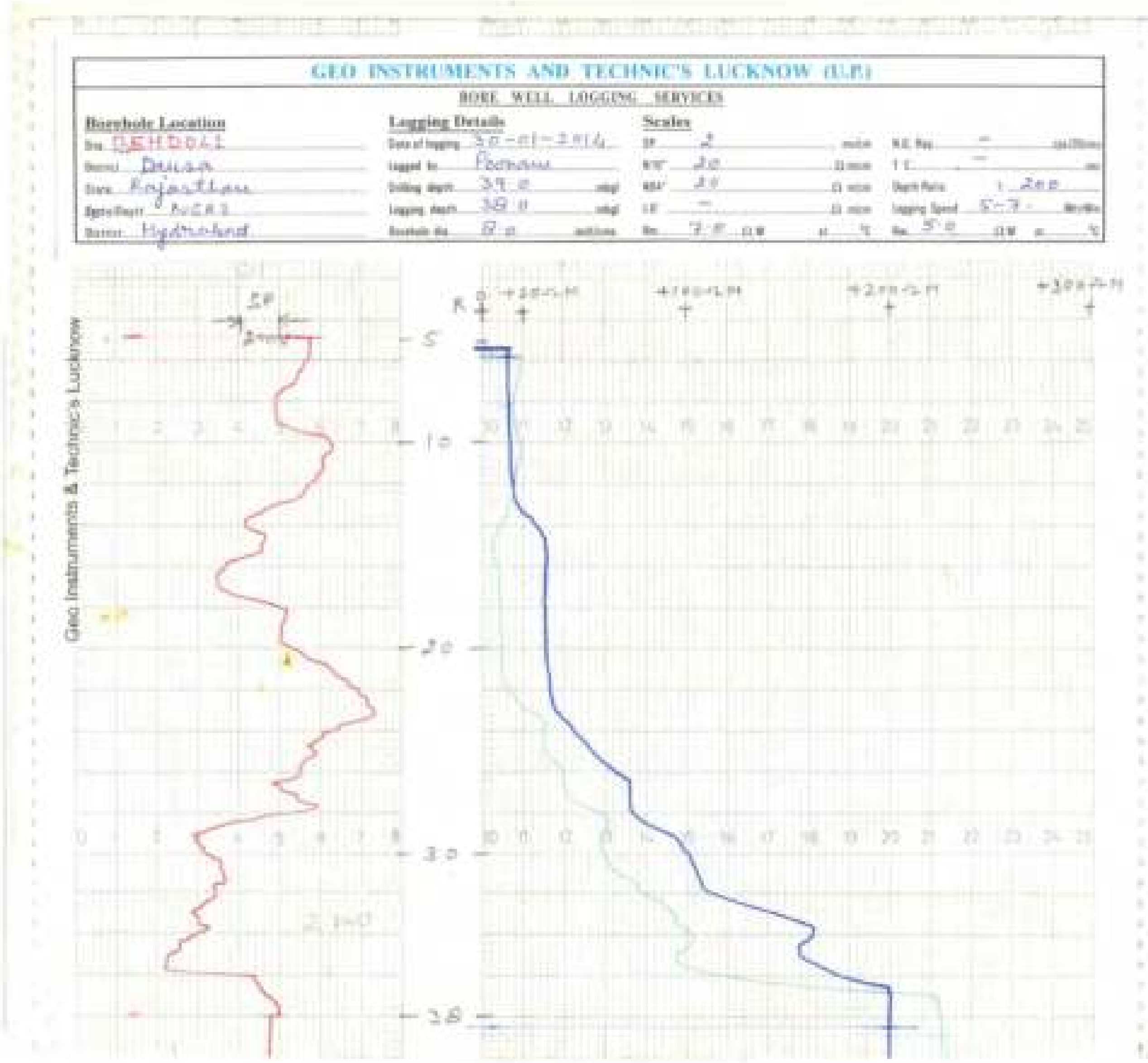
12. Village: Behdoli Block: Bandikui District: Dausa
Lat: 26.98353 Long: 76.41685

DRILL TIME LOG

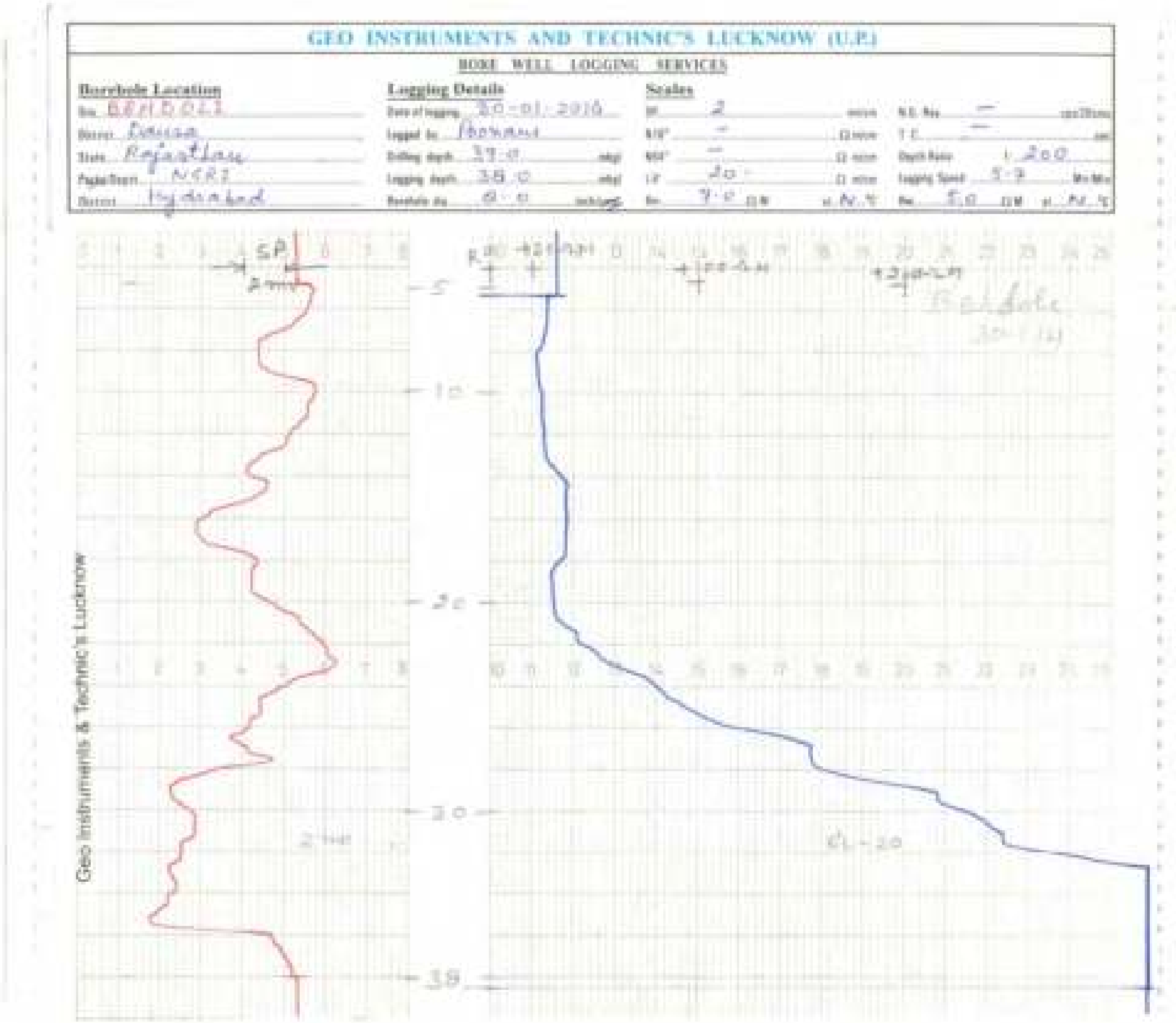
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
23/1/14	3.8	3.8	15	0.253333	RR
	6.84	3.04	20	0.152	
	9.89	3.05	15	0.203333	
	12.93	3.04	16	0.19	
	16	3.07	20	0.1535	
	19.06	3.06	25	0.1224	
	22.13	3.07	50	0.0614	
	23.18	1.05	120	0.00875	
24/1/14	25.18	2	540	0.003704	
25/1/14	28.6	3.42	360	0.0095	
	31.72	3.12	365	0.008548	
26/1/14	34.52	2.8	300	0.009333	
27/1/14	37.22	2.7	660	0.004091	
28/1/14	38.22	1	300	0.003333	

COMPOSITE LITHOLOG

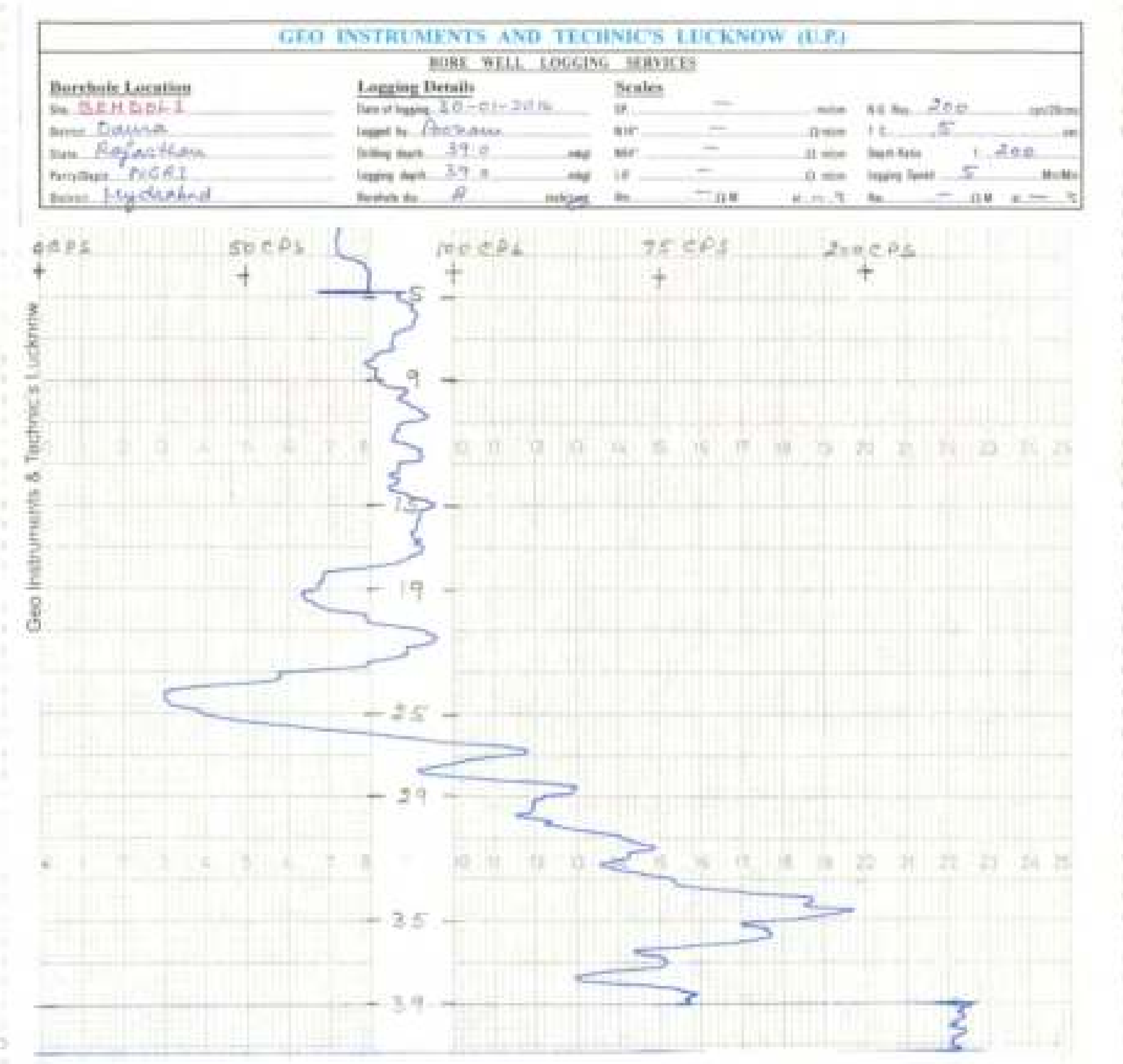
Depth range (mbgl)		Thickness	Lithology
From	To	(m)	
0	4	4	Surface soil
4	10	6	Silty sand with clay
10	13	3	Sand
13	16	3	Clay kankar and silt
16	19	3	Silt
19	25	6	Clay kankar and gravel
25	32	7	Weathered quartzite
32	38	6	Weathered mica schist
38	39	1	Hard rock



GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Geo Instruments & Technic's Lucknow



GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Geo Instruments & Technic's Lucknow


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Geo Instruments & Technic's Lucknow

13. Village: Maukalan Block: Bandikui District: Dausa
Lat: 27.09482 Long: 76.7466

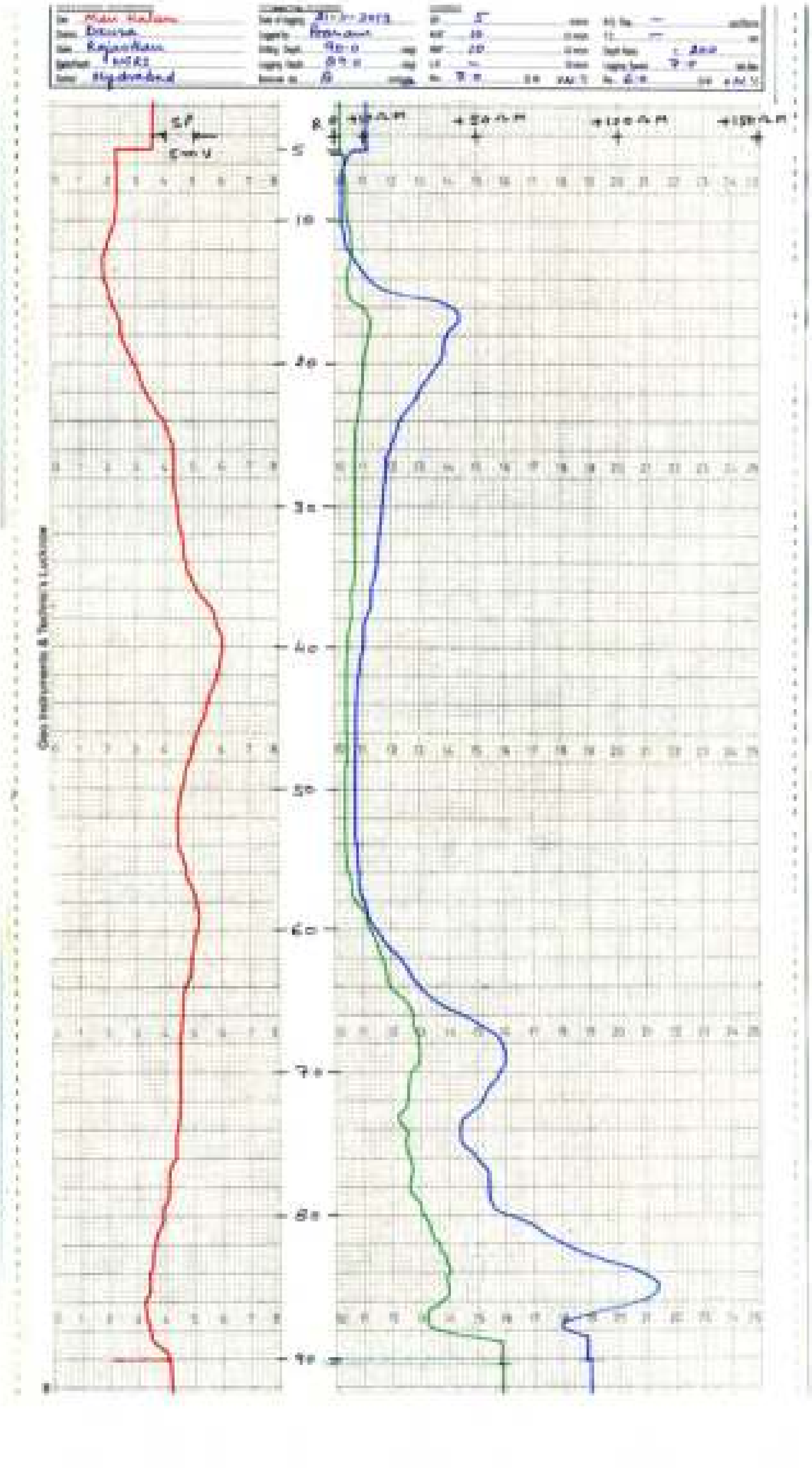
DRILL TIME LOG

Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
13/11/13	3.7	3.7	10	0.37	RR
	6.75	3.05	3	1.016667	
	9.8	3.05	5	0.61	
	12.9	3.1	8	0.3875	
	15.94	3.04	14	0.217143	
	19.01	3.07	8	0.38375	
	22.06	3.05	9	0.338889	
	25.13	3.07	12	0.255833	
	28.18	3.05	10	0.305	
	31.23	3.05	12	0.254167	
	34.29	3.06	13	0.235385	
	37.79	3.5	35	0.1	
	41.59	3.8	10	0.38	
14/11/13	44.29	2.7	13	0.207692	
	47.11	2.82	26	0.108462	
	50.23	3.12	20	0.156	
	54.03	3.8	80	0.0475	
	57.1	3.07	32	0.095938	
	60.15	3.05	106	0.028774	
	63.25	3.1	305	0.010164	
15/11/13	67.11	3.86	354	0.010904	
	68.16	1.05	255	0.004118	
16/11/13	70.16	2	135	0.014815	
	73.21	3.05	268	0.011381	
	76.25	3.04	198	0.015354	
17/11/13	79.29	3.04	950	0.0032	
18/11/13	82.36	3.07	328	0.00936	
	83.36	1	360	0.002778	
	85.42	2.06	600	0.003433	
19/11/13	87.01	1.59	570	0.002789	
20/11/13	90.05	3.04	660	0.004606	

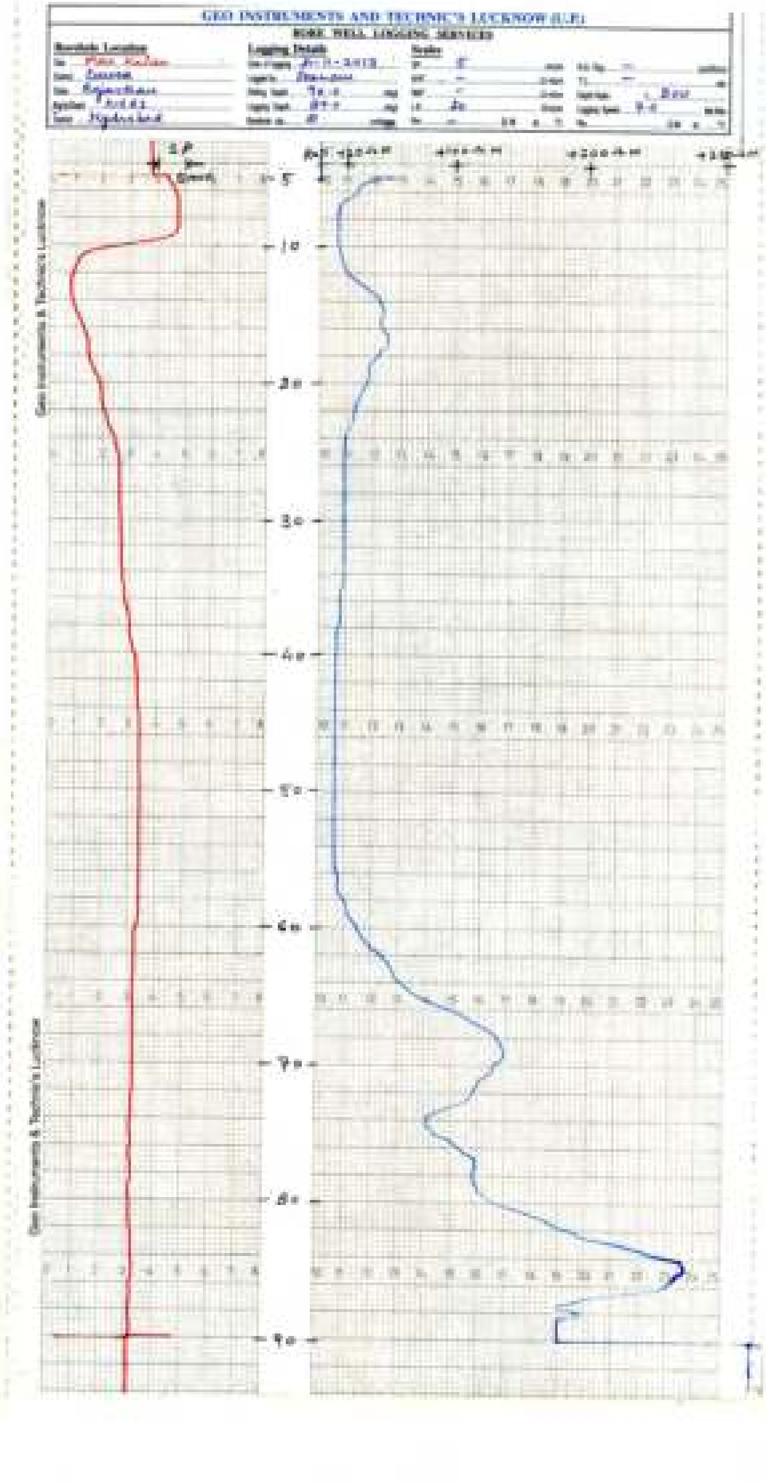
COMPOSITE LITHOLOG

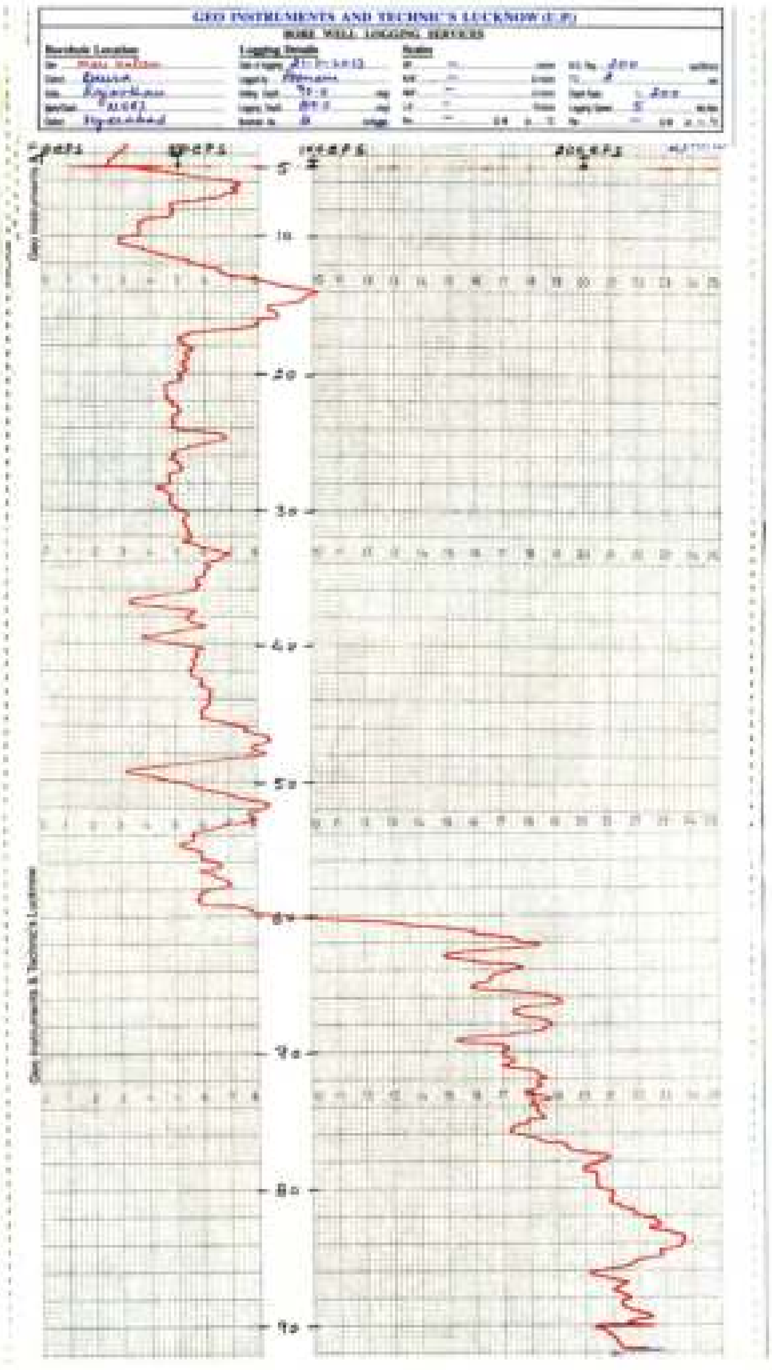
Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	6	6	Surface soil
6	12	6	Sand
12	16	4	Clay
16	33	17	Silty sand
33	35	2	Silty sand with clay

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
35	47	12	Clay kankar with silt
47	51	4	Sand
51	60	9	Silty sand
60	90	30	Weathered Hard Rock
90	91	1	Hard rock



5
10
20
30
40
50
60
70
80
90


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
5
10
20
30
40
50
60
70
80
90

