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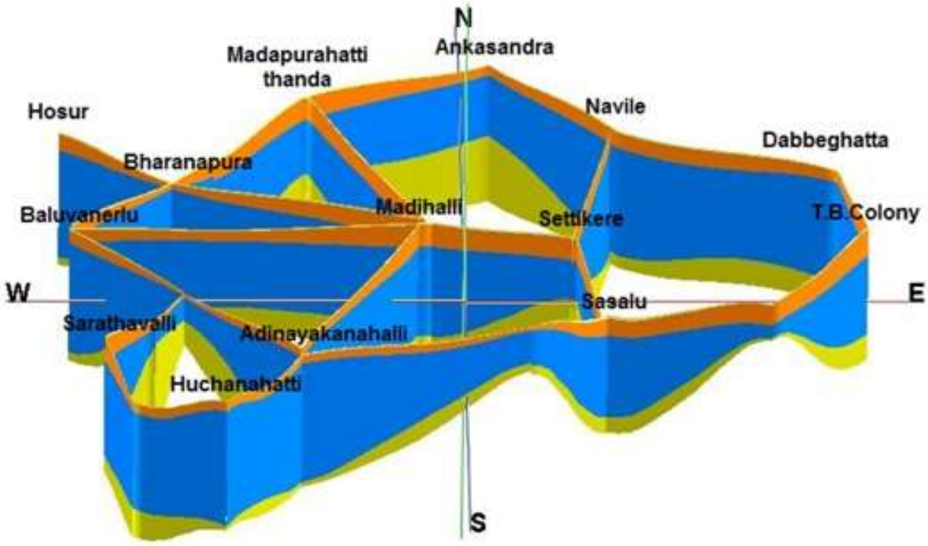
केंद्रीय भूमि जल बोर्ड

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

CENTRAL GROUND WATER BOARD



अंकसंद्रा जल विभाजन भाग, तिपटूर और सी.एन.हल्ली तालुक, तुमकुर जिला, कर्नाटक की प्रायोगिक जल भूतमान चित्रण परियोजना का प्रतिवेदन

PILOT PROJECT ON AQUIFER MAPPING IN ANKASANDRA WATERSHED, PARTS OF TIPTUR & C.N.HALLI TALUKS, TUMKUR DISTRICT, KARNATAKA

दक्षिण पश्चिम क्षेत्र,बेंगलूरु
दिसम्बर-2015

SOUTH WESTERN REGION, BANGALORE
DECEMBER 2015

K. B. Biswas
Chairman

सत्यमेव जयते

केन्द्रीय भूमि जल बोर्ड
जल संसाधन, नदी विकास
एवं गंगा संरक्षण मंत्रालय
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Central Ground Water Board
Ministry of Water Resources,
River Development and Ganga Rejuvenation
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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.

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PREFACE

An accurate and comprehensive micro-level scenario of ground water through aquifer mapping in different hydrogeological setting enables robust ground water management plans up to village level. The paradigm shift from development to management of ground water during the last one decade has necessitated the need for a reliable comprehensive aquifer maps on larger scale for equitable and sustainable management of the ground water resources at local scale. Aquifer mapping study involves integration of multidisciplinary scientific aspects including geological, hydrogeological, geophysical, hydrological, hydrogeochemical and ground water modeling. This helps to characterize the quantity, quality and ground water movement in the aquifers and their optimal management plans.

In view of the wide range in options for ground water resources management, **Central Ground Water Board (CGWB), South Western Region, Bangalore, Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR, RD & GR), Government of India** has carried out **"Pilot project on Aquifer Mapping in Ankasandra Watershed, parts of Tiptur and C.N.Halli taluks, Tumkur district, Karnataka"** covering an area of 375 sq.km representing a hard rock terrain.

The main objectives of the study are (i) identification and mapping of aquifers, (ii) quantification of the available ground water resources, (iii) preparation of appropriate management plans as per demand and supply, (iv) aquifer characterisation and (v) institutional arrangements for participatory management. Based upon these studies, a resource-based management plan is suggested through an integrated approach and two major aquifer management plans have been recommended viz., 'villages favourable for ground water development' and 'villages not favourable for ground water development'. Various water stress mitigating options by integrating technical and non-technical measures are also recommended for sustainable ground water development and management in the area.

This report will go a long way in helping the planners and managers as well as the academicians as a guide and reference volume in the field of Ground Water Resources Management (GWRM) particularly at village level. The untiring and sincere efforts put forth by Scientists of Central Ground Water Board, South Western Region, Bangalore in bringing out this publication is thankfully acknowledged. This report will also act as a stepping stone to take up various studies for National Project on Aquifer Mapping.

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Thanks are also due to the colleagues from CGWB, SWR and Division – XIV, Bangalore who helped in completing the pilot project on aquifer mapping at various levels.

PILOT PROJECT ON AQUIFER MAPPING IN ANKASANDRA WATERSHED, PARTS OF TIPTUR & C.N.HALLI TALUKS, TUMKUR DISTRICT, KARNATAKA

CONTENTS

ABBREVIATIONS

CGWB	Central Ground Water Board
GSI	Geological Survey of India
SOI	Survey of India
DMG	Department of Mines and Geology
IMD	Indian Meteorological Department
PRED	Panchayath Raj & Engineering Department
HP – II	Hydrology Project - II
VRBP	Vedavathi River Basin Project
MLAM	Micro Level Aquifer mapping
HP	Hand Pump
DW	Dug Well
BW	Borewell
BDR	Basic Data Report
E/W/S/N	East/West/South/North
EW	Exploration well
OW	Observation well
Pz	Piezometer well
swl	static water level
bgl	below ground level
agl	above ground level
amsl	above mean sea level
M.P	Measuring Point
lps	liters per second
lpm	liters per minute
lph	liters per hour
m^3	cubic meter
m^2	square meter
sq.km	square kilometer
ha.m	hectare meter
MCM	Million Cubic Meters
MCFT	Million Cubic Feet
PYT	Preliminary Yield Test

APT	Aquifer Performance Test
SDT	Step Drawdown Test
T	Transmissivity
S	Storativity
Sp.Yield	Specific Yield
Sp. Cap	Specific Capacity
mm	millimeter
cm	centimeter
m	meter
min	minutes
dd	drawdown
mdd	meter drawdown
ppm	parts per million
mg/l	milligrams/liter
PGC	Peninsular Gneissic Complex
SD	Standard Deviation
C.o.V	Coefficient of Variation
°C	Degree Centigrade
E.C.	Electrical Conductivity
SAR	Sodium Adsorption Ratio
RSC	Residual Sodium Carbonate
PGWM	Participatory Ground Water Management
SkyTEM	Sky Transient Electro-Magnetic Survey

EXECUTIVE SUMMARY

Ground water plays a vital role in providing food and water security to the nation. Ground water management is the most challenging issue, the country faces now. The number of borewells servicing agriculture is increasing at alarming rate now. The current trend of chasing the declining water table in search of deeper water bearing zones has entailed high risk of drilling dry or very low yielding wells, especially in the Hardrock terrain. Ground water pumping is determined by private decisions; withdrawals are not subjected to any regulation. In Karnataka state, out of 234 watersheds, 63 watersheds fall in over-exploited category (GEC 2011). These statistics point out the need for an integrated water management to make it sustainable. The aquifer mapping is an important step in this direction for providing protected water supply to all population and also to ensure its sustainability through water conservation and artificial recharge measures. Aquifer mapping is a multidisciplinary study wherein a combination of geological, geophysical, hydrologic and hydro chemical information is applied to characterize the quantity, quality and sustainability of aquifers.

Ankasandra watershed with an area of 375 sq.kms in the 4D3D8 watershed, covering 138 villages in parts of Tiptur and C.N.Halli taluks of Tumkur district, Karnatakawas selected for pilot project on aquifer mapping study. The area has mostly clayey, sandy clayey and gravely clayey soils. It is drained by Torehalla stream with dendritic drainage pattern. The important crops grown are coconut, arecanut under irrigation and ragi, castor, red gram, etc., under rain fed cultivation. The area receives about 680 mm rainfall with hot weather and semi-arid climate. The potential evapotranspiration is more than 1500 mm annually. The area has general elevation of 860 m amsl in the south to 720 m amsl in the north. Twenty six minor irrigation tanks existing in the project area, hardly receive any inflow during rainy season. The area is underlain by Achaean group of rocks consisting of Gneiss (72%), Schist (25%) and Granites (3%), with occasional dolerite intrusives.

The depth of weathering ranges from negligible to as high as 40 m. The phreatic zone in most of the project area is de-saturated due to over-draft of the ground water rendering most of the dug wellsdry. Presently, ground water development is mostly through borewells down to depth of about 200 m. Ground water monitoring indicates that certain locations, the depth to ground water level is more than 100 m bgl. The depth to ground water level has continuously been becoming deeper and deeper with each passing day. Depth to ground water level, water-table contour and fluctuation maps are generated using the depth to ground water leveldata.

The water-table fluctuation is about 10 to 20 m. The ground water flow is towards north and north-east with a gradient of about 8m/km. Borewell inventory was carried out at 955 wells to know unit draft, depth of fractures, their yield potential, quality, etc. It reveals that the average yield is about 3.6 to 7.2 m^3/hour. Soil infiltration tests carried out at 20 locations show that tank beds have negligible infiltration rates due to accumulation of clay and silt. These tanks are to be de-silted for augmenting infiltration rate.

Exploratory wells constructed at 14 locations down to the depth of 200 m have drilling discharge ranging from 0.08 to 5.54 lps. Potential fractures are encountered down to the depth of 200 m bgl. Slug tests, short/long duration Pumping tests are conducted on 14 wells to decipher know determine the aquifer parameters. Fractureanalyses of wells indicate that the deeper zones down to 200 m are productive and high yielding when compared to shallow aquifers. Depth to ground water levels ranged from 12.97 to 80.10 m bgl during the drilling. The depth of weathering in the area varies from 18.42 to 51.62 m bgl. The Transmissivity values generally rangbetween 10 and 30 m^2/day. The Storativity values generally range from $2x10^{-2}$ to $2x10^{-4}$. Exploration also revealed the occurrence of Dolerite dykes as intrusivesat various depths with varying thickness at several locations. The contact between Gneiss and Dolerite is not productive.

A total of 125 Vertical Electrical Soundings (VES) carried out by CGWB deciphered the lateral and vertical extension of weathered zone, depth to hardrock and presence of fractured formation. A total of 16 borewells were logged to know the disposition of fractured formation. It is observed that high gamma counts are noticed against fractured zones.

As a part of carrying out advanced integrated geophysical surveys, NGRI was identified and awarded contract for taking up geophysical surveys.

NGRI carried out 60 VES, 26 Ground Time Domain Electro Magnetic (Ground TEM), 32 number (15.6 line km) of 2D ERT resistivity imaging, 2909 line kilometer of HeliTEM, and 37 Ground Resistivity Profile (GRP) to delineate weathered, fractured and depth to basement (massive formation).

SkyTEM survey was also carried out with a line spacing of 150 m having 171 fly-lines in north east-south west direction. Total flown line km works out to be 2909 of which, 2843 line km data was considered for processing. The average flight speed of the helicopter was 17 m/s with an average flight altitude (transmitter frame height) of 35 m above the ground. After processing the data, initially it is found that in general, the HeliTEM has shown the shallowdepth of investigation (DOI) which indicates poor conduction in the compact hardrock. However, the general depth of investigation (GDI) is found to be down to 360 m as per the final interpretation of data.

The net ground water recharge as on March 2014 is 1988 ha.m and the gross ground water draft for all uses is 3729.88 ha.m. The stage of ground water development is 187.61%. However, it is observed that the development is not uniform throughout the watershed and in some of the villages, there is still scope for further development.

Ground water flow modeling was carried out to know the aquifer dynamics for effective ground water management. Five predictive simulations are prepared by changing various variables. Attempt to study the impact of impounding water by filling theexisting minor irrigation tanks to build-up ground water levels was made. It predictedthe in ground water level in the range of 4 to 7m upto a distance of 2 to 3 km from the tanks.

Analysis of ground waters samples indicate that the ground water is mostly suitable for domestic and irrigation purpose except the iron concentrations which is beyond permissible limit at many places. The Radon study at 17 locations revealed the concentration of Radon from 5.86 Bq/l in Schist to 231 Bq/l in Gneissic formation. The concentration of radon exceeds the maximum concentration level at 16 locations as per the US Standards. Hence, it is suggested that the ground water should be used for drinking purpose after 4 days of pumping.

There is scope for future ground water development in Aralikere, Chattasandra, Dasihalli, Gaudanahalli, Kallenahalli, Karehalli, Madihalli, Mallenahalli and Upparahalli in C.N.Halli taluk and Balavaneralu, Bommanahalli, Halkurike, Halkurike Amanaikere, Mayagondanahalli, Rudrapura and Suragondanahalli villages in Tiptur taluk where the depth to ground water level is less than 10m bgl. However, while constructing borewells, spacing norm of 200m between two productive borewells needs to be maintained. Simultaneously, the management practices should also be taken up for sustainable development of ground water resources. In other villages, there is no scope forfurther ground water development.

Desiltation of all the existing minor irrigation tanks is essential to enhance their water-storing capacity increases resulting in enhanced infiltration capacity, which finally will help to augment ground water resources.

As per Model predictions, the sub-surface storage space available to recharge the aquifers is estimated to be 6,39,345 ha.m for raising the ground water level upto 10 m bgl and 7,92,205 ha.m for raising the water up to 5 m bgl. The total amount of water required to build up the levels are estimated to be 14,015 ha.m and 20,120 ha.m respectively. There is no surplus water in the area. Presently, some tanks in Tiptur taluk are impounded with Hemavathi project canal water. Hence, it is recommended to impound all the existing tanks with canal water on regular basis for sustainable management of ground water resources.

Participatory ground water management should be adopted for better understanding of the aquifer system and managing the aquifer by the users themselves and also for sustainability of ground water resources.

To tackle the problem of dwindling yields or drying up of borewells of farmers, the concept of crop insurance may be implemented.

This report highlights the compilation of the available baseline information, data gap analysis and data generation by the combination of geology, geophysics, hydrology, hydrogeology, hydrochemistry, modeling, etc. The report suggests importing of water from adjacent basin, whenever surplus surface water is available to fill up the tanks for sustainability of ground water.

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1.0 INTRODUCTION

The development activities over the years have adversely affected the ground water regime in many parts of the country. It necessiates a need for scientific planning in the development of ground water under different Hydrogeological environs and to evolve effective management practices with the involvement of community for better ground water governance. As India is the largest user of ground water in the world, there is an urgent need for an accurate and comprehensive picture of available ground water resources, through aquifer mapping in different hydro-geological settings to enable the preparation of robust groundwater management plans for this common pool resource. The Aquifer mapping at the appropriate scale has to be devised for a sustainable management plan of this precious resource. This will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural and urban India. It will also help in better management of ground water vulnerable areas. In the present scenario, the ground water assessment and management is broadly based on administrative boundaries. In some of the states, surface watershed boundaries are used to collate the information on regional geology, hydrogeology, aquifer characteristics and ground water geochemistry. These facts underscore the need for the 3-D picture of demarcated aquifer systems of the country. Hence, aquifer mapping has been taken-up to delineate the local aquifers of an extent of 100 to 500 sq.kms, as a unit for water management in the country. The experience gained from the pilot aquifer mapping projects in five States under Hydrology Project-II (HP-II) and its efficacy in getting depth information will be used as guiding tools to replicate in the national project of aquifer mapping.

An ideal micro-level aquifer mapping study consists of:

- **Geologic Mapping:** The geological maps produced by GSI were compiled on 1:50,000 scale. The map provides detailed surface geologic information for the area including the presence of geologic structures such as faults, folds, fractures, dykes, etc.
- **Geophysical Surveys:** VES, ERT, Ground TEM, Logging of borewells etc.
- **Deep drill holes and Interpretation of Subsurface Geology:**Lithologic descriptions, drill cuttings and geophysical logs from deep drill holes for interpreting the nature and extent of aquifers for preparation of fence diagrams and geologic cross sections for two-dimensional view of the subsurface.

- **3-D Geologic Model:** By interpolating between two-dimensional views, geologic information on shallow depths is compiled into three-dimensional, process-based models for predicting what likely occurrence and extent between and beyond the available points of observation.

- **Hydrologic Data Collection and Characterization:**

  - **Water level monitoring:** Representativewells are used as points of measurement to monitor ground water levels in the shallow and the deep aquifers. Established wells with long records of historic ground water levels are an important part of data for analysis.

  - **Hydrographs:** Illustrates the depth to water in an aquifer and how it changes over time.

  - **Hydrologic database:** A user-friendly database to design to store well, ground water level, water quality and location information for long-term use and public distribution.

  - **Ground water conditions:** Converting the ground water level data to produce a map of the water-table surface to understand ground water flow conditions and the effects of geologic features on ground water flow.

  - **Aquifer hydraulic properties:** Estimates of hydraulic conductivity derived from aquifer tests are correlated to mapped geologic units to provide a physical basis for hydraulic properties assigned to aquifers during development of ground water flow models.

  - **Geochemistry and water quality:** Water samples collected from borewells and dug wells are analysed for chemical content in laboratories to find out the natural occurrence of contaminants and to identify waters of similar composition and flow history, differentiate between recent recharge and waters with older residence times.

  - **Hydrologic and Hydrogeologic 3-D Conceptual Model:** Using hydrologic and geologic information in combination with other chemical constituents to provide an accurate conceptual model of the movement of ground water through a complex aquifer system.

1.1 OBJECTIVES AND SCOPE

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.

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

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.

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.

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, ground water level, potential and vulnerability (quality & quantity).

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 2025.

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 Aquifer management involves:

- Identification of aquifer on the basis of geology;
- Identification of recharge and discharge areas;
- Assessment of aquifer capacity and yield through aquifer mapping;
- Protection of recharge area and built-up of groundwater level through artificial recharge.
- Treating groundwater as a common pool resource;
- Encouraging community use of groundwater and restricting individual use;
- Putting in place an institutional mechanism and legal back up for community groundwater management;
- Awareness generation regarding groundwater and science of hydrogeology.

1.3 LOCATION

In Karnataka State, select watershed was identified for pilot Micro Level Aquifer Mapping (MLAM) purpose following the criteria of over exploitation of ground water, deep ground water levels, low rainfall, prevailing drought conditions, etc. Accordingly, Ankasandra watershed has been identified in Tumkur district, which is a part of 4D3D8watershed and covers parts of Tiptur and C.N.Halli taluks. The area is located at a distance of 5 km North of Tiptur town, from Kupparadoddahalli village of Tiptur taluk in the south to Ankasandra village in C.N.Halli taluk towards north. The area falls in the Survey of India toposheet no. 57 C/7 and 57 C/11 and lies between North latitudes 13° 16' 15" to 13° 25' 45" and East longitudes 76° 23' 45" to 76° 38' 40". The total area of the watershed is 375 sq.km and covers 138 villages. Out of 138 villages, 108 villages (51 in Tiptur and 57 in C.N.Halli taluks) are fully covered and 30 villages (17 in Tiptur and 13 in C.N.Halli taluks) are partially covered in the study area. The partially covered villages (with geographical area less than 50% falling in watershed) are not are not considered for assessment. The location map is shown in Fig.1.1.The taluk wise list of villages is given in Annexure 1.1 and 1.2. The satellite image (Google Earth) of the study area is shown in Fig 1.2. The map showing distribution of villages is shown in Fig. 1.3.

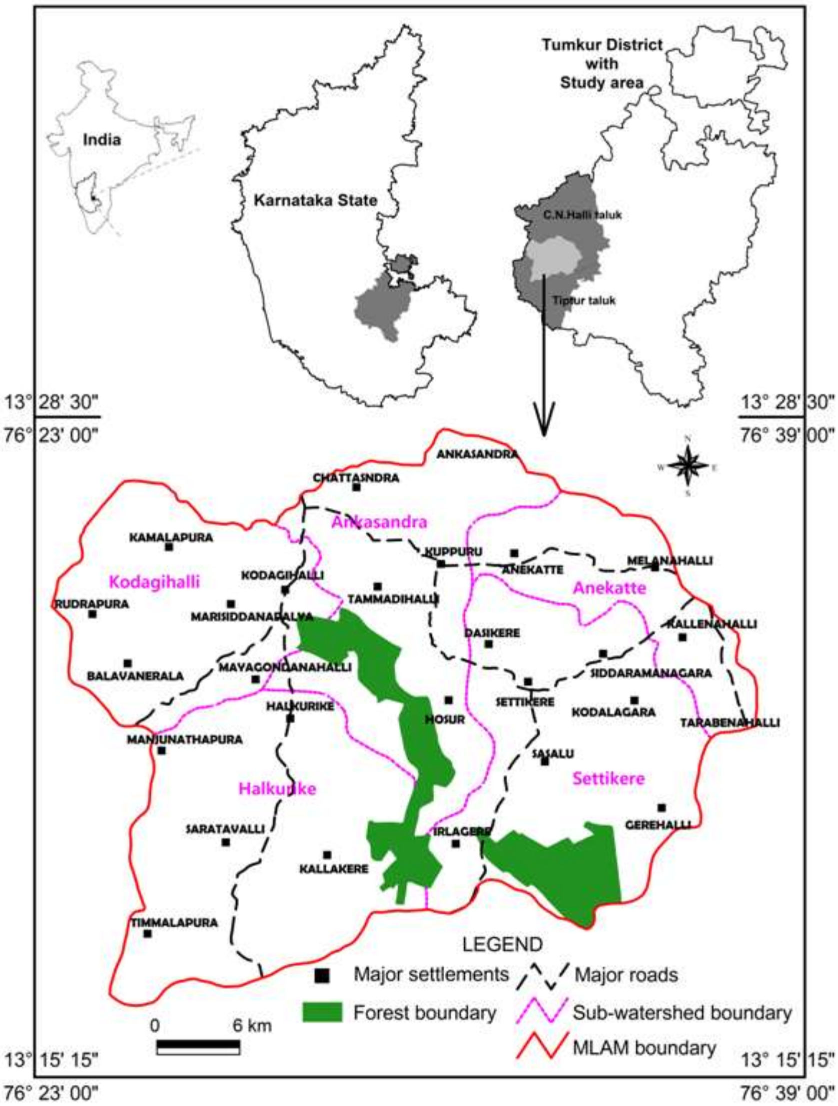


Fig. 1.1: Location map of the study area

Fig. 1.2: Satellite image (Google Earth) of the study area

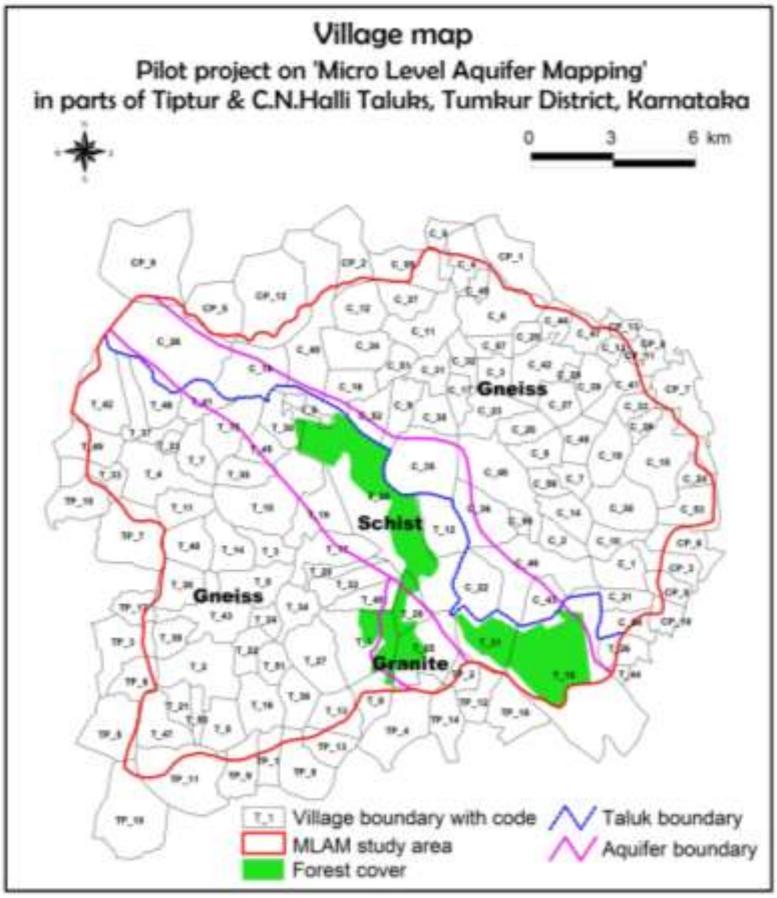


Fig. 1.3: Taluk wise distribution of villages in the study area

1.3.1 Accessibility

The area is well connected to other parts of the district and the state. State Highway No. 47 passes through the area. All the villages are mostly connected by black top roads and occasionally by all weather roads. The NH 206 (Tumkur to Shimoga) passes through Tiptur town which is just south of the area. The nearest railway station is Tiptur. The nearest airport is Bangalore which is about 180 km. The transportation network of the area is shown in Fig. 1.4.

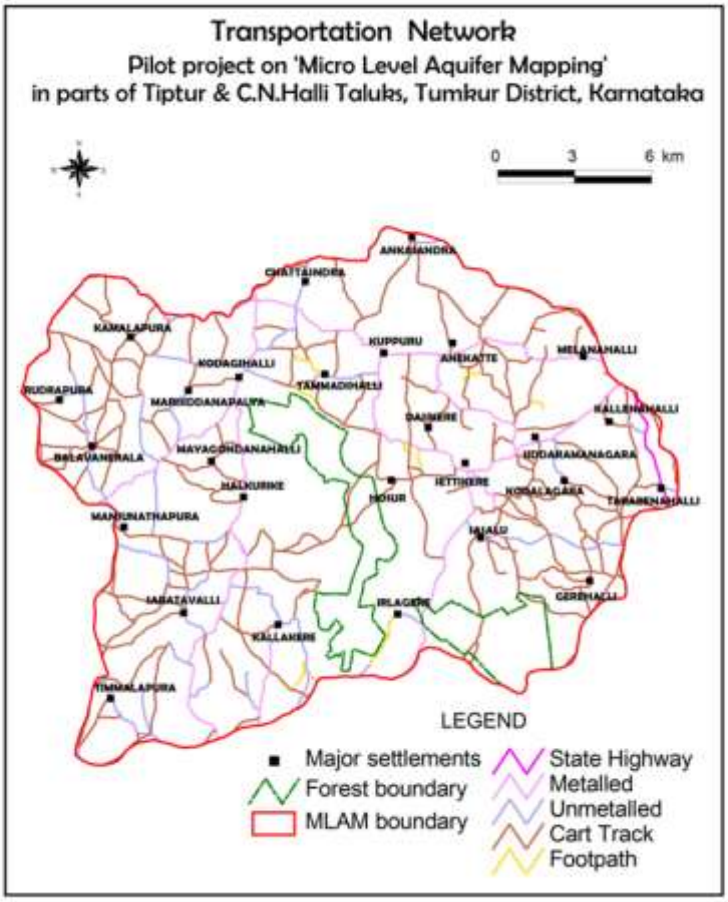


Fig. 1.4: Transportation network

1.3.2 Administrative divisions

Administratively, the area falls in parts of Tiptur and C.N.Halli taluks of Tumkur district. In Tiptur taluk, most of the villages fall in Honnavalli hobli and some villages fall in Tiptur and Kibbanahalli hoblies. In C.N.Halli taluk, the villages are distributed in Settikere, C.N.Halli and Handanakere hoblies. The talukwise and hobli wise distribution of villages in shown in Fig. 1.5.

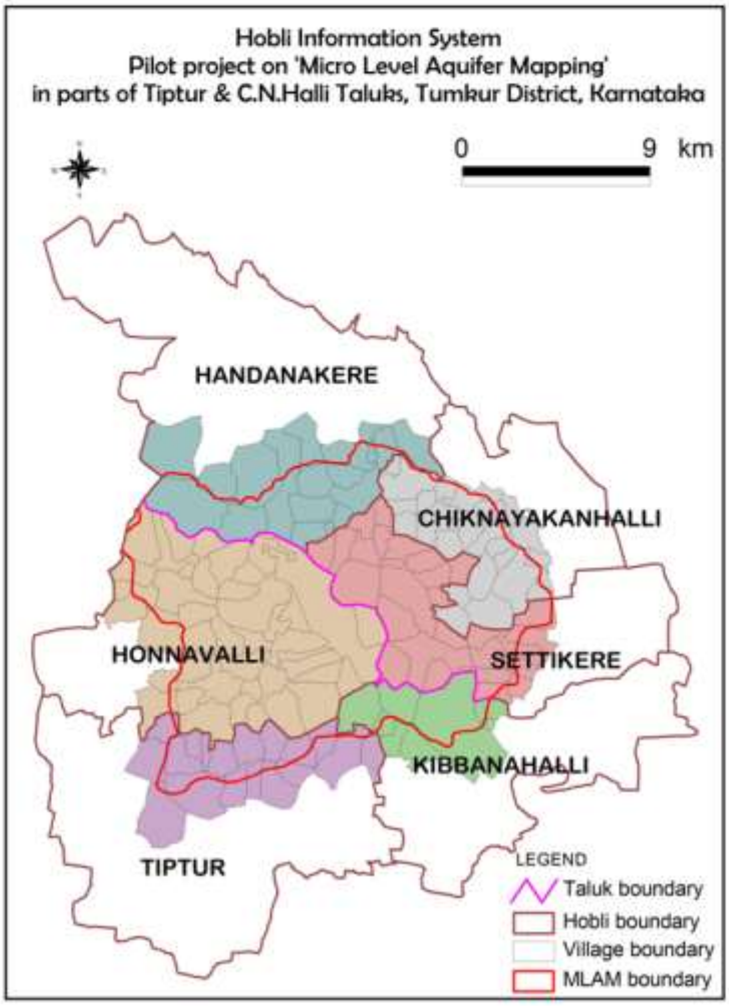


Fig. 1.5: Taluk-wise, Hobli-wise distribution of villages

1.3.3 Demography

The area is predominantly rural with 138 villages. The talukwise and village wise population for 2011 census is given in Annexure 1.1 and 1.2. It is observed that the population of the area is 84,371 (Tiptur – 45,299 and C.N.Halli – 39,072). The statistics indicate that there is no much change in population growth. This is mainly because of the migration of people to urban areas in search of employment, education etc.

1.3.4 Agriculture

Agriculture is the mainstay of the people in the area. The main crops grown are coconut, aracanut under irrigation and ragi, castor, red-gram, etc., under rain-fed cultivation.

1.3.5 Industries

There are no major industries except some coconut based industries, in the study area.

1.3.6 Mining activities

There is no mining activity in the area; however, Granite quarrying is seen around Bandegate village

1.3.7 Urban area

The study area is predominantly rural and is devoid of urban area.

1.3.8 Previous studies

Ground water studies have been carried out in the area by CGWB as a part of Vedavathi River Basin Project (VRBP) during 1977-78. Four exploratory borewells were drilled during this project. The reappraisal Hydrogeological surveys were carried out by Sri K.Kumaresan, Asst. Hydrogeologist in Tiptur taluk during 1995-96. Sri L.J.Balachandra, Scientist-B carried out Ground water management studies in Tumkur, Gubbi and Tiptur taluks of Tumkur district during AAP 2003-04. During AAP 2004-05, three exploration wells were drilled down to 200 m to combat the drought conditions. CGWB is continuously monitoring ground water observation wells and piezometers established in the area apart from ground water quality monitoring once in a year.

2.0 DATA AVAILABILITY & DATA GAP ANALYSIS

The area has deep to very deep ground water levels and the phreatic aquifer is mostly desaturated and dry in most part of the project area. Hence, both the phreatic and the fractured aquifers are considered as a single aquifer system.