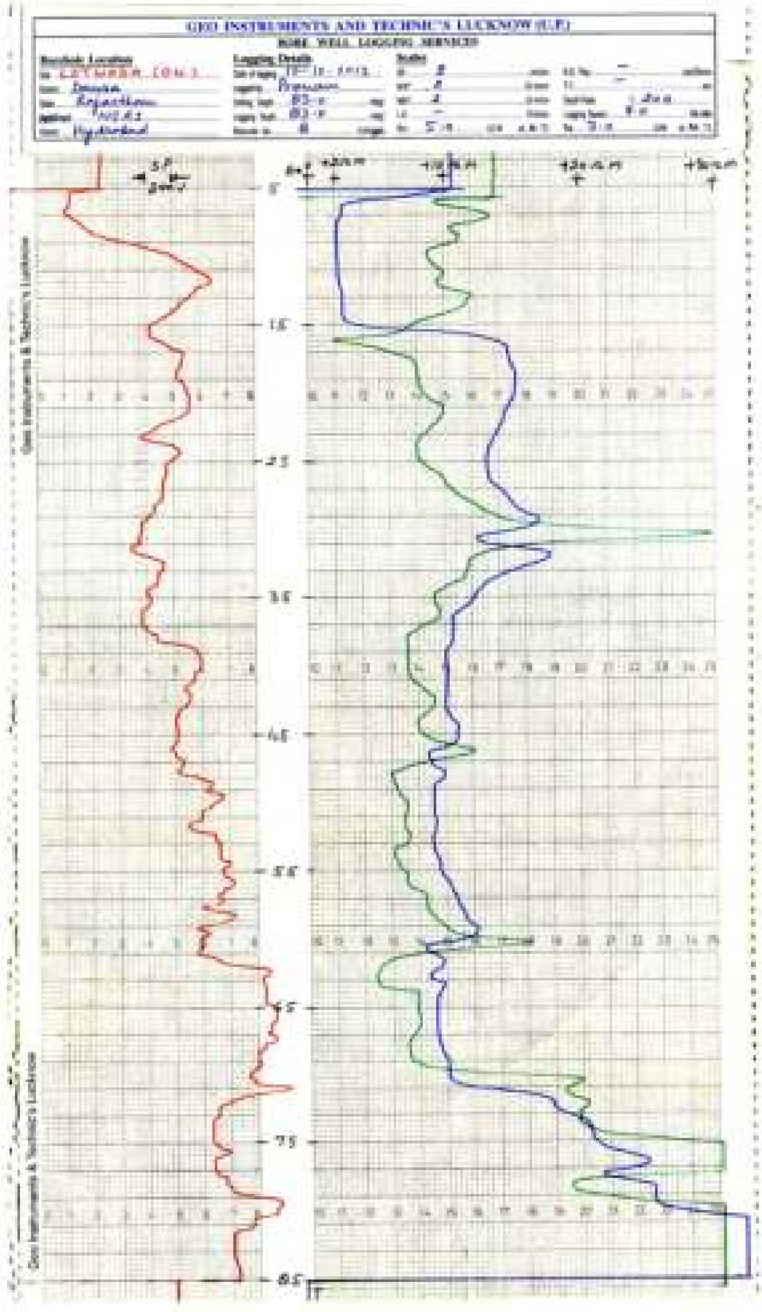
14. Village: Lotwara (East) - II Block: Bandikui District: Dausa
Lat: 27.00525 Long: 76.7425

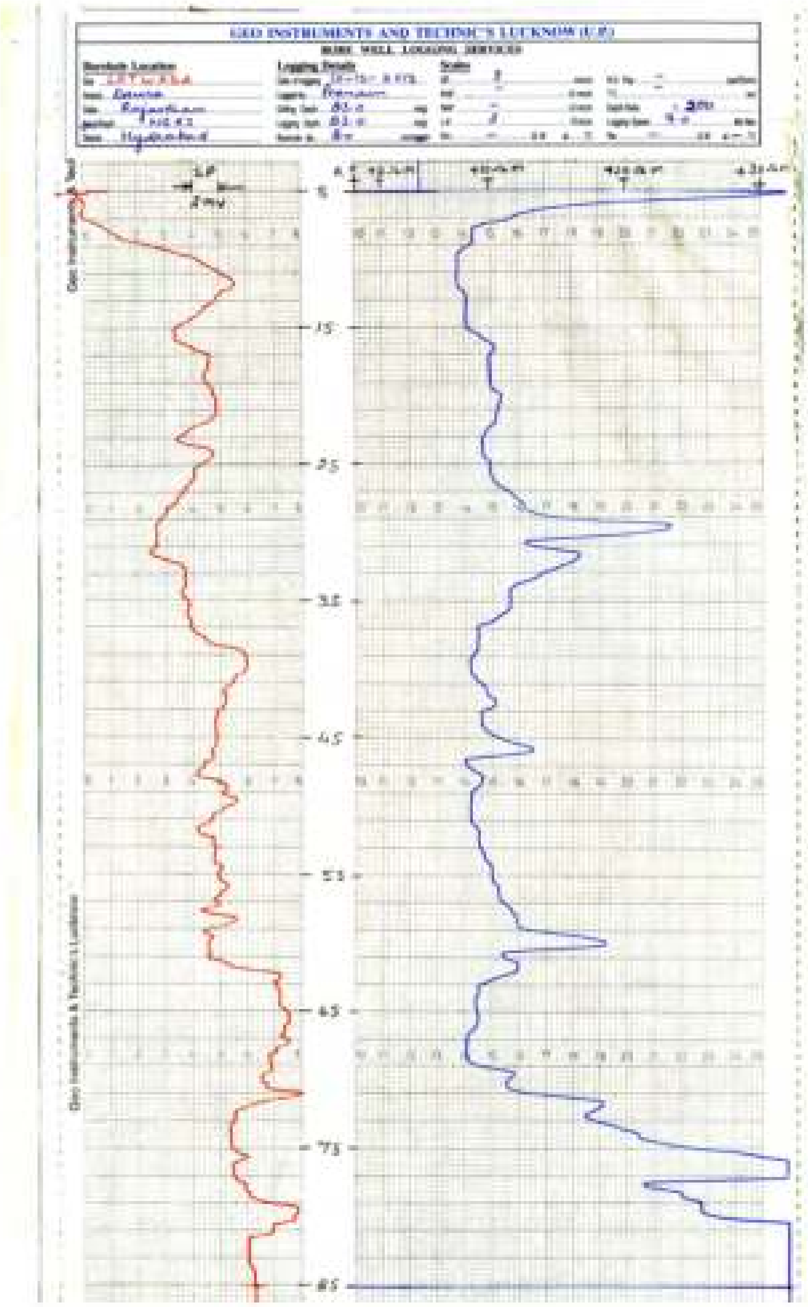
DRILL TIME LOG

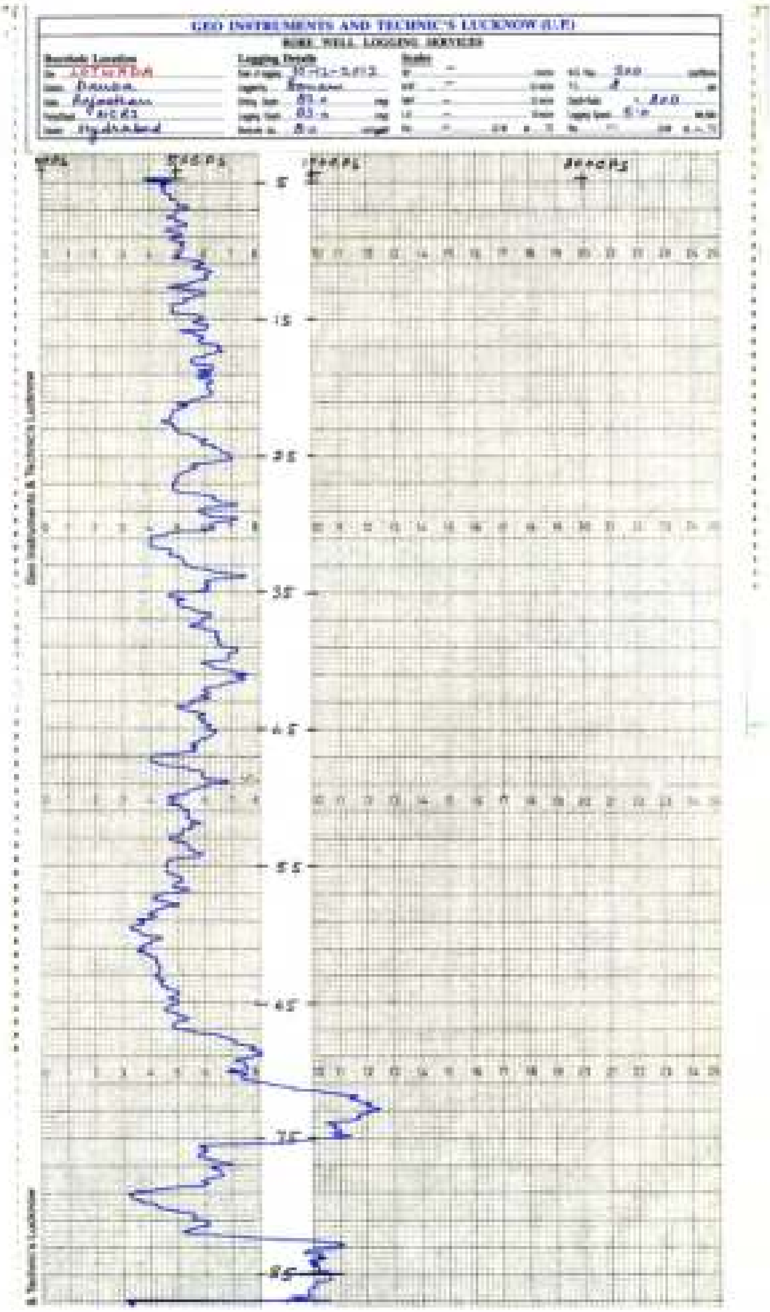
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
02/12/13	3.8	3.8	10	0.38	RR
	7.2	3.4	9	0.377778	
	9.90	2.7	11	0.245455	
	12.7	2.8	18	0.155556	
03/12/13	16.12	3.42	20	0.171	
	19.24	3.12	23	0.135652	
	23.04	3.8	25	0.152	
	26.09	3.05	10	0.305	
	29.16	3.07	70	0.043857	
	32.21	3.05	60	0.050833	
	35.28	3.07	60	0.051167	
	38.33	3.05	65	0.046923	
	41.43	3.10	10	0.31	
	44.47	3.06	10	0.306	
	47.51	3.04	90	0.033778	
04/12/13	50.55	3.04	134	0.022687	
	53.60	3.05	25	0.122	
	58.01	4.41	420	0.0105	
5/12/13	62.32	4.31	120	0.035917	
	66.59	4.27	80	0.053375	
6/12/13	71.09	4.5	70	0.064286	
	74.14	3.05	60	0.050833	
	76.94	2.8	90	0.031111	
7/12/13	79.65	2.71	120	0.022583	
8/12/13	81.20	1.55	600	0.002583	
	82.7	1.50	360	0.004167	

COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness	Lithology
From	To	(m)	
0	5	5	Surface soil
5	11	6	Silty clay
11	21	10	Clay with kankar and silt
21	24	3	Sand
24	26	2	Clay
26	28	2	Sand
28	30	2	Silty clay
30	33	3	Sand
33	38	5	Silty clay
38	40	2	Clay
40	49	9	Silty sand with clay
49	55	6	Silty sand
55	69	14	Sand
69	79	10	Weathered
79	83	4	Hard rock


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Rajasthan
Hyderabad
S.P.
5
15
25
35
45
55
65
75
85
Geo Instruments & Technic's Lucknow


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
SP
5
15
25
35
45
55
65
75
85


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P)
BORE WELL LOGGING SERVICES

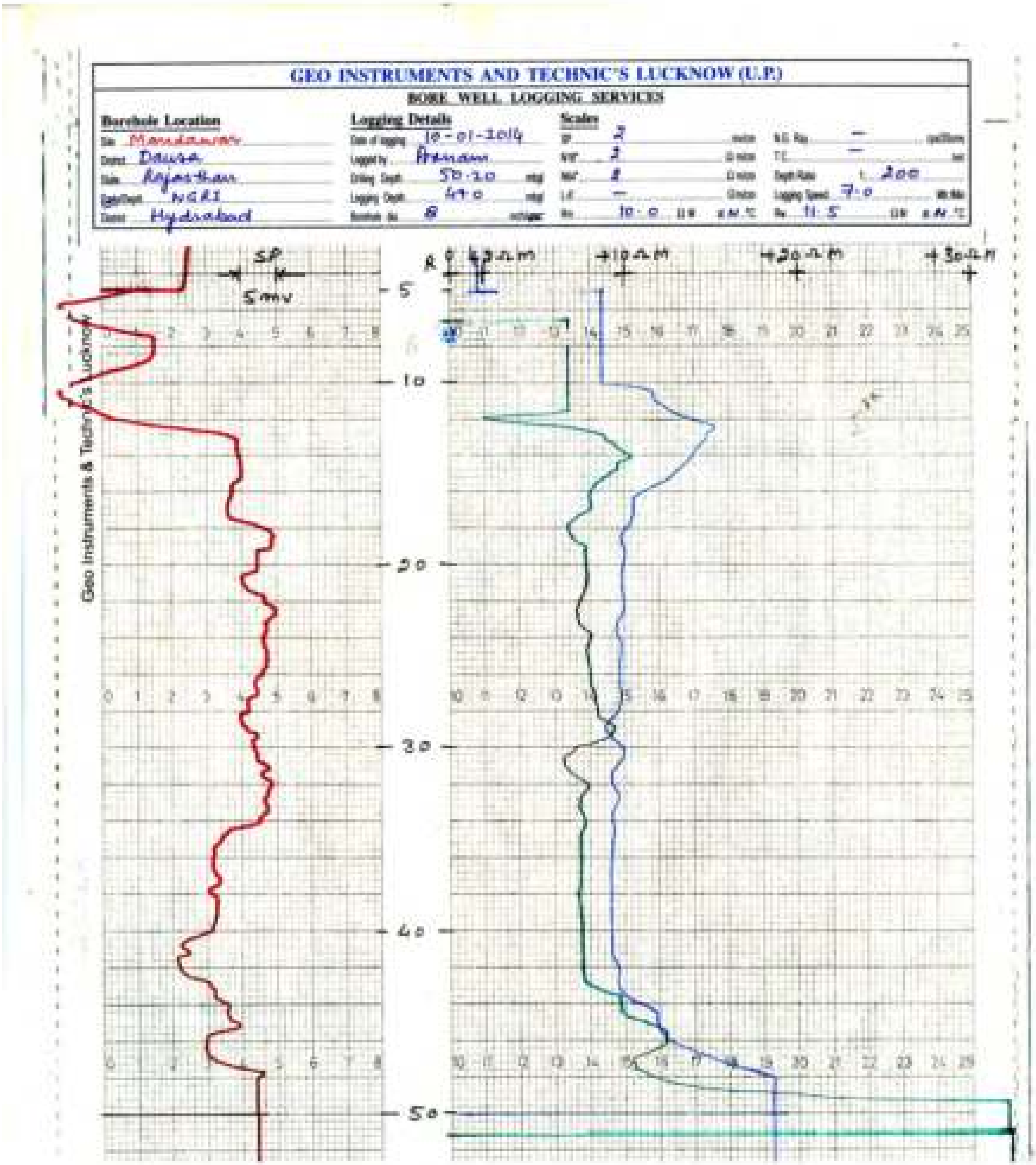
15. Village: Bajoli Block: Bandikui District: Dausa
Lat: 27.13841 Long: 76.73143

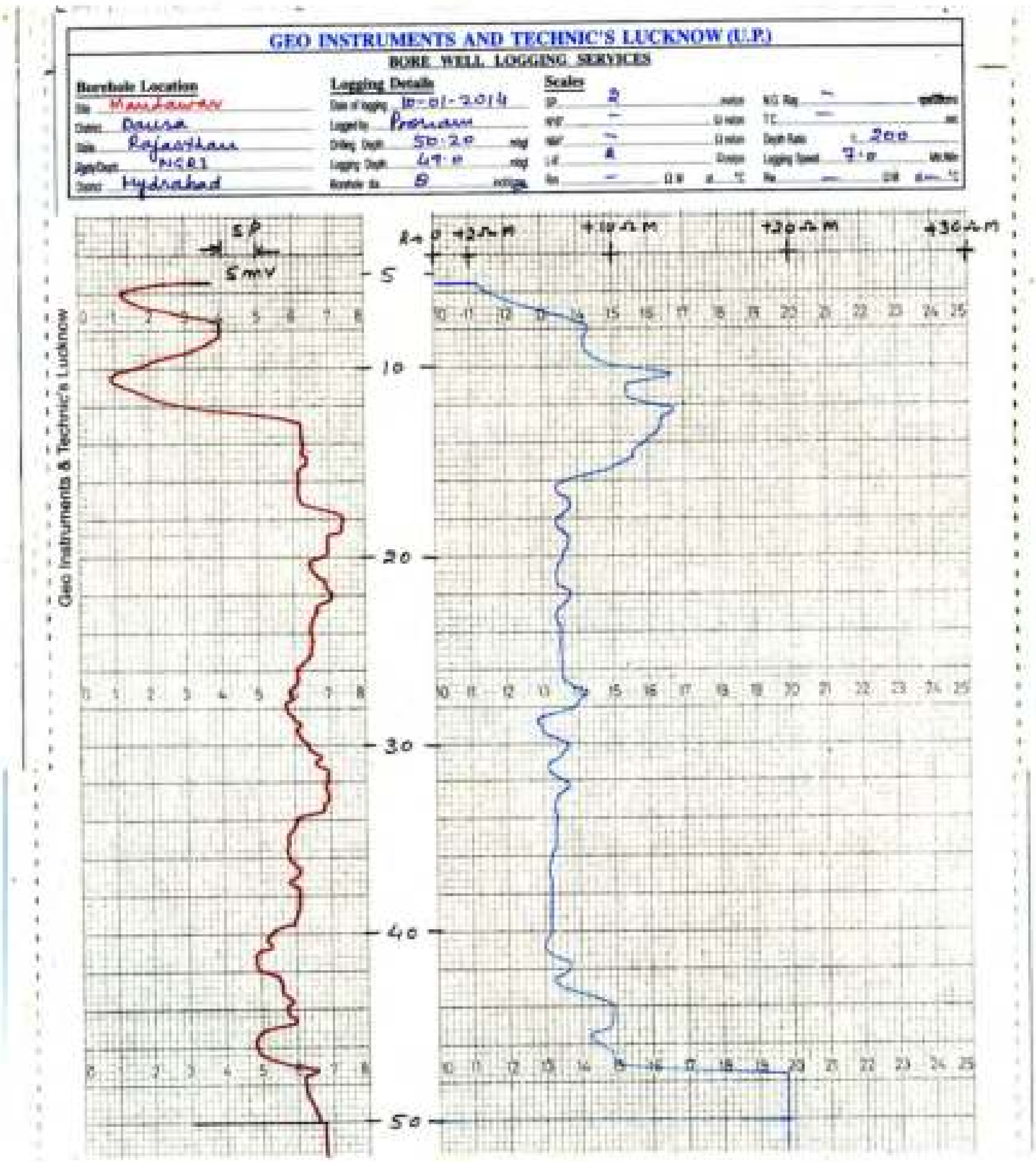
DRILL TIME LOG

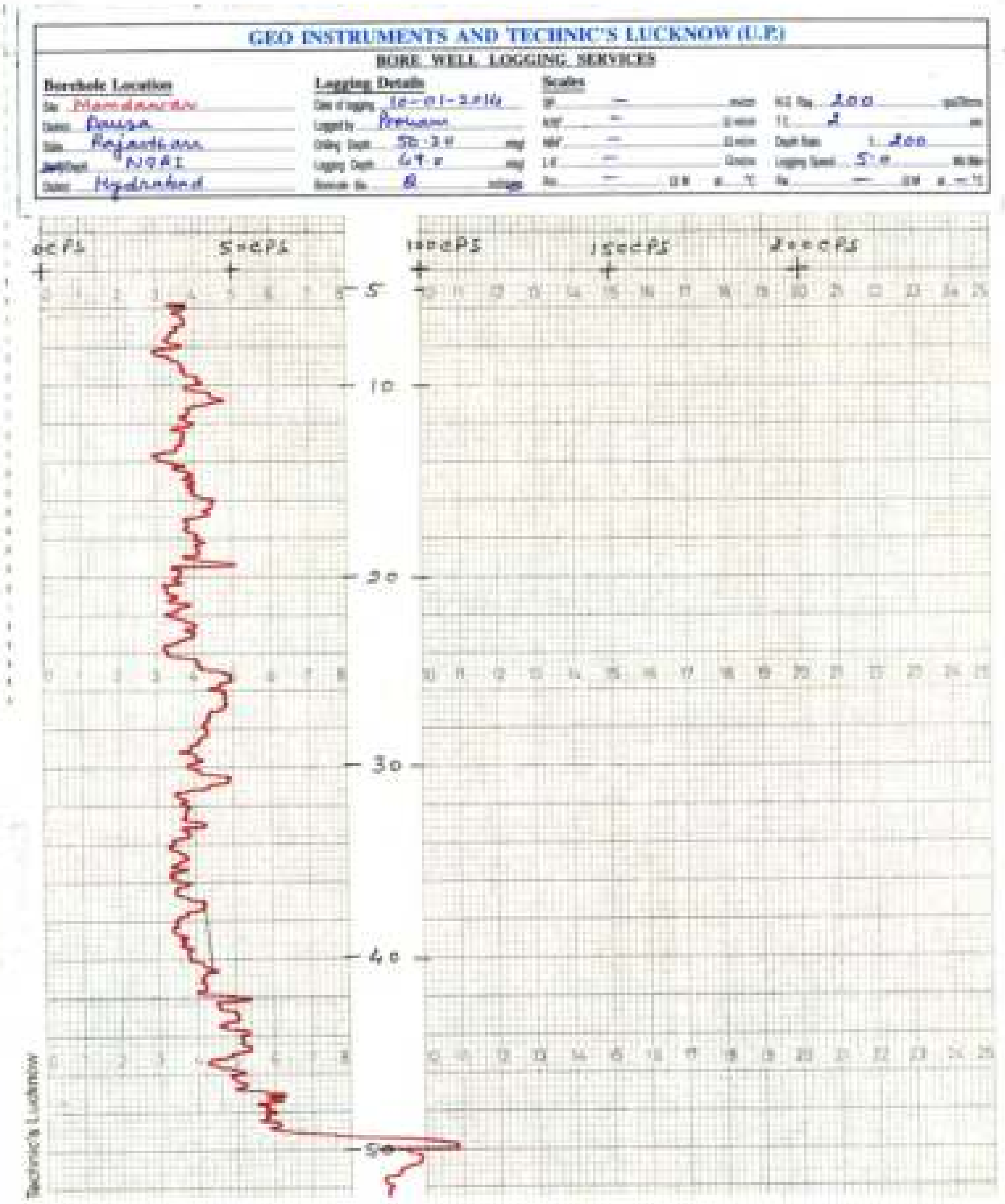
Date	Depth drilled (M bgl)	Thickness(m)	Time taken for drilling(min.)	Penetration rate m/min	Bit type & size
6/1/14	3.8	3.8	7	0.542857	RR
	6.84	3.04	10	0.304	
	9.95	3.11	90	0.034556	
7/1/14	12.99	3.04	10	0.304	
	16.04	3.05	15	0.203333	
	19.08	3.04	10	0.304	
	22.14	3.06	15	0.204	
	25.21	3.07	10	0.307	
	28.28	3.07	5	0.614	
	31.33	3.05	10	0.305	
	34.38	3.05	20	0.1525	
	38.18	3.8	20	0.19	
	40.88	2.7	15	0.18	
	43.88	3	13	0.230769	
	47.9	4.02	20	0.201	
	50.22	2.32	60	0.038667	
	50.32	0.1	120	0.000833	
8/1/14	50.52	0.2	360	0.000556	
9/1/14	50.62	0.1	240	0.000417	

COMPOSITE LITHOLOG

Depth range (mbgl)		Thickness (m)	Lithology
From	To		
0	5	5	Surface soil
5	11	6	Clay
11	25	14	Sand
25	29	4	Silty sand with clay
29	32	3	Clay
32	41	9	Sand
41	49	8	Weathered
49	51	2	Hard rock


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Mandawar
Dausa
Rajasthan
NGRI
Hyderabad
10-01-2014
Pranam
50.20
SP
5mv
5
10
20
30
40
50
Geo Instruments & Technic's Lucknow


GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
Dausa
Rajasthan
NGRI
Hydrabad
10-01-2014
50.20
49.0
SP
5 mV
+10 Ω M
+20 Ω M
+30 Ω M
5
10
20
30
40
50
Geo Instruments & Technic's Lucknow



GEO INSTRUMENTS AND TECHNIC'S LUCKNOW (U.P.)
BORE WELL LOGGING SERVICES
Borehole Location
Logging Details
Scales
0CPS
50CPS
100CPS
150CPS
200CPS
10
20
30
40
Technic's Lucknow