During the project period, various existing data with respect to exploration, depth to ground water levels, water quality, geophysical logging, soils, land use/land cover, geomorphology, etc., have been collected and analysed. Based on the existing data on various themes, data gap analysis has been carried and the detailed survey is taken up and data generated (Table 2.1 and Fig. 2.1).

Table 2.1: Data availability and data generated in the study area

Sl.No.	Themes	Data requirement	Data availability	Data generated
1	Exploration	27	7	14 EWs drilled
2	Ground water level (long term)	85	1	84 wells
3	Water Quality	72	1	71 wells
4	Geophysical logging	17	4	13 logging
5	Geophysical VES	185	-	125 VES 60 VES (NGRI)
6	Soils	1	1	Map updated &revised
7	Land use/land cover	1	1	Map updated &revised
8	Geomorphology	1	1	Map updated &revised
9	Well inventory	955	0	955 borewells

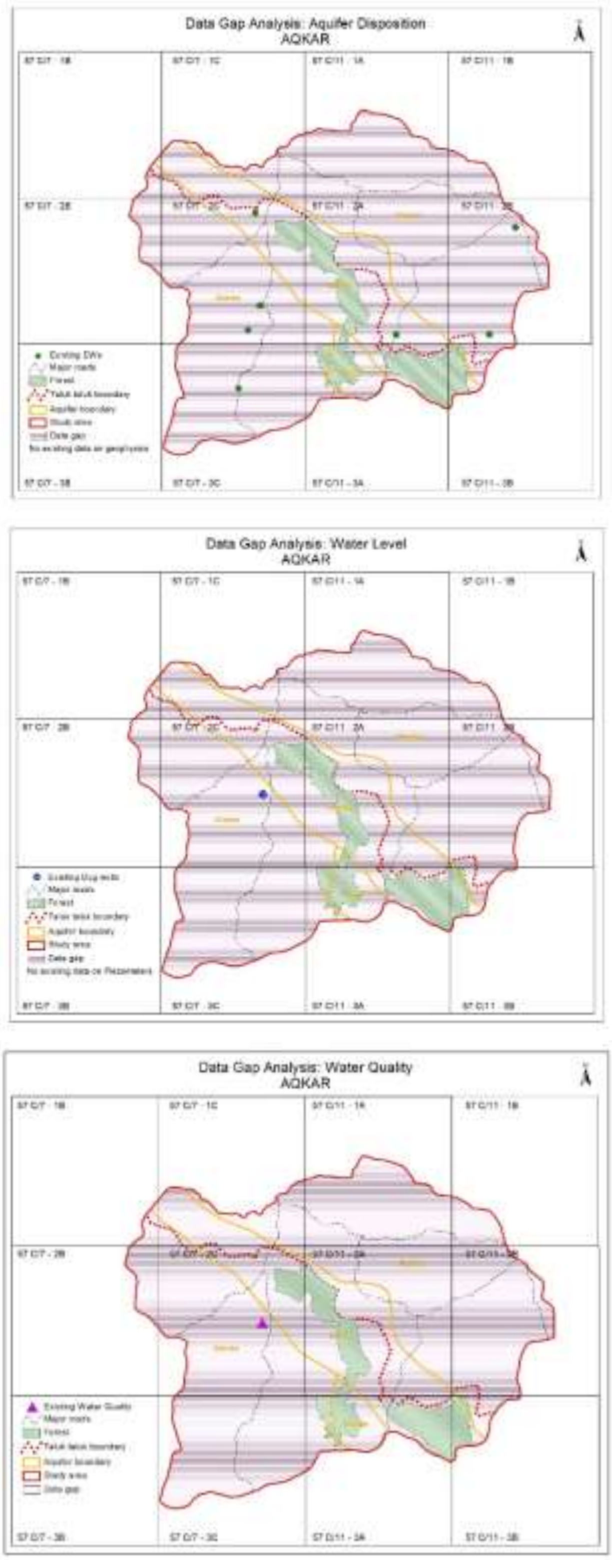


Fig. 2.1: Data gap analysis

Existing piezometer nest constructed under VRB project in Byrapura village

Measurement of ground water level in existing dug well at Halkurike village

2.1 CLIMATE

The area has semiarid type of climate with four seasons namely winter- December to February, summer-March to May, monsoon - June to September, and post monsoon -October and November. There is no meteorological observatory in the study area with long term data. For all the practical purpose the climate parameters like temperature, humidity, wind speed, potential Evapotranspiration of the nearest observatory at Tumkur was considered. However, the rainfall from the local rain gauge stations in and around the area was taken into consideration.

2.1.1 Rainfall

Two revenue rain gauge stations are located in the area at Halkurike and Settikere. Daily rainfall data from these rain gauge stations was collected for the years 2010-2011. At least one rain gauge stations is required for every 520 sq.km area in plain area, as per norms prescribed, hence, no data gap is found.

2.1.2 Temperature

The temperature starts rising from March and reaches to the peak in April/May. The mean maximum temperature is around 34°C but occasionally goes up to 40°C, thereafter it declines with the onset of monsoon. The mean minimum temperature is around 22°C. Normally April is the hottest month and December is the coldest month with minimum temperature of 9°C.

2.1.3 Humidity

The relative humidity varies from lowest during dry season with about 46% during March and highest during monsoons with about 79% during August.

2.1.4 Wind speed

The wind speed in generally moderate and increase during monsoon months. From May to September winds are mainly south-westerly or westerly and in the afternoon north-westerly. North-easterly and easterly winds appear in October and these winds predominate till the end of January. The lowest wind speed is about 4 km/hr during March, April and October and highest wind speed is about 10 km/hr during June and July.

2.1.5 Potential Evapotranspiration (PET)

The annual Potential Evapotranspiration is over 1500 mm with monthly rates around 100mm during November and over 160mm during March which is recorded in the nearest IMD station at Tumkur.

2.2 SOIL

The study area is mainly covered with both rock out crops and very good fertile soil. Based on the remote sensing data and field checks, the soil map was prepared. It indicates that clayey skeletal, clayey mixed, sandy clayey soil and gravely clayey soil are distributed in the study area.

2.3 LAND USE

As per the statistics of 2010-11, forest covers about 4.65% of the total geographical area. Land not available for cultivation (non-agricultural land and barren land) and other uncultivable land (cultivable waste, permanent pastures, trees and groves) cover about 11.78% and 20.53% respectively. The fallow land (current and other fallow lands) covers 3.11% of the total area. The net area sown is 59.90%. The area sown more than once is 12.53%.

2.4 GEOMORPHOLOGY

The study covers an area of375 sq.kms and falls in watershed 4D3D8.The southern boundary of the watershed forms the surface water divide between Cauvery and Krishna basins. It has an undulating terrain forming gentle to moderate slope towards north. The highest elevation of 941 m above MSL (m amsl) is in the southern part of the watershed located just south of Adinayakanahalli state forest. The lowest elevation of 720 m amsl is noticed at Ankasandra village in the northern part of the watershed.

2.5 GEOLOGY

2.5.1 Stratigraphy

The area is occupied by mainly rock types belonging to Archaean age. Major part of the area is underlain by the Migmatite Gneiss of peninsular Gneissic complex (PGC) with enclaves of high grade Meta ultramafic rocks which are older than PGC, belonging to Sargur Group. These rocks are overlain by Dharwar Super Group rocks (Bababudan Group) mostly consisting of Schists trending NW-SE direction cutting across the entire area. A small area is occupied by the grey Granite intrusive in the SE part. The SW part and eastern part is criss-crossed by basic dykes (Dolerite.).The Stratigraphy of the area is presented in Table 2.2.

Majority of the project is occupied by Gneisses which cover about 270 sq.km (72%) of the total area followed by Schists which occupy94 sq.km (25%). A small area of 11 sq.km is occupied by Granites covering only 3% of total project area.

Table 2.2: Stratigraphy of the study area

Age	Super group	Group	Formation	Rock type	Distribution
Palaeo-Proterozoic	-	Younger Intrusives	Acid intrusive	Quartz vein	-
			Basic intrusive	Dolerite	Mostly in SW and eastern part
Archaean	-	-	Intrusive Granites	Grey Granite	SE part in small area
	Dharwar	Bababudan (Chitradurga)	Kibbana-halli	Banded ferruginous quartzite	Very small linear patch
				Metagabbro	Small body
				Agglomerate	Linear patches within Schist
				Metabasalt (Schist)	Major portion
				Quartz sericite Schist	Small linear Patches
	Peninsular Gneissic Complex	Peninsular Gneiss-I	Gneisses	Migmatite Gneiss	Large areas
	-	Sargur	-	Meta –ultramafic rock	Very small Portion

2.5.2 Description of the litho units

The watershed is underlain by the rocks of Sargur Group, Peninsular Gneiss of PGC, Bababudan Group of Dharwar Super Group and Younger Intrusives of Archaean Age and basic Dykes and Quartz veins of Palaeoproterozoic age.

The Sargur Group of rocks are represented by Amphibolite, Banded Iron Formation, Meta-ultramafic rocks and intrusive ultramafics and meta-pyroxenite. These are exposed in the western part of the study area as lenses, pods and disseminated bands. However, these rocks are not prominent in the area as they occur over small areas as isolated patches. These are oldest rocks in the area.

The Peninsular Gneissic complex (PGC) is the predominant rock type in the area mainly represented by Migmatite Gneiss. It is light grey with migmatic structures and gneissic texture, consists mainly of Quartz, Feldspars and little mafic minerals like Hornblende and Biotite.

The PGC is overlain by the Bababudan (Chitradurga) Group of rocks represented by current bedded quartzite, Metabasalt and Banded Iron Formation (BIF). These rocks are exposed as linear bands in N W – S E direction. The current bedded quartzite is well exposed as a narrow linear band east of Halkurike. This quartzite is white to cream in colour, hard, compact, massive consisting of re-crystallized quartz and sericite mica.

Metabasalt is exposed as wide band in the central portion. It is about 2.5 kms wide and about 25 kms long. It is hard, massive, dark grey; exhibits fine granular texture with little or no foliation and consist of plagioclase, hornblende, epidote, sphene and opaques.

Younger intrusive Granites occur as a small patch in the south-eastern part of the watershed near Bandegate village. It is light grey, medium to coarse, granular and consists of Quartz, Feldspars with little mafic minerals like Hornblende and Biotite.

Younger quartz veins intruded in the PGC and Schistose ultramafic rock at the north west of Settikere village on the way to Madihalli village. Swarms of dolerite dykes are seen intruding the PGC and other group of rocks in the area. They trend ENE-WSW and NW-SE. The length of these dykes ranges from few meter to several kilometers.The map showing geology of the area is shown in Fig 2.2.

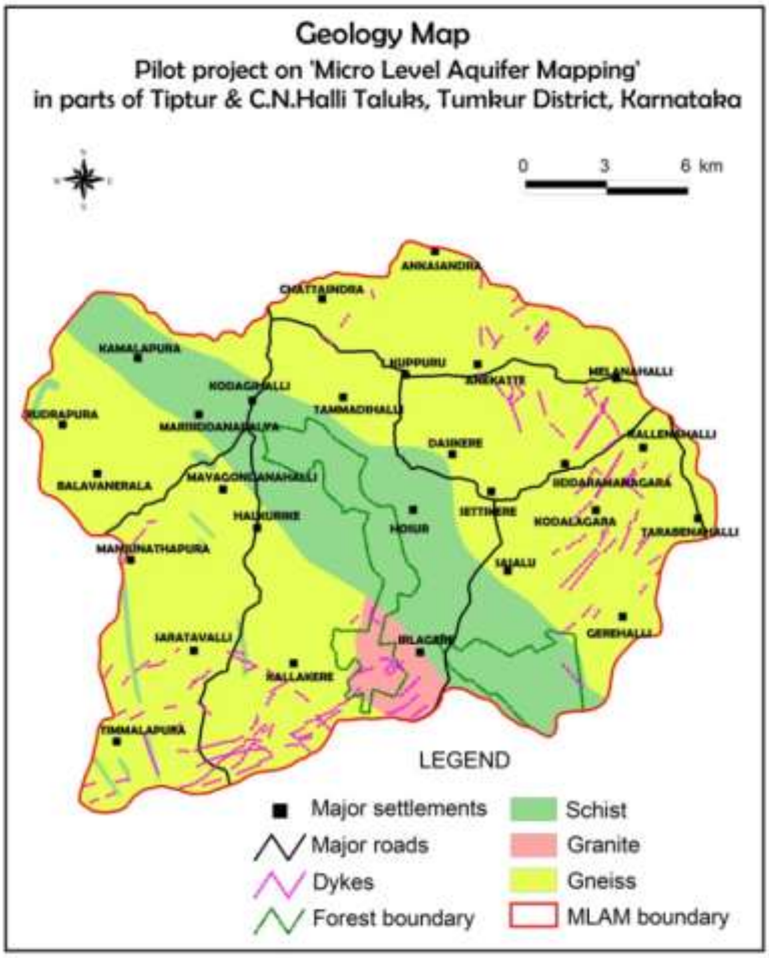


Fig. 2.2: Geology map

Surface exposure of Gneisses near Madapurahatti village

Exposure of Schist on Gopalanahalli – Sasalu gate road

Exposure of quartz vein cutting across dolerite dyke near Kallakere village

Granite quarrying at Bandegate village

2.6 GEOPHYSICS

Geophysical data pertaining to Vedavathi River Basin Project (VRBP) were available prior to the present project. Four exploratory borewells drilled at Bairapura, Kodigahalli, Gopalanhalli and Garehalli villages. Electrical logging was carried out in all four borewells. The logging includes Self potential (S.P.), Point Resistance (P.R)-16" and 64", Gamma logging and Calipher logging.The S.P. logs are not well developed in all the 4 borewells. P.R has given information on depth of weathering etc. Gamma logs show not much variation in three borewells and picked up kaolionised clay at Garehalli site. The Calipher log clearly brought about variations in diameter and picked up fracture zones.

2.7 SUB-SURFACE LITHOLOGICAL INFORMATION

CGWB has constructed four exploratory wells under Vedavathi River Basin Project (VRBP) during 1977-78 down to maximum depth of 90m. The Hydrogeological details of exploratory wells are given in Table 2.3 and Table 2.4. Three more exploratory wells were drilled under outsourcing programme during the AAP 2004-05 down to a depth of 200m and the hydrogeological details of the same is given in Table 2.5.

The seven borewells has given valuable information on the type of formation encountered, depth of weathering, fractures encountered, and their corresponding yield, quality of ground water etc.

Table 2.3: Details of exploratory wells drilled under VRBP

Sl. No.	Village	Latitude	Longitude	Taluk	Total depth drilled (m)	Casing (m bgl)	Geology	Zones Encou-ntered (m)
1	Bairapura	13°21'20"	76°28'25"	Tiptur	46.5	4	Grey Granite	18-19, 20-24, 25-26, 28-30
2	Kodigehalli	13°24'30"	76°28'15"	Tiptur	90	3.9	Chlorite Schist	11-20,28-29
3	Gopalanhalli	13°20'20"	76°33'10"	C.N.Halli	51	2.9	Schist	13-14,16-20, 41-42
4	Garehalli	13°20'20"	76°36'25"	C.N.Halli	40.5	12.5	Granitic Gneiss	31-32,37-38, 39-40

Table 2.4: Details of pumping test parametersof exploratory wells drilled under VRBP

Sl. No.	Village	Discharge (lps)	Type of test conducted	DTWL (m bgl)	Test Discharge (lps)	Draw Down (m)	T (m^2/day)
1	Bairapura	0.4	Air test	0.3	0.71	0.5	1.002
2	Kodigehalli	0.94	Air test	4.28	2.94	0.17	16.29
3	Gopalanhalli	0.84	APT	7.59	2.5	8.77	21.31
4	Garehalli	0.25	Air test	10.86	1	5.8	22.58

Table 2.5: Details of exploratory wells drilled through outsourcing (2004-05)

Sl. No.	Village	Latitude	Longitude	Taluk	Total Depth Drilled (m bgl)	Geology	Zones encoun-tered (m)	Dis-charge (lps)
1	Dabbeghatta	13°24'0"	76°37'20"	C.N.Halli	200	Granite Gneiss	95.00, 120, 165	4.27
2	Harisamudra lambani thanda	13°18'30"	76°27'40"	Tiptur	200	-do-	-	1.2
3	Choulahalli thota	13°20'30"	76°28'0"	Tiptur	200	-do-	Negligible	-Nil-

2.8 HYDROGEOLOGY

2.8.1 Aquifer system

Based on the analysis of available data it is inferred that Gneisses, Schists and Granites are the principal aquifers (hardrock aquifers) in the area. All these formations belong to Archaean group. These rocks are devoid of primary porosity. They were subjected to weathering and tectonic activity and developed secondary porosity which is in the form of fractures/joints in massive formation with regolith on the top.

As already mentioned, Gneisses occupy the major part of the area covering 270 sq.km (72%). From the field study it is observed that the depth to weathering varies from place to place, almost negligible around Halkurike to about 45m near Madapurahatti thanda, in the SE part of the area near Tigalanhalli village. From the field study it is observed that ground water levels are quite deep. Productive fractures are noticed at deeper depths in the area. The success of borewells is moderate to good. The density of borewells is *about 10 to 15 per sq.km* in the plains and upto 30 per sq.km on either side of Torehalla stream near Ankasandra village. The average yield of the borewells is moderate i.e., 3.6 to 7.2 m^3/hour and interference of cone of depression is common.

Schists occupy the central portion in NW-SE direction covering an area of 94.sq. km (25%). However, most part of this area is covered by forests and highly undulating. The dip of the Schist is nearly vertical at the Sasalu junction, whereas, it is gentle near Gandhinagara village towards north. From the field study it is observed that the depth to weathering is moderate in plain lands with limited fractures. The density of borewells is about 5 per sq.km in the plains.

The average yield of the borewells is also limited to 3.6 m^3/ hour showing very low yield of the formation.

Granites occur in the SE part of the area covering 11 sq.km (3%) as a small patch only. The area occupied by Granites is highly undulating with isolated hills, as seen near Bandegate village. From the field study it is observed that the depth to weathering is very limited and occurrence of fractures are also limited to shallow depths. The average yield of the borewells is also limited to 5.4 m^3/ hour.

Ground water is being extracted mostly through borewells in the area. Due to increase in number of borewells over a period of time mostly for irrigation purpose, the depth to ground water levels have gone deeper and deeper and found to be more than 100 m bgl at certain locations (Huchanahatti village). Ground water occurs mostly in fractured system which is in semi-confined to confined condition. However, ground water around Halkurike village occurs in phreatic condition where the depth to ground water level is about five meters.

2.8.1.1 Phreatic aquifers

Phreatic aquifers are developed due to weathering of the formations. All the three principal formations viz., Gneisses, Schists and Granites are subjected to weathering with varying thickness. The exploratory wells data and the borewells inventory indicate that the weathering thickness ranges from a minimum of 5 m to a maximum of 42 m in Gneisses. However, most frequent depth of weathering is between 10 and 20 m. Depth of weathering between 20and 30m was observed in eastern and western part of the project area. More than 40 m depth of weathering is found in isolated patches in SE and NE parts of the area. Most of the phreatic aquifers are desaturated, due to heavy extraction of ground water through borewells for irrigation purpose. Ground water occurs in water-table condition in and around Halkurike village.

In Schistose formation the depth to weathering is less when compared to Gneisses and generally ranges from 5 to 15m. In Granite formation the depth of weathering is very limited and at many places outcrops are seen.

2.8.1.2 Semi-confined to confined aquifers

Ground water occurs in semi-confined to confined conditions in fractured formation at deeper levels in all the three formations. It is common to observe that the ground water level comes up from original level after cessation of drilling due to confined nature of the aquifer.

2.9 AQUIFER DISPOSITION

The area represents typical hard rock terrain with high heterogeneity. The existing information on weathered thickness, fracture system, yield characteristics are very limited. There are only four shallow bore wells of about 50m depth drilled during VRBP period (1977-78) (Table 2.3) and three bore wells of 200 m depth constructed during 2004-05 (Table2.5). Only one NHS station (dug well) exists in the entire project area. The existing information available about aquifer disposition is very limited and that too pertaining to only shallow depth. To prepare a meaningful aquifer disposition of the area, dense precise information on weathered thickness, fracture system, yield characteristics down to 200m depth is very much essential.

2.10 GROUND WATER LEVEL

Historic ground water level data is essential for forecasting of future trends of ground water levels in response to the adoption of modern concepts in ground water reservoir management. One such monitoring well is located in the area at Halkurike. The data generated from the hydrograph station is utilized for making hydrograph.

Depth to ground water levels is being monitored from this monitoring well located at Halkurike on regular basis. The monitoring well shows the depths to ground water levels are very shallow and the hydrograph generated is shown in Fig. 2.3.From the hydrograph it is observed that the depth to water levels, are very shallow and have not changed over the years. However, this data is not representative for the study area as the hydrogeological conditions arund the observation well is localized in nature. Except this monitoring well, there is no other monitoring well which gives the information about the ground water level either by state agency or central agency in all the three aquifer systems in the watershed.

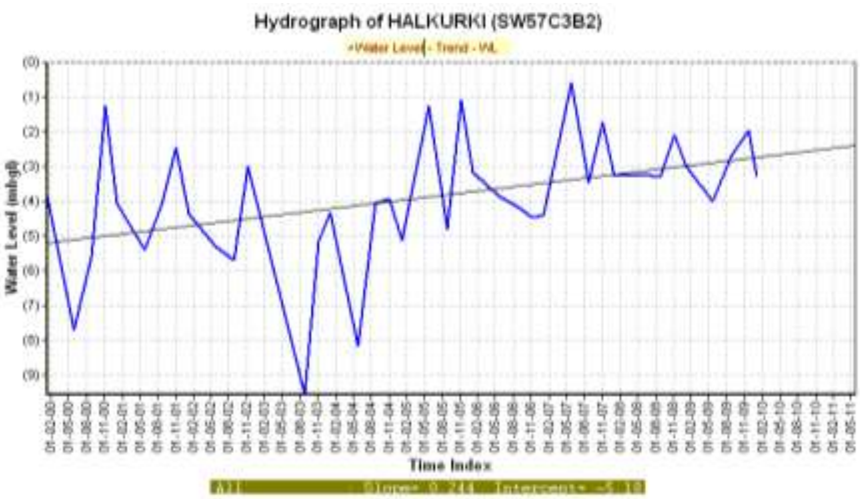


Fig. 2.3: Hydrograph of Halkurike network station

2.11 WATER QUALITY

Water samples collected from NHS station and the chemical analysis results of exploratory wells indicate that the ground water quality is suitable for drinking, domestic and irrigation purposes. The water sample collected from Halkurike hydrograph station during 2013 is analysed and the results are given in Table 2.6.

Table 2.6: Ground water quality of Halkurike network station (2013)

Location	Date of collection	pH	EC	CO_3	HCO_3	Cl	F	NO_3
Halkurike	21.05.2013	8.144	1370	0	207	298	0.56	3.7
		SO_4	**TH**	**Ca**	**Mg**	**Na**	**K**	**SiO_2**
		75	300	48	44	108	90	40

Note: EC is in µS/cm at 25°C, all other parameters in mg/l.

2.12 RECHARGE PARAMETERS

The area falls in 4D3D8 watershed. The total area of the watershed is 122700 ha of which 23937 is of hilly area. The remaining 98763 area falls under non-command category. There is no flood prone area and poor ground water quality area in the watershed. The rainfall infiltration factor in the area is 0.08 (fraction) i.e. 8%. The specific yield of the formation is 0.015 (in fraction) i.e. 1.5%. The season wise unit draft of borewell is 0.3 and 0.7 for monsoon and non-monsoon seasons respectively.The dynamic ground water resource of the area is estimated as on March 2009.The entire area is non-command area. The recharge parameters include recharge from rainfall, return flow from irrigation, recharge from surface water bodies etc.The recharge from rainfall and other sources for the 4D3D8 watershed during monsoon season are 2869 and 1526 ha.m respectively. The recharge from rainfall and other sources during non-monsoon season are 2508 and 2223 ha.m respectively. The total annual ground water recharge is 9126 ha.m.

2.13 DISCHARGE PARAMETERS

Ground water is being extracted through borewells in the area. The important crops grown using ground water irrigation are coconut, aracanut etc. These are perennial crops and require water throughout the year. Hence, ground water is being pumped throughout the year excluding rainy days. Provision for natural discharge is 913 ha.m and the net ground water availability is 8214 ha.m. The existing ground water draft for irrigation is 12435 ha.m. The existing ground water draft for domestic and industrial supply is 567 ha.m. The total ground water draft for all uses is 13002 ha.m. The stage of ground water development is 158% as on March 2009 and the area is categorized as "Over-exploited".

3.0DATA GENERATION

3.1 CLIMATE

3.1.1 Rainfall

Two revenue rain gauge stations are located in the area at Halkurike and Settikere. Two rain gauges stations are also located adjacent to study area at Tiptur and C.N.Halli. Three more rain gauge stations are located in the surrounding area at Kibbanahalli, Honnahalli and Mattighatta villages. The daily rainfall data from these rain gauge stations are collected for the years 2010,2011,2012,2013 for analysis. The monthly rainfall data of the same rain gauge stations are compiled and is given in Table 3.1. Based on the annual rainfall data of each station, isohyetal maps for the years 2010, 2011, 2012 and 2013 are prepared and given in Figs.3.1 to 3.4.

The isohyetal maps show that the rainfall in general is increasing from NW to SE during 2010, 2011 and 2012. During 2013 the rainfall increased from north-west to east central area due to higher rainfallat Settikere village. Even during these four years, rainfall is highly variable ranging from minimum of 163 mm at Mattighatta to 1169 mm at C.N.Halli.

Table 3.1: Month-wise, station-wise rainfall data

	Year 2010											
Stations	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
C.N.Halli	0	0	0	105.2	157.6	57.5	144.3	211.1	69.4	226.4	197.5	0
Mattighatta	0	0	5.1	29.8	34.8	12.6	30.2	81.4	38.8	63.9	65.1	0
Settikere	0	0	0	53	137.1	9.2	84.1	167	111.8	243.2	152.4	0
Honnavalli	0	0	0	16	176	24	72	110	65	129	101	0
Halkurike	0	0	0	117	48	20	80	130	126.2	228.3	135	0
Kibbanahalli	3	0	0	79	158	15	47	134	130	246	133.3	0
Tiptur	22	0	13	43	203	60	132	193	106	144.8	131.4	0
	Year 2011											
Stations	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
C.N.Halli	0	0	5.5	67.1	79.6	37.5	59	72.7	31.6	92.2	31.3	4
Mattighatta	0	0	0	30.3	20.1	23	10	0	23.1	100.5	12.4	0
Settikere	0	0	5.1	127.3	23	44.3	46.7	32.4	51.7	106.8	22.8	1.1
Honnavalli	0	0	0	61	40	15	4	38.6	12.1	63.7	23.4	0
Halkurike	0	0	18	48	39.6	37.6	31.6	37.2	70.2	107.6	35.2	0
Kibbanahalli	0	0	0	107.2	30	48.5	62.3	41.6	77.2	131.2	51.2	0
Tiptur	0	6	9.4	221.4	102.3	59	37.2	66.8	20.7	172.6	29.8	0
	Year 2012											
Stations	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
C.N.Halli	0	0	0	211	38.4	21.6	33.4	149.4	51.7	32.2	104	0
Mattighatta	0	0	0	71.6	44.2	40.2	10.2	40.5	12.1	2	18.4	0
Settikere	0	0	0	174.4	17.8	9.7	33.5	119	46.5	23.4	80.5	0

Honnavalli	0	0	0	24.7	16.6	10.1	5.2	82	12.3	3.1	43.5	0
Halkurike	0	0	0	118	32.6	0	82	119.6	80.1	0	0	0
Kibbanahalli	0	0	0	76.9	34.3	31.1	7.4	78.9	52.7	5.2	184.4	0
Tiptur	0	0	1.6	168.8	23.9	54.5	41.2	117	83.9	11.8	81.5	0
	Year 2013											
Stations	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
C.N.Halli	0	0	7	8	140.3	85.3	55.5	8.4	266.5	44.9	0	0
Mattighatta	0	0	0	0	28.7	5.2	8.4	0	109.2	11.6	0	0
Settikere	0	8.1	8.3	0	86.8	57.8	41.2	70.5	432.6	90.3	5.3	0
Honnavalli	0	15	0	0	19.5	39.9	4.8	0	370.2	24.8	4.2	0
Halkurike	0	23.6	7.6	0	85.2	50.6	30.2	0	300.4	13.8	0	0
Kibbanahalli	0	0	3	0	37.9	22.2	9.3	0	209.4	63.1	0	2.1
Tiptur	0	0	4.4	16.4	99.9	24	31.8	0	223.5	62.5	7.8	5.2

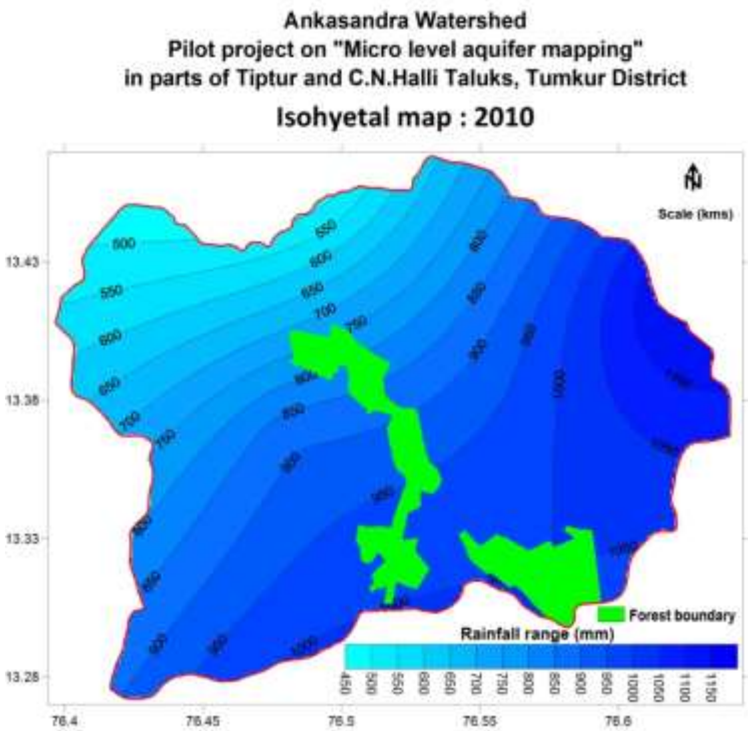


Fig. 3.1: Isohyets (2010)

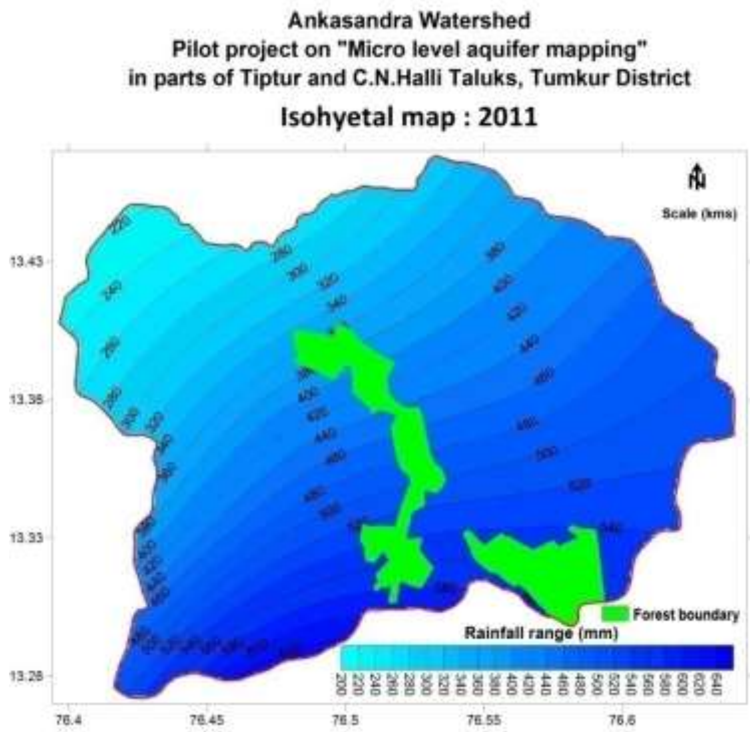


Fig. 3.2: Isohyets (2011)

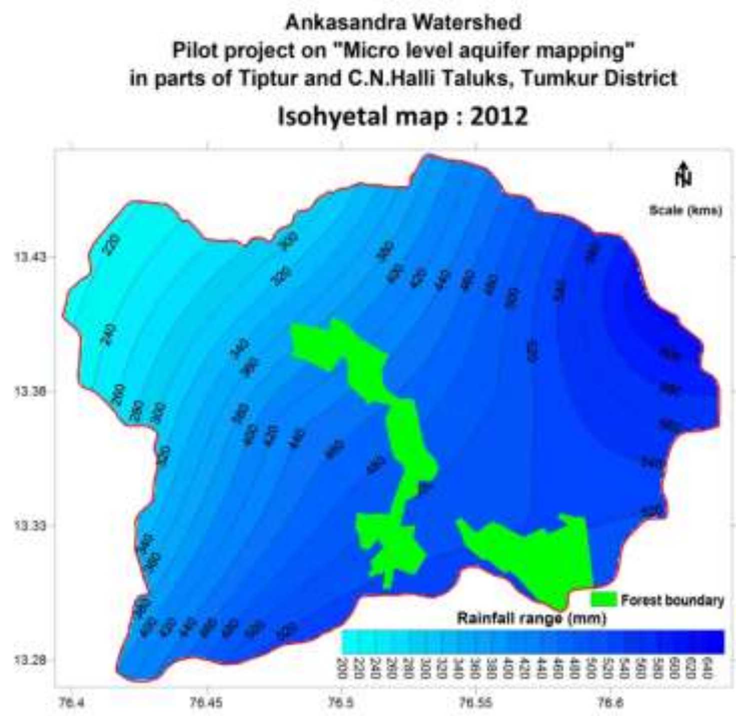


Fig. 3.3: Isohyets (2012)

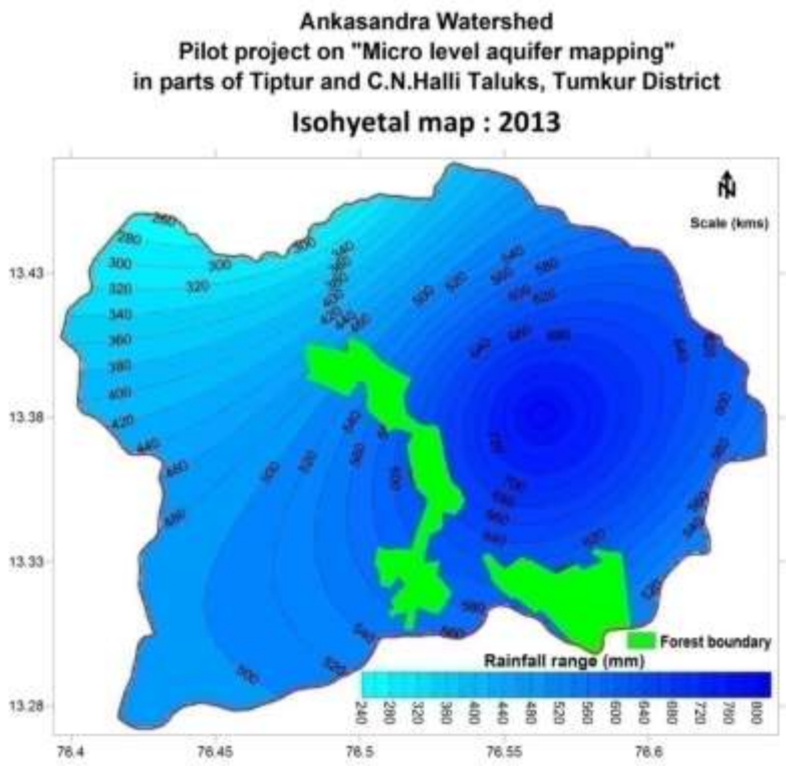


Fig. 3.4: Isohyets (2013)

3.1.2 Drought analysis

The drought analysis is carried out with 30 years (1981-2010) rainfall data of Tiptur and C.N.Halli rain gauge stations. It revealed that the normal rainfall is 704.9 and 684 mm for Tiptur and C.N.Halli stations respectively. The standard deviation is 205.3 mm and 229 mm for Tiptur and C.N.Halli stations respectively. The coefficient of variation is 29.1% and 34% for Tiptur and C.N.Halli stations respectively.

The analysis also revealed that out of 30 years, 19 years are normal rainfall years, 6 are excess rainfall years and 5 are drought years. Out of 5 drought years, 2 are moderate drought (25-50% less rainfall) years, 2 are severe drought (50-75% less rainfall) years and 1 is acute drought (> 75% less rainfall) year for Tiptur station. It also revealed that out of 30 years, 15 years are normal rainfall years, 9 are excess years and 5 are moderate drought years and 1 is severe drought year for C.N.Halli station.

3.2 SOIL

The dominant soil type is fine red soil which covers 176 sq.kms (47%) followed by clayey skeletal soils which covers 145 sq.km (39%). The clayey skeletal soil occurs in the eastern part of the study area. In the remaining area, 27 sq.km (7%) is covered by loamy skeletal soils and water body covers about 16 sq.kms (4%). The soil map of the study area is shown in Fig. 3.5. The details of soil classes are given in Table 3.2. In general, it is found that the area underlain by Granite Gneisses is dominated by fine red soil whereas the Schistose area is dominated by the clayey skeletal soil.

Table 3.2: Classification of soils of the study area

Soil types	Area_sq.km	%
Fine	176	47.09
Clayey Skeletal	145	38.75
Loamy Skeletal	27	7.12
Waterbody	16	4.17
Rock outcrops	4	0.96
Dyke ridges	3	0.85
Fine Loamy	3	0.78
Habitations	1	0.28
Total	**375**	**100**

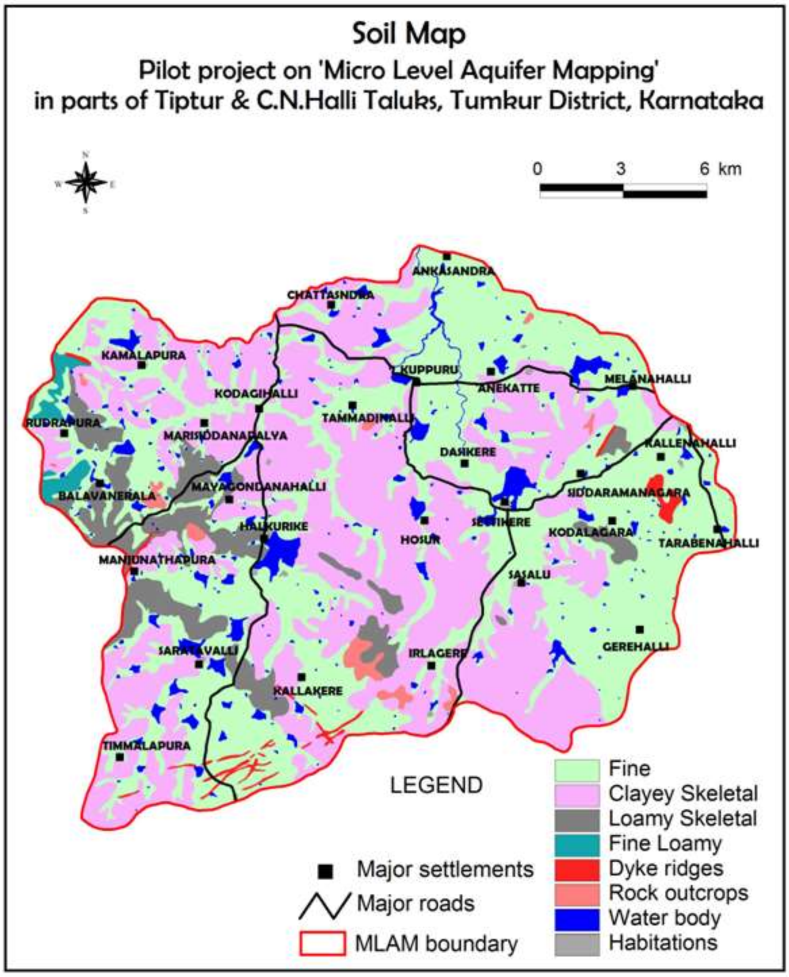


Fig. 3.5: Soil map

3.2.1 Infiltration characteristics of Soil

Soil plays vital role in recharging the aquifers. Rain water after touching the ground enters into the soil by infiltration and thereafter percolates down and finally joins the ground water. To know the infiltration characteristics of soils, 20 infiltration tests were carried out using double ring infiltrometer covering various soil types and geomorphic conditions, open lands, ploughed lands, tank beds, etc.

The test results reveal that the infiltration rates vary from place to place. Higher initial infiltration rates are noticed at Madapurahatti thanda (93cm/hr), followed by Siddaramanagara (78cm/hr) and Kaval villages (60 cm/hr) whereas, the lower initial infiltration rates are noticed at Halkurike and Bhairanayakanhalli (6cm/hr) followed by Rudrapura villages (9cm/hr). Interestingly, the lowest initial infiltration rate isrecorded at tank beds at Halkurike and Bhairanayakanhalli due to the presence of clay and silt. The highest final infiltration rates were recorded at Madapurahatti thanda and Kaval villages (12cm/hr), followed by Siddaramanagara (11.4 cm/hr), whereas, the lowest final infiltration rates are noticed at Halkurike (0cm/hr), Bommanahalli (0.5 cm/hr) Bhairanayakanhalli (0.6 cm/hr) followed by Kuppur and Sasalu (0.9 cm/hr). The highest cumulative depth of infiltration observed, is 110.2 cm in 380 minutes at Madapurahatti thanda, followed by 94.8 cm at Siddaramanagara in 270 minutes and 86.2 cm at Kaval after 300minutes. The lowest cumulative depth of infiltration was recorded at Halkurike with 0.8 cm after 60 minutes, followed by 1.5 cm at Bhairanayakanhalli in 110 minutes.

The locations of infiltration tests carried out are shown in Fig. 3.6. The distribution of final infiltration rates is shown in Figs 3.7.The details of sites, initial infiltration rates, final infiltration rates, cumulative depth of infiltration and duration of test are given in Table 3.3.

Table 3.3: Infiltration test details

Site Id	Site name	Taluk	Initial infiltration rate (cm/hr)	Final infiltration rate (cm/hr)	Cumulative depth of infiltration (cm)	Duration (mins)
1	Bhairanayakanahalli	Tiptur	6	0.6	1.5	110
2	Madapurahatti thanda	C.N.Halli	93	12	110.2	380
3	Kaval	Tiptur	60	12	86.2	300
4	Sarathavalli	Tiptur	15	2.4	9.2	160
5	Halkurike	Tiptur	6	0	0.8	60
6	Misetimmanahalli	Tiptur	18	3	13.1	210
7	Kodagihalli hand post	Tiptur	30	2.4	11.5	170
8	Kamalapura	C.N.Halli	36	11.4	29.9	150
9	Timmarayanahalli	Tiptur	27	0.8	4.75	140
10	Rudrapura	Tiptur	9	1.5	5.3	200
11	Dasanakatte	Tiptur	27	1.2	6.4	140

Site Id	Site name	Taluk	Initial infiltration rate (cm/hr)	Final infiltration rate (cm/hr)	Cumulative depth of infiltration (cm)	Duration (mins)
12	Bommenahalli	Tiptur	24	0.5	4.7	280
13	Arlikere	C.N.Halli	36	1.8	9.2	200
14	Marasandra palya	C.N.Halli	18	1.5	5.7	160
15	Kuppuru	C.N.Halli	18	0.9	5.7	200
16	Kedigehalli palya	C.N.Halli	66	3.9	20.3	240
17	Siddaramanagara	C.N.Halli	78	11.4	94.8	270
18	Settikere	C.N.Halli	54	1.8	9.9	160
19	Sasalu	C.N.Halli	39	0.9	8.7	260
20	Tigalanahalli	C.N.Halli	36	1.8	13.2	160

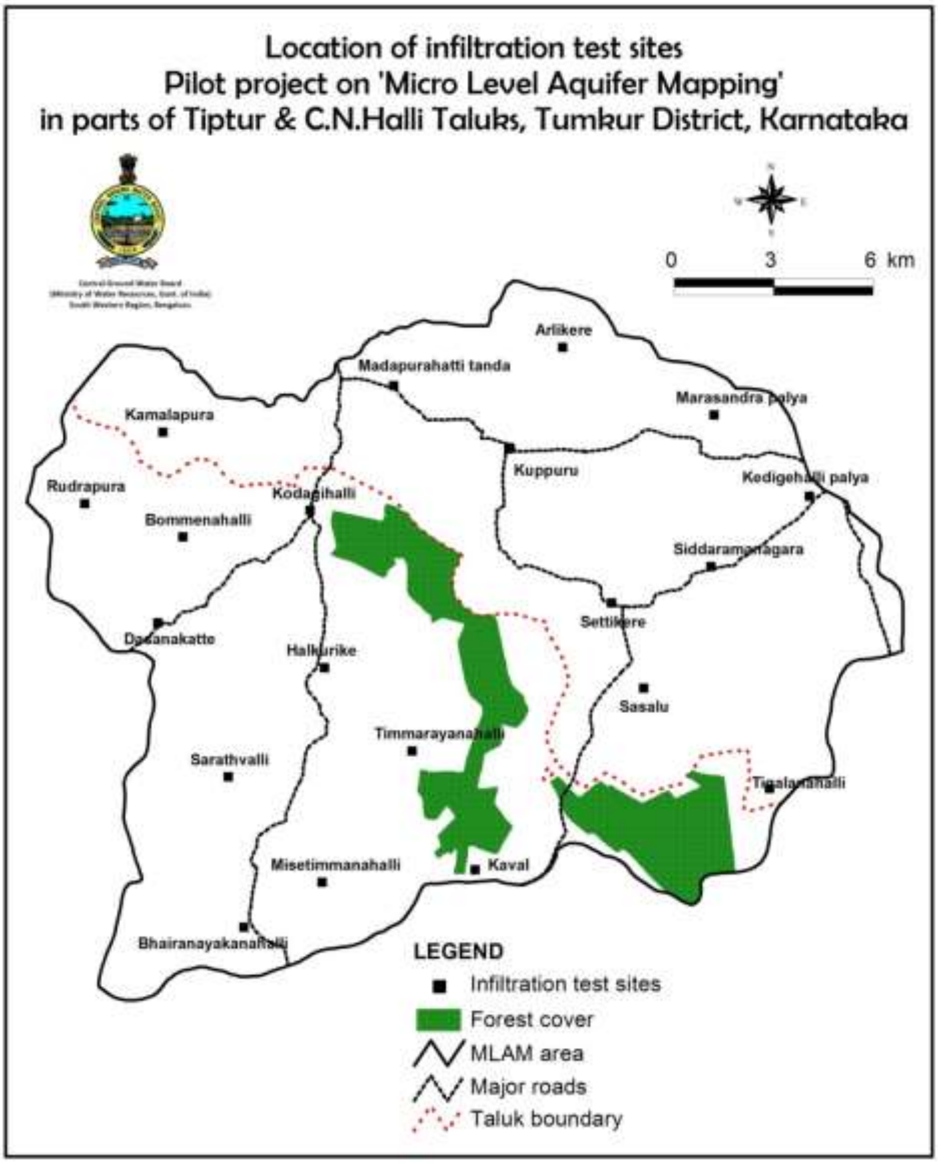


Fig. 3.6: Location of infiltration test sites

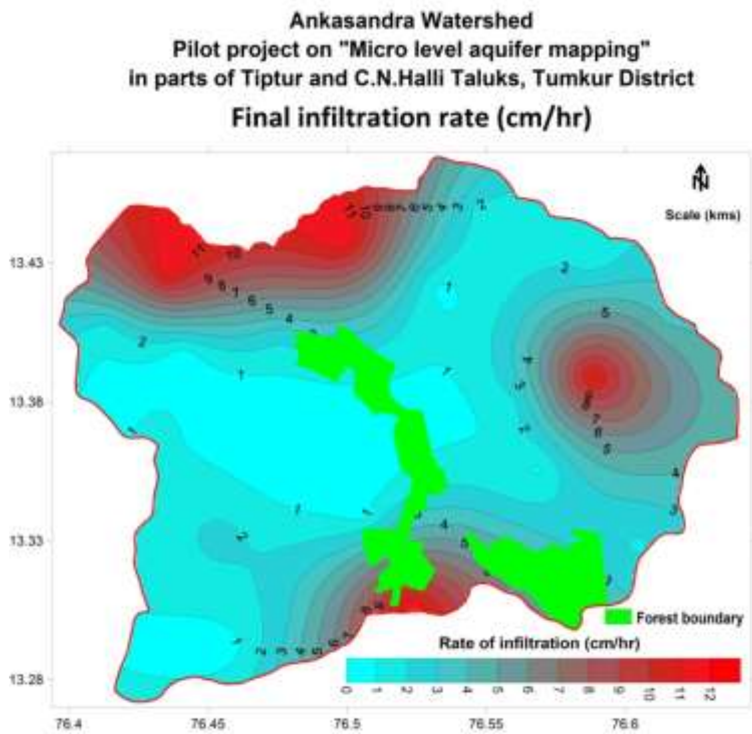


Fig. 3.7: Distribution of final infiltration rates

Double ring infiltration test at Misethimmanahalli village

Double ring infiltration testat Bhairanayakanahalli village tank bed

Double ring infiltration test atRudrapura village

3.3 LAND USE

Land use/land cover map of the study area was preparedbased on the visual interpretation of two seasons' satellite data (Source-KSRSAC Bangalore). The main classes are agricultural land, forest land, waste land and surface water body. Kharif crops and plantation crops cover major part of the study area. Kharif crops are found on the upland, whereas, the plantation crops are found all along the valleys and drainage courses. Degraded forest, forest plantation and land with scrub/without scrub are classified under the forest land. Degraded forest is occupied in the southern parts of the study area covering the Schistose formation. Ravines / Gullied land is classified as wasteland which is mostly found in the SE part around T.B.Halli bovi colony village. Surface water bodies arealigned along the major drainages and show preferred orientation, which indicates that the surface water bodies are formed based on the structural disturbances. The land use and land cover is given in Table 3.4 and shown Fig. 3.8.

From the above table, it is observed that tanks/ponds covered about 15.24 sq.km (4.07 %). The details of minor irrigation tanks with registered ayacut of more than 40 ha and less than 40 ha are given in Table 3.5 and 3.6.

Table 3.4: Land use categorization of the study area

Land use / land cover classes	Area (sq.km)	%
Kharif crop (net sown area)	244.41	65.23
Agricultural Plantation	68.59	18.30
Degraded Forest	24.08	6.43
Lake / Tanks	15.24	4.07
Barren Rocky / Stony Waste / Sheet Rock Area	5.08	1.36
Fallow land	4.94	1.32
Land with scrub	4.08	1.09
Forest Plantations	3.43	0.92
Kharif + Rabi (Double Crop)	1.58	0.42
Gullied / Revinous Land	1.48	0.39
Village	1.05	0.28
River / Stream	0.41	0.11
Sandy area	0.22	0.06
Rabi crop	0.06	0.02
Total	**375**	**100**

Table 3.5: Details of minor irrigation tanks (more than 40 ha)

Sl. No.	Taluk name	Name of tank	Year of construction	Registered Ayacut (Ha)	Catchment area (sq.km)	Live capacity (mcft)	Water spread area (Ha)	Proposed Utilization (mcft)
1	C.N.Halli	Navule	Prior to 1953	147.29	6.32	76.5	76.88	13.38
2	-do-	Settikere	1957	134.98	34.66	70.8	100.4	13.83
3	-do-	Madihalli	1957	58	4.92	6	32.4	5.9
4	-do-	Gopalanahalli	1998	43.3	1.3	4.3	12	6.18
5	-do-	Sasalu-gollarahatti	1980-81	88.7	11.91	28.8	26.1	29.57
6	Tiptur	Halkurike	Prior to 1906	132.8	110.71 (16.83*+ 93.88**)	82.7	125	30
			Total	**605.07**	**169.82**	**269.1**	**372.78**	**98.86**

* Independent
** Intercepted

Table 3.6: Details of minor irrigation tanks (less than 40 ha)

Sl.No.	Taluk name	Village name	Tank name	Registered ayacut (Ha)	Catchment area (sq.km)	Live capacity (mcft)	Water spread area (Ha)	Proposed utilization (mcft)
1	Tiptur	Virupakshapura	Uramundinakere	29.1	2.59	6.2	16.8	2.6
2	-do-	Bhairanayakana halli	Bhairanayakanahalli tank	8	2.59	4	11.2	1
3	-do-	Harachanahalli	Attikatte tank	10.8	5.02	1.8	6	3.92
4	-do-	Harachanahalli	Uramundinakere	9.28	2.84	1.3	4.5	2.65
5	-do-	Sarathavalli	Huralihalli tank	29.9	3.8	19	35.1	6.5
6	-do-	Sarathavalli	Lokammanakatte	2	0.54	0.26	1.6	0.25
7	-do-	Sarathavalli	Amanikere	33.4	5.3	14	9.1	5.5
8	-do-	Chowlihalli	Chowlihalli tank	20.8	3.1	13.7	25	5.76
9	-do-	Gatakanakere	Chikkere	13.6	3.78	0.52	3.51	1.7
10	-do-	Gatakanakere	Gatakanakere tank	14.4	2.12	5.68	15.6	1.8
11	-do-	Halkurike	Kudineeru katte	4.8	0.8	0.23	0.79	0.05
12	-do-	-do-	Mariginchana katte	2	0.38	0.26	0.8	0.25
13	-do-	-do-	Uramundinakere amanikere	-	16.83	82.7	125	29.9
14	-do-	-do-	Siddappana katte	4	0.51	0.23	2.38	0.15
15	-do-	-do-	Hosakatte	20.2	1.73	1.05	3.94	3.3
16	-do-	Mayagondana halli	Uddegowdanakatte	16.4	1.81	1.04	5.26	3.18
17	-do-	Suragondana halli	Seege katte	14.3	1.76	1.3	3.65	2.4
18	-do-	-do-	Uramundinakere	6.87	1.94	0.75	4.05	1.02
19	-do-	-do-	Beeradevarakere	5.72	0.36	1	4.05	1.2
20	-do-	Gudigondana halli	Chikkana katte	21.02	1.9	1.5	20.83	2.21
			Total	**266.59**	**59.7**	**156.52**	**299.16**	**75.34**

Note: The total live capacity of all the tanks is 425.62 mcft. Each mcft = 28,316.80 m^3. The tot al live capacity is calculated as 12,052,196 m^3 or 1,205 ha.m.

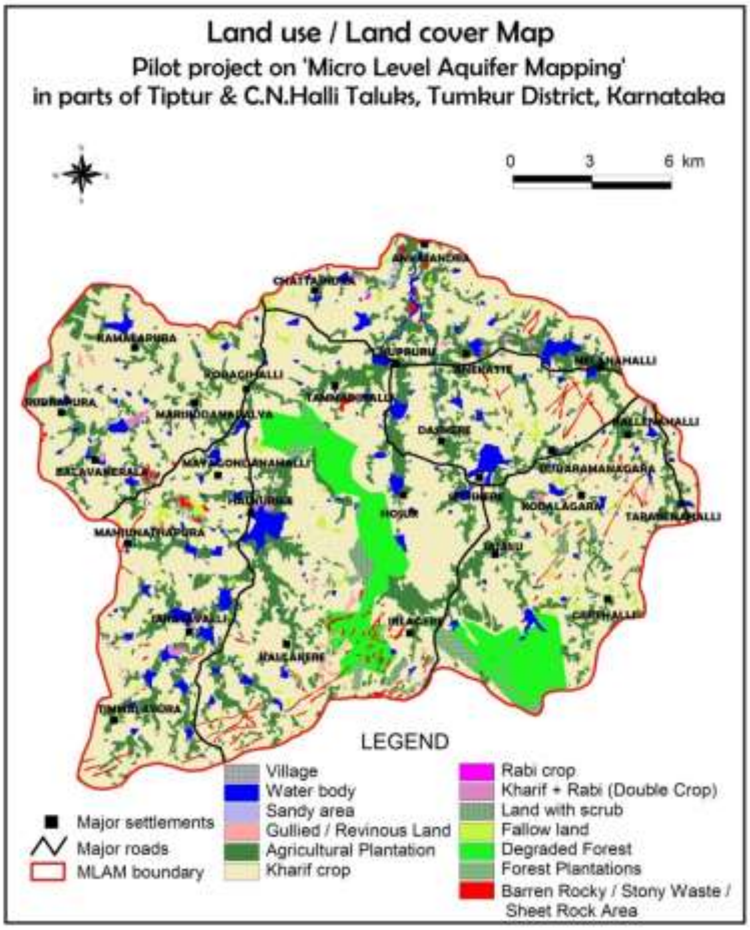


Fig. 3.8: Land use / land cover map

Coconut and Araca nut plantation at Ankasandra village

Tomoto plants near Manjunathanagara village

Coconut plantations on Misetimmanahalli – Kallakere road

Ragi crops around Rudrapura village

Reserve forest area near Thimmarayanahalli village

3.4 GEOMORPHOLOGY

3.4.1 Drainage characteristics

The drainage falls in Vedavathi sub-basin of Krishna basin in parts of 4D3D8 watershed and is drained by 1st to 4th order streams. The drainage is dendritic with flow direction from South to North and ultimately forms the Torehalla stream. The southern boundary of the watershed is a major surface water divide separating Krishna and Cauvery basins. The drainage map is shown in Fig. 3.9. The watershed is further divided into five sub-watersheds namely Kodagihalli, Halkurike, Ankasandra, Anekatte and Settikere with a geographical area of 66,98,79,40 and 92 sq.km respectively. The sub-watersheds are further subdivided into 42 micro-watersheds. Thedelineation of sub-watersheds and micro-watersheds is shown in Fig. 3.10.

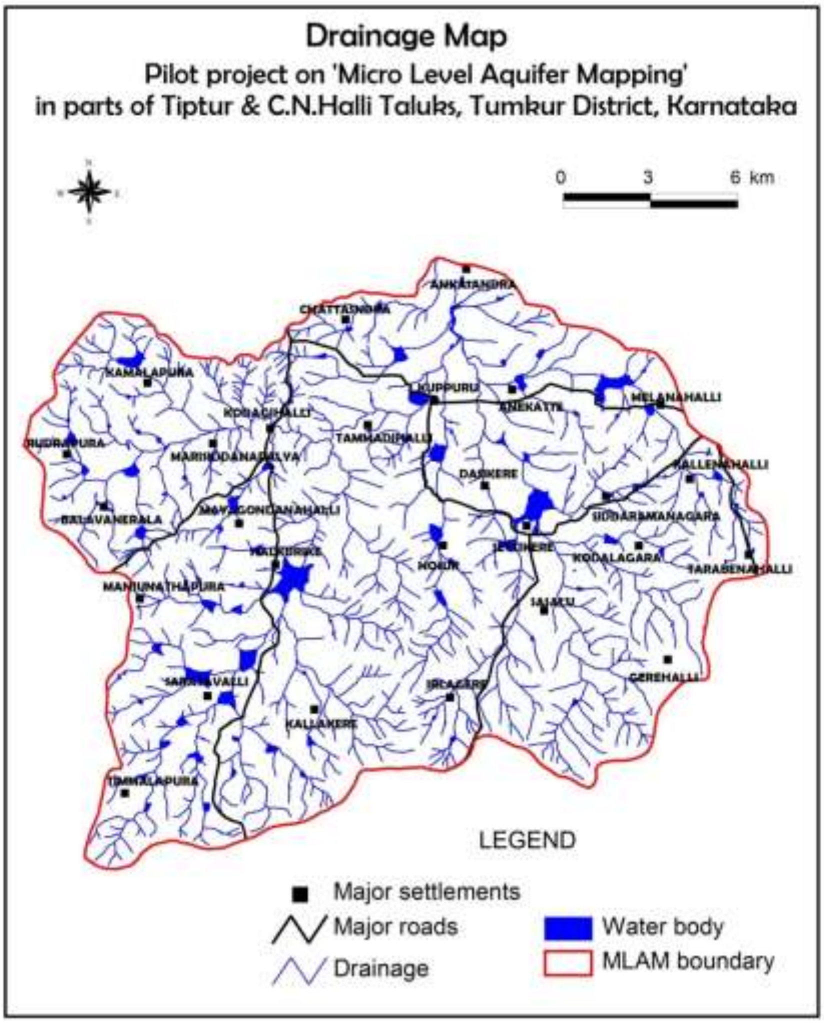


Fig. 3.9: Drainage map

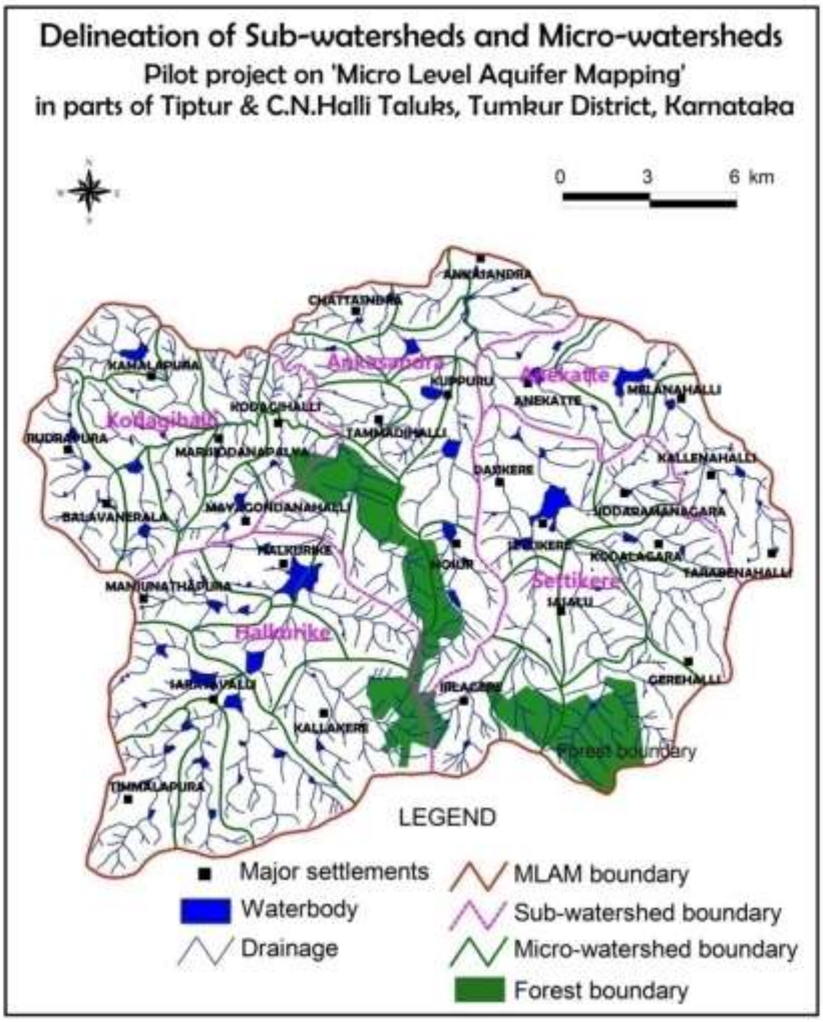


Fig. 3.10: Sub-watershed and micro-watersheds of the area

3.4.2 Sub-watershed wise morphometric parameters

Detailed analysis for various morphometric parameters viz., stream order, stream number, stream length, mean stream length, stream length ratio, bifurcation ratio, mean bifurcation ratio, basin length, basin area, basin perimeter, basin shape, form factor, elongation ratio, drainage texture, circularity ratio, stream frequency, drainage density, drainage intensity, infiltration number, drainage pattern, length of overland flow, total relief, relief ratio and ruggedness number have been carried out to understand different terrain characteristics at sub-watershed level. The results are summarized in Table 3.7 and Sub-watershed wise drainage maps showing stream orders are presented in Fig. 3.11.