Annexure-II

Water Level Data

Location	Latitude	Longitude	MP	June'12	July'12	Sept'12	Oct'12	Jan'13	Feb'13	May'13	July'13	Aug'13	Sept'13	Nov'13	Dec'13	Jan'14	Feb'14	May'14	June'14	Aug'14	Dec'14
KariPahari	26.98333	76.40833	0.9	23.57	23.36	22.93	22.82	23.5	23.67	23.83	23.57	23.15	23.37	23.48	23.56	24.16	23.94	24.82	26.94	27.19	25.29
Sikandra	26.96703	76.57964	0.7	32.67	32.55	31.99	31.64	32.1	32.92	33.06	33.34	32.7	32.31	32.47	32.72	33.66	32.85	34.3	35.38	34.4	33.56
Balahedi	27.06111	76.78889	0.6		38.85	37.58	35.92	39.6	38.67	39.9	39.12	38.52	38.29	38.43	39.57	39.67	39.42	39.96		40.41	40.12
Rampura	27.125	76.77778	0.5	25.98	25.74	24.44	24.07	27.1	27.28	26.25	25.65	25.55	24.16	28.56	27.97	29	29.18	38.19	26.63	25.69	24.96
Tatya	27.04136	76.46389	0.9	11.52	11.35	9.25	7.78	9.34	9.48	10.15	10.25	9.15	7.64	7.67	8.16	8.36	8.4	15.65	10.55	11.45	11.25
Dhanawar	26.96103	76.49203	0.3	22.99	22.75	18.9	22.88	23.2	23.07	23.28	21.8	23.52	23.42	23.46	23.74	23.62	23.7	45.2			
Tigaria	27.11386	76.76853	0.7	37.82	37.58	35.97	35.1	40.4	40.74	39.73	36.17	36.58	34.86	32.95	36.79	39.82	39.8	38.93	39.42	39.68	42.38
Jaisinghpura (ea	27.10856	76.75806	0.1	17.67	16.4	14.79	13.95	14.2	14.06	14.71	14.74	14.1	11.58	11.93	12.34	12.41	12.44	26.95	14.93	14.1	15.6
Simla ka Bas	27.107	76.73922	1	18.93	18.85	16.93	15.99	15.9	15.68	15.76	15.85	15.28	14.32	14.2	14.76	14.23	14.2	26.8	15.43	15.65	16.22
Baori khera	27.12333	76.80833	0.3	23.44	23.06	21.76	25.63	25.4	25.91	21.38	20.38	20.13	19.9	22.26	24.51	24.42	27.86	32.63	21.78	20.57	21.52
Baori khera ki dh	27.11217	76.79361	0.8	28.53	28.7	28.25	27.47	28.6	28.89	27.27	26.98	26.48	26.4	25.2	30.2	27.94	27.5	32	27.2	28.18	28.74
Bedhadi Gujran	27.06694	76.69778	0.9		44.25	42.75	41.65	43.9	44.32	43.5	42.21	40.72	39.58	39.63	40.04	43.24	43.16	42.6	42.85	42.65	46.55
Digaria Bheem	27.07139	76.74	1.1		48.88	48.11	48.56	51	50.98	50.91	49.49	48.51	47.98	48.89	50.04	51.33	50.64	50.09	49.25	48.44	50.7
Piiodi	26.96306	76.71806	1.3		32.7	30.95	30.99	33.1	33.5	33.03	31.44	31.48	30.84	32.05	33.04	32.96	35.89	38.6	34.9	32.08	35.2
Dobbi	27.09389	76.70056	0.9	24.85	20.1	15.95	20.22	24.1	22.6	23.87	23.1	22.25	22.1	22.57	22.97	23.31	23.6	38.55			26.65
Sodan ka bas	27.09758	76.78683	0.7							29.2	29.5	29.04	27.91	28.06	28.52	28.58	28.79	29.46	29.35	28.3	28.36
Ranapada	26.98629	76.67401	1														31.8	33.45	34.17	34.1	34.8
Alipur	27.07851	76.79393	1														40.1	41.2	41.4	41.3	43.15
Khari ki jhopdi	27.11098	76.78696	1														38	66		37.9	39.5
Baswa	27.14583	76.575	0.5	41.8	40.75	33.3	23.5	38.8	39.39	39.75	38.81	35.11	35	35.74	38.8	39.73	39.93	40.55	41.85	42.25	41.15
Phulelia	27.10983	76.5475	0.8	41.18	41.43	36.9	36.41	37.5	37.35	38.28	38.58	38.37	37.36	36.79	38.41	38.36	38.3	51.3	40.23	41	40
Phulelia	27.11333	76.54861	1.1	37.84	37.34	35.24	34.73	36.7	34.86	35.54	36.07	35.28	34.77	34.81	34.83	37.59	35.14	36.82	37.04	36.67	37.37
Jaisinghpura	27.17258	76.59611	1.2	31.8	31.83	31.5	31.34			37.44	37.23	33.17	32.27	34.31	39.01	38.83	37.81	44.2	37.5	37	37.65
VijaiNav	27.17603	76.58681	0.4	32.74	32.46	18.66	22.7		33.03	30.21	26.21	17.79	18.83	29.17	34.26	39.42	36.56	32.36	32.43	32.48	40.63
Charwas ki Dhan	27.07528	76.54722	0.5	40.3	40.05	33.8	32.05	38	39.36	37.5	36.05		32.07	37	40.6	42.3	38.6	49	37.9	37.7	37.52
Kheel pur Kheda	27.13972	76.6875	1	41.14	40.8	33.95	33.3	35.4	38.06	40.14	38.48	32.9	29.26	29.97	46.1	36.56	59.1	54	46.8	46.5	47.2
Muhi	27.07639	76.47167	0.8	22.8	22.83	22.1	17.06	20.5	20.7	20.5	17.72	16.4	14.91	17.2	21.74	19.6	20.3	22.96	25.01	21.95	25.37
Gumaflatia	27.06361	76.46089	1	26.28	25.72	20.8	21.95	22.3	22.46	22.84	22.09	20.16	20.15	20.12	20.32	22.01	20.82	22.88	24.18	22.33	24.23
Rampura	27.02859	76.46531	1.2	27.17	26.93	25.65	25.97	26.8	27.63	26.97	26.57	26	25.75	25.92	26.65	27.18	26.68	27.27	27.6	28.1	28.55
Rajpura bara	27.16958	76.52806	1.2	12.68	12.93	3.95	6.56	12.5	12.5	12.55	9.11	6.63	6.46	12.56	12.8	12.63	12.67	13.8	13.74	13.3	15.16
Surer	27.19778	76.81375	1.3	16.74	16.28	15.2	14.3	14.4	14.67	15.13	13.92	12.95	12.42	12	12.22	12.94	12.5	15.35	15.27	17.1	17.9
Rambaskalan	27.04306	76.37167	1	33.06	28.85	28.2	27.4	30.2	30.25	30.3	29.25	28.3	26.45	27.43	29.92	29.4	29.85	35.9	28.55	27.1	27.4
Kundal	27.00617	76.42669	1.2	33.8	31.35	27.8	28.68	32.5	32.38	32.13	29.21	28	29.58	29.47	32.93	32.6	32.19	34.2	34.4	32.05	33.95
Bandikui	27.04167	76.56194	1	49.86	51.7	49	48.42	55.8	48.98	49.26	49.56	48.95	48.16	47.65	49.15	48.3	47.81	49.4	49.66	49.12	49.52
Lilog	27.0825	76.62222	1.1		33.1	28.25	23.93	25.4	25.46	26.65	26.81	25.27	25.64	25.2	27.9	28.36	28.3	31.2	32.54	30.52	31.12
Badiyal ka-lan	27.04997	76.64925	1		29.7	28.36	27.7	29.9	30.05	30.85	32.08	29.4	29.28	29.33	30.22	32.15	32.15	33		31.45	31.66
Bhandarej	26.89228	76.42208	1.4		11.22	8.95	6.72	8.57	8.68	8.01	8.78	7.73	5.83	5.58	6.64	6.49	6.71	9.81	10.4	9.41	12.8
Badoli kalan	27.02828	76.37786	1.1							22.57	0	22.38	22.2	22.13	22.2	22.44	22.5	25.74	24.34	22.66	23.52
Pichupara	27.00722	76.56667	1.1				51.2	51.9	51.97	51.9	52.22	51.71	50.31	50.97	51.3	51.98	51.4	52.95	52.48	51.12	51.29
Radia	27.09708	76.41856	1.1													11.8	11.56	15.94	14.55	10.99	11.1
Lotwara-I	27.00536	76.7425	1														34.13	49.75	41.73	41.2	41.45
Ralota	27.05214	76.68307	1														44	55.07	44.37	45.7	43.5
Nurpur	27.07121	76.67037	1														46	45.15	45.34	46.35	44.3
Sodala	27.00972	76.82468	1														48	58			
Sumel	27.04206	76.74565	1														49.3	51.05		47.45	52.5
Shyamsinghpura	26.98886	76.53439	1														37	51			
Maukalan	27.09482	76.7466	1														26.32	27.45	27.17	27.6	28.3
Lotwara-II	27.00525	76.7425	1														41.58	41.7	0	40.55	41.32
Bajoli	27.13841	76.73149	1														25.7	35.8	35.6	23.3	27.7
Bhedoli	26.98353	76.41685	1														14	21.3	22.57	21.7	23.5
Uprera	27.13561	76.59356	1.1															25.45	26.64	26.75	26.65

Annexure-III

Chemical Analysis Data

Chemical Analysis of Dug well Samples

SITE	Lat	Long	pH	EC in µS/cm at 25°C	CO3	HCO3	Cl	SO4	NO3	PO4	TH	Ca	Mg	Na	K	F	TDS	SAR
Jhuta khera	27.04	76.46	8.1	1710	0	732	234	32	14	0.05	320	76	32	300	5	1.15	1112	28.92
BHAWTA	27.03	76.46	8.4	11950	12	342	4254	140	4	0.30	3500	760	389	1350	9	0.65	7768	39.82
Jagsoli	27.06	76.44	7.85	2360	0	451	518	80	18	0.10	630	140	68	260	2	0.5	1534	18.02
Unwari	27.09	76.42	7.6	770	0	366	142	25	15	0.10	320	80	29	100	1.1	0.58	501	9.57
Sodan ka bas	27.10	76.79	7.8	690	0	366	71	35	7	0.02	380	80	44	30	1	0.2	449	2.70
Baori khera ki dhani	27.11	76.80	8	3050	0	586	497	380	10	0.03	500	120	49	500	1.1	0.58	1983	38.50
Khora kalan	26.97	76.41	8	3310	0	976	426	285	40	0.10	250	60	24	680	1	8.2	2152	74.05
Nimali	26.98	76.45	8.11	3840	0	1098	639	130	29	0.11	550	120	61	650	1	0.92	2496	48.34
Kundal	27.02	76.41	8	680	0	250	92	15	7	0.10	250	60	24	50	1	1.4	442	5.45
Muhi	27.09	76.48	8	1230	0	549	130	14	14	0.11	450	100	49	100	1	0.65	800	8.20
Rani ka bas	27.00	76.58	8.14	2470	0	610	510	25	11	0.23	580	120	68	310	1	0.65	1606	22.60
Kheda well	27.01	76.68	8.1	2360	0	450	510	80	5	0.11	570	120	66	280	1	0.62	1534	20.55
Keshpura	27.09	76.65	8.1	2610	0	976	121	320	13	0.12	200	44	22	520	3	4.05	1697	64.06
Chemical Analysis of Tubewell Samples																		
Sumel	27.04	76.74	7.1	1200	0	610	142	25	10	0.03	150	40	12.16	270	1	3	780	37.38
Kheda	27.02	76.68	8.14	2110	0	488	461.5	112	10	0.13	500	120	48.64	312	1	0.75	1372	24.03
Ranapada	26.99	76.67	8.1	760	0	244	71	110	6	0.11	200	60	12.16	102	1	1.3	494	12.01
Lotwara I	27.01	76.74	8.1	950	0	481.9	70.9	13	6	0.08	215	58	17.02	138	1	0.9	617.5	15.93
Lotwara II	27.01	76.74	8	940	0	481.9	70.9	13	5	0	215	58	17.02	138	1	0.9	611	15.93
Maukalan	27.09	76.75	7.8	3010	0	854	354.5	15	80	0.06	500	160	24.32	360	1.2	0.3	1957	26.52
Alipur	27.08	76.79	7.8	2105	0	610	390	10	16	0.09	550	160	36.48	240	1	0.35	1368	17.12
Ralota	27.05	76.68	7.85	1210	0	488	177.3	35	6	0.04	300	80	24.32	180	1.1	0.8	786.5	17.62
Bajoli			7.85	2000	0	610	305.3	32	12	0.06	580	140	55.94	180	4	0.8	1300	12.86

SITE	Lat	Long	pH	EC in µS/cm at 25°C	CO3	HCO3	Cl	SO4	NO3	PO4	TH	Ca	Mg	Na	K	F	TDS	SAR
Biwai	27.10	76.69	8.12	3180	0	976	226.9	500	60	0.06	280	58	32.83	650	2	1.45	2067	68.20
Kali pahari	26.98	76.38	8	580	0	366	21.27	20	2	0.02	200	44	21.89	70	1	0.62	377	8.62
Rajakhera	27.07	76.66	7.25	1860	0	732	212.7	40	19	0.01	200	44	21.89	350	4	1.65	1209	43.12
Tigaria	27.11	76.77	7.8	6480	0	610	1172	1030	22	0.35	1300	280	145.9	900	1.3	0.38	4212	43.61
Dhigeria Bhem	27.08	76.75	7.9	2210	0	610	426	85	14	0.1	550	120	60.8	300	2.1	0.68	1437	22.31
Balaheda	27.07	76.77	8.45	2980	48	610	460	330	8	0.12	280	60	31.62	600	3.1	0.92	1937	62.69
Khari ki Jhopdi	27.11	76.78	8.41	5400	36	976	1250	140	23	0.36	940	240	82.69	850	1	0.6	3510	47.32
Phullela	27.11	76.55	7.9	1310	0	610	85.2	70	8	0.23	400	100	36.48	140	1	0.65	851.5	11.98
Kolana	27.08	76.55	8	1250	0	549	163.3	5	8	0.11	300	80	24.32	180	1.1	0.3	812.5	17.62
kesupura	27.09	76.65	7.9	2040	0	854	71	210	32	0.02	130	28	14.59	420	1.3	3.2	1326	64.36
Sonadi	27.07	76.68	7.48	1560	0	610	177.5	20	11	0.03	220	46	25.54	260	1	1.85	1014	30.74
Uprera	27.13	76.60	8.42	3550	36	488	600	425	9	0.04	900	200	97.28	400	1	0.48	2308	23.20

Annexure-IV

Groundwater Unit Draft

Location	Lat.	Long.	Ground water potential zones	Type (DW/ STW/DTW)	Use	Monsoon Irrigation	Monsoon Domestic	Monsoon	Non-monsoon-Irrigation	non-Monsoon Domestic	Non-monsoon
Bhedoli	26.9921	76.4187	Q	DCB	Domestic + Irrigation	**400**	350	750	1000	350	1350
Bhawta	27.0278	76.456	Q	BW	Domestic + Irrigation	**500**	350	850	1750	350	2100
Jagsoli	27.0634	76.44	Q	BW	Domestic + Irrigation	**200**	350	550	300	450	750
Redia	27.1076	76.416	Q	DW	Domestic + Irrigation	0	0	0	1600	750	2350
Unwari	27.0911	76.421	Q	DW	Domestic + Irrigation	**200**	300	500	550	300	850
Jhajha ka bas	27.009	76.624	Q	BW	Domestic + Irrigation	**200**	350	550	220	375	595
Nurpur	27.0729	76.669	Q	BW	Domestic + Irrigation	**500**	350	850	1200	350	1550
Handli	27.0273	76.736	A	TW	Domestic + Irrigation	**160**	350	510	1000	350	1350
Sumail	27.0393	76.744	A	TW	Domestic + Irrigation	**100**	900	1000	2000	750	2750
Dhigariya Bheem	27.0714	76.74	A	TW	Irrigation	**50**	900	950	2000	750	2750
Sodan ka Bas	27.0962	76.788	Non Pot	TW	Domestic + Irrigation	**150**	900	1050	1500	750	2250
Baori khera	27.1186	76.8	Non Pot	TW	Domestic + Irrigation	**150**	500	650	2000	450	2450
Jhiri ki Jhopdi	27.1231	76.808	Non Pot	DW	Domestic + Irrigation	**150**	350	500	1000	300	1300

Location	Lat.	Long.	Ground water potential zones	Type (DW/ STW/DTW)	Use	Monsoon Irrigation	Monsoon Domestic	Monsoon	Non-monsoon-Irrigation	non-Monsoon Domestic	Non-monsoon
Tigeria	27.1126	76.769	Non Pot	TW	Domestic + Irrigation	**170**	750	920	1500	700	2200
Khora kalan	26.9695	76.411	A	DW	Irrigation	**80**	0	80	400	0	400
Nimali	26.9785	76.453	P	DW	Domestic + Irrigation	**30**	175	205	800	250	1050
Kundal	27.02	76.412	P	DW	Domestic + Irrigation	**400**	500	900	3000	650	3650
Bhawra	27.0413	76.464	Gn	DTW	Domestic + Irrigation	**130**	750	880	1000	1000	2000
Muhi	27.0926	76.483	Gn	DW	Domestic + Irrigation	**0**	300	300	100	400	500
Karnawar	27.1177	76.537	A	DW	Domestic	**0**	700	700	0	850	850
Fullela	27.11	76.547	A	DTW	Domestic + Irrigation	**50**	750	800	800	1000	1800
Charwas ki dhani	27.0777	76.543	A	Dw	Domestic + Irrigation	**30**	750	780	1000	1000	2000
Bisanpura	27.0877	76.554	Gn	TW	Domestic + Irrigation	**135**	300	435	1000	600	1600
Uprera	27.1324	76.595	Gn	DTW	Domestic + Irrigation	**200**	700	900	1000	800	1800
Kukarwadi	27.0964	76.609	Gn	DW	Domestic + Irrigation	**10**	700	710	100	600	700
Banapura	27.0914	76.615	Non Pot	TW	Domestic + Irrigation	**40**	500	540	400	500	900
Dubbi	27.0941	76.701	A	DW	Domestic + Irrigation	**100**	2000	2100	2000	2500	4500
Nihalpura	27.0725	76.733	A	TW	Domestic + Irrigation	**100**	750	850	2000	1000	3000
Salawas Khurd	27.0182	76.565	A	TW	Domestic + Irrigation	**150**	1000	1150	1000	1500	2500

Location	**Lat.**	**Long.**	**Ground water potential zones**	**Type (DW/ STW/DTW)**	**Use**	**Monsoon Irrigation**	**Monsoon Domestic**	**Monsoon**	**Non-monsoon-Irrigation**	**non-Monsoon Domestic**	**Non-monsoon**
Moradi	26.9966	76.547	A	TW	Irrigation	**100**	175	275	1500	250	1750
Rani ka Bas	26.9967	76.583	A	TW	Domestic + Irrigation	**50**	300	350	500	400	900
Abhaneri	27.0132	76.602	A	TW	Domestic + Irrigation	**300**	600	900	1500	600	2100
Bhandera	27.0302	76.588	A	TW	Domestic + Irrigation	**100**	370	470	500	250	750
Abhaneri(modal ki dhani)	27.0219	76.598	A	TW	Domestic + Irrigation	**150**	1750	1900	500	2500	3000
Jassapara	26.9942	76.612	A	TW	Domestic + Irrigation	**80**	350	430	500	500	1000
Ranapada	26.9871	76.675	A	TW	Domestic + Irrigation	**200**	350	550	1500	500	2000
Kheda	27.0204	76.676	A	TW	Domestic + Irrigation	**250**	750	1000	3000	1000	4000
Badiyal kalan	27.0358	76.662	A	TW	Domestic + Irrigation	**100**	350	450	1000	500	1500

Annexure- V

Georeferenced elevation of all the principal hydrogeological layers at each cross section of the grid with some additional points on the boundary

Grid No	UTM X	UTM Y	Upper surface of Hydrogeological Layer						Thickness of Hydrogeological layer			
			SURFACE EEVATION	Desaturated /Dewatered Aquifer	Confining Layer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)	Bedrock	Desaturated /Dewatered Aquifer	Desaturated /Dewatered Aquifer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)
1,3	640630	2982263	303	302	301	293	287	278	1	8	6	9
1,4	642617	2982263	304	303	302	284	279	276	1	18	5	3
1,5	644636	2982263	302	296	290	278	273	262	6	12	5	11
1,6	646655	2982263	303	301	287	270	264	260	14	17	6	4
1,7	648611	2982263	300	295	279	265	250	248	16	14	15	2
1,8	650599	2982263	292	282	272	263	258	252	10	9	5	6
1,9	652618	2982263	288	279	268	259	254	253	11	9	5	1
2,3	640630	2984219	335	335	335	309	298	265	0	26	11	33
2,4	642617	2984219	310	304	296	280	270	268	8	16	10	2
2,5	644668	2984219	308	304	297	274	263	248	7	23	11	15
2,6	646624	2984219	305	302	287	272	260	236	15	15	12	24
2,7	648611	2984219	304	302	283	264	259	245	19	19	5	14
2,8	650630	2984219	303	302	279	260	254	241	23	19	6	13
2,9	652618	2984219	297	295	277	257	250	243	18	20	7	7
2,10	654637	2984219	289	281	267	257	248	215	14	10	9	33
2,11	656341	2984219	284	284	267	255	250	240	17	12	5	10
3,2	638611	2986238	317	314	291	287	283	277	23	4	4	6
3,3	640661	2986238	315	311	293	289	285	280	18	4	4	5
3,4	642649	2986238	310	309	288	284	274	267	21	4	10	7
3,5	644668	2986238	310	306	285	280	275	265	21	5	5	10
3,6	646592	2986238	307	304	279	274	268	258	25	5	6	10
3,7	648611	2986238	305	301	275	265	257	252	26	10	8	5
3,8	650630	2986238	300	298	273	261	256	248	25	12	5	8
3,9	652618	2986238	300	296	270	256	245	240	26	14	11	5
3,10	654637	2986238	295	293	271	256	250	235	22	15	6	15
3,11	656656	2986238	292	290	280	249	236	222	10	31	13	14
3,12	658612	2986238	285	284	264	246	236	215	20	18	10	21
3,13	660663	2986238	278	275	252	244	228	200	23	8	16	28
3,15	664606	2986238	280	272	245	235	221	210	27	10	14	11
3,16	666594	2986238	280	274	250	234	222	222	24	16	12	0
3,17	668581	2986238	276	273	245	225	219	212	28	20	6	7
3,18	670632	2986238	270	266	245	225	219	213	21	20	6	6
4,3	640598	2988226	305	305	291	289	286	260	14	2	3	26
4,4	642649	2988226	310	310	288	283	278	267	22	5	5	11
4,5	644636	2988226	310	310	280	274	259	250	30	6	15	9

Grid No	UTM X	UTM Y	Upper surface of Hydrogeological Layer						Thickness of Hydrogeological layer			
			SURFACE EEVATION	Desaturated /Dewatered Aquifer	Confining Layer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)	Bedrock	Desaturated /Dewatered Aquifer	Desaturated /Dewatered Aquifer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)
4,6	646592	2988226	305	305	280	273	262	245	25	7	11	17
4,7	648611	2988226	305	305	275	265	255	240	30	10	10	15
4,8	650662	2988226	300	279	270	260	250	232	9	10	10	18
4,9	652618	2988226	298	295	264	257	248	235	31	7	9	13
4,10	654637	2988226	295	294	262	251	240	220	32	11	11	20
4,11	656688	2988226	293	291	264	254	245	220	27	10	9	25
4,12	658612	2988226	290	289	257	246	235	205	32	11	11	30
4,13	660631	2988226	290	280	264	244	238	228	16	20	6	10
4,14	662587	2988226	285	280	264	244	236	235	16	20	8	1
4,15	664638	2988226	281	279	253	237	225	220	26	16	12	5
4,16	666625	2988226	278	275	250	230	222	210	25	20	8	12
4,17	668581	2988226	277	274	241	226	216	198	33	15	10	18
4,18	670632	2988226	273	270	244	217	210	200	26	27	7	10
4,19	672619	2988226	270	264	230	208	202	188	34	22	6	14
4,20	674607	2988226	260	255	225	213	200	180	30	12	13	20
5,2	638800	2990213	320	310	304	302	301	300	6	2	1	1
5,3	640693	2990213	310	308	301	299	294	288	7	2	5	6
5,4	642586	2990213	308	305	295	291	286	285	10	4	5	1
5,5	644668	2990213	303	301	284	278	271	261	17	6	7	10
5,6	646529	2990213	300	299	289	281	275	272	10	8	6	3
5,7	648580	2990213	287	286	279	270	254	246	7	9	16	8
5,8	650599	2990213	280	276	270	265	260	238	6	5	5	22
5,9	652650	2990213	285	279	274	264	258	252	5	10	6	6
5,10	654669	2990213	288	284	264	255	248	237	20	9	7	11
5,11	656688	2990213	282	276	259	253	248	238	17	6	5	10
5,12	658675	2990213	283	270	258	249	244	230	12	9	5	14
5,13	660600	2990213	288	281	261	248	243	236	20	13	5	7
5,14	662619	2990213	285	282	246	241	223	215	36	5	18	8
5,15	664638	2990213	280	280	253	236	228	219	27	17	8	9
5,16	666625	2990213	278	275	250	228	215	198	25	22	13	17
5,17	668644	2990213	275	272	254	219	205	190	18	35	14	15
5,18	670632	2990213	271	269	251	210	204	192	18	41	6	12
5,19	672683	2990213	270	266	255	208	194	190	11	47	14	4
5,20	674607	2990213	268	265	254	210	193	182	11	44	17	11
6,2	638642	2992264	325	325	325	320	316	315	0	5	4	1
6,3	640661	2992264	302	302	298	296	290	284	4	2	6	6
6,4	642649	2992264	308	308	306	289	285	267	2	17	4	18
6,5	644636	2992264	300	300	292	285	280	270	8	7	5	10
6,6	646655	2992264	295	295	292	281	269	265	3	11	12	4

Grid No	UTM X	UTM Y	Upper surface of Hydrogeological Layer						Thickness of Hydrogeological layer			
			SURFACE EEVATION	Desaturated /Dewatered Aquifer	Confining Layer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)	Bedrock	Desaturated /Dewatered Aquifer	Desaturated /Dewatered Aquifer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)
6,7	648643	2992264	295	295	279	272	266	262	16	7	6	4
6,8	650662	2992264	300	300	276	265	260	253	24	11	5	7
6,9	652618	2992264	297	297	276	263	258	251	21	13	5	7
6,11	656593	2992264	286	286	275	256	251	241	11	19	5	10
6,12	658612	2992264	288	288	254	246	240	234	34	8	6	6
6,13	660663	2992264	278	278	266	253	243	226	12	13	10	17
6,14	662650	2992264	276	266	254	243	239	230	12	11	4	9
6,15	664638	2992264	278	270	250	236	229	213	20	14	7	16
6,16	666625	2992264	278	275	248	227	209	195	27	21	18	14
6,17	668644	2992264	272	259	243	225	212	202	16	18	13	10
6,18	670695	2992264	264	256	245	220	190	178	11	25	30	12
6,19	672619	2992264	254	253	240	209	197	187	13	31	12	10
6,20	674670	2992264	258	253	245	209	192	185	8	36	17	7
6,21	676658	2992264	258	253	234	215	196	194	19	19	19	2
7,3	640630	2994189	307	307	234	295	284	276	73	-61	11	8
7,4	642649	2994189	310	310	305	295	291	280	5	10	4	11
7,5	644605	2994189	309	309	304	295	282	270	5	9	13	12
7,6	646655	2994189	307	307	302	285	276	274	5	17	9	2
7,7	648580	2994189	305	305	295	289	285	272	10	6	4	13
7,8	650630	2994189	302	302	295	272	261	248	7	23	11	13
7,9	652618	2994189	298	298	282	264	254	239	16	18	10	15
7,10	654605	2994189	296	296	278	259	249	240	18	19	10	9
7,11	656656	2994189	294	294	287	264	246	240	7	23	18	6
7,12	658612	2994189	291	291	278	256	246	234	13	22	10	12
7,13	660600	2994189	288	288	264	254	249	239	24	10	5	10
7,14	662619	2994189	289	289	260	244	235	221	29	16	9	14
7,15	664669	2994189	278	274	256	235	226	218	18	21	9	8
7,16	666688	2994189	267	265	250	232	225	211	15	18	7	14
7,17	668613	2994189	265	262	236	224	214	205	26	12	10	9
7,18	670663	2994189	274	270	239	219	211	185	31	20	8	26
7,19	672619	2994189	271	268	236	217	207	202	32	19	10	5
7,20	674639	2994189	269	265	236	214	205	182	29	22	9	23
7,21	676689	2994189	267	261	235	211	204	197	26	24	7	7
8,2	638642	2996271	312	312	302	297	294	286	10	5	3	8
8,3	640630	2996271	320	320	307	304	297	292	13	3	7	5
8,6	646655	2996271	313	306	304	297	292	280	2	7	5	12
8,7	648611	2996271	318	304	294	290	284	272	10	4	6	12
8,8	650630	2996271	305	303	297	286	280	270	6	11	6	10
8,9	652650	2996271	295	289	279	270	255	240	10	9	15	15

Grid No	UTM X	UTM Y	Upper surface of Hydrogeological Layer						Thickness of Hydrogeological layer			
			SURFACE EEVATION	Desaturated /Dewatered Aquifer	Confining Layer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)	Bedrock	Desaturated /Dewatered Aquifer	Desaturated /Dewatered Aquifer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)
8,10	654637	2996271	294	287	279	265	255	234	8	14	10	21
8,11	656656	2996271	290	287	284	264	248	240	3	20	16	8
8,12	658644	2996271	290	288	268	255	250	241	20	13	5	9
8,13	660631	2996271	288	280	262	256	250	235	18	6	6	15
8,14	662650	2996271	277	274	260	248	235	230	14	12	13	5
8,15	664669	2996271	276	274	253	240	230	218	21	13	10	12
8,16	666657	2996271	279	276	255	234	225	210	21	21	9	15
8,17	668644	2996271	276	272	250	225	214	200	22	25	11	14
8,18	670632	2996271	272	270	244	216	204	192	26	28	12	12
8,19	672651	2996271	270	265	235	219	205	193	30	16	14	12
8,20	674639	2996271	266	265	239	210	204	192	26	29	6	12
8,21	676626	2996271	258	253	229	210	205	192	24	19	5	13
8,22	678645	2996271	263	249	237	212	202	183	12	25	10	19
9,3	640630	2998227	322	322	312	311	309	292	10	1	2	17
9,7	648643	2998227	316	316	312	309	303	293	4	3	6	10
9,9	652650	2998227	300	295	284	272	261	254	11	12	11	7
9,10	654637	2998227	296	286	280	270	265	248	6	10	5	17
9,11	656656	2998227	290	285	274	266	261	250	11	8	5	11
9,12	658612	2998227	290	284	279	275	266	253	5	4	9	13
9,13	660631	2998227	292	287	275	272	266	259	12	3	6	7
9,16	666657	2998227	279	276	260	240	234	224	16	20	6	10
9,17	668644	2998227	276	267	266	234	221	203	1	32	13	18
9,18	670632	2998227	273	266	260	219	212	192	6	41	7	20
9,19	672651	2998227	267	261	253	216	210	198	8	37	6	12
9,20	674639	2998227	268	259	235	212	204	196	24	23	8	8
9,21	676658	2998227	264	254	246	208	201	190	8	38	7	11
9,22	678645	2998227	263	253	231	208	200	187	22	23	8	13
10,8	650630	3000277	305	302	298	290	285	275	4	8	5	10
10,9	652650	3000277	299	296	283	275	266	261	13	8	9	5
10,10	654637	3000277	296	294	283	275	270	257	11	8	5	13
10,11	656625	3000277	298	298	294	288	280	272	4	6	8	8
10,12	658675	3000277	312	305	300	295	290	290	5	5	5	0
10,13	650631	3000277	321	308	305	304	303	290	3	1	1	13
10,21	676626	3000277	260	260	240	206	200	170	20	34	6	30
10,22	678645	3000277	260	239	238	206	198	190	1	32	8	8
11,10	654637	3002328	299	296	286	276	265	251	10	10	11	14
11,11	656625	3002328	298	295	289	277	274	273	6	12	3	1
11,12	658644	3002328	306	304	298	292	289	287	6	6	3	2
12,10	654637	3004284	304	300	289	284	275	268	11	5	9	7

Grid No	UTM X	UTM Y	Upper surface of Hydrogeological Layer						Thickness of Hydrogeological layer			
			SURFACE EEVATION	Desaturated /Dewatered Aquifer	Confining Layer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)	Bedrock	Desaturated /Dewatered Aquifer	Desaturated /Dewatered Aquifer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)
12,11	656656	3004284	301	295	290	286	280	270	5	4	6	10
12,12	658644	3004284	308	305	298	292	290	280	7	6	2	10
12,13	650631	3004284	330	330	326	323	321	318	4	3	2	3
13,10	654637	3006335	315	307	296	292	288	284	11	4	4	4
13,11	656625	3006335	310	308	298	291	286	276	10	7	5	10
Additional points on the boundaries												
Boundary	638622	3000277	480	480	480	480	480	480	0	0	0	0
Boundary	639823	3000277	320	317	220	220	180	160	97	0	40	20
Boundary	640638	3000277	365	360	340	340	320	290	20	0	20	30
Boundary	638665	2998227	540	540	540	540	540	540	0	0	0	0
Boundary	639823	2998227	320	316	310	305	300	280	6	5	5	20
Boundary	637807	2994189	500	500	500	500	500	500	0	0	0	0
Boundary	638922	2994189	310	307	307	303	295	285	0	4	8	10
Boundary	637592	2992264	540	540	540	540	540	540	0	0	0	0
Boundary	648617	2980790	290	290	290	290	290	290	0	0	0	0
Boundary	654622	2983278	280	278	267	250	245	230	11	17	5	15
Boundary	658568	2985465	280	277	265	245	240	230	12	20	5	10
Boundary	672595	2987138	265	258	246	205	200	185	12	41	5	15
Boundary	678601	3001680	247	242	225	190	182	163	17	35	8	19
Boundary	653378	3004382	310	307	307	287	282	270	0	20	5	12
Boundary	674568	2999535	267	264	255	205	200	182	9	50	5	18
Boundary	672638	2999664	263	260	260	205	200	190	0	55	5	10
Boundary	670622	2999578	273	270	262	227	220	203	8	35	7	17

Grid No	UTM X	UTM Y	Upper surface of Hydrogeological Layer						Thickness of Hydrogeological layer			
			SURFACE EEVATION	Desaturated /Dewatered Aquifer	Confining Layer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)	Bedrock	Desaturated /Dewatered Aquifer	Desaturated /Dewatered Aquifer	Aquifer-I (Alluvial)	Aquifer-II (Hard rock)
Boundary	680257	2996346	252	248	238	205	198	190	10	33	7	8
Boundary	679297	3001399	263	260	232	212	205	192	28	20	7	13
Boundary	679276	3000814	260	240	228	205	197	190	12	23	8	7
Boundary	679359	2997724	259	256	230	202	197	191	26	28	5	6
Boundary	679401	2996756	255	250	226	206	195	170	24	20	11	25
Boundary	679380	2995427	260	245	228	205	200	192	17	23	5	8
Boundary	656338	3006879	312	309	297	289	285	278	12	8	4	7
Boundary	657240	3006911	310	307	307	298	292	284	0	9	6	8
Boundary	658290	3006827	310	307	307	304	299	290	0	3	5	9
Boundary	659602	3006974	315	312	309	306	302	292	3	3	4	10
Boundary	639503	3001169	320	317	310	300	280	270	7	10	20	10

Annexure VI

Aquifer wise monitoring stations

Location	Aquifer	Latitude	Longitude
KaliPahari	I	26.98333	76.40833
Sikandra	I	26.96703	76.57864
Balahedi	I	27.06111	76.78889
Rampura	I	27.125	76.77778
Tatya	I	27.04136	76.46389
Dhanawar	I	26.96103	76.49203
Tigaria	I	27.11386	76.76853
Jaisinghpura (east)	I	27.10856	76.75806
Simla ka Bas	I	27.107	76.73922
Baori khera	I	27.12333	76.80833
Baori khera ki dhani	I	27.11217	76.79561
Bedhadi Gujran	I	27.06694	76.63778
Digaria Bheem	I	27.07139	76.74
Pilodi	I	26.96306	76.71806
Dobbi	I	27.09389	76.70056
Sodan ka bas	I	27.09758	76.78683
Ranapada	I	26.98629	76.67401
Alipur	I	27.07851	76.79393
Khari ki jhopdi	I	27.11098	76.78696
Kheel pur Kheda	I,II	27.13972	76.6875
GurhaKatla	I,II	27.06361	76.48089
Rampura	I,II	27.02839	76.46531
Badiyal ka lan	I,II	27.04997	76.64925
Bhandarej	I,II	26.89228	76.42208
Pichupara	I,II	27.00722	76.56667
Redia	I,II	27.09708	76.41856
Lotwara-I	I,II	27.00536	76.7425
Ralota	I,II	27.05214	76.68207
Sodala	I,II	27.00972	76.62468
Sumel	I,II	27.04206	76.74565
Shyamsinghpura	I,II	26.98986	76.53439
Maukalan	I,II	27.09482	76.7466
Lotwara-II	I,II	27.00525	76.7425
Bajoli	I,II	27.13841	76.73143
Baswa	II	27.14583	76.575
Phulella	II	27.10983	76.5475
Phulella	II	27.11333	76.54861
Jaisinghpura	II	27.17258	76.59611

Location	Aquifer	Latitude	Longitude
VijaiNav	II	27.17603	76.58681
Charwas ki Dhani	II	27.07528	76.54722
Muhi	II	27.07639	76.47167
Rajpura bara	II	27.16958	76.52806
Surer	II	27.19778	76.61575
Rambaskalan	II	27.04306	76.37167
Kundal	II	27.00617	76.42669
Bandikui	II	27.04167	76.56194
Lilog	II	27.0825	76.62222
Badoli kalan	II	27.02828	76.37786
Nurpur	II	27.07121	76.67037
Bhedoli	II	26.98353	76.41685
Uprera	II	27.13561	76.59356

Annexure VII

Zone Budgeting

Scenario- I

ZONE BUDGET ^{3}/DAY IN
SCENARIO 1
Zone

Stres Perio	Time duration	In: DEP BOUND	In: RECHARGE	In: Zone 2 to	In: Zone 3 to	In: Zone 4 to	Total	Out: HEAD BOUND	Out: RECHARGE	Out: Zone 1 to	Out: Zone 1 to	Out: Zone 1 to	Total	Change storag
1	122	2225	0	0	402.7	500	902.7	4941.	741.9	3536	9920	0	19140.0	-
2	365	2416	0	0	457.2	320.7	777.9	4247.	1573	3131	9554	0	32670.	-
3	487	2240	0	0	481.7	493.0	974.7	4722.	741.9	3091	9506	0	18061.5	-
4	731	2446	0	0	502.4	311.0	813.4	4180.	1573	2825	9219	0	31962.	-
5	853	2267	0	0	516.1	476.2	992.3	4658.	741.9	2828	9218	0	17445.7	-
6	1096	2468	0	8.788	521.1	299.5	829.51	4144	1573	2649	9016	0	31546.	-
7	1218	2287	0	14.76	529.5	460.9	1005.	4628.	741.9	2683	9045	0	17098.3	-
8	1461	2485	0	24.44	526.6	288.7	839.81	4123	1573	2552	8896	0	3130	-
9	1583	2302	0	30.17	532.1	447.	1009.7	4610.	741.9	2601	8946	0	16899.1	-
10	1826	2498	0	37.48	525.0	278.9	841.55	4110.	1573	2496	8834	0	31177.	-
11	1948	2315	0	42.99	529.0	436.4	1008.4	4599.	741.9	2553	8898	0	16792.5	-
12	2192	2510	0	48.11	519.7	269.6	837.54	4100.	1573	2463	8810	0	31111.	-
13	2314	2327	0	53.47	522.8	426.7	1003.0	4590.	741.9	2527	8885	0	16743.8	-
14	2557	2521	0	56.55	512.4	261.6	830.62	4094.	1573	2445	8813	0	31090.	-
15	2679	2337	0	61.82	514.9	418.8	995.63	4584	741.9	2513	8895	0	16733.6	-
16	2922	2531	0	63.03	504.0	253.2	820.36	4087.	1573	2435	8835	0	31094.	-
17	3044	2347	0	68.30	506.3	411.5	986.26	4577.	741.9	2504	8922	0	16746.1	-
18	3287	2540	0	67.81	495.2	243.	806.38	4081.	1573	2427	8869	0	31116.	-
19	3409	2357	0	73.19	497.3	403.	974.38	4571.	741.9	2499	8960	0	16772.6	-

Zone 2

Stress Period	Time	In: HEAD DEP BOUNDS	In: RECHARGE	In: Zone 1 to 2	In: Zone 3 to 2	In: Zone 4 to 2	In: Zone 5 to 2	Total In	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: Zone 2 to 1	Out: Zone 2 to 3	Out: Zone 2 to 4	Out: Zone 2 to 5	Total out	Change in storage
1	122	16646	0	3536	6850	3575	3137	33744.1	1730.5	4976.8	0	12856	0	0	19563.3	14180.8
2	365	20994	0	3131.4	7266	3953	2901	38245.1	892.43	1.04E+05	0	11307	0	0	115839.4	-77594.33
3	487	16966	0	3091.4	7488	3959	3399	34902.9	1495.5	4880.9	0	11287	0	0	17663.4	17239.5
4	731	21279	0	2824.8	7916	4058	3001	39079	836.02	1.00E+05	0	10419	0	0	111685	-72606.02
5	853	17204	0	2827.9	8119	4070	3495	35715.8	1440.8	4729.5	0	10533	0	0	16703.3	19012.5
6	1096	21455	0	2649.3	8467	4069	3055	39695.3	822.9	97429	8.7884	9928	0	0	108188.7	-68493.39
7	1218	17372	0	2683	8618	4096	3559	36328.6	1434.3	4588.2	14.763	10072	0	0	16109.26	20219.34
8	1461	21608	0	2552	8884	4043	3068	40155.5	824.76	93896	24.445	9607.9	0	0	104353.1	-64197.61
9	1583	17532	0	2600.6	9023	4093	3589	36837.7	1438.3	4421.6	30.178	9790.3	0	0	15680.38	21157.32
10	1826	21758	0	2495.6	9209	3964	3050	40476.4	831.14	91647	37.488	9404.3	0	0	101919.9	-61443.53
11	1948	17688	0	2553.4	9339	3985	3586	37151.1	1445.6	4320.7	42.991	9608	0	0	15417.29	21733.81
12	2192	21926	0	2463.1	9462	3842	2995	40688	835.86	88864	48.118	9274.4	0	0	99022.38	-58334.38
13	2314	17857	0	2526.8	9596	3836	3520	37335.2	1450.6	4179.3	53.473	9500.6	1.6617	0	15185.63	22149.57
14	2557	22089	0	2445.1	9667	3752	2953	40905.4	840.64	87258	56.556	9205.5	0	0	97360.7	-56455.3
15	2679	18023	0	2512.5	9806	3768	3474	37583.2	1454.2	4113.7	61.821	9437.1	10.25	0	15077.07	22506.13
16	2922	22260	0	2434.5	9828	3695	2896	41113.4	841.88	85973	63.038	9168.1	0	0	96046.02	-54932.62
17	3044	18191	0	2504.4	9973	3726	3389	37782.8	1455	4053.1	68.307	9405.4	17.167	0	14998.97	22783.83
18	3287	22427	0	2427.2	9951	3654	2880	41339.1	841.53	83510	67.817	9162.4	0	0	93581.75	-52242.65
19	3409	18359	0	2499.1	10096	3630	3369	37952.7	1453.4	3937.1	73.196	9405.8	23.191	0	14892.69	23060.01
20	3652	0	0	2425.3	10015	3622	2858	18919.9	0	81797	71.095	9179.9	2.1645	0	91050.16	-72130.26

Zone 3

Stress Period	Time	In: HEAD DEP BOUNDS	In: RECHARGE	In: Zone 1 to 3	In: Zone 2 to 3	Total In	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: Zone 3 to 1	Out: Zone 3 to 2	Total out	Change in storage
1	122	11762	0	9920.4	12856	34538.4	644.41	3119.4	402.78	6850.4	11016.99	23521.41
2	365	17522	0	9553.9	11307	38382.9	199.57	66166	457.21	7266.1	74088.88	-35705.98
3	487	13732	0	9505.6	11287	34524.6	449.08	3119.4	481.72	7488	11538.2	22986.4
4	731	19224	0	9219.2	10419	38862.2	122.95	66166	502.44	7916.2	74707.59	-35845.39
5	853	15320	0	9217.8	10533	35070.8	361.93	3119.4	516.12	8118.5	12115.95	22954.85
6	1096	20627	0	9015.5	9928	39570.5	82.525	66166	521.17	8467.3	75237	-35666.5
7	1218	16616	0	9045.3	10072	35733.3	284.21	3119.4	529.52	8617.8	12550.93	23182.37
8	1461	21807	0	8896	9607.9	40310.9	44.901	66166	526.64	8884.4	75621.94	-35311.04
9	1583	17717	0	8946.4	9790.3	36453.7	214.61	3119.4	532.11	9023.3	12889.42	23564.28
10	1826	22812	0	8833.5	9404.3	41049.8	11.097	65952	525.09	9209.2	75697.39	-34647.59
11	1948	18658	0	8898	9608	37164	153.63	3109.3	529.03	9339.1	13131.06	24032.94
12	2192	23713	0	8809.6	9274.4	41797	0	65524	519.78	9461.6	75505.38	-33708.38
13	2314	19498	0	8884.6	9500.6	37883.2	112.62	3089.1	522.86	9595.7	13320.28	24562.92
14	2557	24492	0	8813.3	9205.5	42510.8	0	65202	512.44	9666.5	75380.94	-32870.14
15	2679	20231	0	8895.2	9437.1	38563.3	86.926	3073.9	514.98	9805.8	13481.61	25081.69
16	2922	25181	0	8834.7	9168.1	43183.8	0	64667	504.06	9827.9	74998.96	-31815.16
17	3044	20874	0	8922.1	9405.4	39201.5	64.609	3048.7	506.37	9973.1	13592.78	25608.72
18	3287	25777	0	8869.4	9162.4	43808.8	0	64453	495.27	9950.7	74898.97	-31090.17
19	3409	21437	0	8960.1	9405.8	39802.9	45.497	3038.6	497.39	10096	13677.49	26125.41
20	3652	0	0	8911.8	9179.9	18091.7	0	64453	486.4	10015	74954.4	-56862.7

Zone 4

Stress Period	Time	In: HEAD DEP BOUNDS	In: RECHARGE	In: Zone 1 to 4	In: Zone 2 to 4	In: Zone 5 to 4	Total In	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: Zone 4 to 1	Out: Zone 4 to 2	Out: Zone 4 to 5	Total out	change in storage
1	122	0	24495	0	0	67.564	24562.6	521.02	0	500	3575.1	376.9	4973.01	19589.55
2	365	144.04	0	0	0	69.711	213.751	34.339	4595.2	320.76	3952.8	349.5	9252.549	-9038.798
3	487	0	24495	0	0	72.006	24567	415.14	0	493.06	3958.5	398.4	5265.13	19301.88
4	731	216.72	0	0	0	74.387	291.107	18.569	4595.2	311.03	4058.4	363.7	9346.859	-9055.752
5	853	0	24495	0	0	77.078	24572.1	325.87	0	476.26	4070	412.2	5284.37	19287.71
6	1096	281.88	0	0	0	79.531	361.411	2.7349	4595.2	299.56	4068.8	373.7	9339.945	-8978.534
7	1218	9.2717	24495	0	0	82.586	24586.9	255.42	0	460.92	4096.4	422.5	5235.22	19351.64
8	1461	351.29	0	0	0	85.005	436.295	0	4595.2	288.73	4043	381.1	9308.05	-8871.755
9	1583	23.147	24495	0	0	88.359	24606.5	198.54	0	447.5	4093	430.4	5169.48	19437.03
10	1826	412.31	0	0	0	90.595	502.905	0	4595.2	278.98	3964	386.9	9225.09	-8722.185
11	1948	45.233	24495	0	0	94.2	24634.4	161.76	0	436.45	3985.1	436.9	5020.22	19614.21
12	2192	463.36	0	0	0	96.17	559.53	0	4595.2	269.65	3842.2	391.5	9098.55	-8539.02
13	2314	63.544	24495	0	1.6617	99.967	24660.2	132.6	0	426.75	3836.2	442.3	4837.87	19822.3
14	2557	496.94	0	0	0	101.63	598.57	0	4595.2	261.63	3751.9	395.8	9004.52	-8405.95
15	2679	81.828	24495	0	10.25	105.6	24692.7	120.94	0	418.83	3767.8	447.3	4754.91	19937.77
16	2922	518.55	0	0	0	106.93	625.48	0	4595.2	253.27	3695.2	399.5	8943.17	-8317.69
17	3044	98.165	24495	0	17.167	111.02	24721.4	118.78	0	411.59	3725.6	451.7	4707.64	20013.71
18	3287	529.79	0	0	0	112.02	641.81	0	4595.2	243.3	3654	402.6	8895.1	-8253.29
19	3409	105.31	24495	0	23.191	116.23	24739.7	117.33	0	403.8	3630	455.4	4606.53	20133.2
20	3652	0	0	0	2.1645	116.9	119.065	0	4595.2	221.45	3621.9	405.3	8843.89	-8724.826

Zone 5

Stress Period	Time	In: HEAD DEP BOUNDS	In: RECHARGE	In: Zone 2 to 5	In: Zone 4 to 5	Total In	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: Zone 5 to 2	Out: Zone 5 to 4	Total Out	Change in storage
1	122	0	23803	0	376.89	24179.89	517.63	0	3136.6	67.56	3721.794	20458.1
2	365	47.164	0	0	349.45	396.614	191.24	6098.8	2900.8	69.71	9260.551	-8863.937
3	487	0	23803	0	398.43	24201.43	420.11	0	3399	72.01	3891.116	20310.31
4	731	64.242	0	0	363.66	427.902	177.52	6098.8	3000.6	74.39	9351.307	-8923.405
5	853	0	23803	0	412.24	24215.24	392.79	0	3495.4	77.08	3965.268	20249.97
6	1096	78.119	0	0	373.65	451.769	169.06	6098.8	3054.9	79.53	9402.291	-8950.522
7	1218	0.53487	23803	0	422.48	24226.01	372.05	0	3559.4	82.59	4014.036	20211.98
8	1461	89.804	0	0	381.12	470.924	161.79	6098.8	3068.1	85.01	9413.695	-8942.771
9	1583	10.73	23803	0	430.44	24244.17	363.71	0	3588.8	88.36	4040.869	20203.3
10	1826	99.538	0	0	386.91	486.448	155.74	6098.8	3049.6	90.6	9394.735	-8908.287
11	1948	20.181	23803	0	436.91	24260.09	357.81	0	3585.5	94.2	4037.51	20222.58
12	2192	109.45	0	0	391.5	500.95	151.67	6098.8	2995.1	96.17	9341.74	-8840.79
13	2314	28.192	23803	0	442.32	24273.51	352.42	0	3519.5	99.97	3971.887	20301.63
14	2557	118.18	0	0	395.79	513.97	149.77	6098.8	2952.9	101.6	9303.1	-8789.13
15	2679	34.573	23803	0	447.34	24284.91	348.25	0	3474.1	105.6	3927.95	20356.96
16	2922	126.14	0	0	399.5	525.64	148.82	6098.8	2895.8	106.9	9250.35	-8724.71
17	3044	39.605	23803	0	451.67	24294.28	345.01	0	3388.7	111	3844.73	20449.55
18	3287	132.08	0	0	402.6	534.68	148.31	6098.8	2880.2	112	9239.33	-8704.65
19	3409	43.375	23803	0	455.4	24301.78	342.62	0	3368.6	116.2	3827.45	20474.33
20	3652	0	0	0	405.34	405.34	0	6098.8	2857.7	116.9	9073.4	-8668.06