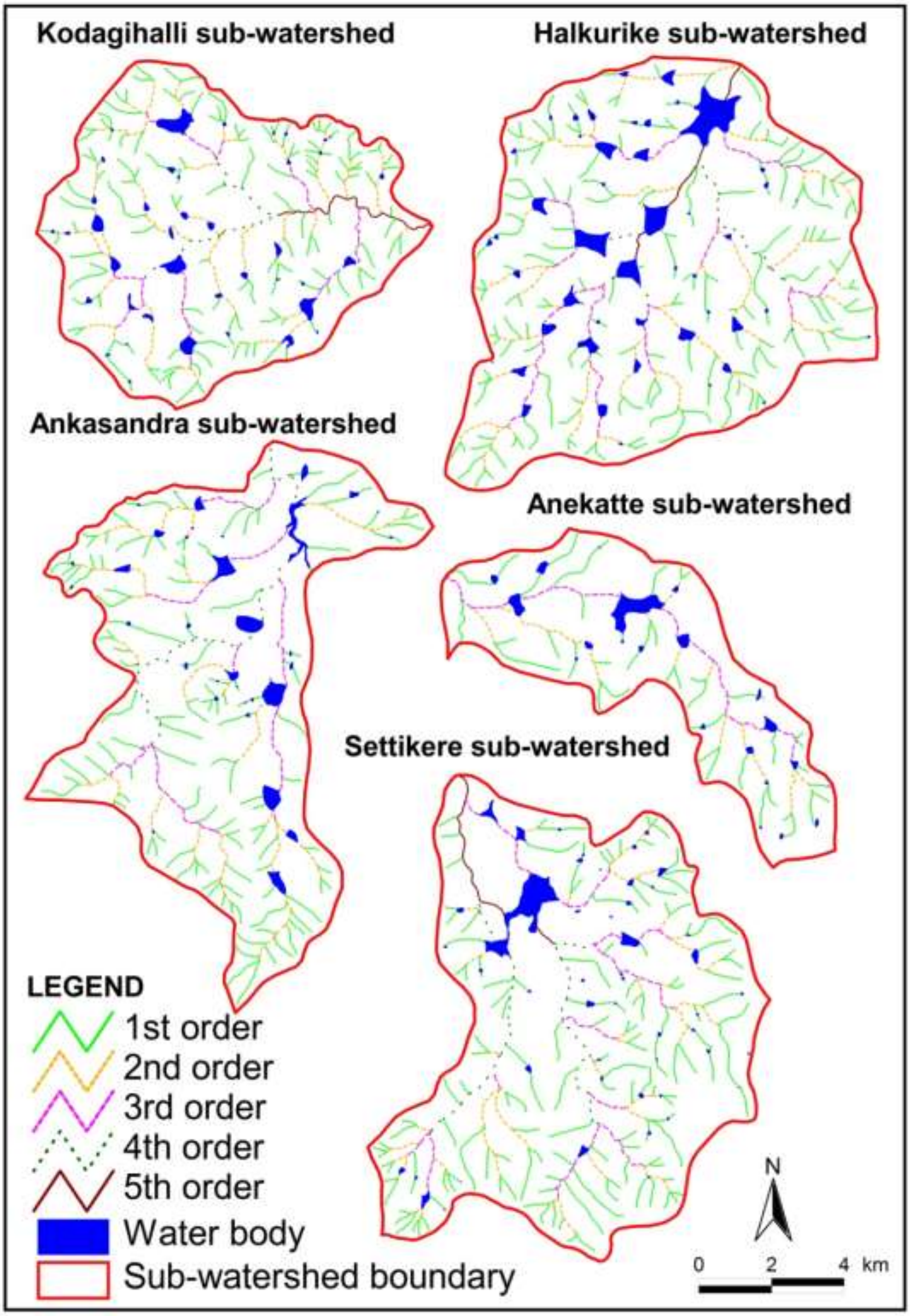


Fig.3.11: Sub-watershed wise drainage map showing stream orders

The stream orders for all 5 sub-watersheds revealed that Anekatte sub-watershed has attained third order, Ankasandra has attained fourth order and the remaining three sub-watersheds viz., Kodagihalli, Halkurike, and Settikere have attained fifth order. The maximum frequency is observed in the first order streams. The results of stream numbers show that the maximum numbers of stream segments are recognized in Halkurike sub-watershed while minimum segments are in Anekatte sub-watershed. It is also observed that the number of streams gradually decreases as the stream order increases. The variation in order and size largely depends on physiographic conditions and structural control of the area. It is observed from the stream length that, the total length of stream segments is higher in first order streams and decreases as the stream order increases. However, in case of Anekatte sub-watershed, the stream segments of various orders show variation from general observation, this variation may be attributed to flowing of streams from high altitude, lithological variation and moderately steep slopes.

Check dam constructed across the third order stream near Kodalagara village

Table 3.7: Sub-watershed wise morphometric parameters

Sl. No.	Sub-watershed name	Stream order	Basin area (A) (sq.km)	Perimeter (Bp) (kms)	Basin length (Bl) (in km)	No. of streams (Nu)					Total no. of streams	Stream length (Lu) in kms				
						I	II	III	IV	V		I	II	III	IV	V
1	Kodagihalli	V	66	32	10.89	130	31	7	2	1	171	71.02	37.91	14.36	7.17	5.27
2	Halkurike	V	98	41	13.91	147	37	11	4	1	200	97.37	44.87	26.08	8.52	6.51
3	Ankasandra	IV	79	49	15.71	119	20	6	1	-	146	84.39	32.10	21.31	13.41	-
4	Anekatte	III	40	35	13.08	38	10	1	-	-	49	35.66	13.27	13.64	-	-
5	Settikere	V	92	41	13.47	138	34	10	3	1	186	103.37	28.64	22.48	14.96	6.53

Sl. No.	Sub-watershed name	Mean stream length (Lsm) in kms					Stream length ratio (Slr)				Bifurcation ratio (Br)			
		I	II	III	IV	V	II/I	III/II	IV/III	V/IV	I/II	II/III	III/IV	IV/V
1	Kodagihalli	0.55	1.22	2.05	3.58	5.27	0.53	0.38	0.50	0.74	4.19	4.43	3.50	2.00
2	Halkurike	0.66	1.21	2.37	2.13	6.51	0.46	0.58	0.33	0.76	3.97	3.36	2.75	4.00
3	Ankasandra	0.71	1.60	3.55	13.41	-	0.38	0.66	0.63	-	5.95	3.33	6.00	-
4	Anekatte	0.94	1.33	13.64	-	-	0.37	1.03	-	-	3.80	10.00	-	-
5	Settikere	0.75	0.84	2.25	4.99	6.53	0.28	0.78	0.67	0.44	4.06	3.40	3.33	3.00

Sl. No.	Sub-watershed name	Mean bifurcation ratio (Mbr)	Total relief (Tr) (kms)	Relief ratio (Rr)	Drainage density (Dd) (km/km^2)	Drainage texture (Dt)	Stream frequency (Sf)	Form factor (Ff)	Circularity ratio (Cr)	Elongation ratio (Er)
1	Kodagihalli	3.53	0.094	0.009	2.07	5.11	2.60	0.55	0.74	0.84
2	Halkurike	3.52	0.098	0.007	1.88	4.89	2.05	0.51	0.73	0.80
3	Ankasandra	5.09	0.204	0.013	1.91	2.88	1.84	0.32	0.39	0.64
4	Anekatte	6.90	0.110	0.008	1.58	1.40	1.24	0.23	0.41	0.54
5	Settikere	3.45	0.201	0.015	1.91	4.11	2.02	0.51	0.57	0.80

Sl. No.	Sub-watershed name	Length of overland flow (Lof)	Basin shape (Bs)	Ruggedness number (Rn)	Drainage intensity (Di)	Infiltration number (In)
1	Kodagihalli	0.97	1.80	0.00019	1.26	5.37
2	Halkurike	1.07	1.98	0.00018	1.09	3.84
3	Ankasandra	1.05	3.11	0.00039	0.97	3.51
4	Anekatte	1.27	4.31	0.00017	0.78	1.95
5	Settikere	1.05	1.97	0.00038	1.06	3.85

The bifurcation ratio values vary from 2 to 10. It is observed that it is not the same from one order to its next order. These irregularities are dependent upon the geological and lithological characteristics of the drainage basin. The higher values of bifurcation ratio indicate strong structural control on the drainage pattern while, lower values are indicative of sub-watersheds which are less affected by structural disturbances. Mean bifurcation ratio varies from 3.45 to 6.90 and all sub-watersheds except Anekattefall under normal basin category and less structural control on the drainage development.

Basin length varies from 10.89 to 15.71 kms and high basin length indicates elongated nature of the watershed. The sub-Basin areas have been computed which range from 40 to98 sq.kms. The analysis indicates that the Halkurike is the largest sub-watershed while Anekatte is the smallest. Basin perimeter varies from 32 kms (Kodagihalli sub-watershed) to 49 (Ankasandra sub-watershed).

Basin shape values for each sub-watershed indicate that, Kodagihalli, Settikere and Halkurike sub-watersheds show lower basin shape values and have sharply peaked flood discharge periods while, Anekatte and Ankasandra sub-watersheds show weaker flood discharge periods.

Form factor values were observed and analysed that Anekatte and Ankasandra sub-watersheds show an elongated basin nature with lower peak flows of longer duration due to lower form factor value (0.23 and 0.32 respectively); Halkurike, Settikere and Kodagihalli sub-watersheds are close to circular basins due to higher form factor values.

Elongation ratio values generally vary from near to 0.6 to 1.0 over a wide variety of climatic and geologic types. These values can be grouped into three categories namely (a) circular (>0.9), (b) oval (0.9 to 0.8), (c) elongated (<0.7). In the present study, these values were derived for each sub-watersheds and it varies from 0.54 to 0.84 indicating that Settikere, Halkurike and Kodagihalli sub-watersheds are circular, while, Anekatte and Ankasandra sub-watersheds are falling under elongated type.

Circularity ratio value ranges from 0.39 to 0.74 and reveals that Ankasandra (0.39) and Anekatte sub-watersheds (0.41) are representing elongated nature of basin type.

Drainage texture has been classified into five different textures i.e., very coarse (< 2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (> 8). In the present study, the drainage texture varies from 1.40 to 5.11 which indicate that Anekatte sub-watershed falls under very coarse, Ankasandra sub-watershed under coarse and Settikere, Halkurike and Kodagihalli sub-watersheds fall under moderate type of drainage texture. Stream frequency varies from 1.24 to 2.60. It exhibits almost positive correlation with the drainage density values of the sub-watersheds indicating the increase in stream population with respect to increase in drainage density.

Drainage density varies between 1.58 (Anekatte sub-watershed) and 2.07 km/ km^2 (Kodagihalli sub-watershed). It may be pertinent to note that the low values of drainage density are characteristics of regions underlain by highly permeable material with vegetative cover and low relief, whereas, the high values of drainage density indicate regions of weak and impermeable subsurface material, sparse vegetation and mountainous relief. Drainage Intensity varies between 0.78 (Anekatte sub-watershed) and 1.26 (Kodagihalli sub-watershed). The lower value of drainage intensity implies that drainage density and stream frequency have little effect (if any) on the extent to which the surface has been lowered by agents of denudation. With lower values of drainage density, stream frequency and drainage intensity, surface run-off is not quickly removed from the watershed, making it highly susceptible to flooding, gully erosion and landslides.

Drainage pattern is dendritic type. This is most common pattern which is formed in a drainage basin composed of fairly homogeneous rock without control by the underlying geologic structure. The longer the time of formation of a drainage basin, the more easily the dendritic pattern is formed. Length of overland flow values vary from 0.97 to 1.27. It is revealed that the length of overland flow is less in Kodagihallisub-watershed as drainage density is high when compared to the remaining sub-watersheds.

Total relief varies from 0.204 kms (Ankasandra sub-watershed) to 0.094 (Kodagihalli sub-watershed).Relief ratio ranges from 0.007 in Halkurike sub-watershed to 0.015 in Settikere sub-watershed. It is also observed that the high values of relief ratio indicate steep slope and high relief, while the lower values may indicate the presence of basement rocks exposed in the form of small ridges and mounds with lower degree of slope.

Ruggedness number values were calculated which varies from 0.00018 to 0.00039. The low ruggedness value of sub-watershed implies that the area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density.

3.4.3 Slope

Slope of a land is classified as nearly level, very gentle slope, gentle slope, moderate slope, strong slope, moderately steep slope and steep slope if the slope is up to 1%,1-3%,3-5%,5-10%,10-15%,15-35% and more than 35% respectively. The slope of the area is studied and presented in Table 3.8 and Fig 3.12. The major part is covered under gentle slope with 145 sq.kms (38.75%) followed by nearly level with 132 sq.km (35.11%), very gentle slope with 56 sq.km (14.84%), moderate slope with 33 sq.km (8.87%), strong slope with 7 sq.km (1.86%) and moderately steep slope with 2 sq.km (0.57%) indicating less surface run-off in the area. It is also observed that nearly level and very gentle slopes exist all along the valley portions. Gentle slope is observed adjacent to valley portions.

Table 3.8: Slope classification of the study area

Slope classification	Area_sq.km	%
Gentle Slope (3-5%)	145	38.75
Nearly Level (0-1%)	132	35.11
Very Gentle Slope (1-3%)	56	14.84
Moderate Slope (5-10%)	33	8.87
Strong Slope (10-15%)	7	1.86
Moderately Steep Slope (15-35%)	2	0.57
Total	**375**	**100**

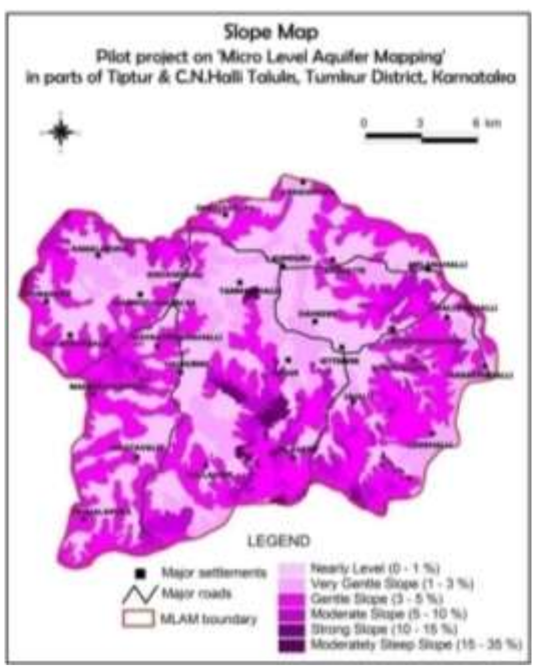


Fig. 3.12: Slope map

3.4.4 Hydrogeomorphology

The various geomorphological features noticed in the study area are structural hill, residual hill, pediment inselberg complex, inselberg, pediment, shallow weathered pediplain, moderately weathered pediplain, valley-fills and water bodies. The shallow weathered pediplain is the dominant geomorphological feature covering 195.26 sq.km (52%) followed by valley-fills covering 98.64 sq.km (26.32%),whilethe pediment covers 25.47 sq.km (6.80%). These threealtogether cover about 85% of total area(Table 3.9). The map showing geomorphology of the area is shown in Fig. 3.13. The shallow, moderately weathered pediplain and the valley-fills which cover majority of the area, are more weathered compared to other units and are suitable for ground water storage and development.

Table 3.9: Hydrogeomorphological classification of the study area

Geomorphic units	Area_sq.km	%
Shallow weathered pediplain	195.26	52.10
Valley fill	98.64	26.32
Pediment	25.47	6.80
Water body	15.76	4.21
Moderately weathered pediplain	14.19	3.79
Structural hill	13.75	3.67
Pediment inselberg complex	8.98	2.40
Residual hill	2.38	0.64
Inselberg	0.35	0.09
Total	**375**	**100**

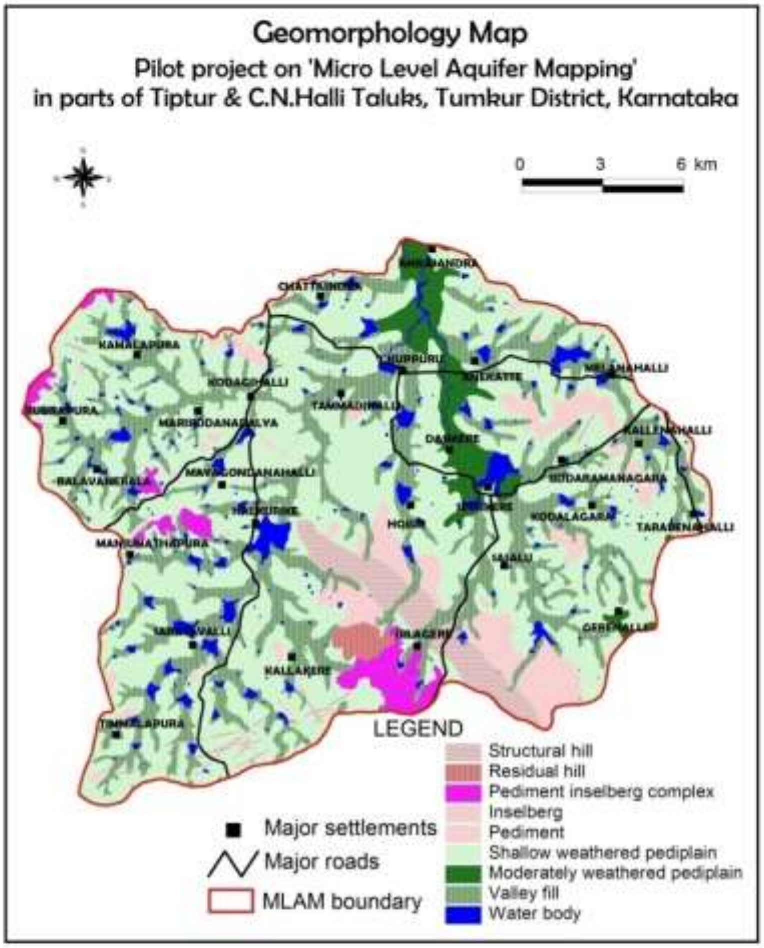


Fig. 3.13: Geomorphology map

3.4.5 Lineament mapping

The lineament map of the study area is prepared based on the visual interpretation of IRS-ID and LISS-III satellite data. It reveals that there are about 38 drainage lineaments which are identified by straight alignment of drainage and vegetation representing surface manifestation of underlying structural features. Most of the lineaments are trending in NNE-SSW direction. About 151 dykes were mapped which are mostly present in SW and NE parts of the study area. Majority of dykes are trending in NE-SW direction. The map showing the lineaments and dykes is presented in Fig.3.14. The rose diagram showing distribution of lineaments and dykes is given in Fig. 3.15 and the number of lineaments and dykes present in the study area is presented in the Table 3.10.

Table 3.10: Number of lineaments and dykes in the study area

No. of Lineaments: 38			No. of Dykes: 151		
Start_AZ	End_AZ	Count	Start_AZ	End_AZ	Count
0	10	9	0	10	9
10	20	10	10	20	10
20	30	10	20	30	10
30	40	9	30	40	10
			40	50	10
			50	60	10
			60	70	10
			70	80	10
			80	90	10
			90	100	10
			100	110	10
			110	120	10
			120	130	10
			130	140	10
			140	150	10
			150	160	2

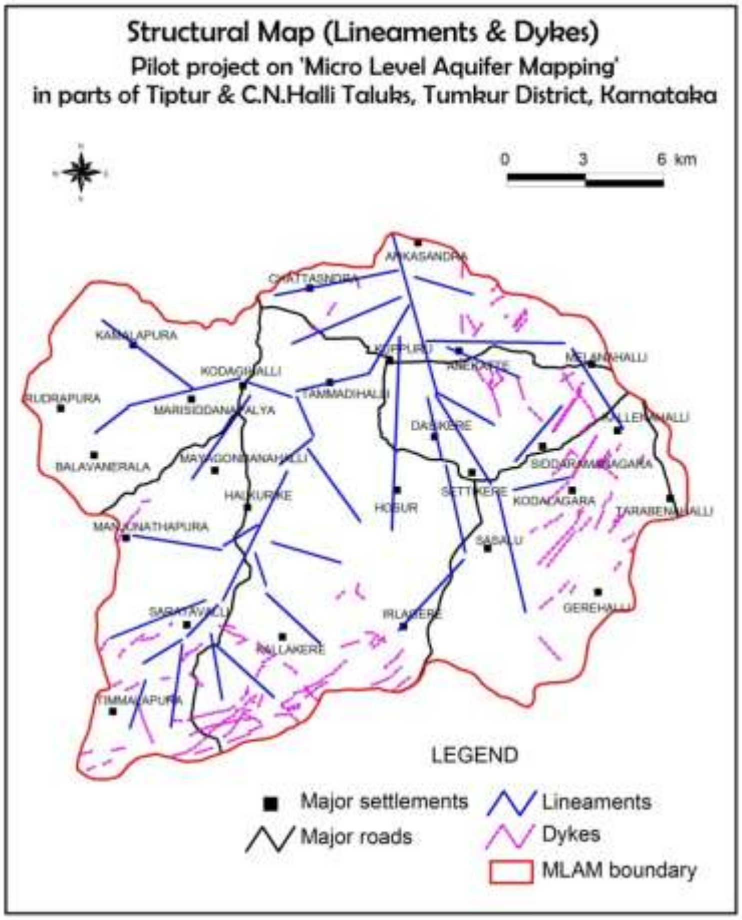
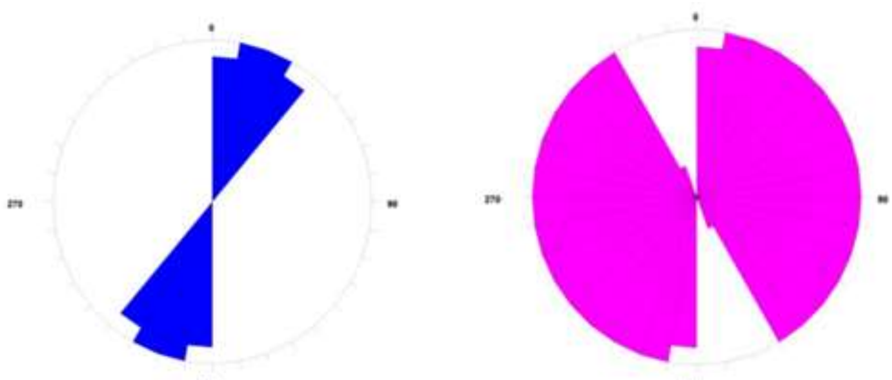


Fig. 3.14: Lineaments and Dykes



Lineaments

Dykes

Fig. 3.15: Rose diagrams of lineaments and dykes

Residual hill near Tammadihalli village

Gullied land near T.B.Colony village

A farmer ploughing at his agricultural land at Madapurahatti village

Dry tank at Bevinahalli village

Exposure of dolerite dyke on Bandegate – Gopalanhalli road

Pediplains near Nelagondanahalli village

3.5 GEOPHYSICS

3.5.1 Geophysics (CGWB)

3.5.1.1 Surface geophysics

Surface geophysical surveys in the form of Vertical Electrical Soundings (VES) were conducted in the study area. The preliminary objective of the survey is to decipher the weathered layer thickness and the fractured thickness, layer resistivity of weathered, fractured and massive formations. In addition, the surveys were also aimed at computing subsurface geophysical parameters in the area.

3.5.1.1.1 Data acquisition and interpretation

A total 125 VES were carried out with station interval 2 km in grid pattern using IGIS Hyderabad, make ATS-SSR-MP and Mac-Ohm, OYO Japan make Resistivity meters. Schlumberger electrode spreading was used with maximum current electrode separation of AB/2=300 m. The apparent resistivity from the field plotted in a log-log graph paper shows that most of the sounding curves reflect the presence of three to four geoelectric layers of A, H and HA types. The initial interpretation of the VES data was accomplished using a conventional partial curve matching technique with a two layer master curve and auxiliary diagrams. Estimation of resistivity layers and thickness were obtained and used as starting models. The computer aided interpretation (Schum and IP2WIN) based on optimization techniques were used to analyse the data. Dug well/borewell information was incorporated and the layered earth models from the VES interpretation were kept as simple as possible by not allowing results with too many thin layers. The geo-electrical parameters of VES are given in Annexure 3.1.

3.5.1.1.2 Results and discussion

Based on the survey results, contour maps of weathered thickness, depth to basement, apparent resistivity contour maps (AB/2=25m, AB/2=100m, AB/2=200m), second layer resistivity and third layer resistivity maps have been prepared.

3.5.1.1.3 Weathered thickness contour map

The weathered thickness map indicated that in 70% of the area, the depth to weathering is around 10m. In Ankasandra watershed area, in north east and eastern part of C.N.Halli taluk, the weathered thickness varies between 30 and 40 m. The weathered thickness contour map is shown in Fig. 3.16.

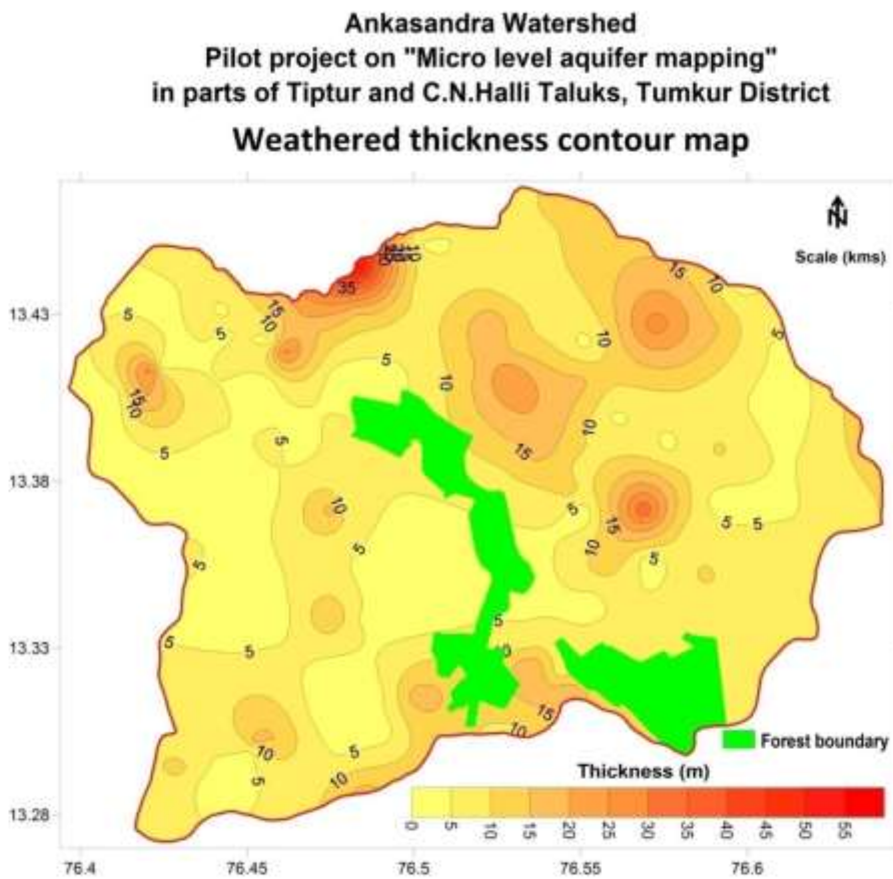


Fig. 3.16: Weathered thickness contour map

3.5.1.1.4 Depth to basement contour map

Depth to hardrock in general is less than 20 – 60 m in the study area. In Schistose formations the depth to hardrock is less than 30m. In areas of Migmatic Gneiss, it is between 30-60m. In the eastern and the south eastern part depth to hardrock is more than 100m. This zone can be demarcated as fractured, wherein the resistivity is in the range of 200-400m. The depth to basement contour map is shown in Fig. 3.17.

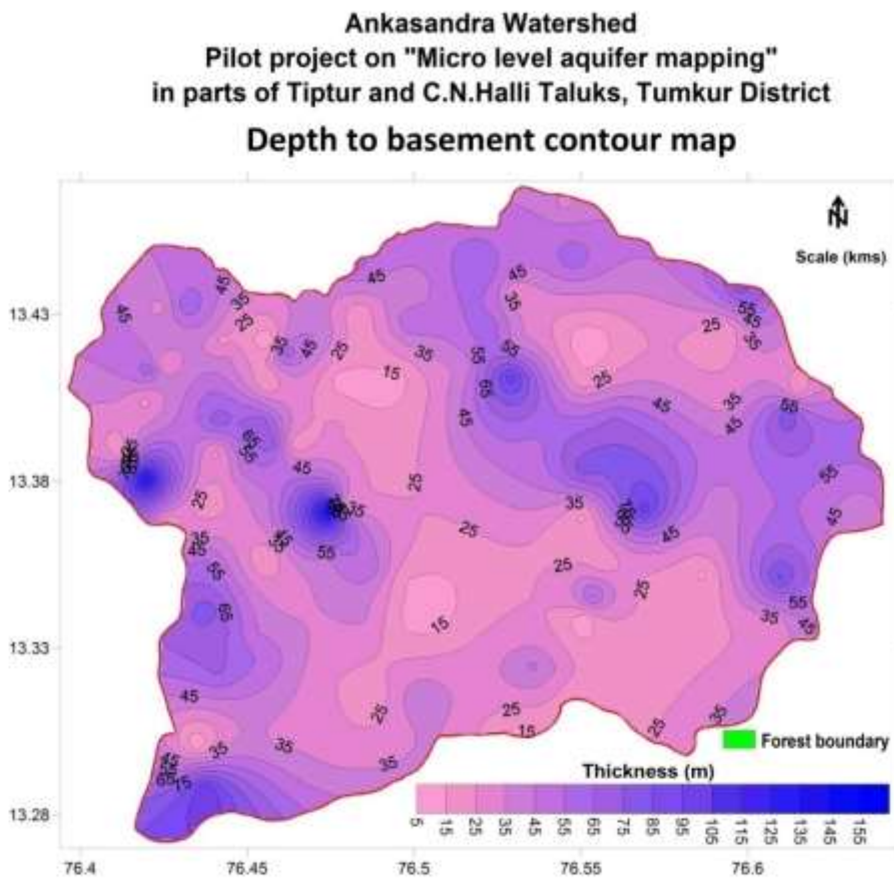


Fig. 3.17: Depth to basement contour map

3.5.1.1.5 Resistivity behaviour of formations

The apparent resistivity at AB/2=100m and AB/2= 200m shows the presence of fractured zones both at shallow and deeper depths. Resistivity values of < 200 Ohm.m in Schists and 200- 400 Ohm.m in Gneisses indicate shallow fractures. Deeper fractures are indicated with in resistivity zone of 300-600 Ohm.m. A sizeable portion in the south and the fringe areas of NW (Gandhinagar) and SE (Bandegate) ismassive zone in hardrocks which indicated higher resistivity of more than 400 Ohm.m and more than 600 Ohm.m. True resistivity of second layer(weathered) and Third layer (Hard-Fractured /massive) are discussed below. The Apparent Resistivity at AB/2=25m, AB/2=50 m, AB/2=100 and AB/2=200 m are shown in Fig. 3.18 to Fig. 3.21.