Scenario- III

Zone 1	Alluvium Non-potential																		
Stress Period	From	To	Time in day	In: WELLS	In: HEAD DEP BOUNDS	In: RECHARGE	In: Zone 2 to 1	In: Zone 3 to 1	In: Zone 4 to 1	In: Total IN	Out: WELLS	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: Zone 1 to 2	Out: Zone 1 to 3	Out: Zone 1 to 4	Out: Total OUT	Change in storage	
1	01-Jun-14	30-Sep-14	122	9.3976	22245	0	0	399.53	500.4	23154.328	0	4944.4	741.98	3474.5	9766.9	0	18927.8	4226.5476	
2	01-Oct-14	31-May-15	365	0	24139	0	0	455.69	320.75	24915.44	0	4253.9	15738	3116.7	9539	0	32647.6	-7732.16	
3	01-Jun-15	30-Sep-15	487	9.3976	22377	0	0	477.09	493.38	23356.868	0	4733.3	741.98	3018.9	9339.5	0	17833.7	5523.1876	
4	01-Oct-15	31-May-16	731	0	24425	0	0	500.03	310.91	25235.94	0	4191.8	15738	2803.2	9193.8	0	31926.8	-6690.86	
5	01-Jun-16	30-Sep-16	853	9.3976	22624	0	0	510.87	476.46	23620.728	0	4670.6	741.98	2749.5	9041.4	0	17203.5	6417.2476	
6	01-Oct-16	31-May-17	1096	0	24626	0	9.1395	518.56	299.37	25453.07	0	4158.7	15738	2623.9	8981.1	0	31501.7	-6048.6305	
7	01-Jun-17	30-Sep-17	1218	9.3976	22806	0	15.142	524.21	461.07	23815.82	0	4643.6	741.98	2601.2	8860	0	16846.8	6969.0396	
8	01-Oct-17	31-May-18	1461	0	24780	0	24.796	524.18	288.55	25617.526	0	4140	15738	2524.3	8854.1	0	31256.4	-5638.874	
9	01-Jun-18	30-Sep-18	1583	9.3976	22948	0	30.551	527	447.69	23962.639	0	4627.8	741.98	2516.5	8753.8	0	16640.1	7322.5586	
10	01-Oct-18	31-May-19	1826	0	24900	0	37.867	522.96	278.92	25739.747	0	4129	15738	2466.4	8785.2	0	31118.6	-5378.853	
11	01-Jun-19	30-Sep-19	1948	9.3976	23064	0	43.415	524.29	436.74	24077.843	0	4618.3	741.98	2468.1	8699.3	0	16527.7	7550.1626	
12	01-Oct-19	31-May-20	2192	0	25011	0	48.576	518.02	269.79	25847.386	0	4120.6	15738	2433.6	8755.9	0	31048.1	-5200.714	
13	01-Jun-20	30-Sep-20	2314	9.3976	23171	0	53.987	518.48	427.2	24180.065	0	4610.8	741.98	2441.1	8680.6	0	16474.5	7705.5846	
14	01-Oct-20	31-May-21	2557	0	25106	0	57.135	511.1	262.04	25936.275	0	4115.2	15738	2415.6	8754.8	0	31023.6	-5087.325	
15	01-Jun-21	30-Sep-21	2679	9.3976	23267	0	62.47	511.03	419.49	24269.388	0	4605.3	741.98	2427.1	8686.6	0	16461	7808.4076	
16	01-Oct-21	31-May-22	2922	0	25201	0	63.793	503.12	254.09	26022.003	0	4109.5	15738	2405.7	8772.1	0	31025.3	-5003.297	
17	01-Jun-22	30-Sep-22	3044	9.3976	23360	0	69.129	502.79	412.56	24353.877	0	4599.8	741.98	2419.7	8709.4	0	16470.9	7882.9966	
18	01-Oct-22	31-May-23	3287	0	25290	0	68.786	494.68	245.14	26098.606	0	4104.4	15738	2399.5	8803	0	31044.9	-4946.294	
19	01-Jun-24	30-Sep-23	3409	9.3976	23450	0	74.23	494.18	405.44	24433.248	0	4594.3	741.98	2415.4	8744.1	0	16495.8	7937.4676	
20	01-Oct-23	31-May-24	3652	0	0	0	72.319	486.15	223.85	782.319	0	0	15631	2398.9	8842.2	0	26872.1	-26089.781	

Zone 2	Alluvium Younger																			
Stress Period	From	To	Time in day	In: WELLS	In: HEAD DEP BOUNDS	In: RECHARGE	In: Zone 1 to 2	In: Zone 3 to 2	In: Zone 4 to 2	In: Zone 5 to 2	In: Total IN	Out: WELLS	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: Zone 2 to 1	Out: Zone 2 to 3	Out: Zone 2 to 4	Out: Zone 2 to 5	Out: Total OUT	Change in storage
1	01-Jun-14	30-Sep-14	122	18842	16578	0	3474.5	6990.4	3965.1	3106.9	52956.9	0	1758.4	4976.8	0	12721	14.352	0	1211693	-1158736.32
2	01-Oct-14	31-May-15	365	0	20958	0	3116.7	7234.6	4227.8	2864.9	38402	0	913.15	1.05E+05	0	11289	0	0	1192223	-1153820.67
3	01-Jun-15	30-Sep-15	487	18842	16871	0	3018.9	7580.9	4560.7	3342.4	54215.9	0	1538.7	4926.4	0	11136	8.2244	0	1075521	-1021304.62
4	01-Oct-15	31-May-16	731	0	21224	0	2803.2	7839.3	4507.1	2946.9	39320.5	0	865.69	1.03E+05	0	10393	0	0	1057911	-1018590.7
5	01-Jun-16	30-Sep-16	853	18841	17092	0	2749.5	8162.4	4817.3	3426.1	55088.3	0	1491.8	4850.7	0	10381	8.4909	0	991146	-936057.736
6	01-Oct-16	31-May-17	1096	0	21385	0	2623.9	8347.4	4649.2	2992.2	39997.7	0	857.58	99784	9.1395	9901.3	0	0	1086585	-1046587.64
7	01-Jun-17	30-Sep-17	1218	18839	17246	0	2601.2	8621.8	4964.5	3484.8	55757.3	0	1490	4704.3	15.142	9928.8	12.766	0	1024008	-968250.206
8	01-Oct-17	31-May-18	1461	0	21525	0	2524.3	8731.1	4713.3	3002.1	40495.8	0	862.6	96251	24.796	9584.9	0	0	1121104	-1080607.83
9	01-Jun-18	30-Sep-18	1583	18836	17393	0	2516.5	9002	5037.5	3513.8	56298.8	0	1497.1	4532.7	30.551	9664.3	18.141	0	1063473	-1007173.9
10	01-Oct-18	31-May-19	1826	0	21664	0	2466.4	9033.2	4727.6	2984.3	40875.5	0	871.23	94645	37.867	9387.1	0	0	1162167	-1121291.77
11	01-Jun-19	30-Sep-19	1948	18835	17538	0	2468.1	9297.9	5050.6	3513.6	56703.2	0	1506.6	4462	43.415	9496.6	23.102	0	1107419	-1050715.38
12	01-Oct-19	31-May-20	2192	0	21821	0	2433.6	9275.6	4693.3	2935.2	41158.7	0	877.57	92611	48.576	9264.6	0	0	1207412	-1166253.45
13	01-Jun-20	30-Sep-20	2314	18834	17698	0	2441.1	9546.2	4979.6	3456.7	56955.6	0	1513.2	4366.1	53.987	9403.4	27.22	0	1155879	-1098923.6
14	01-Oct-20	31-May-21	2557	0	21975	0	2415.6	9483.8	4620.8	2897.5	41392.7	0	883.55	90363	57.135	9203.5	0	0	1257044	-1215651.05
15	01-Jun-21	30-Sep-21	2679	18834	17854	0	2427.1	9757	4893.1	3415.4	57180.6	0	1518	4260.1	62.47	9353.1	30.587	0	1208781	-1151600.76
16	01-Oct-21	31-May-22	2922	0	22138	0	2405.7	9644.9	4589.6	2848.2	41626.4	0	885.72	89506	63.793	9170.3	0	0	1310493	-1268866.82
17	01-Jun-22	30-Sep-22	3044	18833	18014	0	2419.7	9921.8	4852.4	3339.1	57380	0	1520	4219.7	69.129	9331.2	35.239	0	1264018	-1206638.09
18	01-Oct-22	31-May-23	3287	0	22297	0	2399.5	9777.6	4575.3	2842.4	41891.8	0	886.28	87793	68.786	9168.7	0	0	1366237	-1324345.22
19	01-Jun-24	30-Sep-23	3409	18833	18175	0	2415.4	10051	4838.6	3329.3	57642.3	0	1519.2	4139	74.23	9337.2	41.695	0	1322312	-1264670.18
20	01-Oct-23	31-May-24	3652	0	0	0	2398.9	9865.5	4557.7	2830.7	19652.8	0	0	86401	72.319	9188.9	0	0	1425073	-1405419.78

Zone 3	Alluvium -Older																
Stress Period	From	To	Time in day	In: WELLS	In: HEAD DEP BOUNDS	In: RECHARGE	In: Zone 1 to 3	In: Zone 2 to 3	In: Total IN	Out: WELLS	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: Zone 3 to 1	Out: Zone 3 to 2	Out: Total OUT	Change in storage	
1	01-Jun-14	30-Sep-14	122	2643.3	11743	0	9766.9	12721	36874.2	0	646.05	3119.4	399.53	6990.4	11155.38	25718.82	
2	01-Oct-14	31-May-15	365	0	17487	0	9539	11289	38315	0	203.36	66166	455.69	7234.6	74059.65	-35744.7	
3	01-Jun-15	30-Sep-15	487	2643.3	13678	0	9339.5	11136	36796.8	0	454.25	3119.4	477.09	7580.9	11631.64	25165.16	
4	01-Oct-15	31-May-16	731	0	19155	0	9193.8	10393	38741.8	0	128.43	66166	500.03	7839.3	74633.76	-35892	
5	01-Jun-16	30-Sep-16	853	2643.3	15234	0	9041.4	10381	37299.7	0	370.09	3119.4	510.87	8162.4	12162.76	25136.94	
6	01-Oct-16	31-May-17	1096	0	20523	0	8981.1	9901.3	39405.4	0	89.416	66166	518.56	8347.4	75121.38	-35716	
7	01-Jun-17	30-Sep-17	1218	2643.3	16495	0	8860	9928.8	37927.1	0	294.52	3119.4	524.21	8621.8	12559.93	25367.17	
8	01-Oct-17	31-May-18	1461	0	21665	0	8854.1	9584.9	40104	0	52.805	66166	524.18	8731.1	75474.09	-35370.1	
9	01-Jun-18	30-Sep-18	1583	2643.3	17559	0	8753.8	9664.3	38620.4	0	226.61	3119.4	527	9002	12875.01	25745.39	
10	01-Oct-18	31-May-19	1826	0	22634	0	8785.2	9387.1	40806.3	0	19.732	66166	522.96	9033.2	75741.89	-34935.6	
11	01-Jun-19	30-Sep-19	1948	2643.3	18464	0	8699.3	9496.6	39303.2	0	167.03	3119.4	524.29	9297.9	13108.62	26194.58	
12	01-Oct-19	31-May-20	2192	0	23491	0	8755.9	9264.6	41511.5	0	0	65631	518.02	9275.6	75424.62	-33913.1	
13	01-Jun-20	30-Sep-20	2314	2642.9	19265	0	8680.6	9403.4	39991.9	0	122.09	3094.1	518.48	9546.2	13280.87	26711.03	
14	01-Oct-20	31-May-21	2557	0	24239	0	8754.8	9203.5	42197.3	0	0	65202	511.1	9483.8	75196.9	-32999.6	
15	01-Jun-21	30-Sep-21	2679	2642.6	19968	0	8686.6	9353.1	40650.3	0	96.776	3073.9	511.03	9757	13438.71	27211.59	
16	01-Oct-21	31-May-22	2922	0	24900	0	8772.1	9170.3	42842.4	0	0	64881	503.12	9644.9	75029.02	-32186.6	
17	01-Jun-22	30-Sep-22	3044	2642.6	20587	0	8709.4	9331.2	41270.2	0	74.68	3058.8	502.79	9921.8	13558.07	27712.13	
18	01-Oct-22	31-May-23	3287	0	25477	0	8803	9168.7	43448.7	0	0	64667	494.68	9777.6	74939.28	-31490.6	
19	01-Jun-24	30-Sep-23	3409	2642.2	21131	0	8744.1	9337.2	41854.5	0	55.606	3048.7	494.18	10051	13649.49	28205.01	
20	01-Oct-23	31-May-24	3652	0	0	0	8842.2	9188.9	18031.1	0	0	64560	486.15	9865.5	74911.65	-56880.6	

Zone 4 Granite-Gneiss

Stress Period	From	To	Time in day	In: WELLS	In: HEAD DEP BOUNDS	In: RECHARGE	In: Zone 1 to 4	In: Zone 2 to 4	In: Zone 5 to 4	In: Total IN	Out: WELLS	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: Zone 4 to 1	Out: Zone 4 to 2	Out: Zone 4 to 5	Out: Total OUT	Change in storage
1	01-Jun-14	30-Sep-14	122	5912.7	0	24495	0	14.352	67.629	30489.681	0	525.01	0	500.4	3965.1	376.93	5367.44	25122.241
2	01-Oct-14	31-May-15	365	0	136.36	0	0	0	69.718	206.078	0	40.057	4595.2	320.75	4227.8	349.17	9532.98	-9326.899
3	01-Jun-15	30-Sep-15	487	5912.7	0	24495	0	8.2244	72.077	30488.001	0	432.58	0	493.38	4560.7	397.77	5884.43	24603.571
4	01-Oct-15	31-May-16	731	0	198.01	0	0	0	74.398	272.408	0	25.221	4595.2	310.91	4507.1	362.11	9800.54	-9528.133
5	01-Jun-16	30-Sep-16	853	5912.7	0	24495	0	8.4909	77.148	30493.339	0	355.01	0	476.46	4817.3	409.99	6058.76	24434.579
6	01-Oct-16	31-May-17	1096	0	257.33	0	0	0	79.536	336.866	0	14.439	4595.2	299.37	4649.2	370.55	9928.76	-9591.893
7	01-Jun-17	30-Sep-17	1218	5912.7	4.9454	24495	0	12.766	82.646	30508.057	0	291	0	461.07	4964.5	418.52	6135.09	24372.967
8	01-Oct-17	31-May-18	1461	0	308.58	0	0	0	84.989	393.569	0	3.5829	4595.2	288.55	4713.3	376.65	9977.28	-9583.7139
9	01-Jun-18	30-Sep-18	1583	5912.7	17.357	24495	0	18.141	88.393	30531.591	0	242.56	0	447.69	5037.5	425.01	6152.76	24378.831
10	01-Oct-18	31-May-19	1826	0	356.98	0	0	0	90.549	447.529	0	0	4595.2	278.92	4727.6	381.41	9983.13	-9535.601
11	01-Jun-19	30-Sep-19	1948	5912.7	27.402	24495	0	23.102	94.194	30552.398	0	202.55	0	436.74	5050.6	430.38	6120.27	24432.128
12	01-Oct-19	31-May-20	2192	0	400.29	0	0	0	96.089	496.379	0	0	4595.2	269.79	4693.3	385.31	9943.6	-9447.221
13	01-Jun-20	30-Sep-20	2314	5912.7	41.294	24495	0	27.22	99.92	30576.134	0	176.02	0	427.2	4979.6	434.96	6017.78	24558.354
14	01-Oct-20	31-May-21	2557	0	429.67	0	0	0	101.51	531.18	0	0	4595.2	262.04	4620.8	389.04	9867.08	-9335.9
15	01-Jun-21	30-Sep-21	2679	5912.7	52.477	24495	0	30.587	105.5	30596.264	0	160.91	0	419.49	4893.1	439.45	5912.95	24683.314
16	01-Oct-21	31-May-22	2922	0	445.47	0	0	0	106.77	552.24	0	0	4595.2	254.09	4589.6	392.7	9831.59	-9279.35
17	01-Jun-22	30-Sep-22	3044	5912.7	58.75	24495	0	35.239	110.89	30612.579	0	156.02	0	412.56	4852.4	443.8	5864.78	24747.799
18	01-Oct-22	31-May-23	3287	0	448.51	0	0	0	111.84	560.35	0	0	4595.2	245.14	4575.3	396.17	9811.81	-9251.46
19	01-Jun-24	30-Sep-23	3409	5912.7	59.842	24495	0	41.695	116.07	30625.307	0	156.16	0	405.44	4838.6	447.89	5848.09	24777.217
20	01-Oct-23	31-May-24	3652	0	0	0	0	0	116.71	116.71	0	0	4595.2	223.85	4557.7	399.39	9776.14	-9659.43

Zone 5 Quartzite & Phyllite

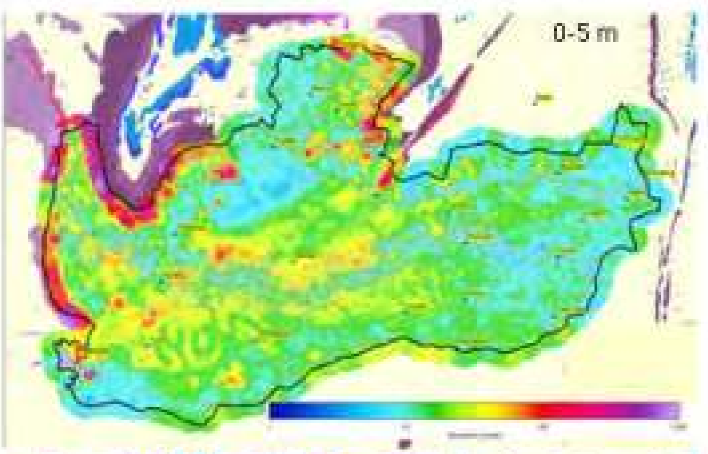
Stress Period	From	To	Time in day	In: WELLS	In: HEAD DEP BOUNDS	In: RECHARGE	In: Zone 2 to 5	In: Zone 4 to 5	In: Total IN	Out: WELLS	Out: HEAD DEP BOUNDS	Out: RECHARGE	Out: Zone 5 to 2	Out: Zone 5 to 4	Out: Total OUT	Change in storage
1	01-Jun-14	30-Sep-14	122	18.447	0	23803	0	376.93	24198.38	0	517.69	0	3106.9	67.629	3692.219	20506.16
2	01-Oct-14	31-May-15	365	0	47.131	0	0	349.17	396.301	0	191.28	6098.8	2864.9	69.718	9224.698	-8828.4
3	01-Jun-15	30-Sep-15	487	18.447	0	23803	0	397.77	24219.22	0	420.25	0	3342.4	72.077	3834.727	20384.49
4	01-Oct-15	31-May-16	731	0	64.187	0	0	362.11	426.297	0	177.6	6098.8	2946.9	74.398	9297.698	-8871.4
5	01-Jun-16	30-Sep-16	853	18.447	0	23803	0	409.99	24231.44	0	392.99	0	3426.1	77.148	3896.238	20335.2
6	01-Oct-16	31-May-17	1096	0	78.046	0	0	370.55	448.596	0	169.17	6098.8	2992.2	79.536	9339.706	-8891.11
7	01-Jun-17	30-Sep-17	1218	18.447	0.44861	23803	0	418.52	24240.42	0	372.2	0	3484.8	82.646	3939.646	20300.77
8	01-Oct-17	31-May-18	1461	0	89.718	0	0	376.65	466.368	0	161.93	6098.8	3002.1	84.989	9347.819	-8881.45
9	01-Jun-18	30-Sep-18	1583	18.447	10.603	23803	0	425.01	24257.06	0	363.87	0	3513.8	88.393	3966.063	20291
10	01-Oct-18	31-May-19	1826	0	99.442	0	0	381.41	480.852	0	155.92	6098.8	2984.3	90.549	9329.569	-8848.72
11	01-Jun-19	30-Sep-19	1948	18.447	20.044	23803	0	430.38	24271.87	0	358	0	3513.6	94.194	3965.794	20306.08
12	01-Oct-19	31-May-20	2192	0	109.31	0	0	385.31	494.62	0	151.86	6098.8	2935.2	96.089	9281.949	-8787.33
13	01-Jun-20	30-Sep-20	2314	18.447	28.055	23803	0	434.96	24284.46	0	352.64	0	3456.7	99.92	3909.26	20375.2
14	01-Oct-20	31-May-21	2557	0	117.99	0	0	389.04	507.03	0	149.91	6098.8	2897.5	101.51	9247.72	-8740.69
15	01-Jun-21	30-Sep-21	2679	18.447	34.421	23803	0	439.45	24295.32	0	348.51	0	3415.4	105.5	3869.41	20425.91
16	01-Oct-21	31-May-22	2922	0	125.92	0	0	392.7	518.62	0	148.99	6098.8	2848.2	106.77	9202.76	-8684.14
17	01-Jun-22	30-Sep-22	3044	18.447	39.445	23803	0	443.8	24304.69	0	345.3	0	3339.1	110.89	3795.29	20509.4
18	01-Oct-22	31-May-23	3287	0	131.86	0	0	396.17	528.03	0	148.49	6098.8	2842.4	111.84	9201.53	-8673.5
19	01-Jun-24	30-Sep-23	3409	18.447	43.21	23803	0	447.89	24312.55	0	342.92	0	3329.3	116.07	3788.29	20524.26
20	01-Oct-23	31-May-24	3652	0	0	0	0	399.39	399.39	0	0	6098.8	2830.7	116.71	9046.21	-8646.82

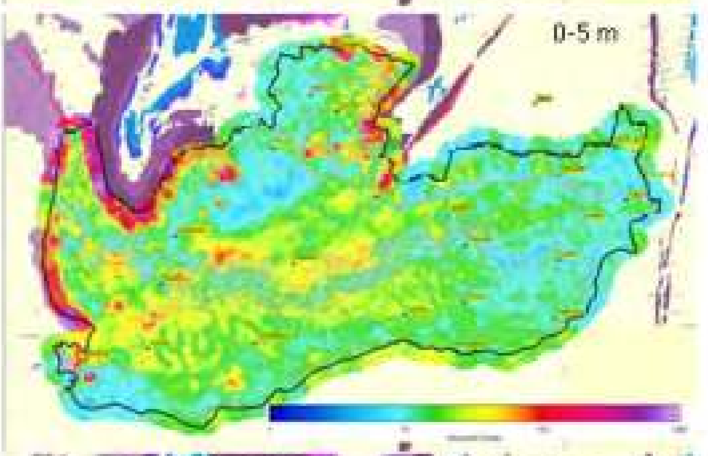
Appendix –I

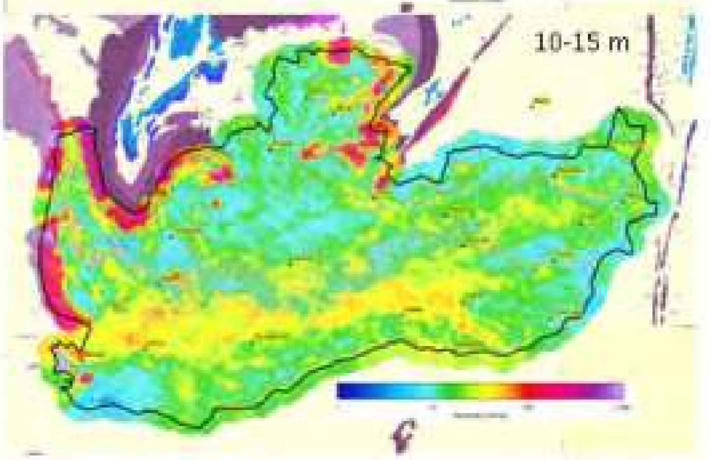
Mean Resistivity Maps

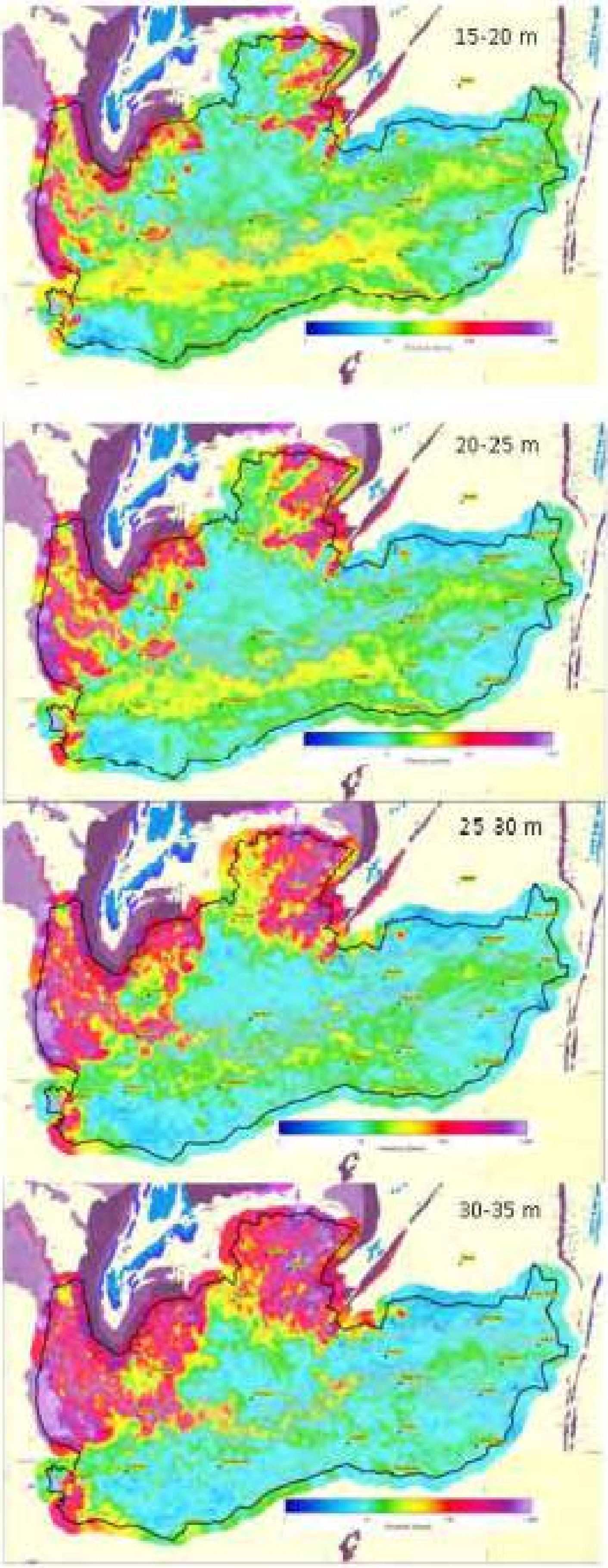
This appendix shows mean resistivity maps generated from the smooth model inversion result.

The mean resistivity maps have been generated in 5 m elevation intervals down to a depth of 150m belowground. Models below the GDI lower have been blinded. The gridding is done using the Kriging method, with a node spacing of 25 m and a search radius of 500 m. The nodes have further been subdivided by a factor of 4 to obtain the interpolated resistivity pixels for the bitmaps that make up the maps.