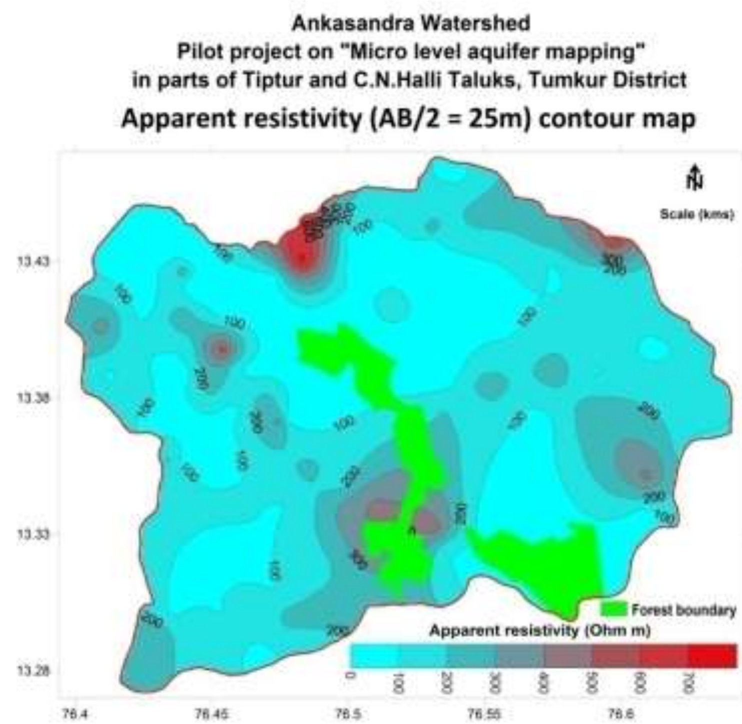


Fig. 3.18: Apparent Resistivity at AB/2=25 m

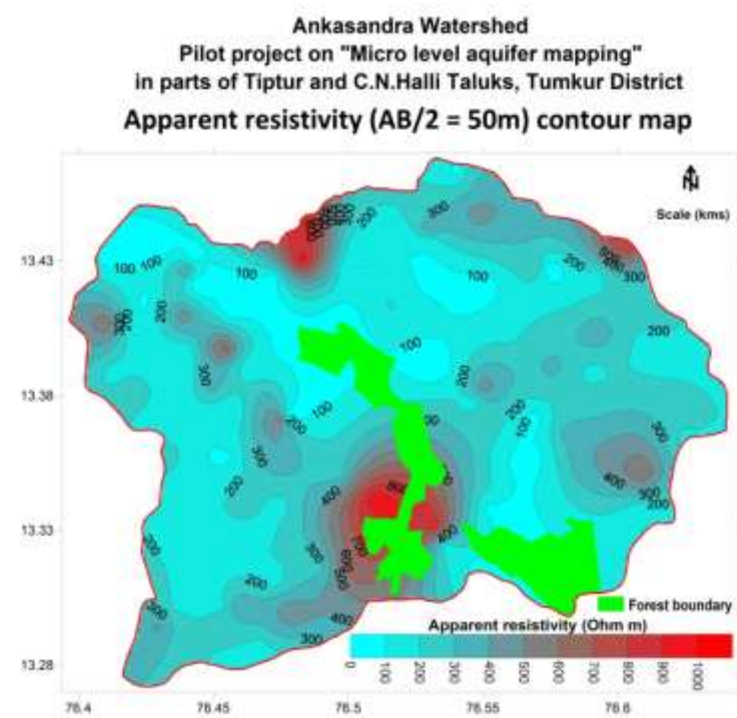


Fig. 3.19: Apparent Resistivity at AB/2=50 m

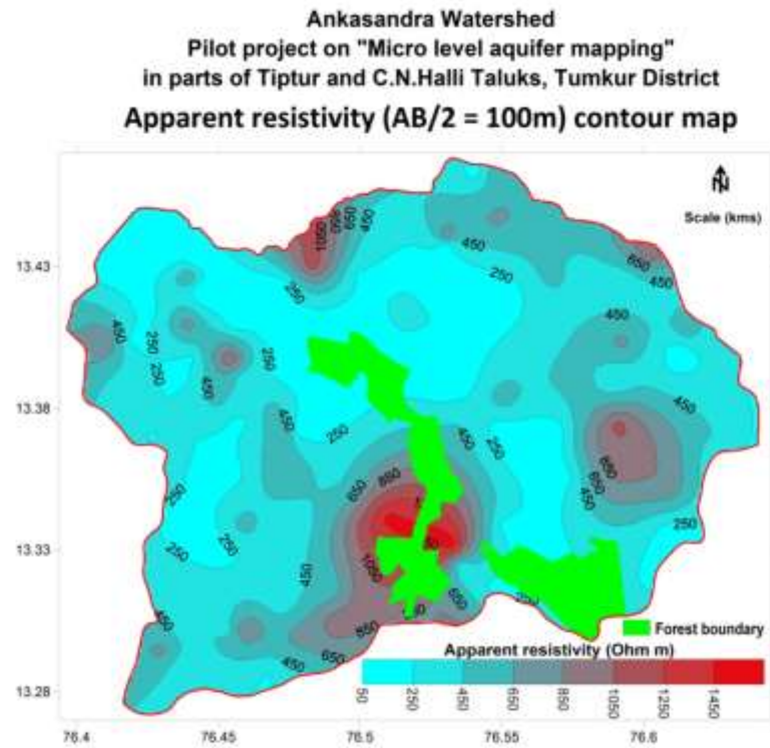


Fig. 3.20: Apparent Resistivity at AB/2=100 m

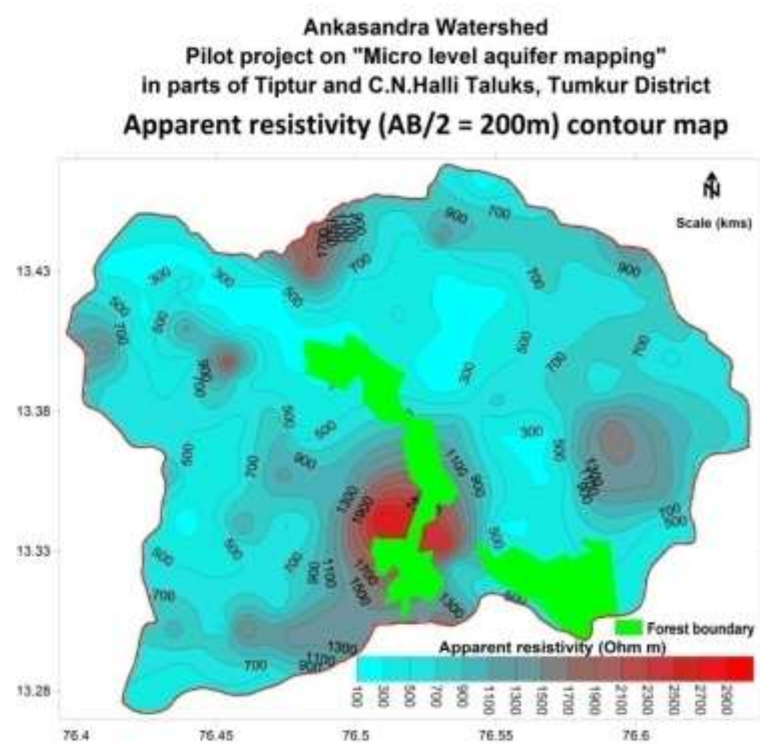


Fig. 3.21: Apparent Resistivity at AB/2=200 m

Second layer resistivity contour map with resistivity up to 100 Ohm.m indicates highly weathered nature in the major part. Virupakshapura, Halkurike, Hulihalli, Gandhinagara, Khaimara junction, Bangarakere, Savsettihalli, Settikere, Agasarahalli villages show resistivity values of more than 200 ohm m indicating shallow basement depth. Third layer shows resistivity value of 200-400 Ohm.m in the western half of the study area, which can be attributed to fractured formations.

Higher Resistivity values of more than 600 m and above are present in south east, north east and fringe areas of north (Gandhinagar), east and south east indicating massive nature of the formations. The resistivity maps indicated high resistivity in the northern fringe areas near Gandhinagar, which can be attributed to massive formation and shallow basement. The first, second and third layer resistivity is given in Fig. 3.22 to 3.24.

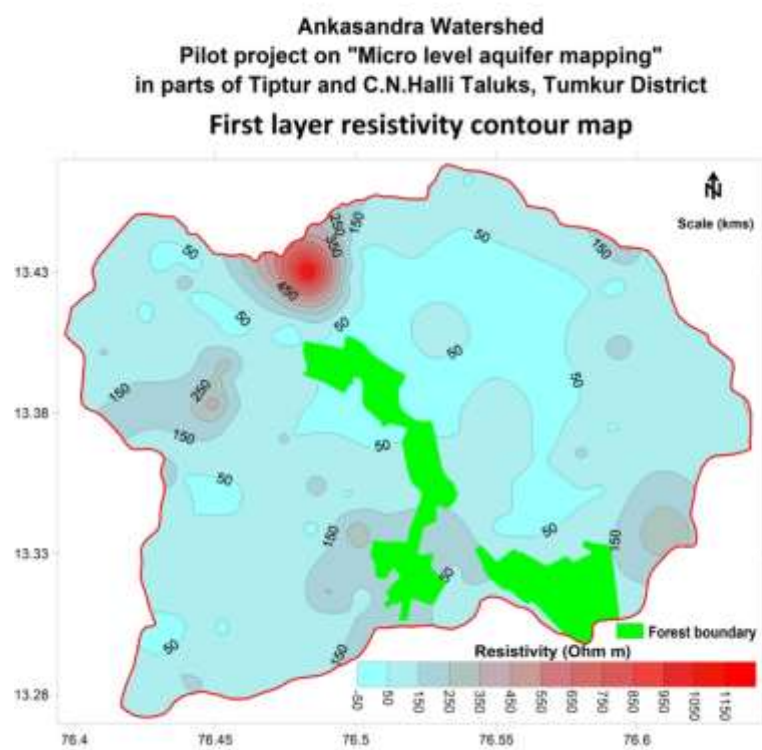


Fig. 3.22: First layer resistivity map

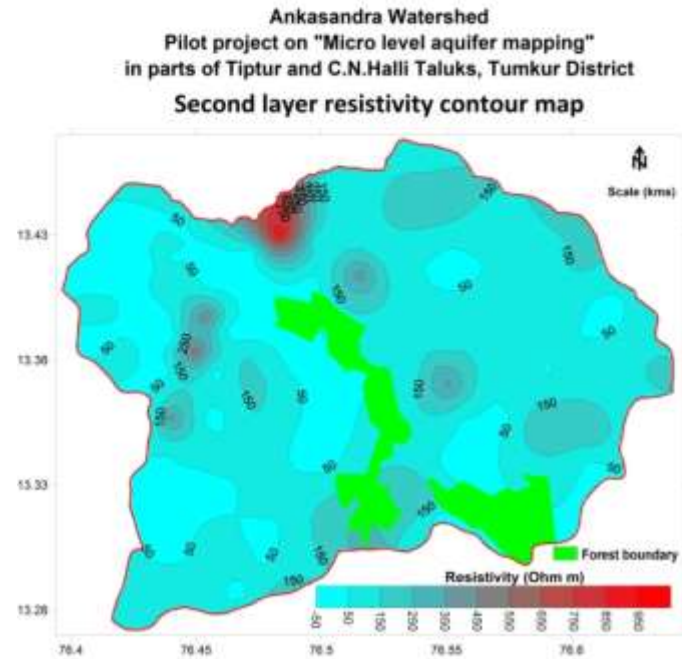


Fig. 3.23: Second layer resistivity map

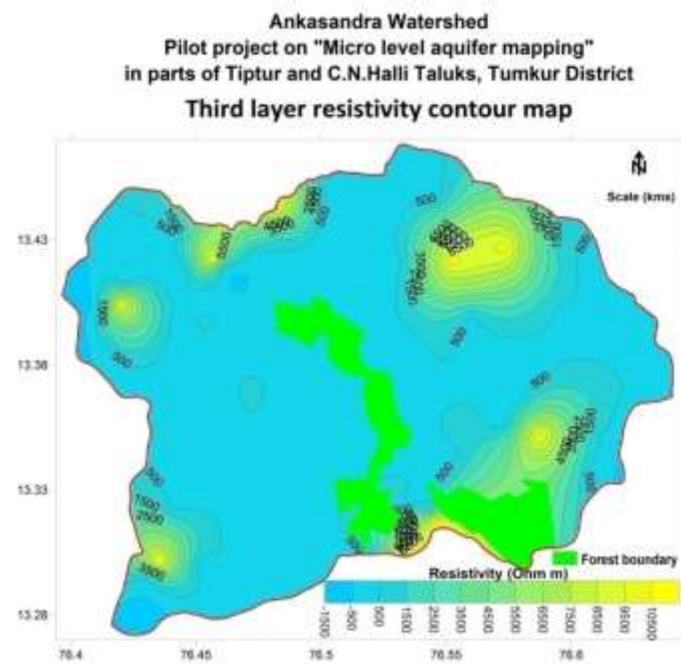


Fig. 3.24: Third layer resistivity map

3.5.1.2 Borehole geophysics

After drilling boreholes in Pilot Project area, 13 borewells have been logged for multiple parameters like Spontaneous Potential for detecting the quality of ground water and resistivity logging with N16” and N64” for determining the fracture dispositions in the sub surface.

Fractures are encountered at Shallow depths i.e. 52-56 m in Settikere and Sasalu. Deeper fractures are indicated i.e. 150 - 198 m in Huchanahatti, Adinayakanahalli, Navule, Hosur, Madihalli, Balavaneralu, Bommanahalli thanda, and Sasalu. Shallow fractures are not potential. The ground water levelis varying from 6.5 m in Hosur to 119 m in Huchanahatti. The details of the geophysical logging are given in Table 3.11.

In addition to this, three boreholes were logged (2 in Tiptur taluk in the southern and south western part and one well in the eastern part bordering C.N.Halli taluk) for multiple parameters like Spontaneous potential for quality of ground water and resistivity logging with N16” & N64” and Natural gamma for determining the fracture dispositions in the subsurface. Self-Potential log was not considered for detailed interpretation; the SP log did not show much deflection which may be inferred due to potable quality of ground water. The geophysical logging of exploratory borewells along with lithologs is given in Annexure 3.2.

Table 3.11: Details of borehole logging of CGWB wells

Sl. No.	Site name	Depth drilled	Depth Logged	Logging Parameters	Water Level	Formation	Depth of fractures encountered	Quality of formation	Remarks
1	Huchanahatti	185	182	SP, N16” N64”	119 m	Dyke	165-167m, 179-182m	Good	Formation change in 125-140m
2	Adinayakanahalli	200	198	SP, N16” N64”	40m	Gneiss	190-191m, 195-198m	Good	
3	Sarathvalli	200	190	SP, N16” N64”	60m	Gneiss	100-105m	Good	
4	Bommanahalli thanda	200	195	SP, N16” N64”	26m	Gneiss	191-192	Good	Formation change in 65-70m, 100-105m
5	Balavaneralu	200	195	SP, N16” N64”	23m	Gneiss	60-65 m, 155-157m	Good	Formation change in 105-110m, 125-130m, 143-145
6	Hosur	200	195	SP, N16” N64”	6.5m	Schist	118-120m, 190-192m	Good	
7	Bharanapura	200	195	SP, N16” N64”	19m	Dyke	45-47, 125-127m	Good	Formation change in 105-106m, 150-155m,165-170
8	Madihalli	200	195	SP, N16” N64”	20 m	Dyke	171-173m,	Good	Formation change in 105-107m, 134-135m
9	Navile	200	195	SP, N16” N64”	65m	Gneiss	147-150m, 180-185m	Good	Formation change in 166-168m
10	Ankasandra	200	195	SP, N16” N64”	90m	Gneiss	93-94m	Good	
11	Madapurahatti thanda	200	195	SP, N16” N64”	20m	Gneiss	65-67m, 105-110m	Good	Formation change in 148-150m,
12	Shettikere	200	195	SP, N16” N64”	31m	Gneiss	52-56m, 78-80m	Good	Formation change in 173-175m
13	Sasalu	183	180	SP, N16” N64”	24m	Gneiss	55-57m, 94-96m, 112-114m, 130-134m 159-162m	Good	

a) Huchanahatti:

Bore hole logged up to 182 m with the parameters of SP, N16" and N64". Two major fractures are encountered in the depth range of 165—167 m bgl (resistivity ranges between 80- 200 ohm m in N64" and 500-700 ohm m in N16") and 179-182 m bgl (resistivity ranges between 240- 360 ohm m in N64" and 860-900 ohm m in N16"). Electrical log is matching with the litholog. Depth to ground water level is deep i.e.119 m bgl in this site. Formation change is observed in the depth range of 140 m bgl onwards based on the resistivity behaviour.

b) Adinayakanahalli:

Bore hole is logged up to a depth of 198 m with the parameters of SP, N16" and N64". Two fractures are observed at the depth of 75-77 m bgl (resistivity ranges between 40- 200 ohm m) 190-191 m bgl (resistivity ranges between 220- 280 ohm m). Formation is Gneiss and depth to ground water levelis 40 m bgl.

c) Sarathavalli:

Bore hole is logged up to 190 m with the parameters of SP, N16" and N64". Only one fracture is encountered in this site at the depth of 98-104m bgl (Resistivity ranges between 120-360 ohm m). Formation is Gneiss and depth to ground water levelis 60 m bgl.

d) Bommanahallithanda:

Bore hole is logged up to 195 m with the parameters of SP, N16" and N64". Fractures are observed in the depth range of 66-68,(resistivity ranges between 240- 300 ohm m in N64" and 400-520 ohm m in N16"), 88-90 m bgl (resistivity ranges between 50- 500 ohm m in N64" and 560-760 ohm m in N16"), 98-102 m bgl (resistivity ranges between 160- 200 ohm m in N64" and 360-400 ohm m in N16"), 188-190 m bgl (resistivity ranges between 200- 400 ohm m in N64" and 380-500 ohm m in N16") . Formation is Gneiss and depth to ground water levelis 26 m bgl.

e) Baluvanerlu:

Bore hole is logged up to 195 m with the parameters of SP, N16" and N64". Two fractures are observed at the depth range of 60-65 m bgl (resistivity ranges between 50- 160 ohm m in N64" and 280-440 ohm m in N16"), 108-110 m bgl (resistivity ranges between 200- 240 ohm m in N64” and 400-440 ohm m in N16”), 125-126 m bgl (resistivity ranges between 40- 200 ohm m in N64” and 1060-1160 ohm m in N16”)and 155-157 m bgl (resistivity ranges between 240-320 ohm m in N64” and 860-1360 ohm m in N16”). Formation is Gneiss and depth to ground water levelis 23 m bgl.

f) Hosur:

Bore hole is logged up to 195 m with the parameters of SP, N16” and N64”. Two fractures are encountered in this site at the depth of 119-120 m bgl (resistivity ranges between 560- 620 ohm m in N64” and 1280-1450 ohm m in N16”) and 195-196 m bgl (resistivity ranges between 560-640 ohm m in N64” and 1100-1600 ohm m in N16”). Formation is Schist and depth to ground water level is very shallow i.e. 6.5 m bgl.

g) Bharanapura:

Bore hole is logged up to 195 m with the parameters of SP, N16” and N64”. Two fractures are encountered in this site at the depth of 45-47 m bgl (resistivity ranges between 1400- 1480 ohm m in N64” and 2200-2280 ohm m in N16”), 73-75 m bgl (resistivity ranges between 400- 1200 ohm m in N64” and 200-400 ohm m in N16”), 105-106 m bgl (resistivity ranges between 360-1200 ohm m in N64” and 1800-2000 ohm m in N16”) and 125-127 m bgl (resistivity ranges between 1200- 1840 ohm m in N64” and 1800-2080 ohm m in N16”). Formation is Dyke and depth to ground water levelis 19 m bgl.

h) Madhihalli:

Bore hole is logged up to 195 m with the parameters of SP, N16” and N64”. Only one fracture is encountered in this site at the depth of 171-173 m bgl (resistivity ranges between 100- 120 ohm m in N64” and 120-200 ohm m in N16”). The formation change is observed between Dyke and Gneiss with lowering of resistivity in the depth range of 107-108 to 134-136 m bgl. Depth to ground water levelis 20 m bgl.

i) Navule:

Bore hole is logged in this site up to 195 m with the parameters of SP, N16” and N64”. Only one fracture is encountered in this site at the depth between 183-185 m bgl (resistivity ranges between 122- 160 ohm m in N64” and 240- 400 ohm m in N16”). The formation is Gneiss and depth to ground water levelis 65 m bgl.

j) Ankasandra:

Bore hole is logged up to 195 m with the parameters of SP, N16" and N64". Only one fracture is encountered in this site at the depth of 93-94 m bgl. Formation is Gneiss and depth to ground water levelis 65 m bgl.

k) Madapurahattithanda:

Bore hole is logged in this site up to 195 m with the parameters of SP, N16" and N64". Formation change is observed as lowering of resistivity in the depth of 65- 67 m bgl & 102 – 105 m bgl. Fractures are observed between the depth range of 158-160 m bgl (resistivity ranges between 100- 120 ohm m in N64" and 400-780 ohm m in N16") and 174-176 m bgl (resistivity ranges between 40- 140 ohm m in N64" and 500-600 ohm m in N16"). The formation is Gneiss and depth to ground water level is 20 m bgl.

l) Settikere:

Bore hole is logged up to 195 m with the parameters of SP, N16" and N64". Two fractures are encountered in this site at the depth of 52-56 m bgl (resistivity ranges between 200- 400 ohm m in N64" and 440-500 ohm m in N16") and 78-80 m bgl (resistivity ranges between 100- 240 ohm m in N64" and 400-500 ohm m in N16"). The formation is Gneiss and depth to ground water levelis 31 m bgl.

k) Sasalu:

Bore hole is logged up to 180 m with the parameters of SP, N16" and N64". Five fractures are encountered in this site at the depth of 55-57 m bgl (resistivity ranges between 1300- 1700 ohm m in N64" and 1240-1280 ohm m in N16"), 94-96 m bgl (resistivity ranges between 700- 1200 ohm m in N64" and 1280-1760 ohm m in N16"), 112-114 m bgl (resistivity ranges between 840-1640 ohm m in N64" and 1200-2720 ohm m in N16"), 130-134 m bgl (resistivity ranges between 500- 700 ohm m in N64" and 900-1140 ohm m in N16"), 159-162 m bgl (resistivity ranges between 700- 2300 ohm m in N64" and 1600-2000 ohm m in N16") and 172-173, m bgl (resistivity ranges between 1440- 2560 ohm m in N64" and 1280-2400 ohm m in N16") Formation is Gneiss and depth to ground water levelis 24 m bgl.

l) Khaimara Junction:

Two highly fractured zones from 67-72 and 76-80 m bgl were observed. In the gamma log, two distinct zones of gamma counts were observed viz., from 10-70 m bgl – high gamma count and generally less gamma count from 70-135 m bgl.

m) Manakikere:

It is observed that, natural gamma indicated high counts in the fractured zone. Also, between depths of 65-108, which is reflected as massive/hard formation in the resistivity log, has been depicted as low gamma counts in general with minor kinks in between indicating minor fractures in that depth range.

n) Timmarayanahalli:

In normal resistivity log, greater variation of resistivity is observed below 115m. Similarly, Natural gamma log also indicated grater variation in gamma counts (low as 60 to>350) below 145m depth, which may be attributed to highly disturbed formation at depth. The S.P. log indicated clear development below 90m with positive deflection against low resistivity zones reflected in Normal resistivity log. Logging indicated shallow weathered zone at Khaimara junction in C.N.Halli taluk and deeper weathered zone up to 33m in Manakikere and Timmarayanahalli. The fractures are more frequent up to depth of 90 m in all the wells and deeper fractures are encountered in Manakikere and Timmarayanahalli at 113-125 m and 172-176 m respectively. Natural gamma log indicated high gamma counts against resistivity lows at fractured zones. Also, distinct behaviour of resistivity and gamma counts were observed where greater variations of values were indicated.

3.5.1.3 Conclusion and correlation

Results have revealed the lateral and vertical extent of weathered zone, depth to hardrock, fractured formations and massive formations, which were demarcated based on distinct geophysical signatures. Borehole logging indicated disposition of fractured formations, especially, the natural gamma logging which showed high gamma counts against fractured zones. Indication of fractured zones in the western half of the study area from resistivity behaviour and deeper fractures indicated from logging at Manakikere and Timmarayanahalli are well correlated with hydrogeological features such as lineaments and intrusions in the western part of the study area.

The geophysical surveys revealed the thickness of weathered formation in the study area which is highly useful in knowing whether the area is suitable for construction of dug wells for domestic and irrigation purposes. It also reveals the length of casing to be lowered in construction of borewells and the cost of casing thereon. The geophysical surveys reveal the vertical extension of the fractured aquifers in massive formation i.e., below the weathered formation. It is very useful for the owner of the borewell to what depth the borewell can be drilled to get high yields and minimize the cost of construction of borewells.

3.5.2 Geophysics (from NGRI Report)

Data Acquisition:

In addition to the data generated by CGWB, the ground geophysical data (i.e, VES, ERT, GRP, GTEM, SkyTEM and HeliMAG) collection were done during pre- and post- SkyTEM phases. Table 3.12 shows the details of geophysical data acquisition with brief mark on instrument used system parameters.

Table 3.12: Total data collection in AQKAR by NGRI

DatasummaryatAQKAR,Tumkur(Karnataka)							
NameofActivity		Target	Pre SkyTEM	SkyTEM	Post SkyTEM	Total	Instruments used
1-D GEOPHYSICS	VES (no.)	100	43		17	60	Syscal(IRIS)and Terrameter-LS (ABEM)systems wereused
	TEM (no.)	20	26		0	26	TEMfast48HPC systemwith50mx 50mloopsize,1and 4Acurrentwere used
2-D GEOPHYSICS	ERT (LKM)	20	32		0	32 (15.6 km)	Syscal(IRIS)and Terrameter-LS (ABEM)systems wereused
	GRP	0	19		18	37	Syscal(IRIS)and Terrameter-LS (ABEM)systems wereused
HeliTEM	SkyTEM(LKM)			2909		2909	TEMandMagnetic datausingLine/Tie line spacing: 200/2000ms

GroundGeophysics: 1DGeophysics

Vertical Electrical Soundings:

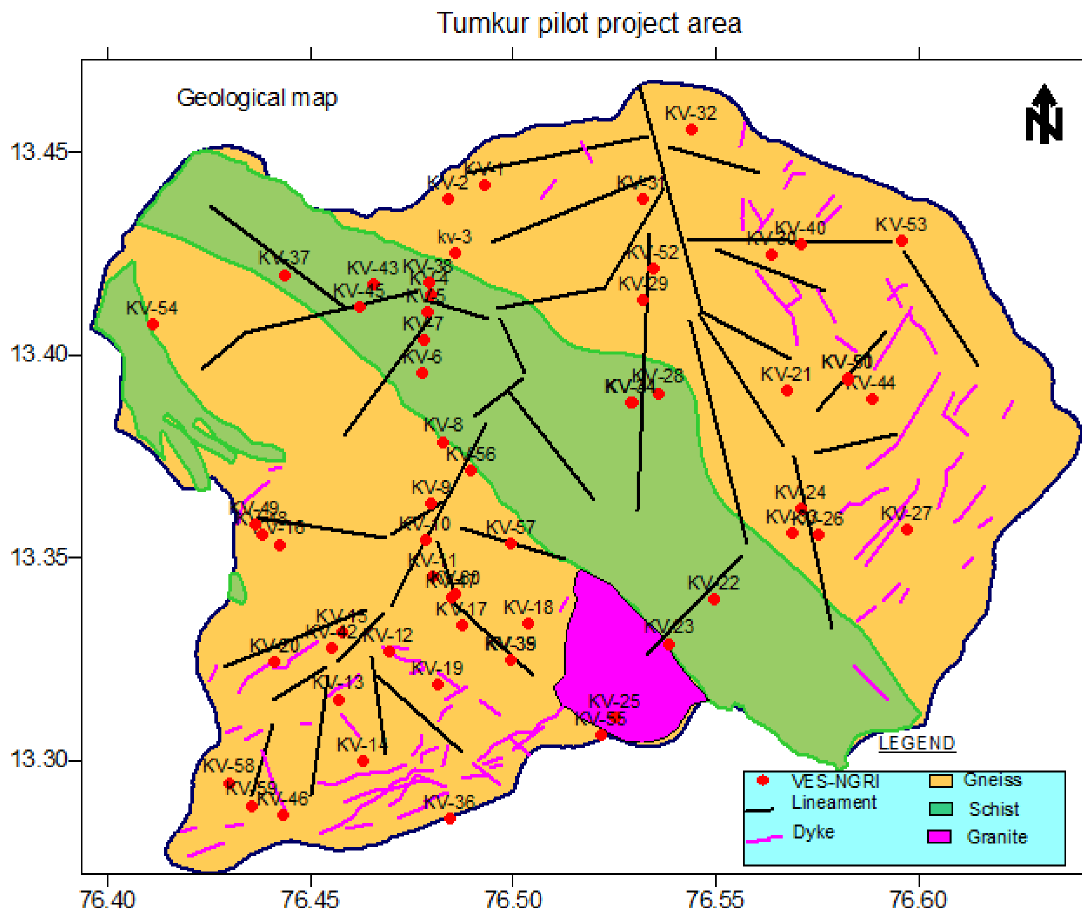


Fig. 3.25: Location map VES survey

Typical VES Curves

Out of the 32 VESconducted in the study area(Fig. 3.25) a few VES curves are quite significant, characterizing the groundwater targets under the present objective of the study and are discussed here. The VES KV-8 was observed at Halkurike village qualitative interpretation of the VES curve through curve-break method (Ballukarya and Sakthivadivel, 1984) reveals presence of a number of fracture zones at depths 65-70, 80-100 and 110-140 m bgl. Other typical VES curves e.g. KV-5, KV-12 and KV-20 are also show fractures at depths. The same are shown in Fig. 3.26.

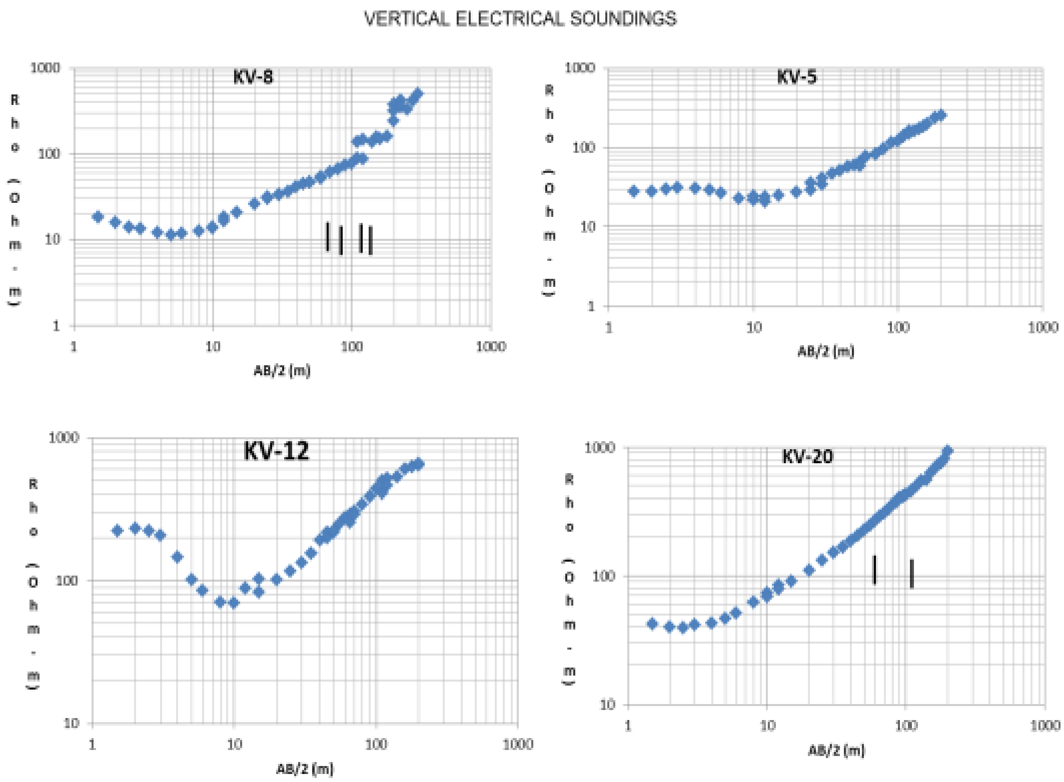


Fig. 3.26: Typical curves in the study area

Standardization of layer-resistivities

Based on the available borehole information, an attempt has been made to establish the resistivity ranges obtained from VES for different lithological units. The same is given below in Table 3.12b:

Table 3.12b: Resistivity ranges for different litho units and hydrogeological conditions

Lithological Unit	Resistivity Range (Ohm-m)	Hydrogeological conditions
Surface layer	4-1635	Higher resistivities indicate dry condition
Weathered Gneiss	15-80	Saturated, lower limit of resistivity indicates higher clay content leading to less permeability
Weathered Schist	4-60	Saturated, lower limit of resistivity indicates higher clay content leading to less permeability
Semi-weathered Schist	100-160	Saturation is expected
Semi-weathered Gneiss	120-300	Saturation is expected, higher limit indicates less saturation to dryness

Jointed & fractured Gneiss	300-800	Saturation only in fracture zones and joints, higher resistivities indicate dryness
Hard compact rock	>1500	Very little possibility of saturated yielding fractures

It is observed that the resistivity ranges overlap for different litho units. The resistivity values established for different litho units have been used for deducing the hydrogeological conditions from VES interpretation.

Geo-electrical cross section

Preparation of geoelectrical cross-section in hardrock is not justified because of the rapid hydrogeological variations. However, a north-south geo-electrical cross section along Huliyar-Tiptur road was attempted using VES data and available subsurface information (Fig. 3.27). In general, the section has brought out a three layered subsurface setup with hard and compact basement overlain by semi-weathered zone and highly weathered layer successively. Only in a few patches either the highly weathered zone is directly underlain by hard and compact bedrock (between VES KV-8 and A-77, and between VES KV-12 and A-23) or it is almost absent and the semi-weathered zone starts right from the surface (below very thin veneer of weathered layer) and is underlain by the compact bed rock as seen between VES A-13 and A-12, at the site of VES KV-11, and between VES A-23 and KV-13.

The thickness of highly weathered zone varies from 1.1 m (KV-3) to 12.2 m (KV-8) in the Schist zone and is found to have the maximum extent of 14 m at KV-12. The semi-weathered zone has attained larger thickness in the topographic depressions along the section and is estimated to have maximum thickness of 49.5m at KV-14 (near village Gedlahalli). It has the minimum thickness of about 7.5 m at VES A-7.

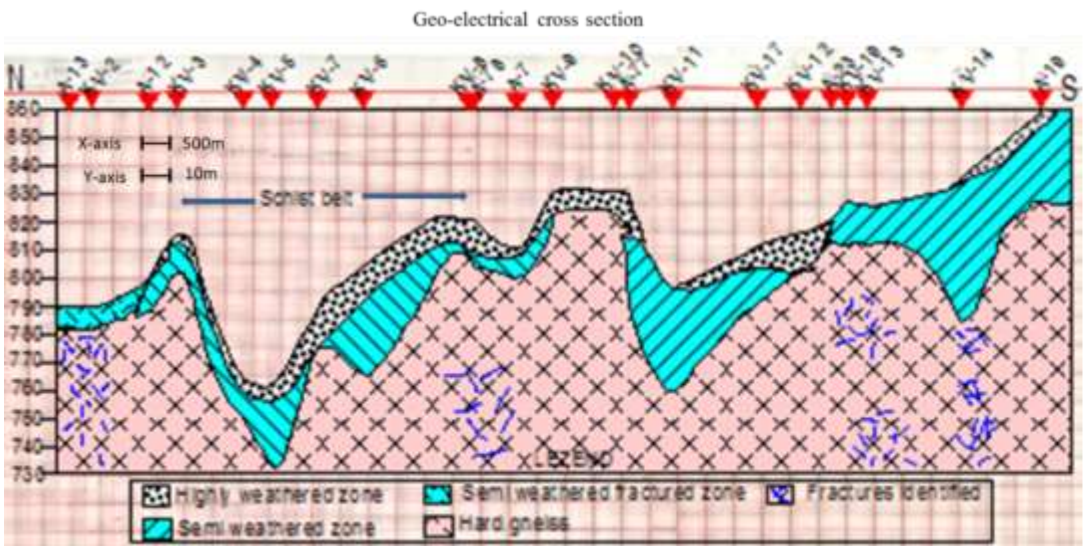


Fig. 3.27: Geo-electrical section along Huliar-Tiptur road (Database NGRI & CGWB)

The depth to resistive compact bedrock along this section varies from8.2 m (at VES KV-10) to 68.8 m (at the VES KV-2), where the presence of fracture zones is indicated below 13.7 m with fractures at 40-45 m, 50-60 m and 70-80 m. The presence of fractures is also revealed at VES KV-8 (at depths 65-70 m and 80-100 m), KV-13 (at 30-35 m, 45-50 m and 90-100 m) and at KV-14 (between depths 40-45 m, 50-60 m, 70-80 m and 100-110 m).

Transient Electromagneticmeasurement (TDEM)

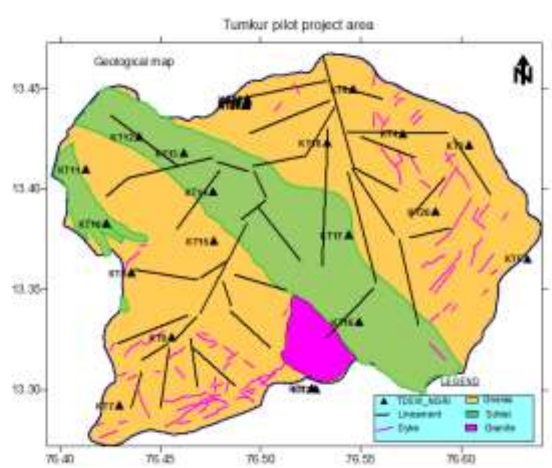


Fig. 3.28: Location map of TDEM survey

TDEM survey was conducted at 26 locations in the study area in order to delineate subsurface layer parameters and fractures (Fig. 2.28). The data was collected with varying current and frequencies to reduce the error. The collected data is plotted in **Res TEM** computer based software to prepare the subsurface model. Most of the soundings reflect two to three layer models. At some of the TDEM locations VES was also conducted for the correlation. From the results it is found that TDEM technique can be helpful in delineation of first two layers (i.e. weathered zone and semi-weathered zone) after that more noises were observed in the data. This advanced technique could be useful in delineating deeper zones with higher capacity equipment. The results of TDEM and VES are not correlating in hardrock area.

The below figure 3.29 shows the TEM results along the ERT line which was conducted across the dyke near Madhapurahatti. In all the TEM sections found that it is giving two to three layer models of the subsurface. From centre to towards right all three sections show dyke effect after first layer and left side sections show top high resistivity layer followed by low resistivity layer. These results are to be further reinterpreted with available CGWB hydrogeological data.

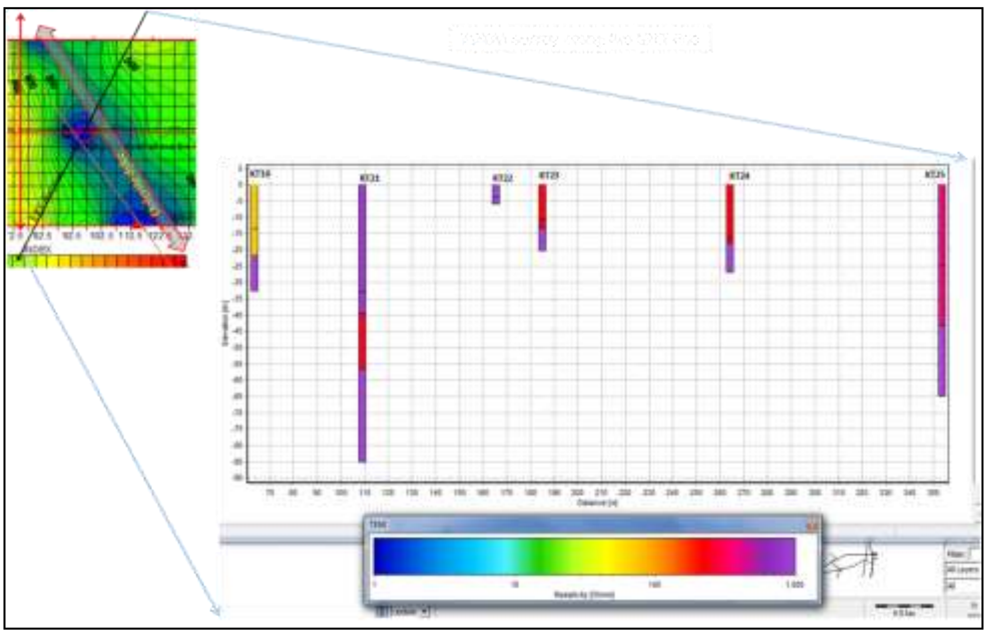


Fig. 3.29: TEM sections showing the subsurface layers

Aarhus work bench has been utilized to carry out 3D gridding along the line and generate vertical resistivity section. Two sections along the N-S traverse have been prepared based on the VES and TEM data shown in Fig. 3.30. Both the images found well corraborating with eah other. This has also shown the potential appplication of the TEM soundings. However, its applicability in mapping the fissured Granite needs to be established with the use of high transmitter TEM instrument.

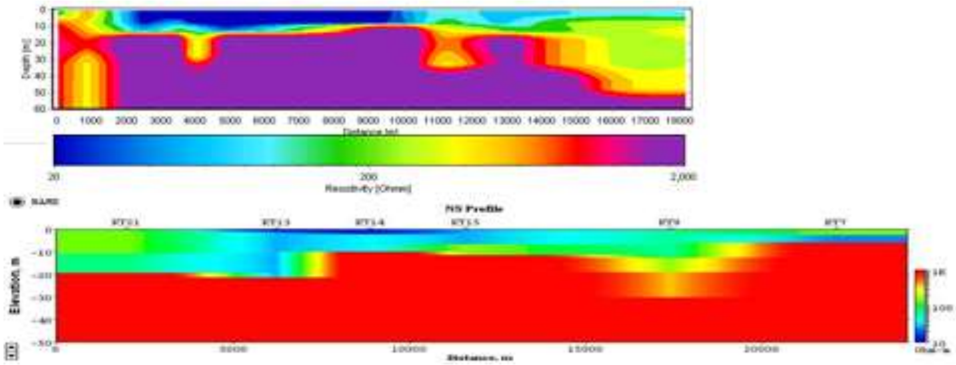


Fig. 3.30: Resistivity section along NS profile derived from VES (upper) and TEM data

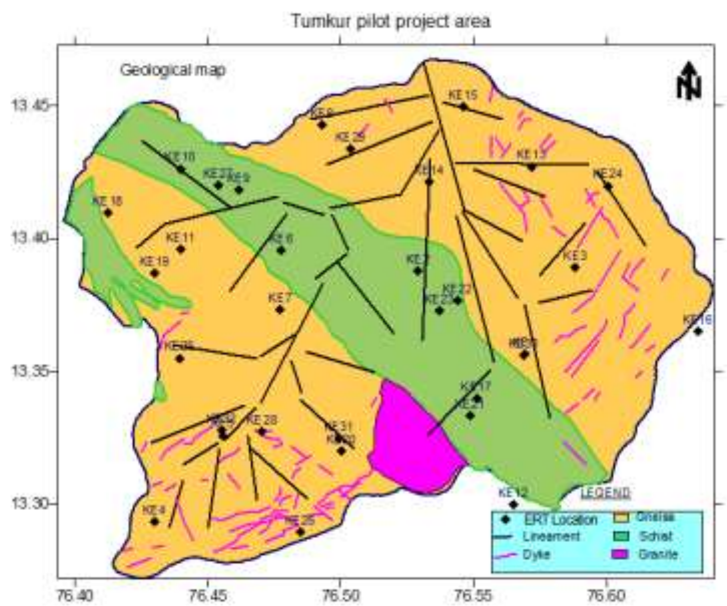


Fig. 3.31: ERT location map, AQKAR, Tumkur, Karnataka

GroundGeophysics: 2DGeophysics

Electrical resistivity tomography survey was carried out at 29 locations in the project area (Fig.3.31) using Sisal Jr. Switch 48 Multi-electrode Resistivity Meter with 10 m electrode spacing. The processed ERT images have been interpreted in terms of hydrogeological conditions. The results are briefly given in Table 3.13 and hydrogeological inferences are given in Table 3.14.

Table 3.13: ERT results in the Tumkur Pilot Project Area

ERT No.	Location	Weathered zone maximum thickness (m)	Weathered zone Resistivity (Ωm)	Depth to bedrock along the profile (m)		Bed rock Resistivity ((Ωm)
				min	max	
KE-1	Sasalu	20	180	10	30	950
KE-2	Madhihalli	20	175	23	25	1500
KE-3	Siddaramanagara	25	176	25	31	1000
KE-4	Thimmalapura	19	150	15	48	823
KE-5	Sarathvalli	30	186	20	50	1000
KE-6	Baswarajpura	41	190	15	68	926
KE-7	Halkuriki	18	190	15	32	850
KE-8	Madhapurahatti	25	150	13	39	900
KE-9	Baranapura	25	180	35	39	1300
KE-10	kamalapura	20	170	12	26	1000
KE-11	Bommanahalli	32	200	27	62	1000
KE-12	Bandegate	5	140	10	57	1200
KE-13	Navile	24	166	33	34	1000
KE-14	Kuppuru	35	160	48	70	1000
KE-15	Ankasandra	19	190	15	32	1100
KE-16	Bovicolony	35	160	18	67	1100
KE-17	Gopalanahalli	18	190	12	18	820
KE-18	Rudrapura	10	190	12	18	1000
KE-19	Balavanerla	18	220	3	31	1100
KE-20	Adinayakanahalli	18	150	8	35	900
KE-21	Irlagire	36	160	18	58	1100
KE-22	Gollarahatti	18	160	31	48	1200
KE-23	Hosur	30	160	31	35	900
KE-24	Melanahalli	12	170	10	25	800
KE-25	Manjunathapura	32	220	35	50	1100
KE-26	Hucchanahatti	25	170	20	48	1200
KE-27	Kamalapura	28	150	25	35	900
KE-28	Harisamudra	18	170	15	32	850
KE-29	Alakatte	25	150	18	35	1250

Table 3.14: ERTs showing possible presence and absence of deeper saturated fracture zones

ERT No.	Location	Weathered zone Resistivity (Ωm)	Weathered zone thickness variation (m)	Bed rock Resistivity (Ωm)	Hydrogeological Inferences
ERTs along which variation in thickness of weathered zone is considerable indicating better possibility of fracture zone development					
KE-6	Baswarajpura	190	53	926	Deepening of weathering with relatively less resistivity of the underlying compact bed rock indicates possibility of deeper occurrences of saturated fracture zone
KE-16	Bovicolony	160	49	1100	Deepening of weathering indicates possibility of deeper occurrences of saturated fracture zone
KE-12	Bandegate	140	47	1200	Deepening of weathering indicates possibility of deeper occurrences of saturated fracture zone
KE-21	Irlagire	160	40	1100	Deepening of weathering indicates possibility of deeper occurrences of saturated fracture zone
KE-11	Bommanahalli	200	35	1000	Deepening of weathering indicates possibility of deeper occurrences of saturated fracture zone
KE-4	Thimmalapura	150	33	823	Relatively less resistivity of weathered zone and also that of the underlying compact bed rock indicates possibility of deeper occurrences of saturated fracture zone
KE-5	Sarathvalli	186	30	1000	Deepening of weathering indicates possibility of deeper occurrences of saturated fracture zone
KE-19	Balavanerla	220	28	1100	Deepening of weathering indicates possibility of deeper occurrences of saturated fracture zone
KE-26	Hucchanahatti	170	28	1200	Though the variation in weathered zone thickness is same as KE 19, this is hydrogeologically more favourable as compared to KE 19 because the minimum weathered zone thickness along KE26 is 20 m while that along KE 19 is 3 m
KE-20	Adinayakanahalli	150	27	900	relatively less resistivity of the underlying compact bed rock indicates possibility of deeper occurrences of saturated fracture zone
KE-8	Madhapurahatti	150	26	900	Relatively less resistivity of weathered zone and also that of the underlying compact bed rock indicates possibility of deeper occurrences of saturated fracture zone
KE-14	Kuppuru	160	22	1000	Deepening of weathering indicates possibility of deeper occurrences of saturated fracture zone
KE-1	Sasalu	180	20	950	relatively less resistivity of the underlying compact bed rock indicates possibility of deeper

					occurrences of saturated fracture zone
ERTs along which variation in thickness of weathered zone is negligible indicating lesser possibility of fracture zone development					
KE-2	Madhihalli	175	2	1500	Hydrogeologically not favourable because of least variation in weathered zone thickness and relatively resistive bed rock,
KE-3	Siddaramanagara	176	6	1000	Hydrogeologically may not be favourable for fracture zone development
KE-9	Baranapura	180	4	1300	Hydrogeologically not favourable because of least variation in weathered zone thickness and relatively resistive bed rock,
KE-13	Navile	166	3	1000	Hydrogeologically not favourable because of least variation in weathered zone thickness and relatively resistive bed rock,
KE-17	Gopalanahalli	190	6	820	Though weathered zone variation is same as KE3 and KE18, it could be hydrogeologically better as resistivity of the bed rock is comparatively less
KE-18	Rudrapura	190	6	1000	Among the ERTs hydrogeologically most unfavourable as weathered zone thickness is less
KE-23	Hosur	160	4	900	Though weathered zone variation is same as KE9 and also weathered zone thickness is comparable, it could be hydrogeologically better as resistivity of the bed rock is comparatively less

Electrical Resistivity Tomography (ERT) surveys revealed the vertical and lateral extent of subsurface layers, weathered zone thickness, and variation in the depth to bed rock in the watershed. The 2D data is interpreted using the calibrated results based on borewell lithologs obtained from the farmers-the owners of the borewells. The maximum thickness of weathered zone is found varying from 5 m in southern part to 41 m in north-western part of the watershed. At some of the locations in the NE and NW parts of the watershed thick weathered zone was observed as compared to the thin zones in the southern part of the watershed. The resistivity of weathered zone varies from 100 to 220 Ohm-m depending upon its thickness and degree of saturation or moisture content. The depth to the bed rock is found varying from 3 m in west to 70 m (including fractured zone) in the eastern part of watershed. The resistivity of the bedrock varies from 800 to 1300 Ohm-m (Fig. 3.32).

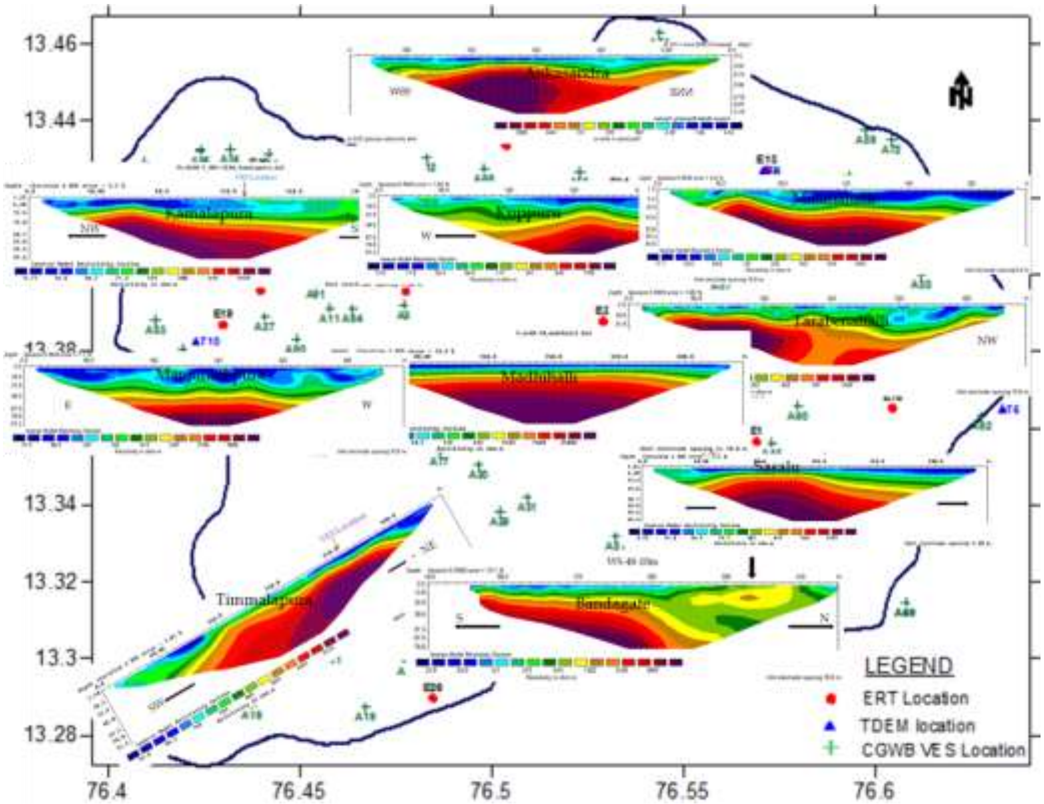


Fig. 3.32: Over view of the selected ERT sections in the Tumkur watershed, showing weathered zone thickness and variations in depth to bedrock

Weathered zone thickness map

The weathered zone map (Fig. 3.33) is prepared using the interpreted results of VES conducted by NGRI and CGWB and the map is shown below. The weathering in the watershed varies from place to place depending on a number of parameters like drainage, topography, recharge, soil cover, composition of formation etc. The weathered zone thickness is found varying from almost zero near the exposures to 41 m in the study area. In the eastern part of the watershed (at Bandegate village) the observed thickness is very low whereas in the north-western part (at K.Halli village) it has the maximum thickness.

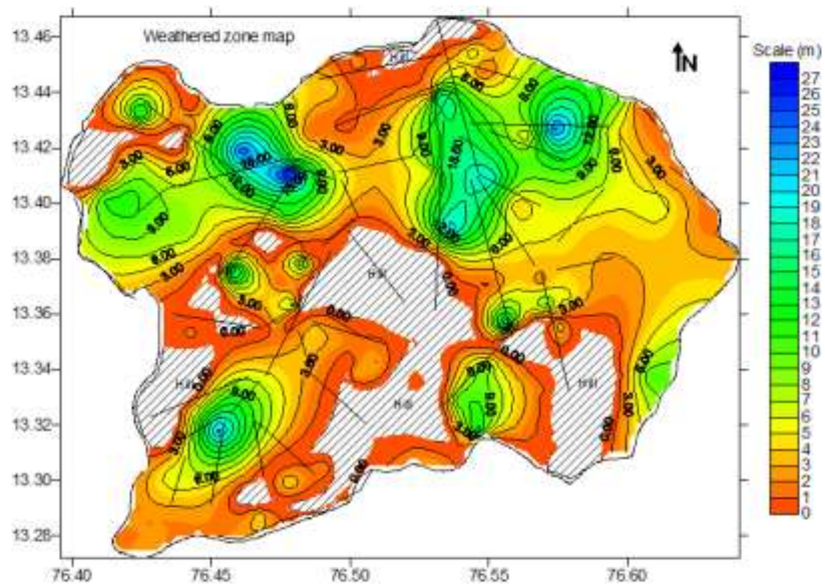


Fig. 3.33: Weathered zone thickness contour map (Data base NGRI & CGWB)

Saturated zone thickness map

Saturated zone thickness map (Fig. 3.34) is prepared for the month of Feb 2013 by subtracting the depth to ground water level obtained from CGWB, from the depth of the bed rock which was obtained from VES data interpretations. It was found that the thickness of the saturated zone varies from 0 to 20 m and higher thicknesses were observed at a few locations.

A major part of the study area exhibits negative values indicating that the depth to the ground water level is greater than the bed rock depth that is, in such areas the weathered zone is almost dry and water is tapped from the fractured zones within the bedrock. In the map shown below zero values indicate where the depth of bedrock and depth to ground water level in the month of February 2013 arethe same.

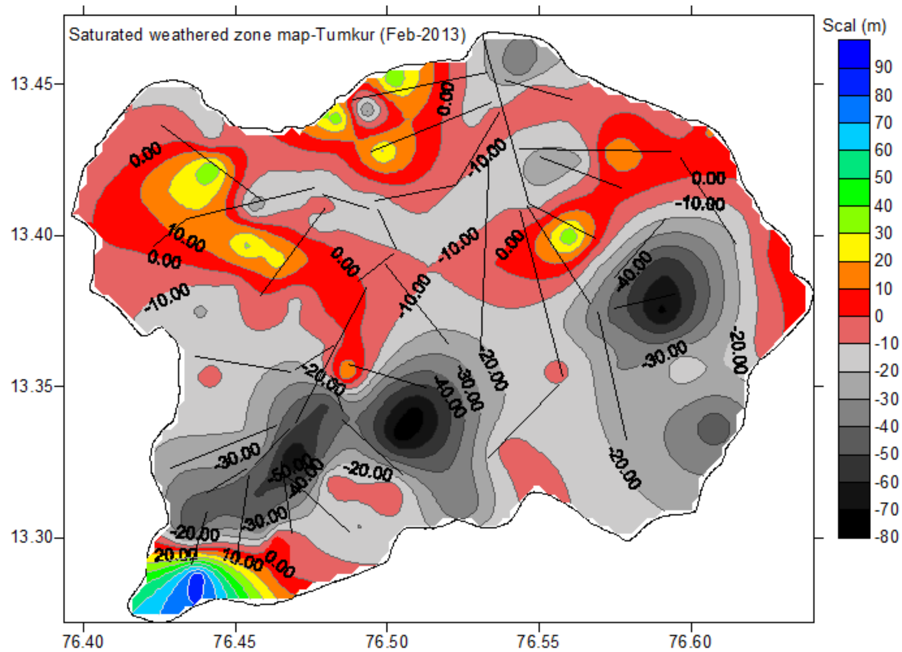


Fig. 3.34: Saturated zone thickness map (Data base NGRI & CGWB)

Gradient Resistivity Profile (GRP)

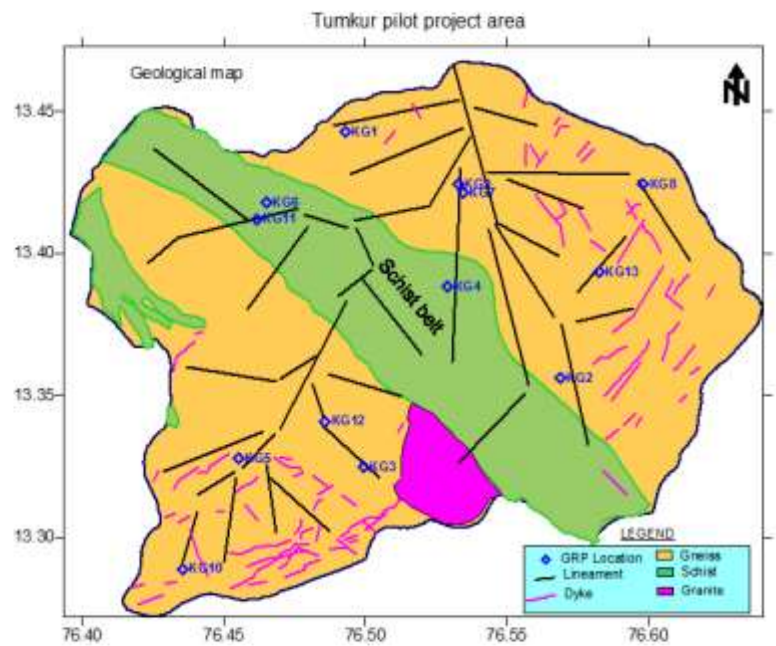


Fig. 3.35: GRPsurveylocation map, AQKAR, Tumkur, Karnataka

Heliborne Geophysical Surveys:

SKYTEM & HELIMAG Surveys

The modern state of art Heliborne Geophysical survey, the major component of the AQUIM project has been done in collaboration with Aarhus University, Denmark using dual movement SkyTEM system developed at Aarhus University and operated and owned by SkyTEM Survey Aps, Denmark.

Dual moment ensures high-resolution information from top to deep level by means of low and high transmitter moments. Originally, it was planned to carry out SkyTEM surveys first, followed by the ground based investigation for spot geophysical character verification. However, due to time and administrative constraints, the heliborne survey was carried out only in the early part of the year 2014.

The aim of the survey was to map the principal dewatered unconfined aquifer at shallow level and fractured aquifers occurring at an average depth below 100 m under recently induced stress of exploitation for agriculture over the entire area. The heliborne survey data was acquired with closely spaced fly line based acquisition. The result of this project also focused towards highlighting the applicability of heliborne survey for complex hydrogeological environment similar to that of AQKAR where over-exploitation prevails with major influencing semi-arid environment. The pilot study aims to demonstrate that the heliborne surveys provide a very efficient, cost effective and rapid methodology with high resolution information for wide aquifer mapping programme (NAQUIM).

In the surveyed area, agricultureis the main activity and agriculture produce based industries essentially depend on ground water which is in vulnerability stage of scarcity and drying up. Though geologically the area seems to be simple with Gneiss and Schists due to hydrogeological complexity of tectonic remnants related conditions, the survey is important in understanding the aquifer system and its areal extension. With a moderate degree of variability in topography, lithological composition, air pressure, quality of ground water, etc., which are likely to influence the data quality, adequate care has been taken while using the state of art data processing and inversional algorithms while generating the output through using the laterally and spatially constrained diversion (LCI & SCI) approaches.

3.6 SUB-SURFACE INFORMATION

3.6.1 Ground water exploration through outsourcing (AAP 2013-14)

Under the pilot project on aquifer mapping, it is proposed to construct 20 exploratory wells (EW) to know the aquifer type, yield, geometry, ground water quality and Specific capacity, Transmissivity (T) and Storage coefficient up to 200m depth. However, only 14 exploratory wells were drilled in the area.

3.6.2 Selection of sites for exploratory wells

For test drilling of 14 EWs, 30 tentative sites were selected in Government lands based on interpretation of geology, topography, spatial distribution etc. on 1:50,000 scale maps followed by field reconnaissance and geophysical investigations. No objection certificates (NOC) were collected from the concerned Government authorities.

3.6.3 Construction of exploratory wells

After receiving the NOC from state authorities, 14 (70 % - before heliborne survey) sites were shown to drilling consultancy for construction of wells. Drilling at Sarathavalli was commenced on 24/7/2013. The other 13 EWs were taken up at Balavaneralu, Bommanahalli thanda, Bharanapura, Hosur, Madapurahatti thanda, Navule, Ankasandra, Huchanahatti, Adinayakanahalli, Settikere, Sasalu, Madihalli and T.B.Colony villages subsequently. The drilling activity was completed on 02/10/2013.