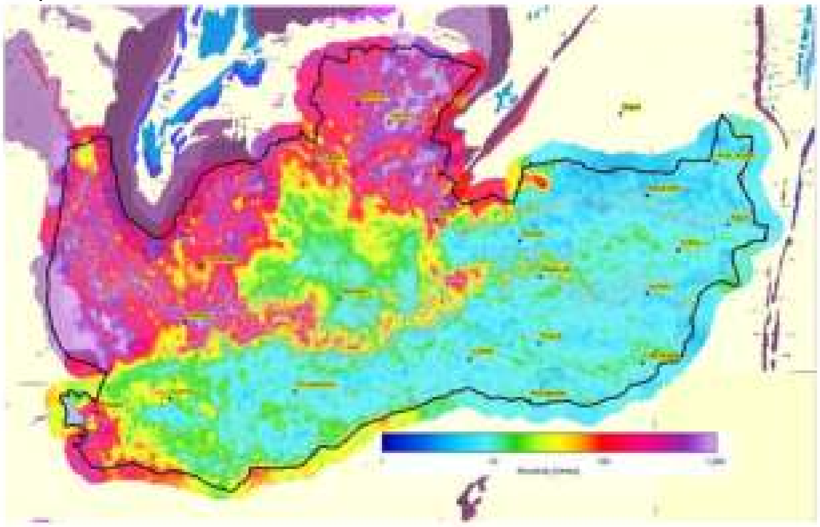




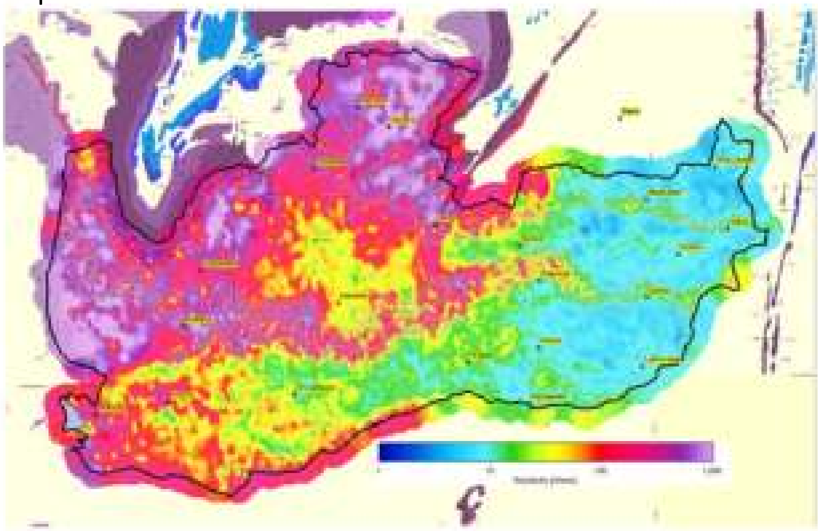



15-20 m
20-25 m
25-30 m
30-35 m

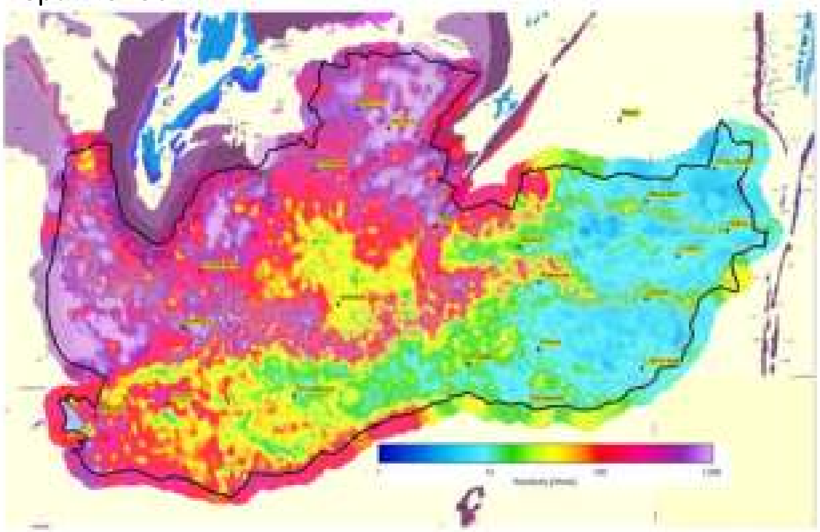
Depth 35- 40 m



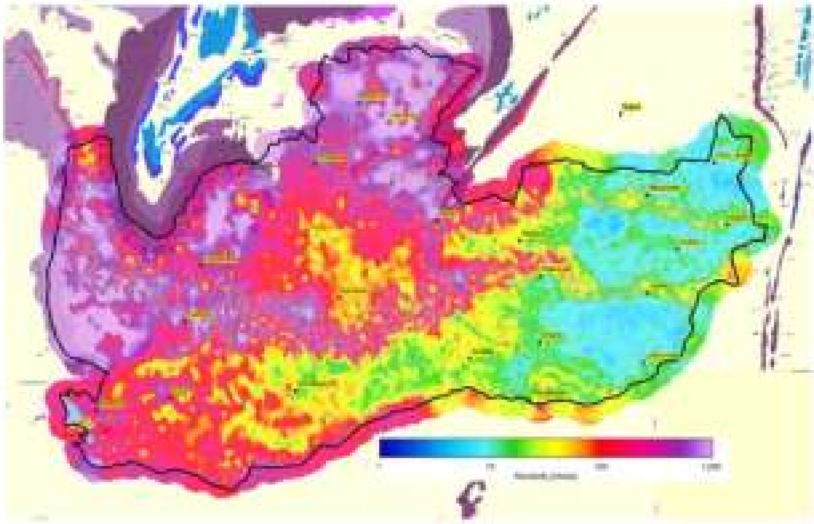
Depth 40- 45 m



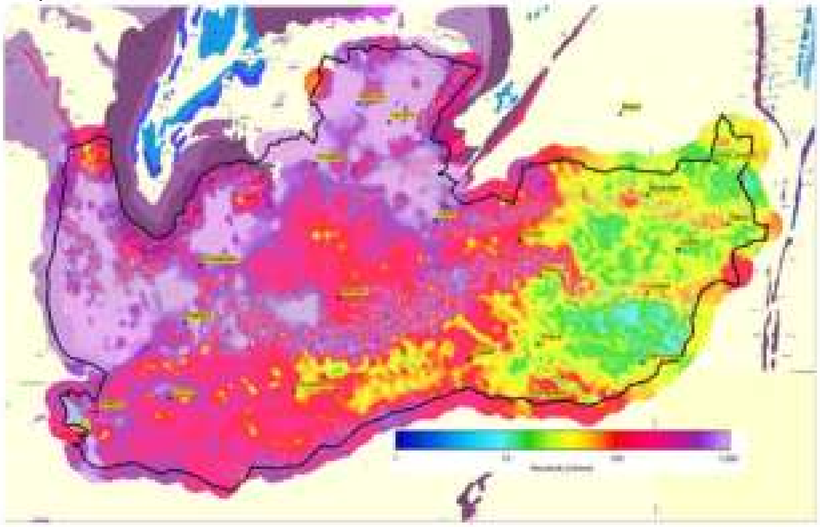
Depth 45- 50 m



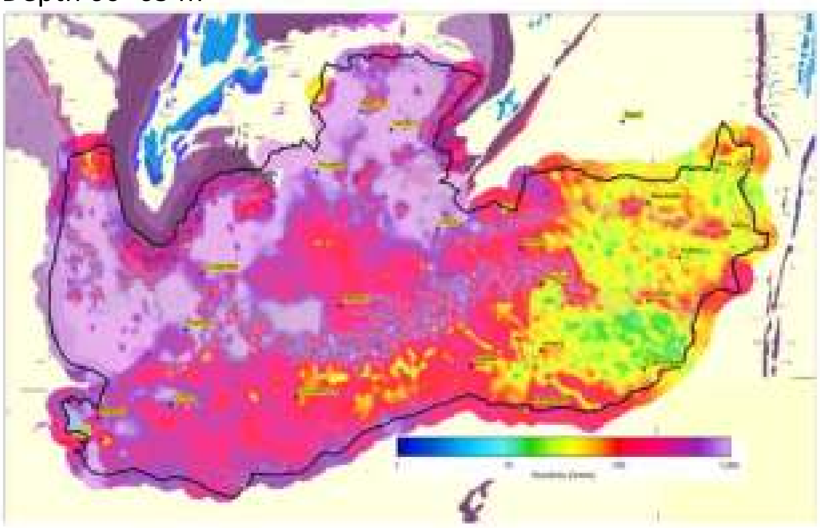
Depth 50- 55 m



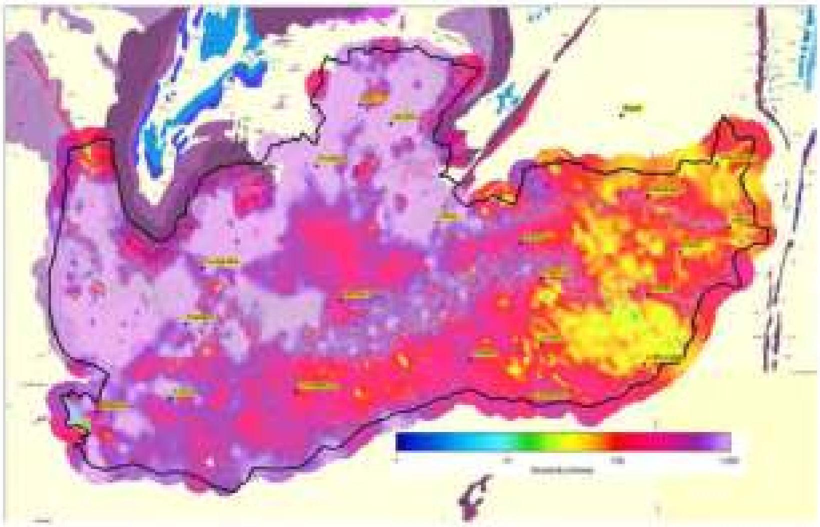
Depth 55- 60 m



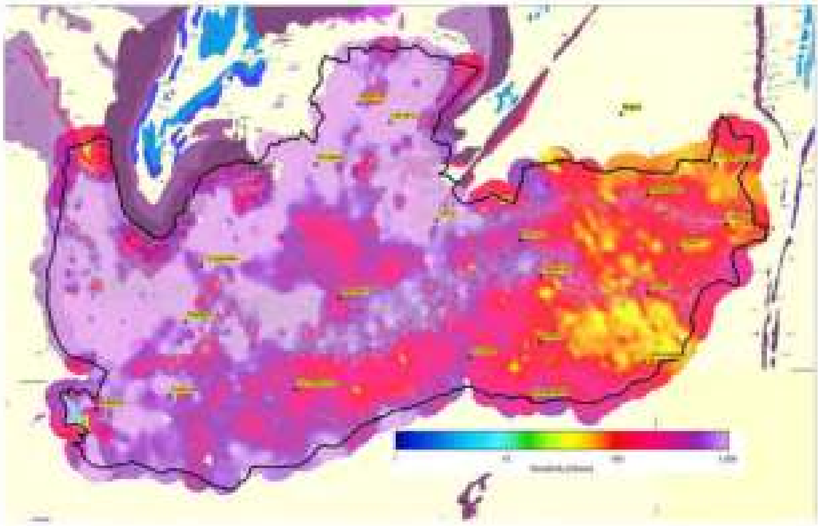
Depth 60- 65 m



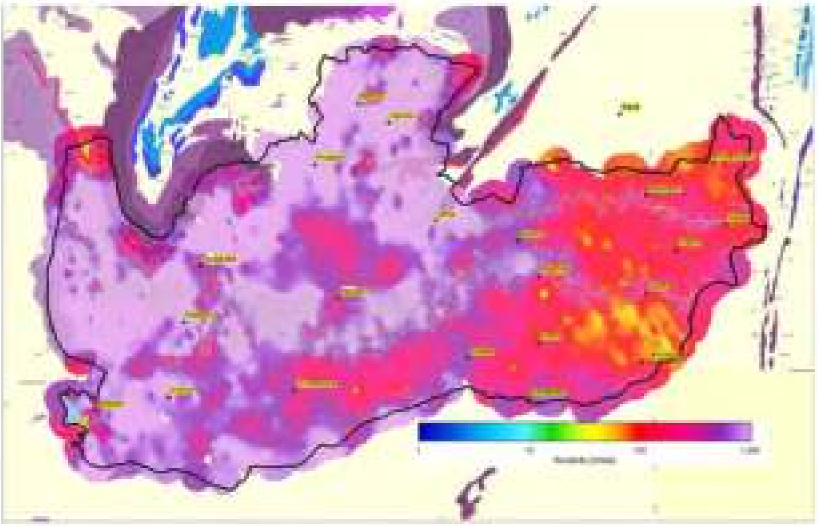
Depth 70- 75 m



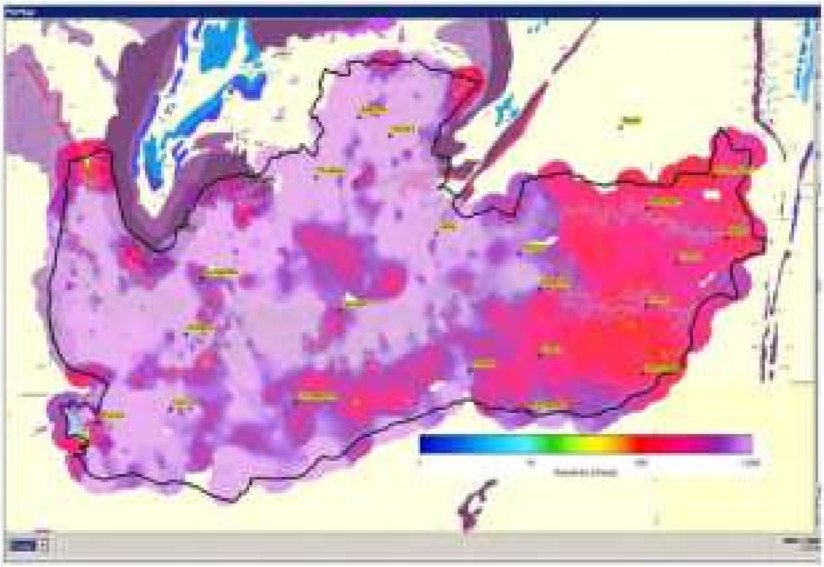
Depth 75- 80 m



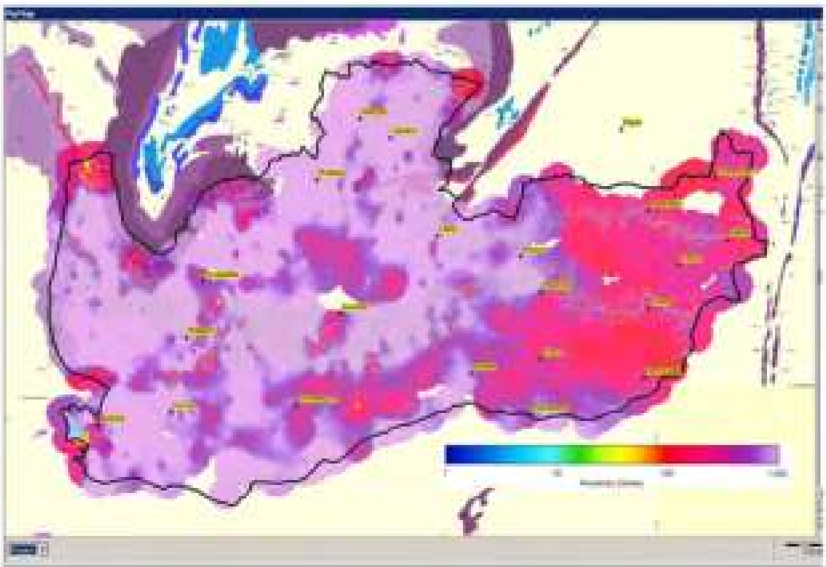
Depth 80- 85 m



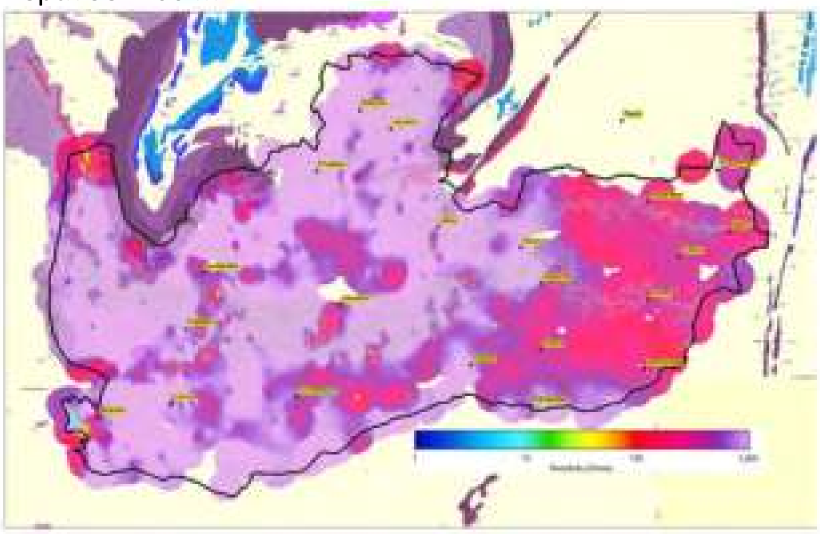
Depth 85- 90 m



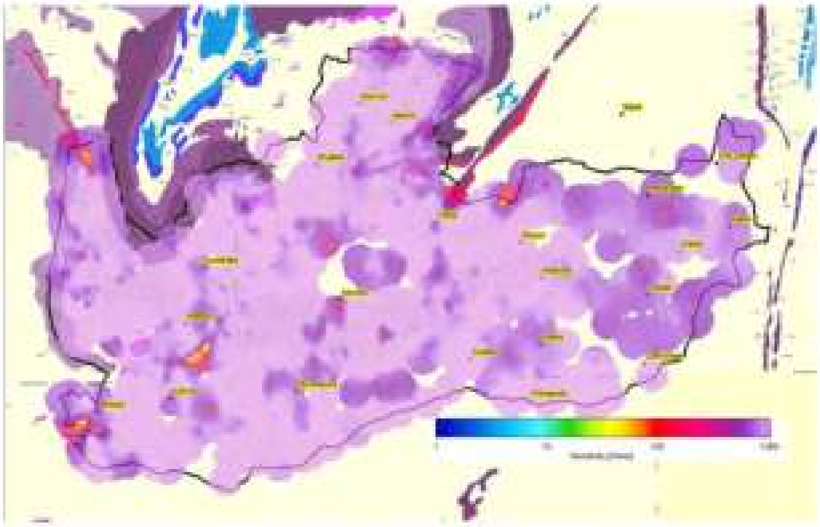
Depth 90- 95 m



Depth 95- 100 m



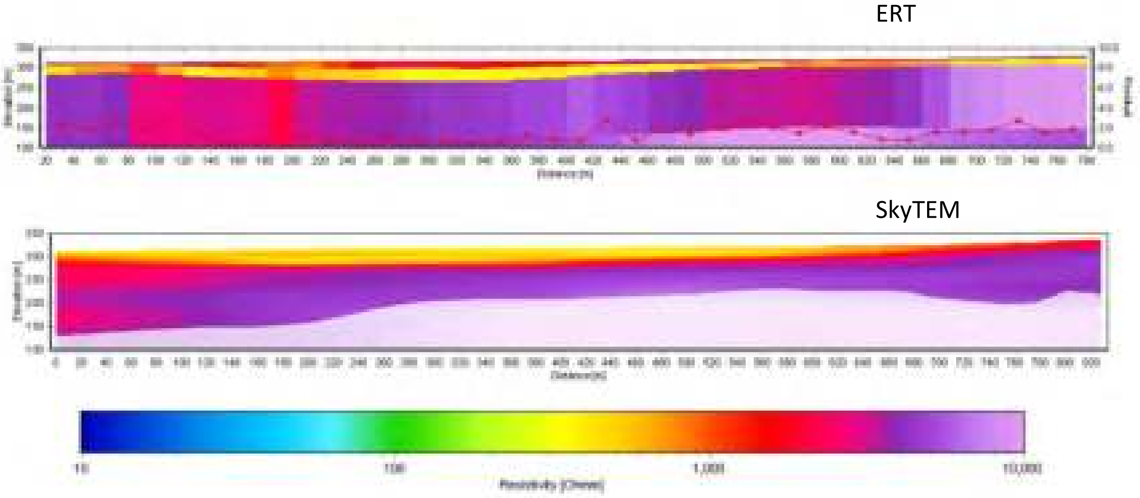
Depth 95- 100 m



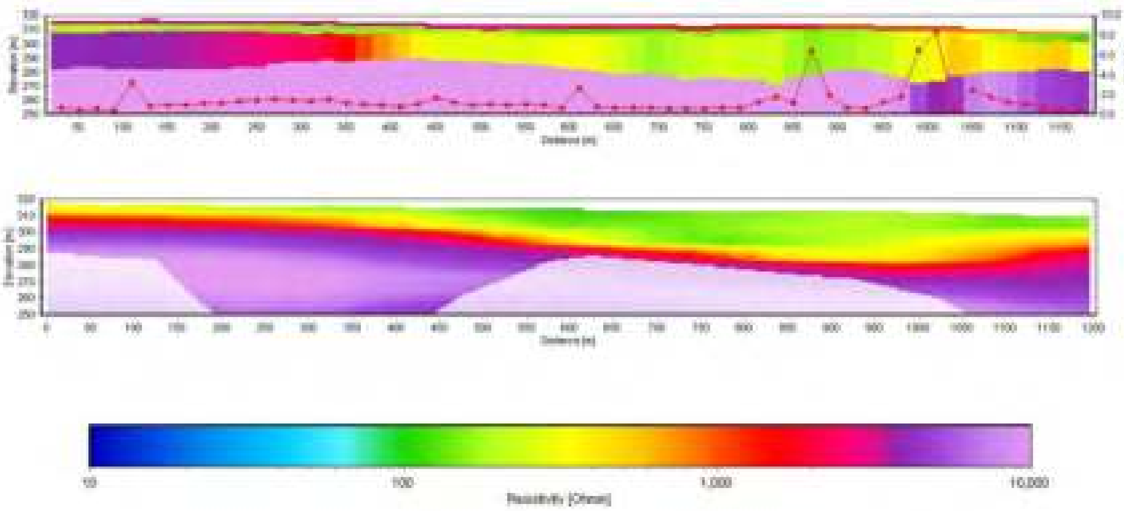
APPENDIX-II

COMPARATIVE PERFORMANCE OF SKYTEM VS ERT SECTIONS

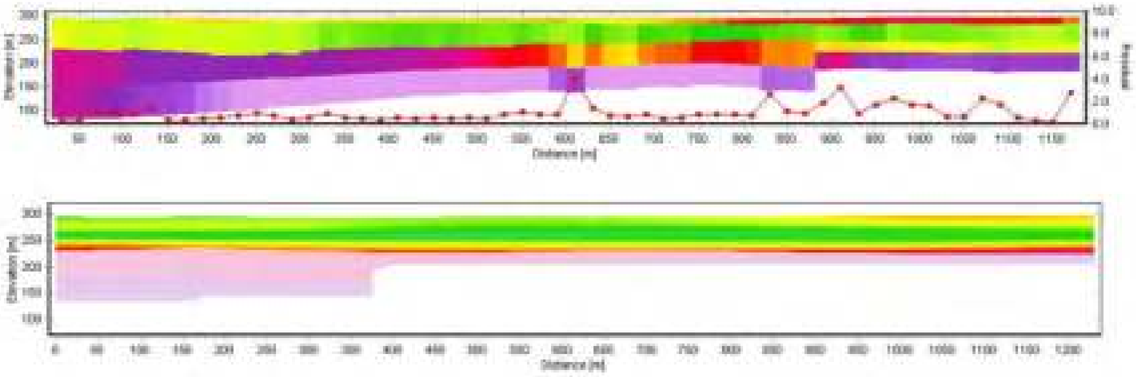
2. Radia Dam_GRP



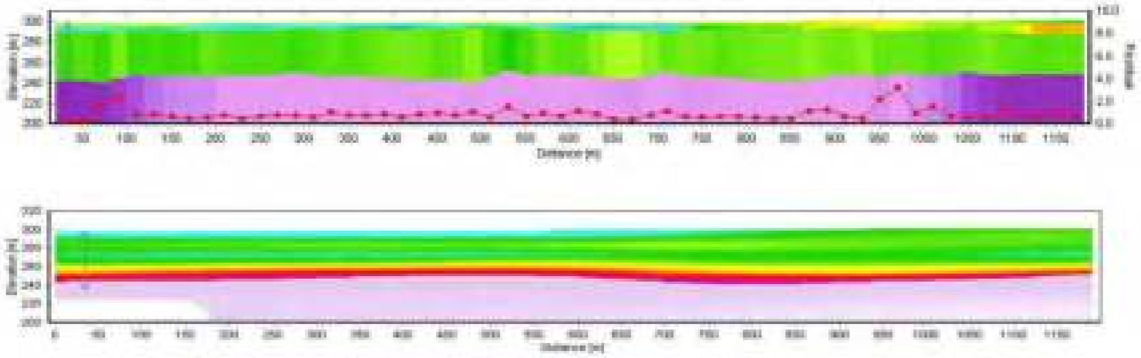
4. Chaubdiwala_GRP



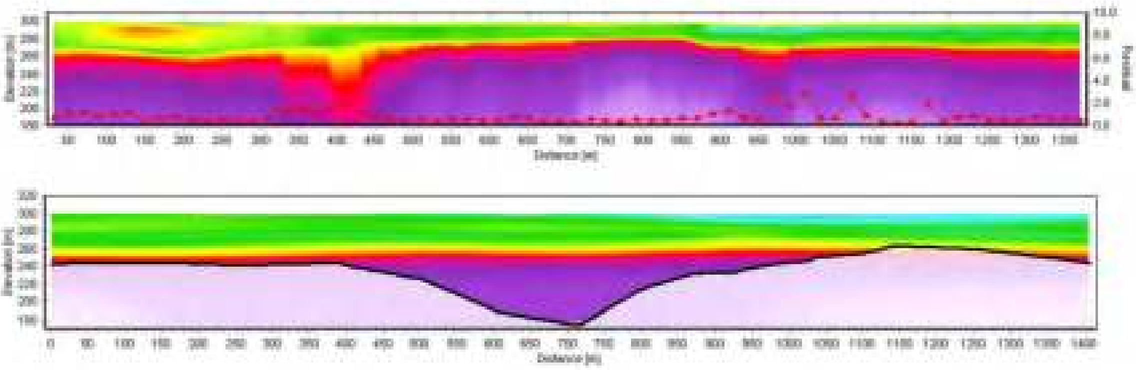
5. Pichpura_GRP



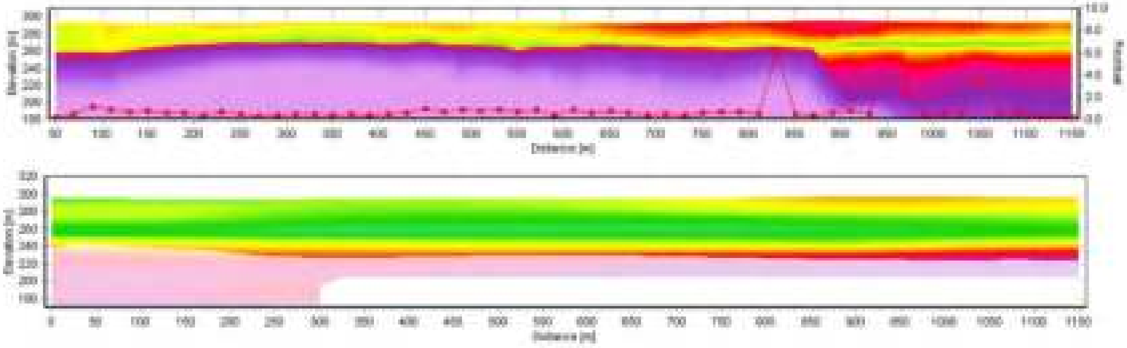
6. Kolana_GRP



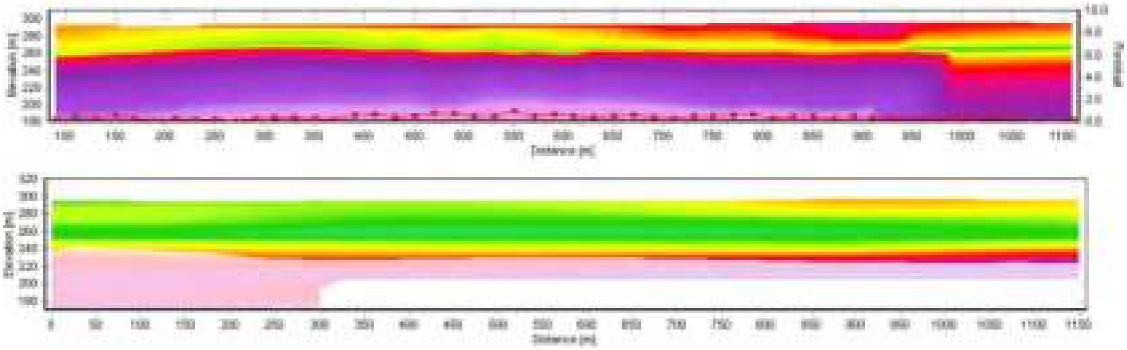
7. Pulala_GRP



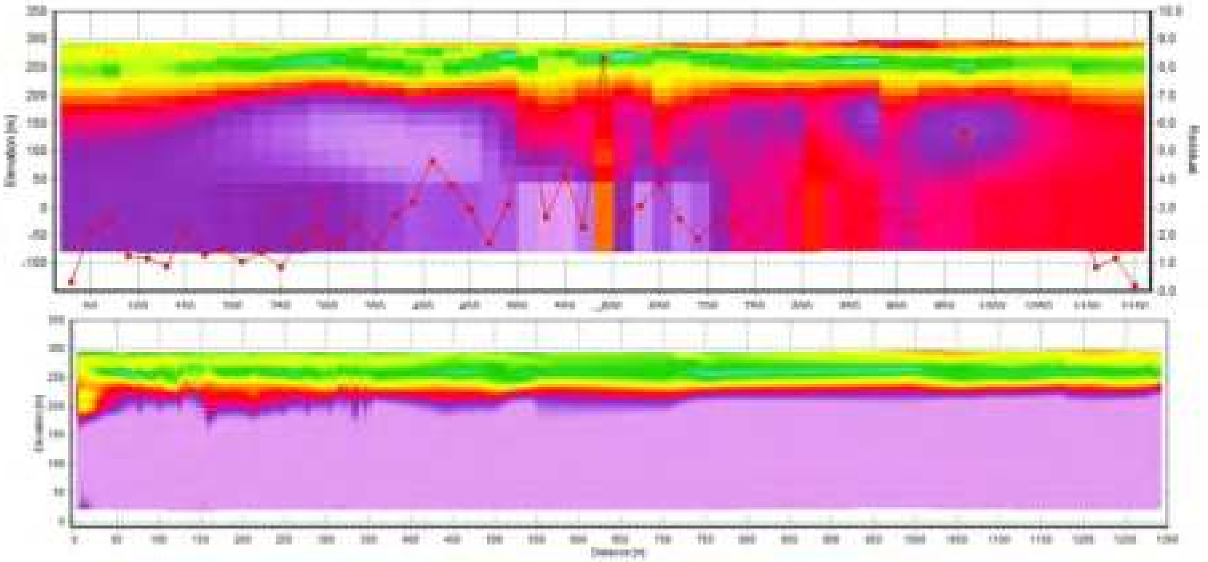
8. Pichpura_GRP

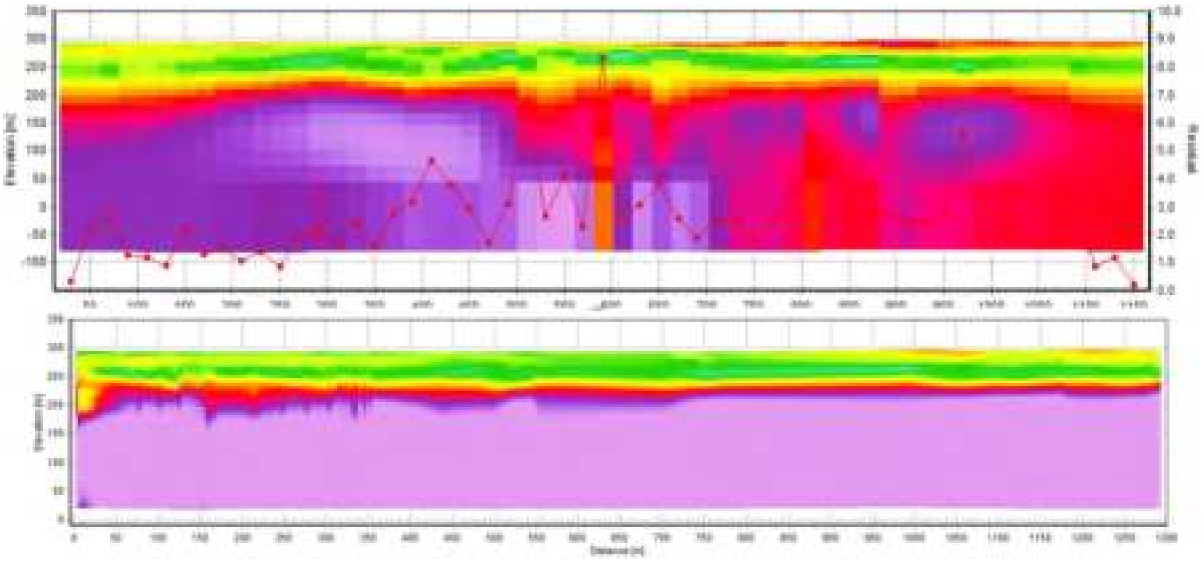


9. Pichpura_Wenner

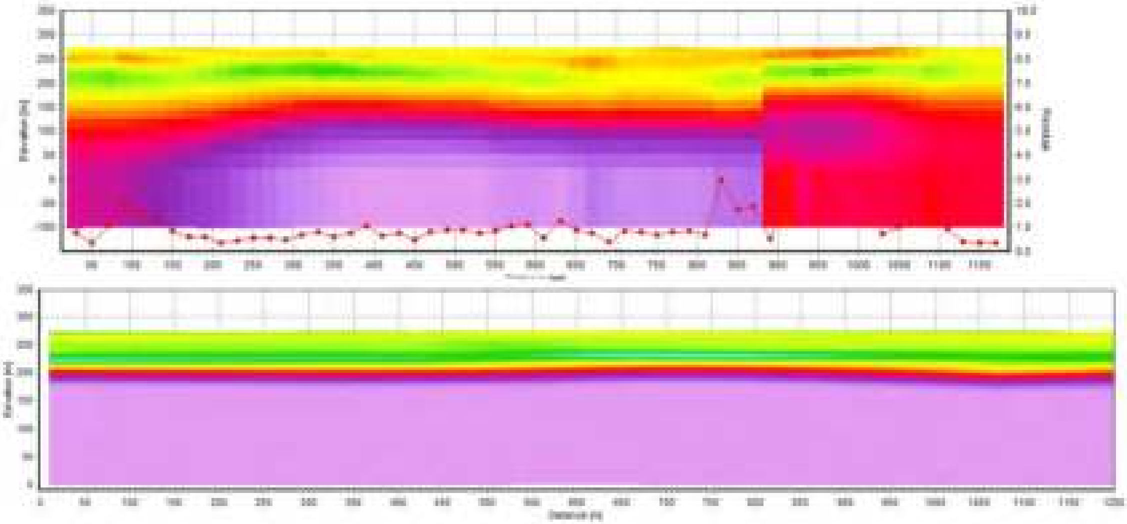


10. Pichpura_DD

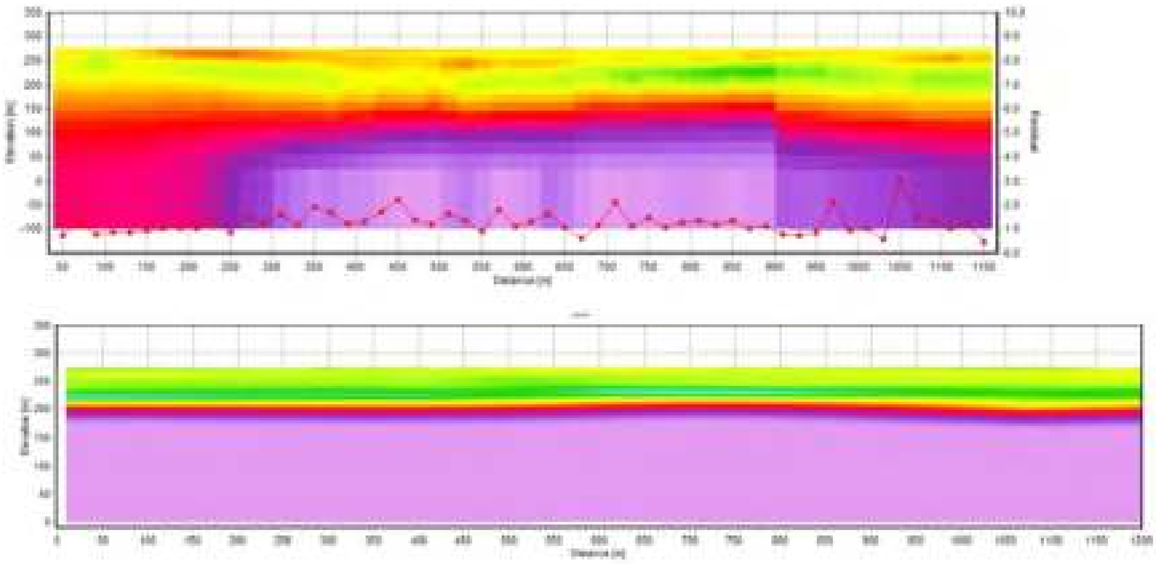