Construction of EWs began with drilling in weathered formation from the ground until hard formation is reached. The soft formation is cased with 8" casing pipe up to desired depth to avoid collapsing. Subsequently, drilling continued with 61/2 or 6 inch drilling bit down to depth of 200 m. Lithological samples were collected for every 3 m to know the subsurface geology of the area. The fractures encountered at different depth were recorded down along with yields and water samples were collected to know the change in ground water quality with depth. Wherever high yields are encountered, drilling to the target depth of 200 m could not be done due to high water pressure. After completion of the well, the well was fitted with suitable well cap and protection box.

In these 14 EWs, the length of casing lowered ranges from 18.92 m at Ankasandra to 52.12 mat Madapurahatti thanda site. The static ground water level ranges from 12.97 m bgl at Hosur to

80.10 m bgl at Sarathavalli site. The drilling discharges ranges from 0.08 lps (Madapurahatti thanda) to 5.54 lps at Sasalu. Out of 14 EWs, 12 EW were constructed in Gneissic formation, one in Schist (Hosur) and one in Dolerite dyke formation (Bharanapura).

At Sasalu (181 m) and Huchanahatti (189.63 m) EWs could not be drilled down to targeted depth of 200 m due to high discharge and also due to hard formation (dolerite) at Huchanahatti village. The location of exploratory wells is shown in Fig.3.36. The hydrogeological details of exploratory wells are given in Table 3.15 and 3.16.

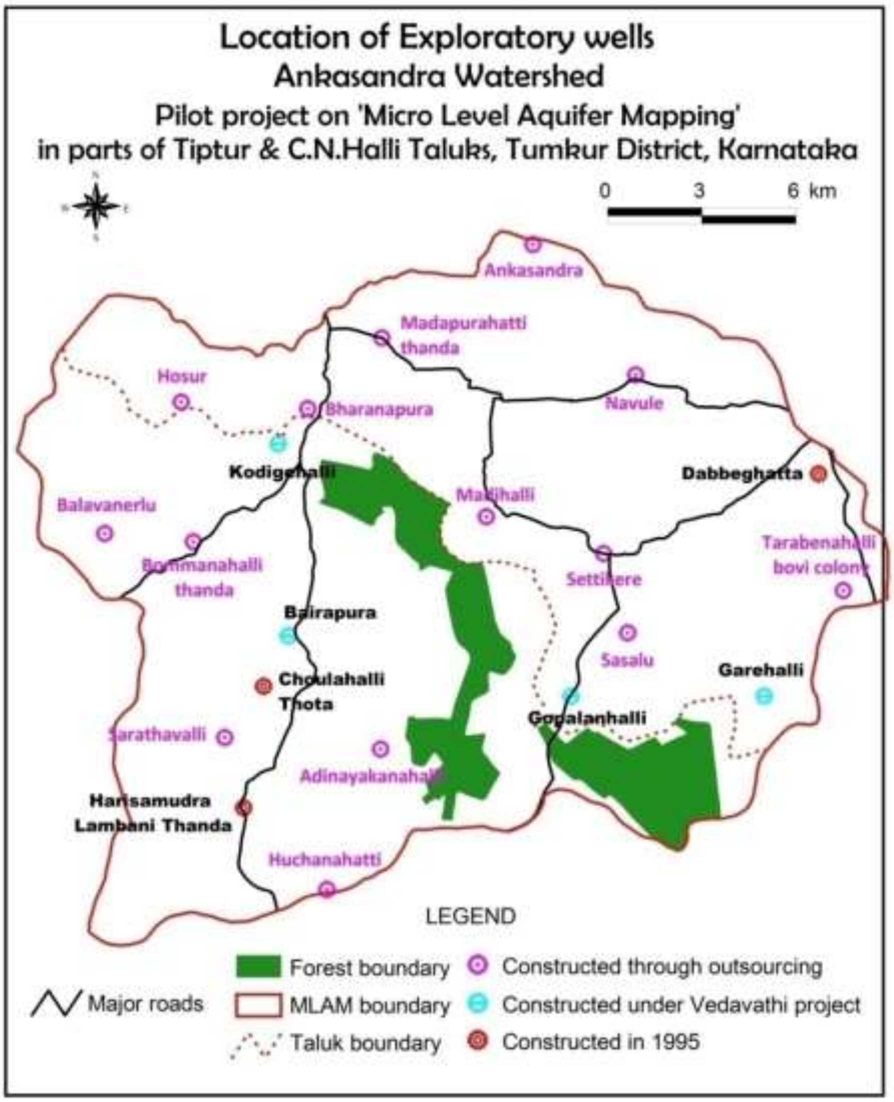


Fig. 3.36: Location of exploratory borewells

Table 3.15: Hydrogeological details of exploratory wells (2013-14)

Sl. No.	Name of the site/location	Taluk	Topo-sheet No.	Aquifer	Co-ordinates (Decimals)		RL (m amsl)	Drilling Details							Drilling discharge (lps)
					Latitude	Longitude		Comm-enced	Comple-ted	Depth (m bgl)	Casing Details				
											Dia. (inch)	m bgl	m agl	bgl +agl	
1	Sarathavalli	Tiptur	57 C/7	Gneiss	13.32758	76.45583	803.420	12.08.2013	20.08.2013	200.00	8	44.70	0.50	45.20	2.91
2	Balavanerlu	Tiptur	57 C/7	Gneiss	13.38367	76.42222	808.545	24.08.2013	28.08.2013	200.00	8	25.50	0.50	26.00	1.79
3	Bommanahalli thanda	Tiptur	57 C/7	Gneiss	13.38142	76.44703	816.815	28.08.2013	29.08.2013	200.00	8	24.17	0.50	24.67	0.08
4	Bharanapura	C.N.Halli	57 C/7	Dyke	13.41797	76.47914	766.055	29.08.2013	30.08.2013	200.00	8	34.20	0.80	35.00	0.59
5	Hosur	C.N.Halli	57 C/7	Schist	13.41983	76.44367	776.445	30.08.2013	31.08.2013	200.00	8	30.68	0.50	31.18	1.22
6	Madapurahatti thanda	C.N.Halli	57 C/7	Gneiss	13.43742	76.49990	769.115	31.08.2013	01.09.2013	200.00	8	51.62	0.50	52.12	0.08
7	Navule	C.N.Halli	57 C/11	Gneiss	13.42721	76.57100	763.125	01.09.2013	02.09.2013	200.00	8	34.92	0.50	35.42	4.36
8	Ankasandra	C.N.Halli	57 C/11	Gneiss	13.46306	76.54227	731.135	11.09.2013	12.09.2013	200.00	8	18.42	0.50	18.92	4.36
9	Huchanahatti	Tiptur	57 C/7	Gneiss	13.28583	76.48442	863.565	13.09.2013	14.09.2013	189.63	8	24.00	0.50	24.50	4.36
10	Adinayakanahalli	Tiptur	57 C/7	Gneiss	13.32445	76.49943	800.600	14.09.2013	16.09.2013	200.00	8	37.96	0.50	38.46	3.84
11	Settikere	C.N.Halli	57 C/11	Gneiss	13.37811	76.56196	766.615	17.09.2013	18.09.2013	200.00	8	38.18	0.50	38.68	1.79
12	Sasalu	C.N.Halli	57 C/11	Gneiss	13.35631	76.56867	780.455	27.09.2013	28.09.2013	181.00	8	32.02	0.50	32.52	5.54
13	Madihalli	C.N.Halli	57 C/11	Gneiss	13.38828	76.52911	765.130	29.09.2013	01.10.2013	200.00	8	42.00	0.64	42.64	0.22
14	T.B.Colony	C.N.Halli	57 C/11	Gneiss	13.36789	76.62906	836.410	01.10.2013	02.10.2013	200.00	8	45.20	0.50	45.70	0.59

Table 3.16: Hydrogeological details of exploratory wells (2013-14)

Sl. No.	Name of the site/location	Drilling Details		Water bearing zones		Cumulative drilling discharge (lps)	SWL (m bgl)
		Depth (m bgl)	Casing (with agl)	Depth (m bgl)	Discharge (lps)		
1	Sarathavalli	200.00	45.20	99.00-100.00 99.56-100.56 101.64-102.64 188.00-189.00	Wet 0.08 1.49 2.91	2.91	80.10
2	Balavanerlu	200.00	26.00	60.35-61.35 66.00-67.00 154.97-155.97	0.08 0.44 1.79	1.79	32.21
3	Bommanahalli thanda	200.00	24.67	192-193	0.08	0.08	31.33
4	Bharanapura	200.00	35.00	44.96-45-96 134.88-135.88 178.84-179.84	Wet 0.08 0.59	0.59	22.54
5	Hosur	200.00	31.18	123-124 191-192	Wet 1.22	1.22	12.97
6	Madapurahatti thanda	200.00	52.12	68-69 88-89 110-111	0.08 0.04 0.08	0.08	28.83
7	Navule	200.00	35.42	150-151 159-160 185-184	1.22 2.91 4.36	4.36	25.57
8	Ankasandra	200.00	18.92	36-37 100-101	Wet 4.36	4.36	20.42
9	Huchanahatti	189.63	24.50	67-68 130-131 170.60-171.60 185.20-186.20	Wet Wet 3.35 4.36	4.36	45.72
10	Adinayakanahalli	200.00	38.46	189-190 197-198	1.49 3.84	3.84	49.47
11	Settikere EW	200.00	38.68	74.06-75-06 82-83	Wet 1.79	1.79	25.66
12	Sasalu	181.00	32.52	54-55 55-56 77-78 96-97 111-112 128-129 143-144 161-162	Wet 0.08 0.14 0.22 2.13 2.50 3.35 5.54	5.54	24.08
13	Madihalli	200.00	42.64	171-172	0.22	0.22	13.39
14	T.B.Colony	200.00	45.70	77-78 161-162	0.22 0.59	0.59	34.00

3.6.4 Dykes

During exploration, the dykes were encountered at various depths. The thickness of the dykes encountered in the exploratory borewells ranges from a few meters to more than 100m. Table 3.17 gives the detailson dykes encountered in exploratory wells.

Table 3.17: Details of dykes encountered in the exploratory borewells

Sl. No.	Location	Depth at which dolerite dyke encountered (m)	Thickness (m)	Remarks
1	Huchanahatti	143.5-189.36	45.86	Dolerite dyke continues below
2	Sarathavalli	123.0-129.0	6.00	-
		195.23-200	4.77	Dolerite dyke continues below
3	T.B.Colony	182.2-187.80	5.60	-
4	Adinayakanahalli	81.10-110.0	28.20	-
5	Madihalli	59.0-70.20	11.20	-
		78.40-106.40	28.0	-
		117.60-134.40	16.8	-
		172-200	28.0	Dolerite dyke continues below
6	Balavaneralu	22.50-119.73	97.23	-
7	Bharanapura	16.86-200	183.14	Dolerite dyke continues below

3.6.5 Aquifer parameters

To know the aquifer parameters, like Specific capacity, Transmissivity (T), Storativity (S), Slug tests / short duration test / step drawdown test (SDT) and long duration tests (APT) were carried out depending on the discharge of the well.

3.6.5.1 Slug tests

Slug tests were conducted at Bommanahalli thanda, Bharanapura, Madapurahatti thanda, Madihalli and T.B.Colony where the drilling discharge is less than one lps. The slug tests revealed the Transmissivity (T) of the formation which ranges from 0.0704 to 8.667 m^2/day. The hydraulic conductivity ranges from 0.0104 to 0.05378 m/day.

3.6.5.2 Short duration tests

Short duration tests were carried out at Balavaneralu, Hosur and Ankasandra sites from 12 to 60 minutes duration. The test at Ankasandra site stopped after 12 minutes of pumping because of heavy drawdown of 47.97 m at one lps pumping. The test at Hosur site also was stopped after 30 minutes of pumping because of heavy drawdown of 45.21 m at one lps pumping. The tests revealed that the specific capacity of the formation ranges from 1.25 lpm/mdd at Ankasandra to 2.47 lpm/mdd at Balavaneralu, which indicates very low capacity of the aquifer at these sites. The 'T' ranges from 0.46 to 1.43 m^2/day indicatinglow 'T' values of the aquifer.

3.6.5.3 Long duration tests

Long duration tests varyingfrom 250 to 1000 minutes duration werecarried out at six sites i.e., Sarathavalli, Huchanahatti, Adinayakanahalli, Settikere, Sasalu, and Balavaneralu. The tests revealed that the specific capacity of the formation ranges from 14.41 lpm/mdd at Settikere to 61.97 lpm/mdd at Sarathavalli which indicates good capacity of the aquifer in these locations. The tests indicated a moderate 'T'values ranging from 13.03 to 33.64 m^2/day. The pumping test and slug test details of exploratory wells are given in Table 3.18.

3.6.6 Fracture analysis

The fracture analysis shows that only five percent (5%) of fractures are falling in 0 to 50 m depth range. About 35% of fractures are falling in depth range of 50 to 100 and 150 to 200 m each and the remaining 25% are falling in depth range of 100 to150 m indicating the presence of deep seated fractures in the area. The details of fracture analysis carried out for 14 EWs are given Table 3.19. The same is graphically represented in Fig. 3.37.

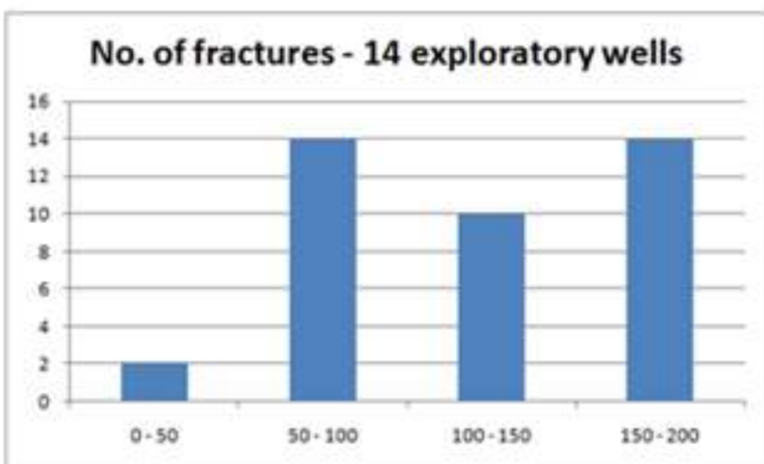


Fig. 3.37: Fracture analysis of 14 exploratory wells

Table 3.18: Details of pumping test/slug test of exploratory wells (2013-14)

Sl. No.	Name of the Site/location	Taluk	Aquifer	Aquifer test	Date	Duration (mins)	Discharge (lps)	DD (m)	Sp. Capacity (lpm/m)	"T" Value (DD) (m^2/day)	"T" Value (RDD) (m^2/day)	"T" Value by Slug test (m^2/day)	"C" Value By Slug test (m/day)
1	Sarathavalli	Tiptur	Gneiss	APT	24.04.2014	1000	2.2	2.13	61.97	33.64	37.29	-	-
2	Balavanerlu	Tiptur	Gneiss	PYT	26.10.2013	60	1	24.32	2.47	1.30	1.09	-	-
3	Bommanahalli thanda	Tiptur	Gneiss	Slug test	25.04.2014	250	-	-	-	-	-	0.174	0.0104
4	Bharanapura	C.N.Halli	Dyke	Slug test	26.04.2014	300	-	-	-	-	-	2.158	0.0125
5	Hosur EW	C.N.Halli	Schist	PYT	27.10.2013	30	1.08	45.21	1.43	0.63	0.55	-	-
6	Madapurahatti thanda	C.N.Halli	Gneiss	Slug test	26.04.2014	120	-	-	-	-	-	8.667	0.0534
7	Navule	C.N.Halli	Gneiss	APT	08.01.2014	380	5.59	14.19	23.64	27.10	136.08	-	-
8	Ankasandra	C.N.Halli	Gneiss	APT	30.04.2014	12	1	47.97	1.25	0.46	0.34	-	-
9	Huchanahatti	Tiptur	Gneiss	APT	27.04.2014	250	1.85	2.91	38.14	22.44	33.78	-	-
10	Adinayakanahal li	Tiptur	Gneiss	APT	13.01.2014	380	4.2	14.28	17.65	13.03	19.9	-	-
11	Settikere	C.N.Halli	Gneiss	APT	19.12.2013	650	4.63	19.28	14.41	14.80	19.28	-	-
12	Sasalu	C.N.Halli	Gneiss	APT	03.01.2013	600	6.17	9.93	37.28	32.21	79.62	-	-
13	Madihalli	C.N.Halli	Gneiss	Slug test	28.04.2014	250	-	-	-	-	-	0.0704	0.04219
14	T.B.Colony	C.N.Halli	Gneiss	Slug test	28.04.2014	280	-	-	-	-	-	0.9175	0.05378

Table 3.19: Fracture analysis of 14 EWs (2013-14)

Analysis of yield potentials (for 14 exploratory wells)								
Depth Range (m bgl)	No. of fractures	% of fractures	< 1 lps		1 - 3 lps		> 3 lps	
			No. of fractures	% of fractures	No. of fractures	% of Fractures	No. of fractures	% of fractures
0 - 50	2	5	2	9	0	0	0	0
50 - 100	14	35	12	52	1	10	0	0
100 - 150	10	25	5	22	3	30	2	29
150 - 200	14	35	4	17	6	60	5	71

3.6.7 Summarized results of ground water exploration

- Depth range of 14 borewells drilled is 181 m (Sasalu) to 200 m.
- Out of 14 EWs, 12 EWs are drilled in Gneisses, 1 in Schist (Hosur) and 1 in dolerite dyke (Bharanapura).
- Depth to water levels range from 12.97 m bgl at Hosur to 80.10 m bgl at Sarathavalli during the drilling period.
- Length of casing lowered is 18.42 m bgl at Ankasandra to 51.62 m bgl at Madapurahatti thanda.
- Drilling discharges range from 0.08 lps at Bommanahalli thanda to 5.54 lps at Sasalu. Five EW yielded less than 1 lps (Bommanahalli thanda, Bharanapura, Madapurahatti thanda, Madihalli and T.B.Colony), 4 EWs yielded 1 to 3 lps (Sarathavalli, Balavaneralu, Hosur and Settikere) and 5 EW yielded more than 3 lps (Navule, Ankasandra, Huchanahatti, Adinayakanahalli and Sasalu).
- Productive fractures are encountered down to depth of 200 m.
- During drilling, dolerite dyke is encountered at various depths- Example-Huchanahatti (143.50 to189.36 m bgl), Adinayakanahalli (81.10 to110 m bgl).
- Highly productive fracture is noticed within dolerite at 170.60 m at Huchanahatti site.
- Contact between Gneiss and dolerite is not productive (Huchanahatti and Adinayakanahalli).
- Ground water quality is generally good for drinking and irrigation.

Field inspection by the Regional Director and other senior officers at Settikere EW site

Demo of litholog sample by the Site hydrogeologist at Settikere EW site

Litholog samples of fracture collected during drilling at Sasalu EW site

High drilling discharge encountered during drilling at Sasalu EW site

Measurement of drilling discharge through 90° V-Notch at Ankasandra EW site

Litholog samples collected at Madihalli EW site

Long duration pumping test at Settikere EW site

Monitoring of ground water level during pumping test at Huchanahatti EW site

Long duration pumping test at Navule EW site

Field inspection by Region Director and other senior officers' druing pumping test Sarathavalli EW site

Slug test conducting at Bommanahalli thanda EW site

Slug test conducting at Bommanahalli thanda EW site

Monitoring of ground water level after completion of drilling at Huchanahatti EW site

The exploratory well converted into piezometer for periodical monitoring

3.6.8 Micro level hydrogeological inventory

Borewell inventory was carried out at 955 locations (573 in C.N.Halli taluk and 382 in Tiptur taluk) covering the entire area with the following details viz., name of the village, year of construction, coordinates, owner, total depth, casing length, fractures encountered at different depths with corresponding yield, total yield, number of hours of pumping per day, total number of pumping days per year, formation, soil type, irrigated area, crops grown, ground water quality etc. The model borewell inventory form is given in Table 3.20. The overlay of well inventory data on village boundary map of the study area is shown in Fig. 3.38. The talukwise and village wise number of wells inventoried are given in Table 3.21.

Table 3.20: Model borewell inventory form

Sl.No.	Database requirement	Model example
1	Sl.No	1
2	GPS_No	GPS_1
3	GPS Elevation (m amsl)	781
4	Village name	Anekatte
5	Well type	Agricultural well
6	Year of construction	2010
7	Latitude	13.36992
8	Longitude	76.57528
9	Owner	Rajashekar S/o Mahalingappa
10	Total depth drilled (m bgl)	183
11	Casing lowered (m bgl)	24
12	Fracture1_m bgl	65.85
13	Yield1_lps	0.5
14	Fracture1_m bgl	93
15	Yield2_lps	1
16	Fracture3_m bgl	158.3
17	Yield3_lps	2
18	Fracture4_m bgl	182
19	Yield4_lps	2.5
20	Availability of electricity (hrs/day)	4.5
21	Geology/Aquifer	Gneiss
22	Soils	Red
23	Major crops	Coconut and Arecanut
24	Cropped area (acres)	5
25	Remarks	High yielding well

Table 3.21: Taluk-wise, village-wise number of borewells inventoried

Well inventory data in C.N.Halli taluk	
Village Name	**Nos.**
Abhujihalli	13
Agasarahalli	3
Ajjenahalli	3
Anekatte	38
Ankasandra	7
Arlikere	19
Bachihalli	1
Ballenahalli	4
Banjara thanda	4
Benakanakatte	2
Bete Ranganahalli	1
Bevinahalli	4
Byadarahalli	2
Chattasandra	14
Chikkenahalli	4
Chunganahalli	7
Dabbeghatta	40
Dasihalli	10
Dasihalli palya	17
Dibbadahalli	1
Dugganahalli	1
Dugudihalli	2
Gerehalli	4
Gopalanahalli	4
Hesarahalli	6
Kadenahalli_1	2
Kallenahalli	16
Kamalapura	6
Kantalagere	1
Kedagihalli	10
Kodalgara	7
Kuppuru	46
Kurubarahalli_1	31
Kurubarahalli_2	11
Madapura	11
Madihalli	10
Makuvalli	8
Manchasandra	2
Marasandra	2
Navule	109
Pinnenahalli	3
Sasalu	8
Savsettihalli	6
Settikere	13
Shavigehalli	2
Siddaramanagara	1
Suleman palya	3
Tammadihalli	16
Tarabenahalli	6

Well inventory data in Tiptur taluk	
Village Name	**Nos.**
Adinayakanahalli	1
Alur	46
Baluvanerlu	3
Basaveshwarapura	2
Bennayakanahalli	7
Bhairanayakanahalli	45
Bhairapura	4
Bommanahalli	4
Chaudlapura	1
Chaulihalli	8
Dasanakatte	2
Doddakatte	1
Gatakanakere	5
Gollarahatti-Bhairanayakanahatti	11
Gollarahatti-Harisamudra	39
Gollarahatti-Timmalapura	1
Gowdanakatte	4
Halenahalli	2
Halkurike	9
Halkurike kaval	22
Harachanahalli	25
Harisamudra	13
Hurlihalli	9
Irlagere	5
Jakkanahalli	4
Kallakere	2
Kibbanahalli	1
Kodagihalli	6
Kugihalla	2
Lakshmanapura	1
Mallidevihalli	1
Manakikere	5
Manjunathapura	5
Mayagondanahalli	1
Misetimmanahalli	2
Muddenahalli	2
Nelagondanahalli	7
Paragondanahalli	19
Ramashettihalli	1
Rangapura	2
Rudrapura	3
Sarathavalli	38
Suragondanahalli	3
Timmalapura	5
Timmarayanahalli	1
Vittlapura	2
Total	**382**

Well inventory data in C.N.Halli taluk	
Village Name	**Nos.**
Tigalanahalli	3
Upparahalli	2
Vaderahalli_1	3
Vaderahalli_2	1
Yerehalli	23
Total	**573**

Well inventory data in Tiptur taluk	
Village Name	**Nos.**

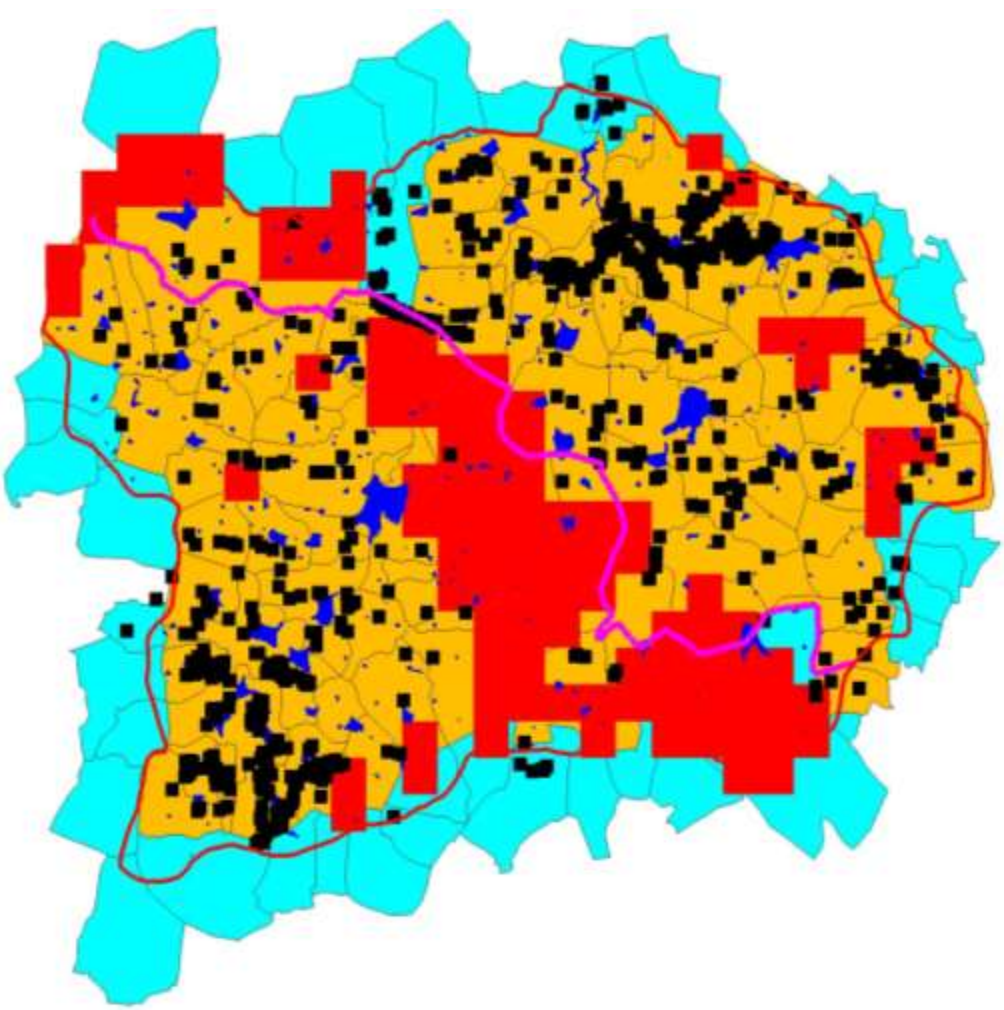


Fig. 3.38: Overlay of well inventory data on village boundary

Map showing village wise, depth wise distribution of borewells in given in Fig. 3.39. In majority of the villages, drilling depth is in the range of 150 – 200 m bgl followed by 200 – 250 m. More than 250 m drilling depths are noticed in certain villages like Agasarahalli, Bhairanayakanhalli, Chikkenahalli, Hulihalli, Kedigahalli, Manjunathapura, Navule and Tigalanhalli. The village-wise distribution of total depth is given in Table 3.22.

Table 3.22: Village distribution of total depth of borewells

Drilling depth-wise analysis					
Sl. No.	**Upto 100 m bgl**	**100 to 150 m bgl**	**150 to 200 m bgl**	**200 to 250 m bgl**	**250 to 280.42 m bgl**
1	Doddakatte	Abhujihalli	Arlikere	Ajjenahalli	Agasarahalli
2	Kantalagere	Adinayakanahalli	Ballenahalli	Alur	Bhairanayakanahalli
3	Rangapura	Bhairapura	Baluvanerlu	Anekatte	Chikkenahalli
4		Dibbadahalli	Banjara thanda	Ankasandra	Hurlihalli
5		Dugganahalli	Basaveshwarapura	Bachihalli	Kedagihalli
6		Gatakanakere	Bete Ranganahalli	Benakanakatte	Manjunathapura
7		Gopalanahalli	Bevinahalli	Bennayakanahalli	Navule
8		Halkurike kaval	Bommanahalli	Byadarahalli	Tigalanahalli
9		Mayagondanahalli	Chattasandra	Chaulihalli	
10		Ramashettihalli	Chaudlapura	Dabbeghatta	
11		Siddaramanagara	Chunganahalli	Dasihalli	
12			Dasanakatte	Gerehalli	
13			Dasihalli palya	Gollarahatti-Harisamudra	
14			Dugudihalli	Gowdanakatte	
15			Gollarahatti-Bhairanayakanahatti	Halkurike	
16			Gollarahatti-Timmalapura	Hesarahalli	
17			Halenahalli	Kallakere	
18			Harachanahalli	Kodagihalli	
19			Harisamudra	Kodalgara	
20			Irlagere	Kurubarahalli_1	
21			Jakkanahalli	Kurubarahalli_2	
22			Kadenahalli_1	Makuvalli	
23			Kallenahalli	Manakikere	
24			Kamalapura	Manchasandra	
25			Kibbanahalli	Sarathavalli	
26			Kugihalla	Sasalu	
27			Kuppuru	Savsettihalli	
28			Lakshmanapura	Settikere	
29			Madapura	Tammadihalli	
30			Madihalli	Timmalapura	
31			Mallidevihalli	Vittlapura	
32			Marasandra		
33			Misetimmanahalli		
34			Muddenahalli		
35			Nelagondanahalli		
36			Paragondanahalli		
37			Pinnenahalli		
38			Rudrapura		
39			Shavigehalli		
40			Suleman palya		

Drilling depth-wise analysis					
Sl. No.	Upto 100 m bgl	100 to 150 m bgl	150 to 200 m bgl	200 to 250 m bgl	250 to 280.42 m bgl
41			Suragondanahalli		
42			Tarabenahalli		
43			Timmarayanahalli		
44			Upparahalli		
45			Vaderahalli_1		
46			Vaderahalli_2		
47			Yerehalli		

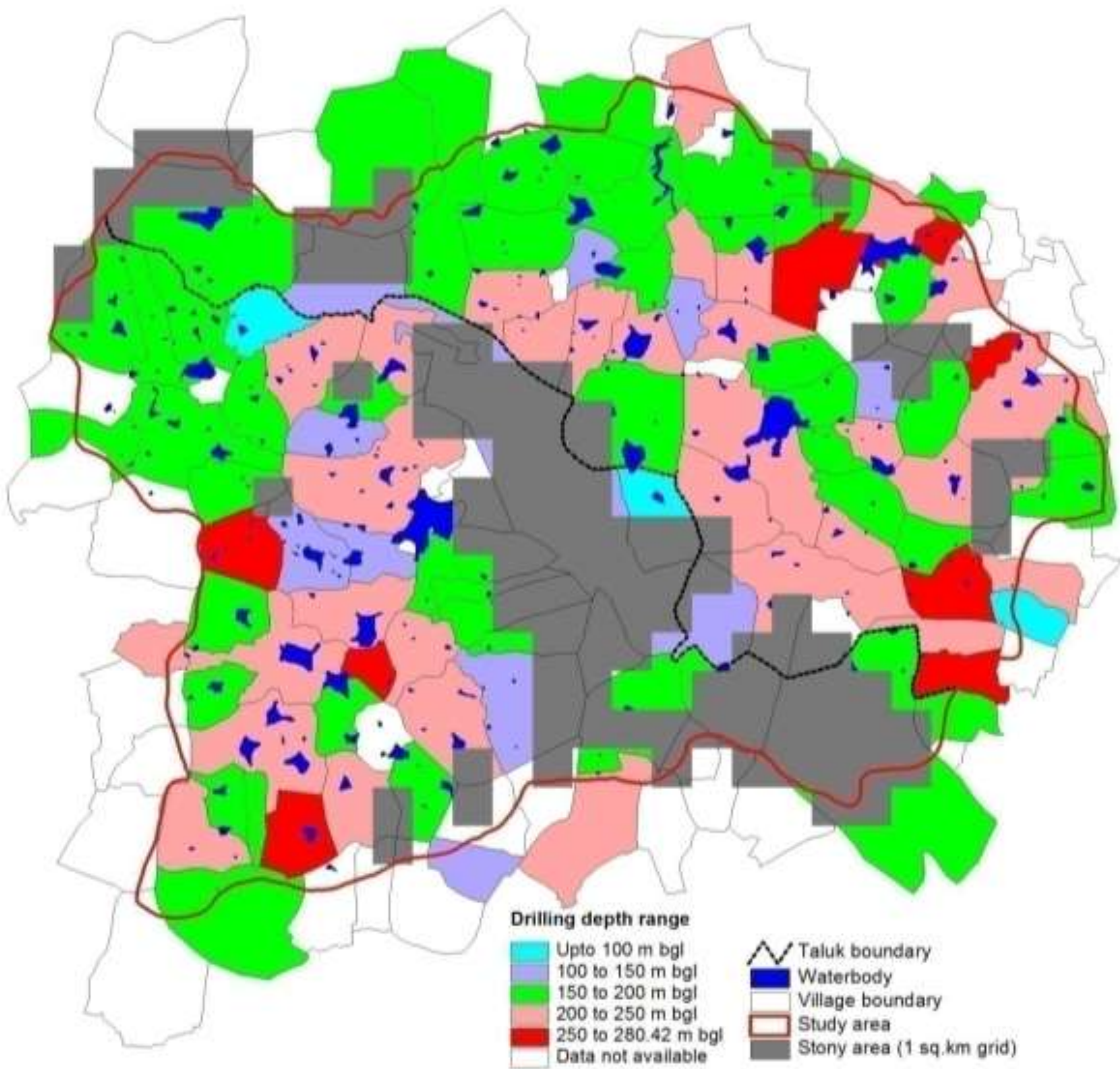


Fig. 3.39: Village-wise, depth-wise distribution of borewells

During well inventory, the depth of casing is taken as the depth of weathering. The analysis shows that in most of the villages, the depth of weathering is about 10-20 m bgl. The weathering depth of 20 to 30 m bgl and 30 to 40 m bgl is noticed in less number of villages. More than 40 m weathering is noticed in few villages like Navule and Tigalanahalli. The village-wise depth of weathering based on casing length lowered is given in Table 3.23 shown in Fig. 3.40.