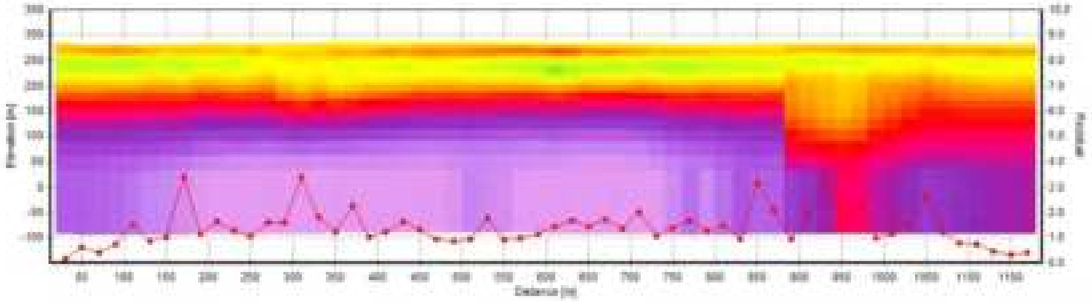
15.Tikariya_Forward

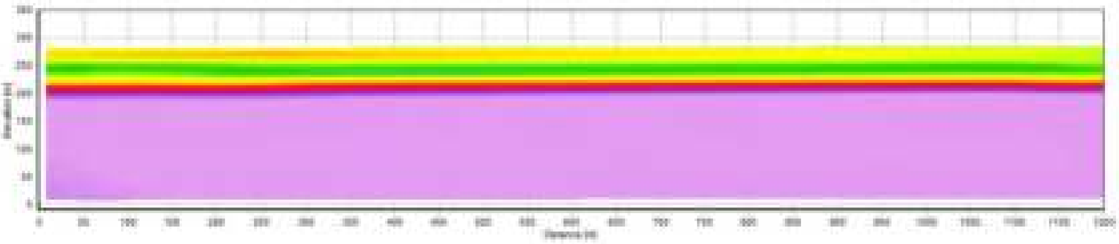


16.Tikariya_Reverse

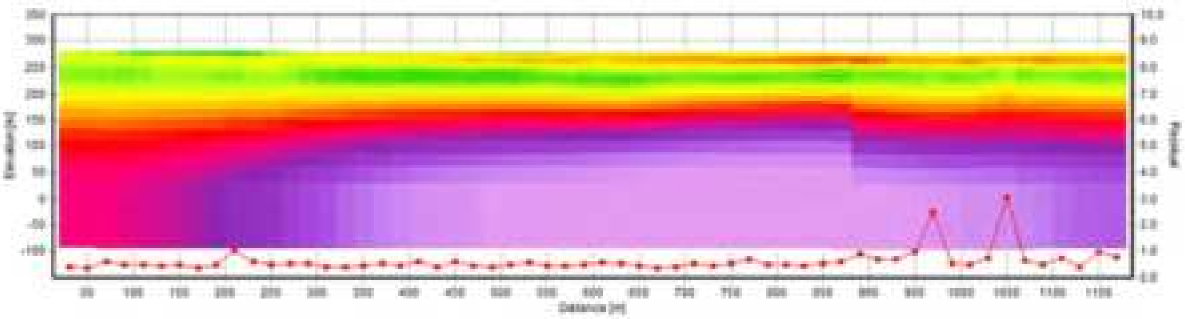


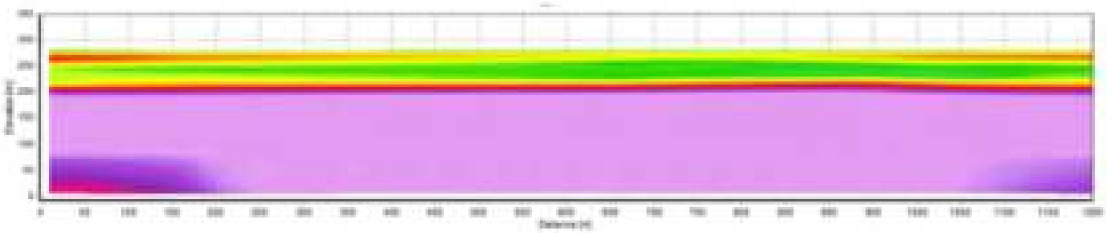
17.Jhopadiya



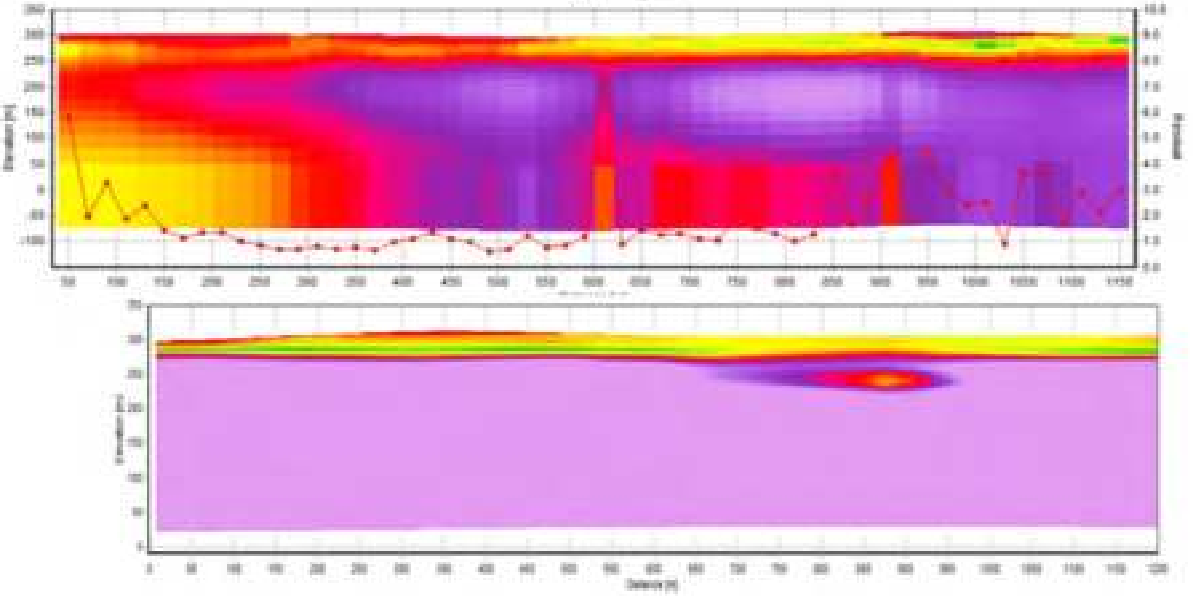


18.Rampura

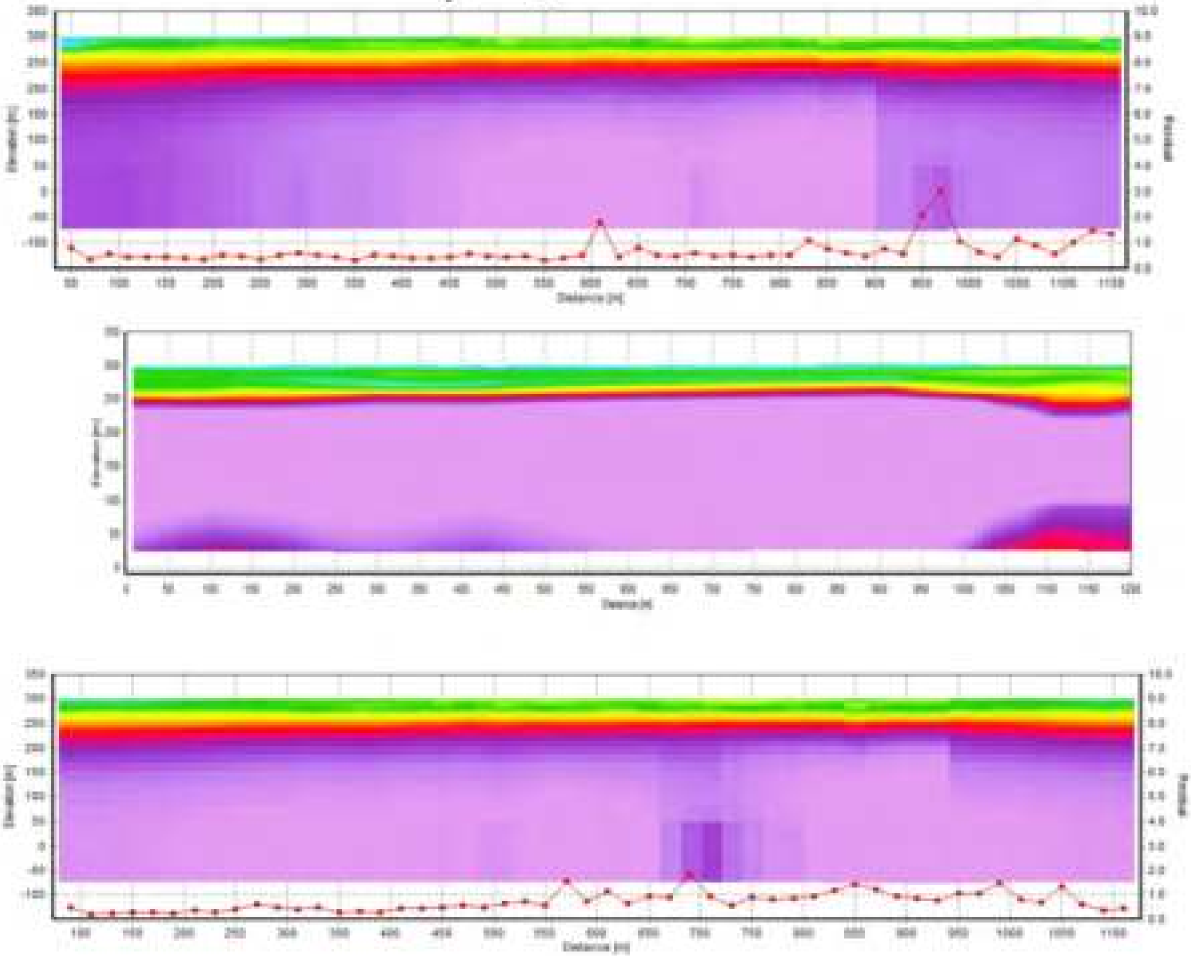




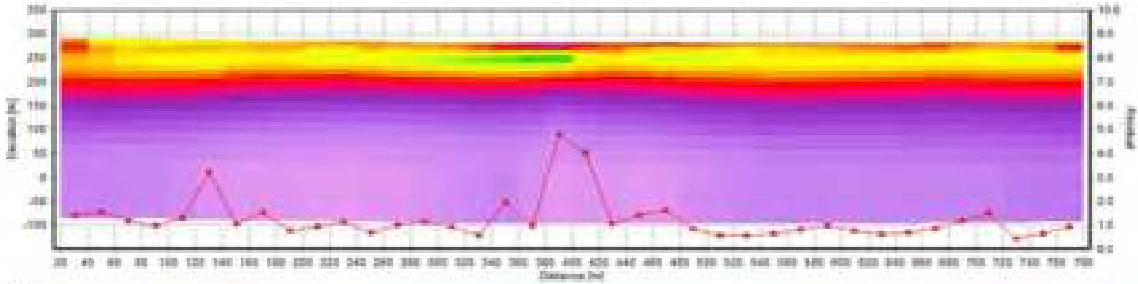
19.Dolkiya_

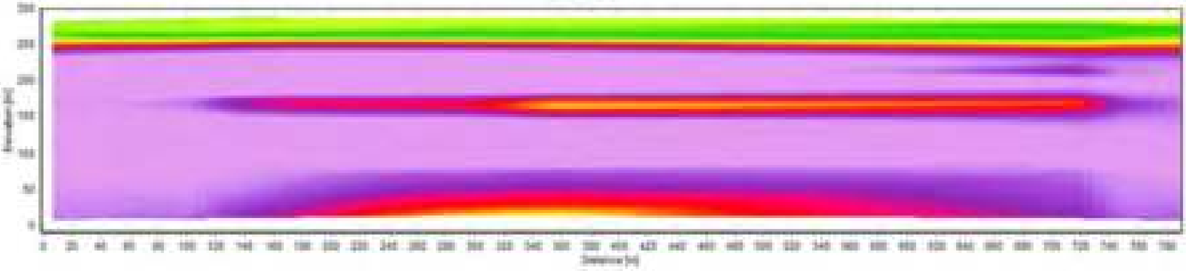


21.Badiyal_GF

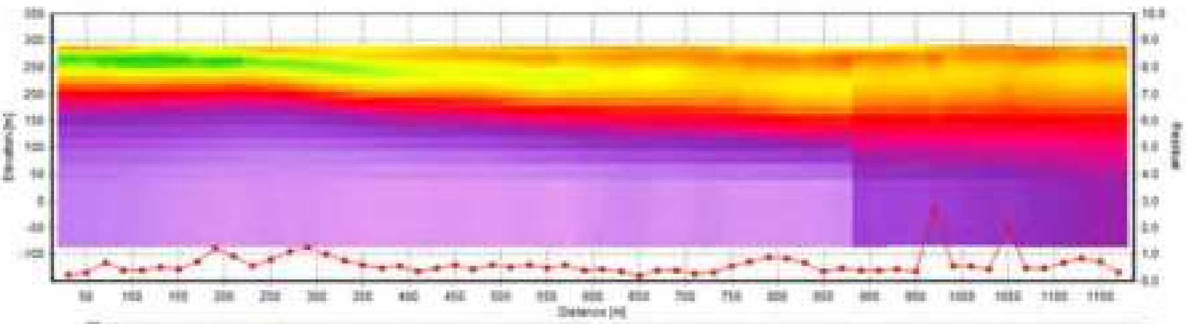


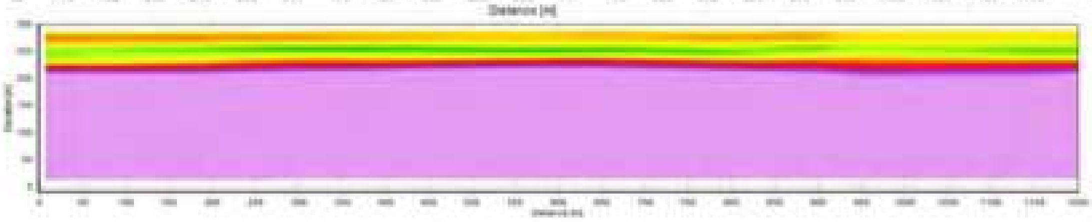
23.Shaliwas_GF



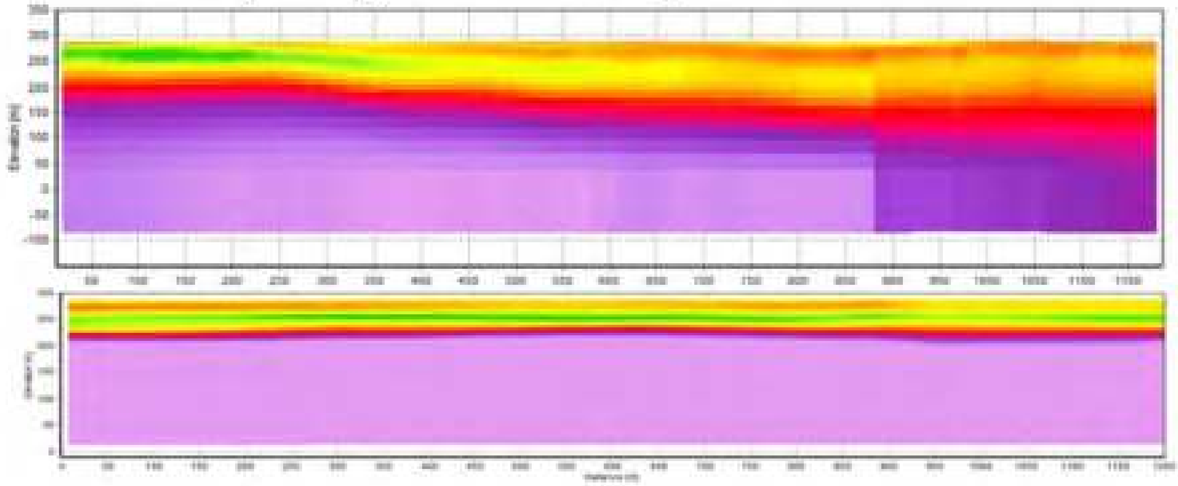


25.Janiya ka Bas_176

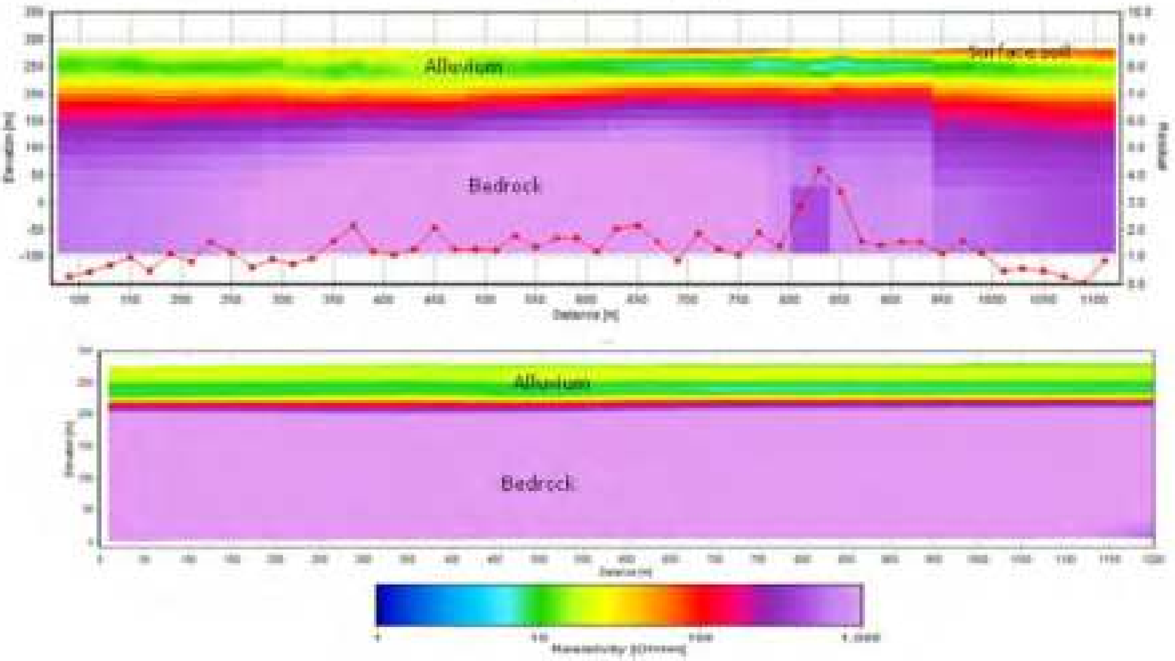




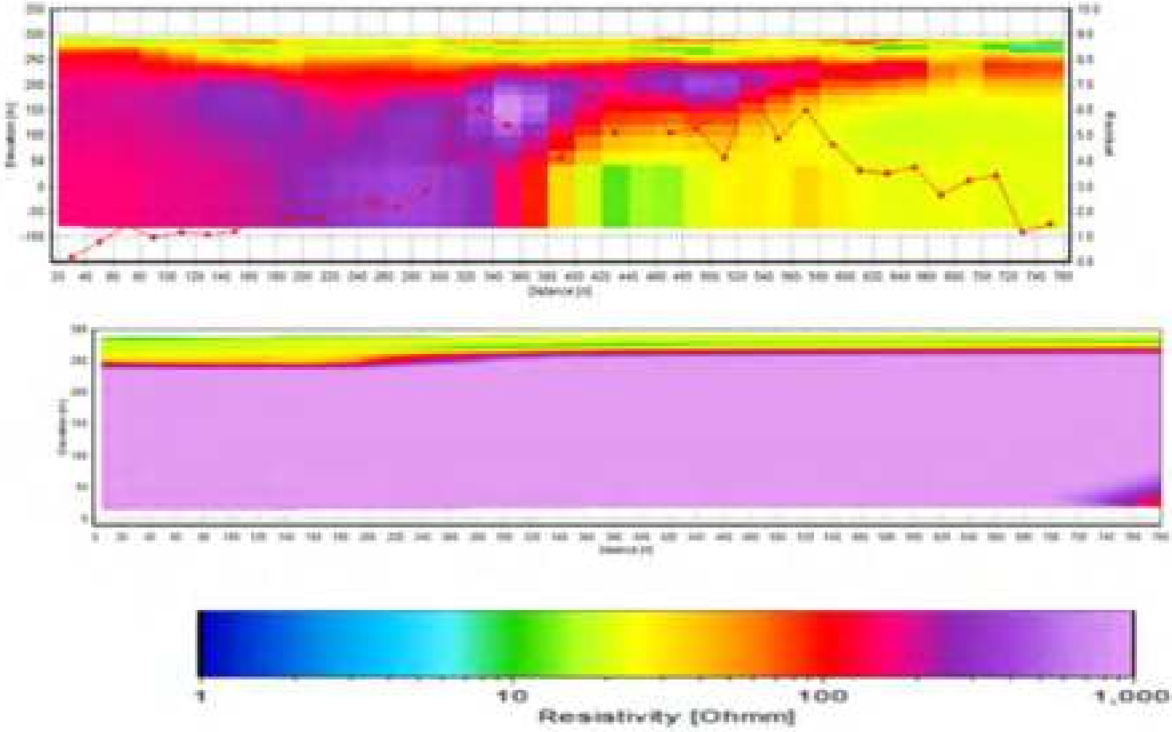
26.Janiya ka Bas_172



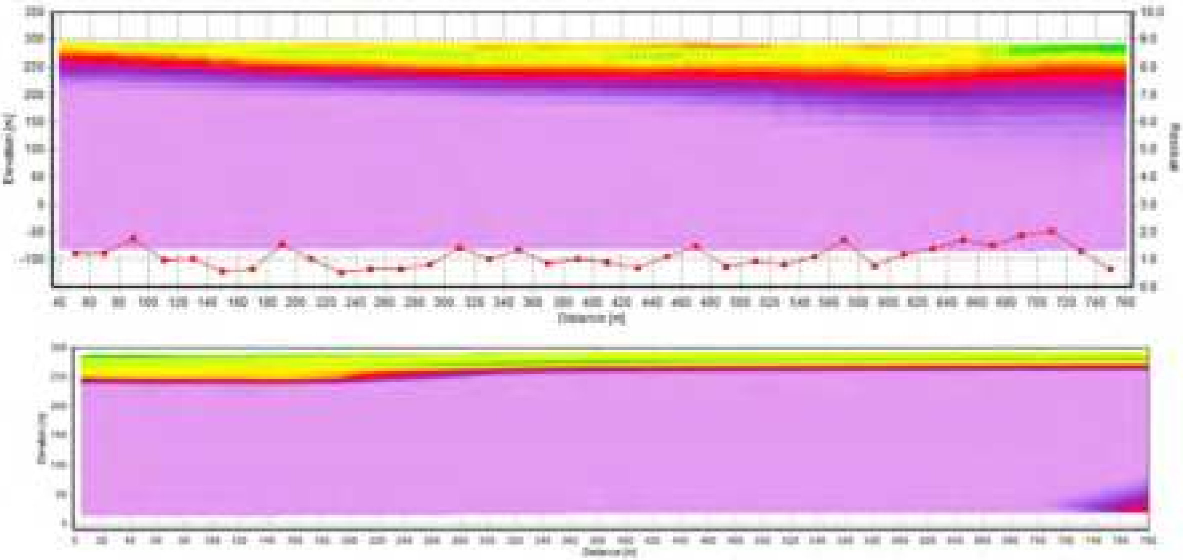
Nurpur_S



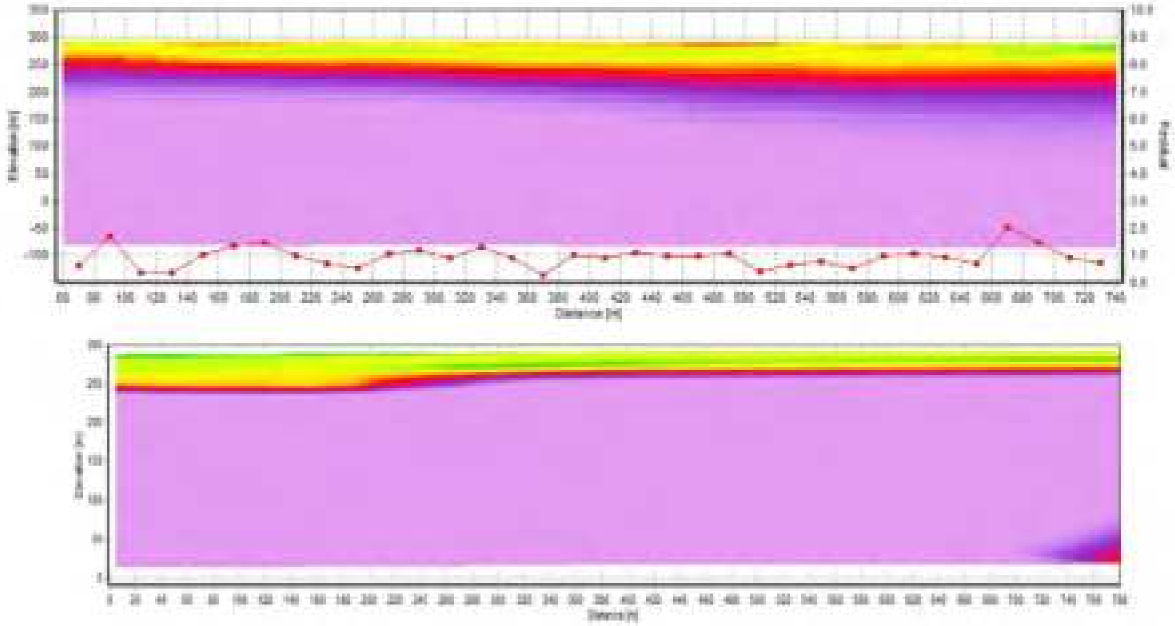
28.Golana_DD



29.Golana_GF



30.Golana_W

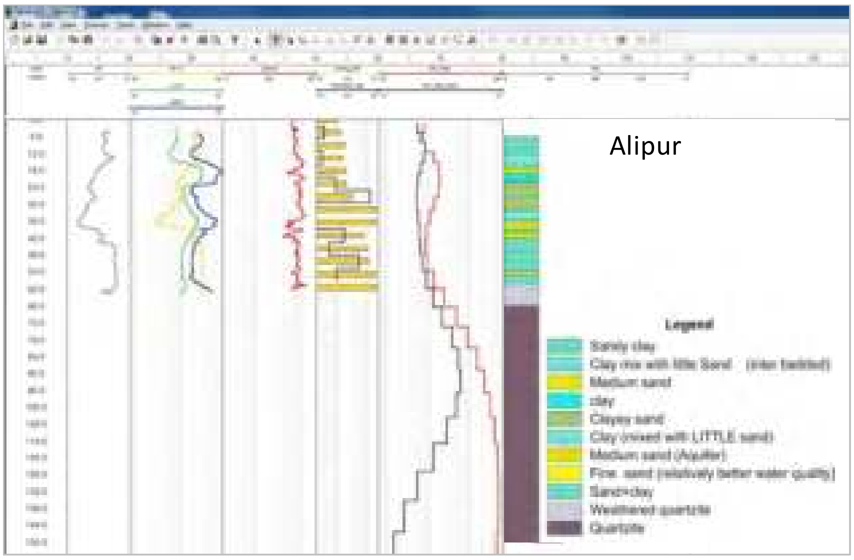


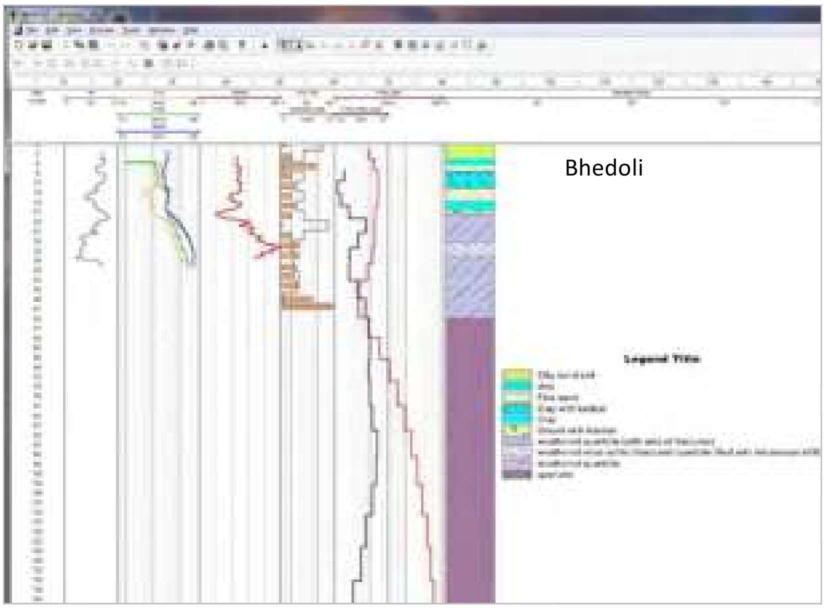
Notation: S- Schlumberger; GF- Multiple gradient; dd-Dipole-dipole; W-Wenner

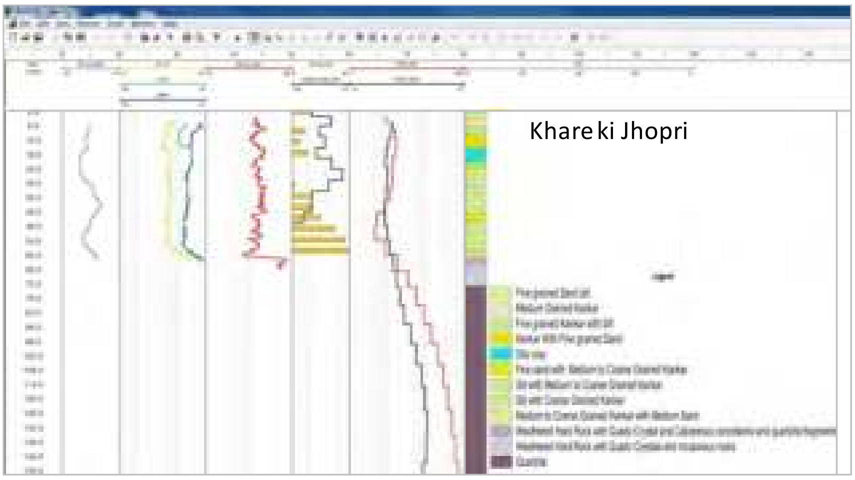
APPENDIX-III

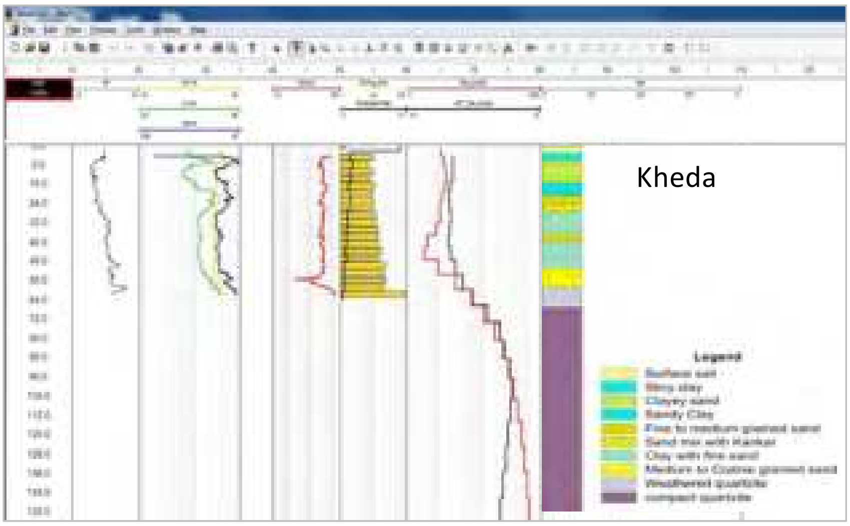
VALIDATION AND DATA INTEGRATION

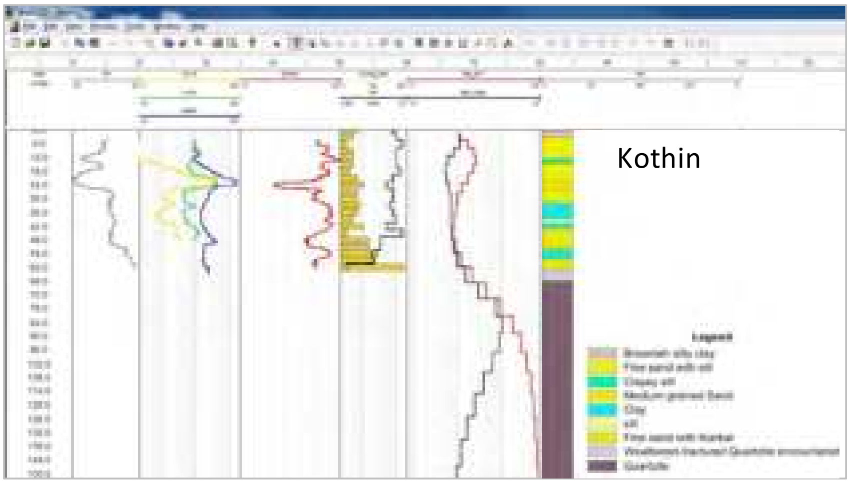
S. no.	Site	Latitude	Longitude	Depth(m)	Detail Location
6	**Alipur**	27.0783	76.7942	63	In the campus of govt primary school
11	**KharikiJhopdi**	27.11123	76.78726	67	In the premises of Primary School
3	**Khera**	27.0164	76.6814	63	In the premises of Government School.
7	**Kothin**	27.065	76.6814	61	In front of govt primary school on govt land
1	**Lotwara East 1**	27.0056	76.7428	77	In the premises of Government Hospital
13	**Lotwara East 2**			83	In the premises of Upper Primary girls School
12	**Maukalan**	27.09479	76.74659	90	In the premises of Primary School
5	**Nurpur**	27.07119	76.67036	55	In the premises of Government School
4	**Ralaota**	27.05209	76.68204	61	Near Temple of the village
2	**Ranapada**	26.9867	76.6747	63	At the entrance of village near river bed, behind temple .
10	**Shyamsinghpura**	26.99291	76.53491	52	In the campus of Govt Middle School
8	**Sodala**	27.01197	76.74591	57	In the campus of Govt Middle School
9	**Sumel**	27.04217	76.74591	67	In the campus of Govt Primary School
					Source: CGWB

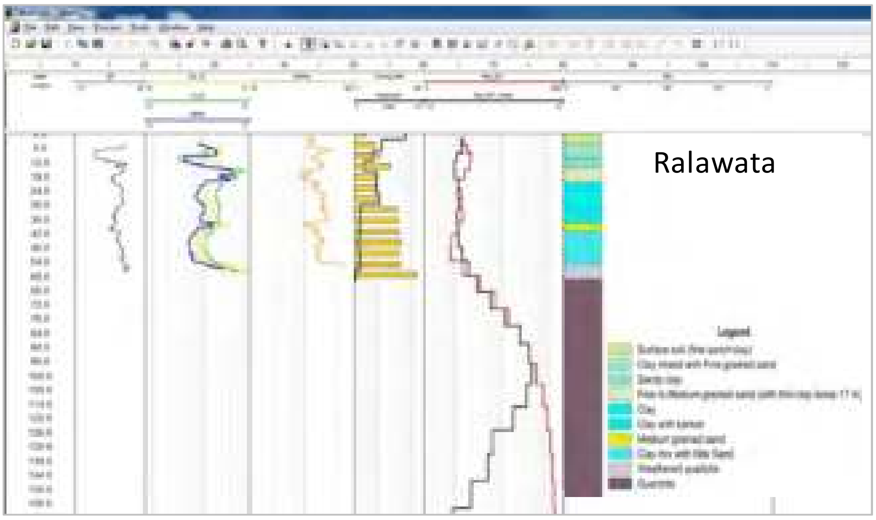

Alipur
Legend
Sandy clay
Clay mix with little Sand (inter bedded)
Medium sand
clay
Clayey sand
Clay (mixed with LITTLE sand)
Medium sand (Aquifer)
Fine sand (relatively better water quality)
Sand+clay
Weathered quartzite
Quartzite

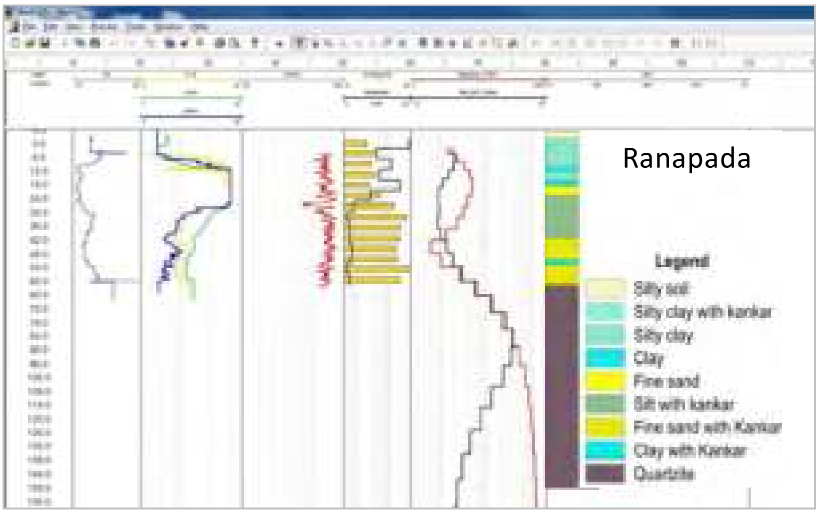

Bhedoli
Legend Title

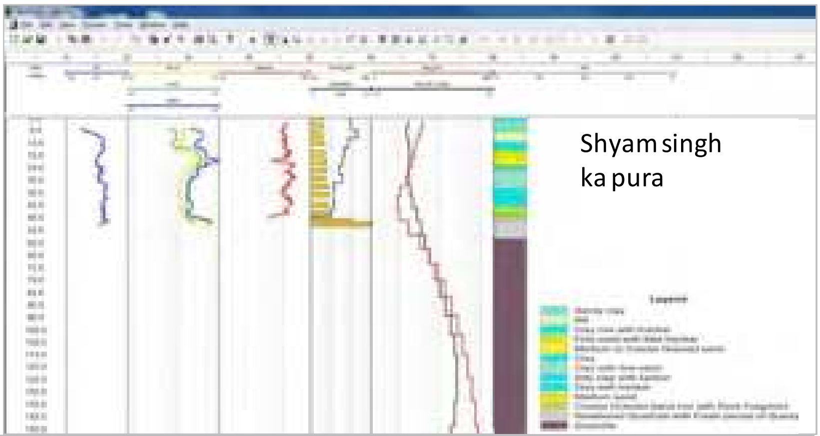

Khare ki Jhopri

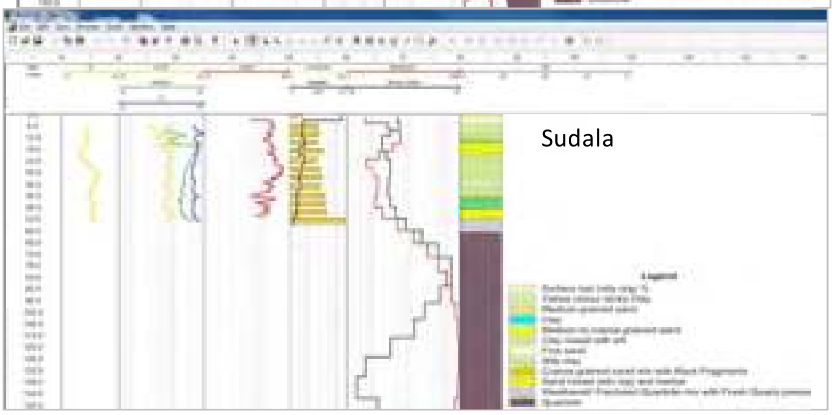

Kheda

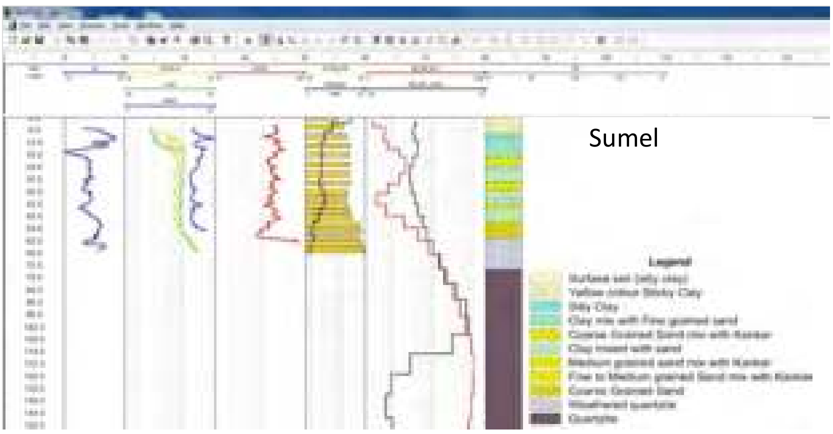

Kothin


Ralawata


Ranapada
Legend
Silty soil
Silty clay with kankar
Silty clay
Clay
Fine sand
Silt with kankar
Fine sand with Kankar
Clay with Kankar
Quartzite


Shyam singh ka pura


Sudala


Sumel

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