Table 3.23: Village-wise depth of weathering

Casing depth-wise analysis					
Sl.No.	**Upto 10 m bgl**	**10 to 20 m bgl**	**20 to 30 m bgl**	**30 to 40 m bgl**	**40 to 42.67 m bgl**
1	Gollarahatti-Timmalapura	Adinayakanahalli	Abhujihalli	Agasarahalli	Navule
2	Kibbanahalli	Ajjenahalli	Anekatte	Alur	
3	Kodalgara	Ankasandra	Basaveshwarapura	Dabbeghatta	
4	Kugihalla	Arlikere	Bhairanayakanahalli	Gerehalli	
5	Siddaramanagara	Bachihalli	Chaulihalli	Gollarahatti-Harisamudra	
6	Timmarayanahalli	Ballenahalli	Chunganahalli	Jakkanahalli	
7		Baluvanerlu	Dasihalli	Kedagihalli	
8		Banjara thanda	Doddakatte	Kuppuru	
9		Benakanakatte	Halkurike kaval	Kurubarahalli_1	
10		Bennayakanahalli	Harisamudra	Makuvalli	
11		Bete Ranganahalli	Hesarahalli	Sarathavalli	
12		Bevinahalli	Hurlihalli	Savsettihalli	
13		Bhairapura	Kallenahalli	Suragondanahalli	
14		Bommanahalli	Kodagihalli	Tarabenahalli	
15		Byadarahalli	Kurubarahalli_2	Tigalanahalli	
16		Chattasandra	Paragondanahalli		
17		Chaudlapura	Sasalu		
18		Chikkenahalli	Tammadihalli		
19		Dasanakatte			
20		Dasihalli palya			
21		Dibbadahalli			
22		Dugganahalli			
23		Dugudihalli			
24		Gatakanakere			
25		Gollarahatti-Bhairanayakanahatti			
26		Gopalanahalli			
27		Gowdanakatte			
28		Halenahalli			
29		Halkurike			
30		Harachanahalli			
31		Irlagere			
32		Kadenahalli_1			
33		Kallakere			
34		Kamalapura			
35		Kantalagere			

Casing depth-wise analysis					
Sl.No.	Upto 10 m bgl	10 to 20 m bgl	20 to 30 m bgl	30 to 40 m bgl	40 to 42.67 m bgl
36		Lakshmanapura			
37		Madapura			
38		Madihalli			
39		Mallidevihalli			
40		Manakikere			
41		Manchasandra			
42		Manjunathapura			
43		Marasandra			
44		Mayagondanahalli			
45		Misetimmanahalli			
46		Muddenahalli			
47		Nelagondanahalli			
48		Pinnenahalli			
49		Ramashettihalli			
50		Rangapura			
51		Rudrapura			
52		Settikere			
53		Shavigehalli			
54		Suleman palya			
55		Timmalapura			
56		Upparahalli			
57		Vaderahalli_1			
58		Vaderahalli_2			
59		Vittlapura			
60		Yerehalli			

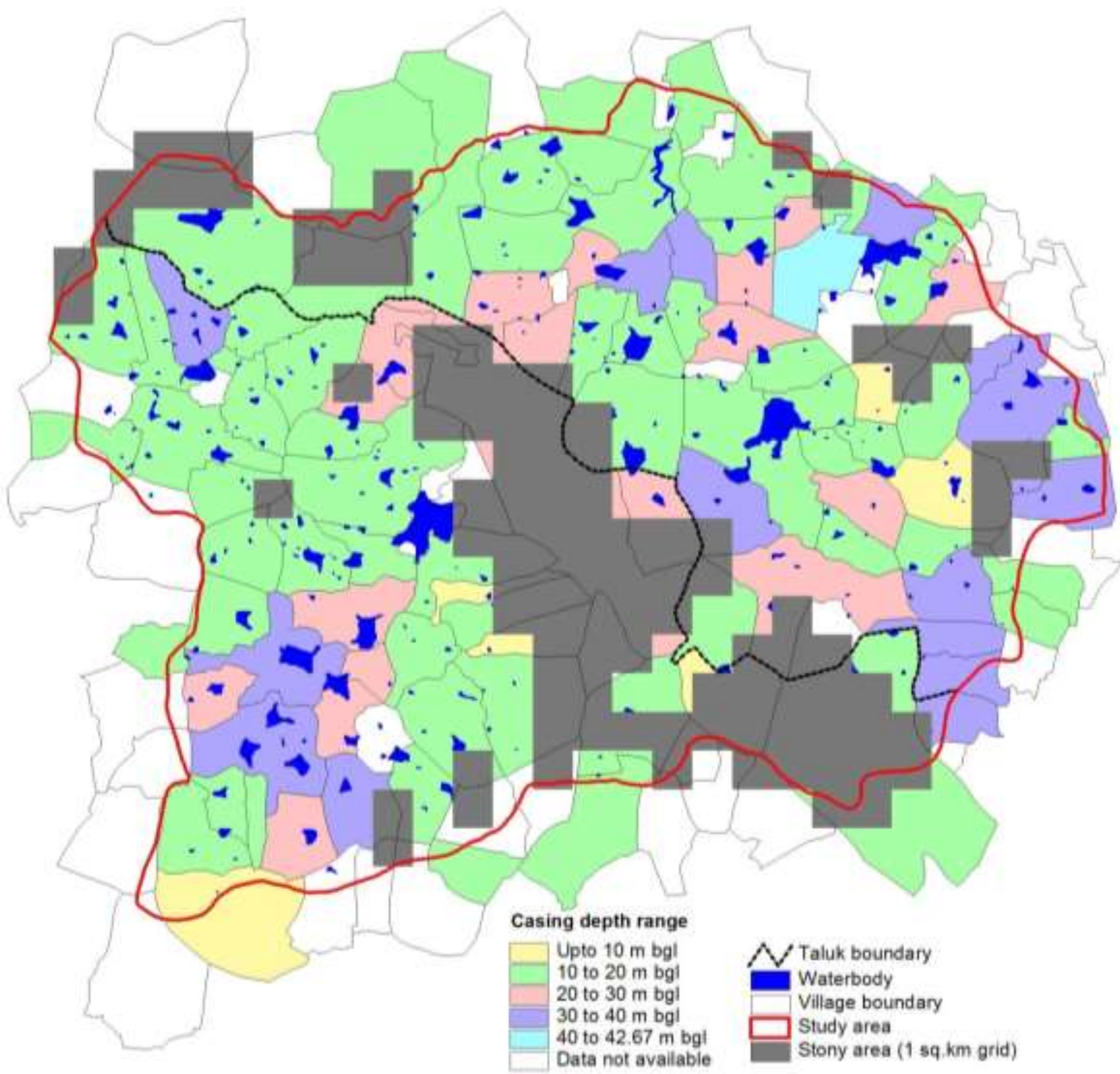


Fig. 3.40: Village-wise thickness of weathering

The village wise, depth wise distribution of fractures is presented in Fig. 3.41. Depth wise occurrence of fractures at various villages is given in Table 3.24. It is seen that shallow fractures are occurring at Bhairapura, Kantalagere, Mallidevihalli and Mayagondanahalli villages. Deep fractures up to 250 m are occurring in Agasarahalli, Ajjehalli, Bhairanayakanhalli, Chaulihalli, Chikkenahalli, Dabbeghatta, Madihalli, Garehalli, Kallakere, Kedigahalli, Kodalgara, Manakikere, Manchasandra, Manjunathapura, Settikere, Tammadahalli, Tigalanahalli, Timmalapura villages. In majority of villages, the fractures are encountered up to 200 m depth.

Table 3.24: Depth-wise occurrence of fractures

Occurrence of fracture at different depths					
Sl. No.	Upto 50 m bgl	Upto 100 m bgl	Upto 150 m bgl	Upto 200 m bgl	Upto 250 m bgl
1	Bhairapura	Abhujihalli	Adinayakanahalli	Anekatte	Agasarahalli
2	Kantalagere	Bete Ranganahalli	Alur	Ankasandra	Ajjenahalli
3	Mallidevihalli	Bevinahalli	Arlikere	Bachihalli	Bhairanayakanahalli
4	Mayagondanahalli	Dasanakatte	Ballenahalli	Banjara thanda	Chaulihalli
5		Doddakatte	Baluvanerlu	Basaveshwarapura	Chikkenahalli
6		Dugudihalli	Bennayakanahalli	Benakanakatte	Dabbeghatta
7		Gatakanakere	Bommanahalli	Byadarahalli	Dasihalli
8		Gollarahatti-Bhairanayakanahatti	Chattasandra	Chaudlapura	Gerehalli
9		Halenahalli	Chunganahalli	Gollarahatti-Harisamudra	Hurlihalli
10		Halkurike kaval	Dasihalli palya	Gollarahatti-Timmalapura	Kallakere
11		Harachanahalli	Dibbadahalli	Hesarahalli	Kedagihalli
12		Paragondanahalli	Dugganahalli	Irlagere	Kodalgara
13		Rangapura	Gopalanahalli	Kamalapura	Kurubarahalli_2
14		Siddaramanagara	Gowdanakatte	Kodagihalli	Manakikere
15		Suragondanahalli	Halkurike	Kugihalla	Manchasandra
16		Timmarayanahalli	Harisamudra	Kurubarahalli_1	Manjunathapura
17			Jakkanahalli	Madapura	Settikere
18			Kadenahalli_1	Makuvalli	Tammadihalli
19			Kallenahalli	Misetimmanahalli	Tigalanahalli
20			Kibbanahalli	Muddenahalli	Timmalapura
21			Kuppuru	Navule	
22			Lakshmanapura	Nelagondanahalli	
23			Madihalli	Pinnenahalli	
24			Marasandra	Rudrapura	
25			Ramashettihalli	Sarathavalli	
26			Shavigehalli	Sasalu	
27			Yerehalli	Savsettihalli	
28				Suleman palya	
29				Tarabenahalli	
30				Upparahalli	
31				Vaderahalli_1	
32				Vaderahalli_2	
33				Vittlapura	

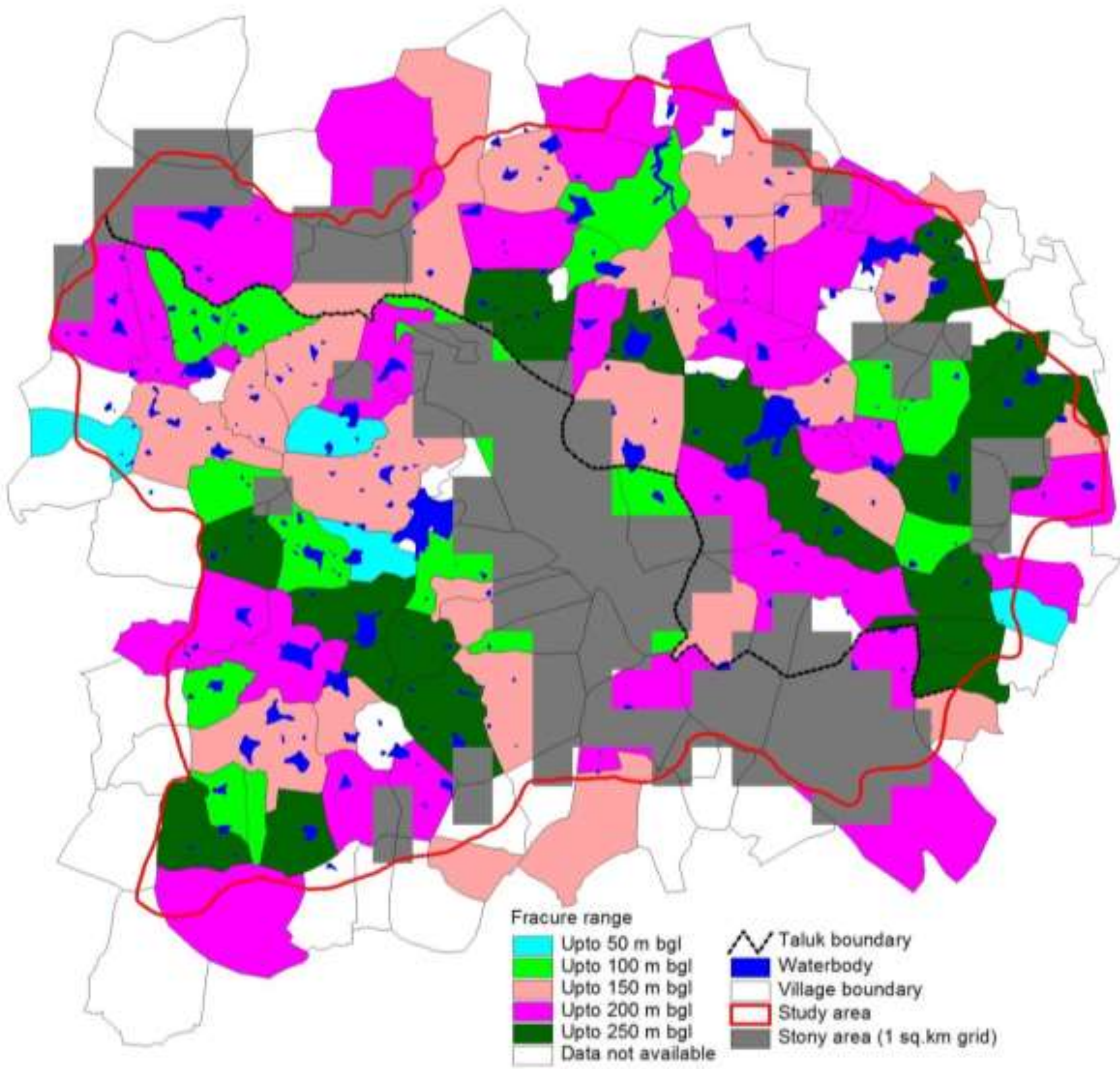


Fig. 3.41: Village-wise occurrence of fractures

The analysis of depth vs. fractures encountered shows that 40% of fractures are falling in the depth range of 100 – 150 m followed by 28% of fractures in the depth range of 150-200 m and 22% of fractures in the depth range of 50 - 100 m. Presence of fractures in the depth ranges of 0-50 m, 200-250 m and more than 250 m depth are negligible. It reflects that most of the fractures are falling in 100 – 200 m depth range. The analysis of depth vs. fractures is shown in Table 3.25 and presented in Figs. 3.42 and Fig. 3.43.

Table 3.25: Analysis of depth vs. fractures

Analysis of Depth vs. Fracture						
Depth drilled (m bgl)	**Casing range (m bgl)**	**No. of fractures**	**No. of villages covered**	**No. of failed wells**	**No. of wells Inventoried**	**Fractures (%)**
0 - 50	3.05 - 18.29	27	13	-	27	3
50 - 100	6.10 - 36.58	234	49	-	210	22
100 - 150	6.10 - 36.58	437	70	1	386	40
150 - 200	6.10 - 36.58	311	76	5	265	28
201 - 250	6.10 - 42.67	74	37	3	59	6
250 - 280.42	3.05 - 36.58	6	8	1	8	1
				Total	**955**	**100**

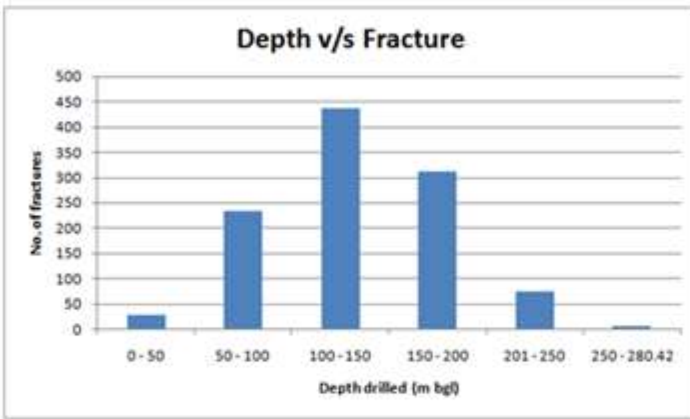


Fig. 3.42: Analysis of depth vs. fractures (scale bar)

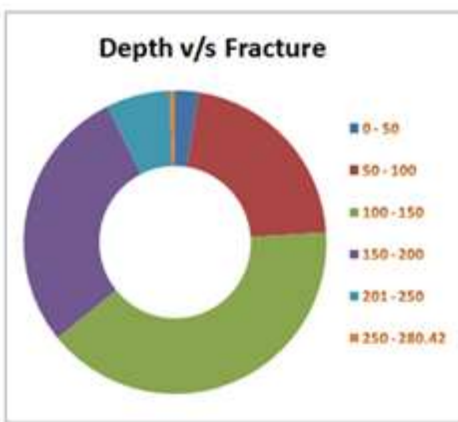


Fig. 3.43: Analysis of depth vs. fractures (pie diagram)

Analysis of depth vs. yield shows that 0 - 50 m,50-100m,150-200m and 200-250m are yielding 0.5 to 2 lps discharge , 100- 150 m depth range is yielding 0.5 to 3 lps and more than 250 m depth range is giving yield range of 0.5 to 1 lps. It is observed that, the most of potential fractures are found within depth range of 100 - 150 m. The analysis of depth vs. yield is given in Table 3.26.

Table 3.26: Analysis of depth vs. yield

Depth drilled (m bgl)	Yield (lps)
0 - 50	0.5 - 2
50 - 100	0.5 - 2
100 - 150	0.5 - 3
150 - 200	0.5 - 2
201 - 250	0.5 - 2
250 - 280.42	0.5 - 1

Analysis of village wise distribution of yield is carried out. It shows that majority of the villages are giving yield up to 1.5 lps followed by 1 lps and 2 lps. Very limited villages are yielding up to 3 lps. Village wise distribution of yield of borewells is given in Table 3.27 shown in Fig. 3.44.

Table 3.27: Village-wise distribution of yield.

Village-wise yield analysis					
Sl.No.	Upto 1 lps	Upto 1.5 lps	Upto 2 lps	Up to 2.5 lps	Up to 3 lps
1	Adinayakanahalli	Abhujihalli	Agasarahalli	Chaudlapura	Alur
2	Bachihalli	Ajjenahalli	Ballenahalli		
3	Banjara thanda	Anekatte	Bevinahalli		
4	Bete Ranganahalli	Ankasandra	Bhairapura		
5	Byadarahalli	Arlikere	Chattasandra		
6	Chikkenahalli	Baluvanerlu	Dasihalli palya		
7	Dasanakatte	Basaveshwarapura	Gollarahatti-Harisamudra		
8	Doddakatte	Benakanakatte	Halkurike kaval		
9	Dugganahalli	Bennayakanahalli	Harachanahalli		
10	Dugudihalli	Bhairanayakanahalli	Harisamudra		
11	Gollarahatti-Timmalapura	Bommanahalli	Hurlihalli		
12	Kantalagere	Chaulihalli	Kallenahalli		
13	Kugihalla	Chunganahalli	Kibbanahalli		
14	Lakshmanapura	Dabbeghatta	Kuppuru		
15	Mallidevihalli	Dasihalli	Manakikere		
16	Manjunathapura	Dibbadahalli	Manchasandra		
17	Mayagondanahalli	Gatakanakere	Marasandra		
18	Misetimmanahalli	Gerehalli	Navule		
19	Paragondanahalli	Gollarahatti-Bhairanayakanahatti	Sarathavalli		
20	Pinnenahalli	Gopalanahalli	Tammadihalli		
21	Ramashettihalli	Gowdanakatte	Tarabenahalli		
22	Shavigehalli	Halenahalli			
23	Siddaramanagara	Halkurike			
24	Tigalanahalli	Hesarahalli			

Village-wise yield analysis					
Sl.No.	**Upto 1 lps**	**Upto 1.5 lps**	**Upto 2 lps**	**Up to 2.5 lps**	**Up to 3 lps**
25	Timmarayanahalli	Irlagere			
26	Vaderahalli_2	Jakkanahalli			
27	Vittlapura	Kadenahalli_1			
28		Kallakere			
29		Kamalapura			
30		Kedagihalli			
31		Kodagihalli			
32		Kodalgara			
33		Kurubarahalli_1			
34		Kurubarahalli_2			
35		Madapura			
36		Madihalli			
37		Makuvalli			
38		Muddenahalli			
39		Nelagondanahalli			
40		Rangapura			
41		Rudrapura			
42		Sasalu			
43		Savsettihalli			
44		Settikere			
45		Suleman palya			
46		Suragondanahalli			
47		Timmalapura			
48		Upparahalli			
49		Vaderahalli_1			
50		Yerehalli			

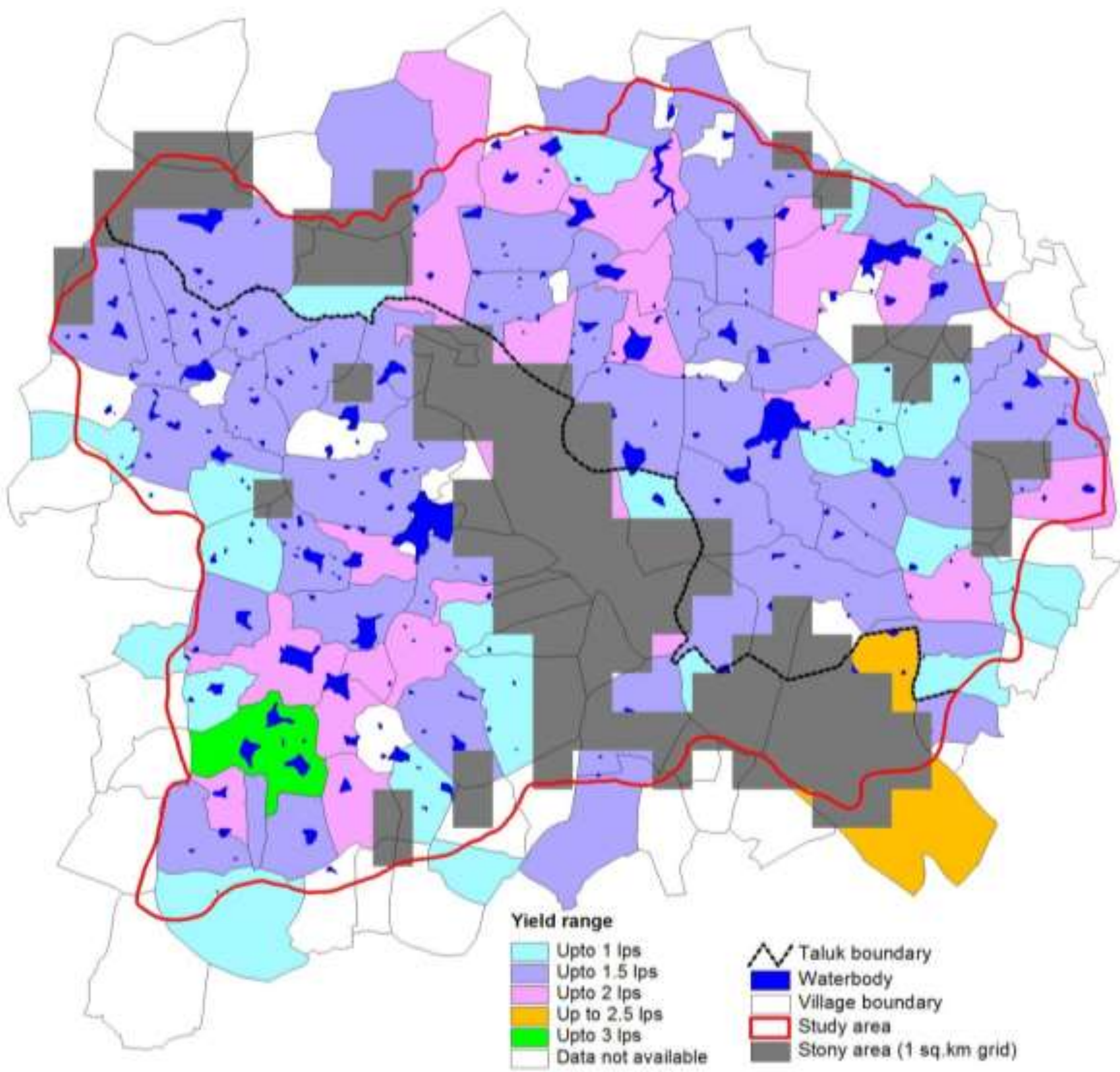


Fig. 3.44: Village-wise distribution of yield

Analysis is also done for aquifer wise distribution of inventoriedborewells. Itshows that out of 955 wells, 858 (90%) wells inventoried are distributed in Gneisses, followed by Schist 95 (10%) and only two wells are located in Granite formation.

An attempt is made to know the aquifer wise information on depth range of drilling, casing length lowered, depth of fractures encountered and yield range of wells. Maximum depth drilled and casing lowered is in Gneisses (281m), followed by Schist (245 m) and Granite (167 m). The fractures encountered up to maximum depth are distributed in Gneisses (250 m) followed by Schist (190 m) and Granite (150 m). Highest yield of up to 3 lps is noted in Gneisses followed by Schist (up to 2 lps)and Granite (up to 1.5 lps). The hydrogeology map is shown in Fig. 3.45.

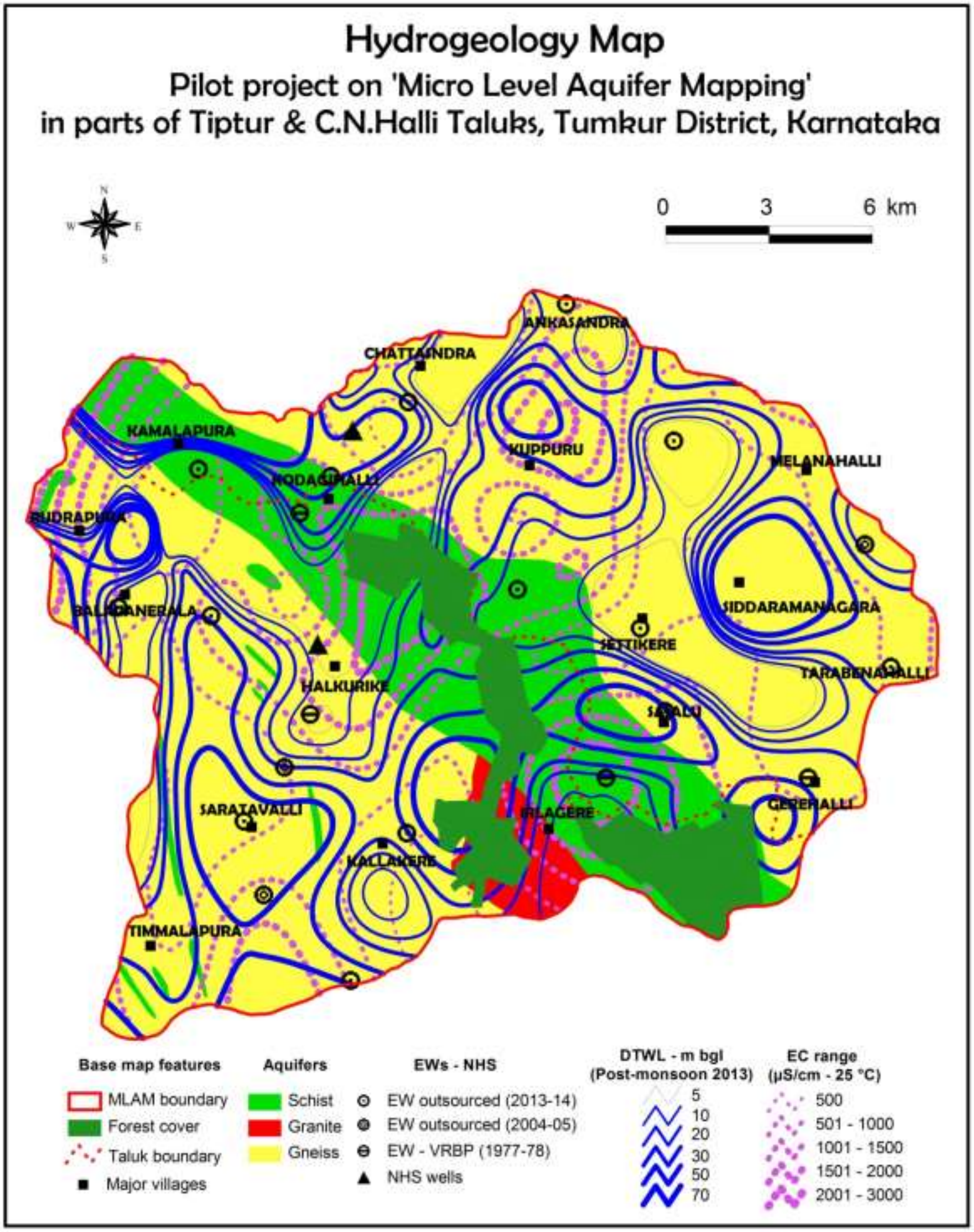


Fig. 3.45: Hydrogeology map

3.6.9 Conclusions

- Out of 955 borewells inventoried, in majority of villages, depth range of borewells is 150 – 250 m.
- Depth of weathering in general is 10 – 20 m only and it is lesser in granitic formation**.**
- Majority of the fractures are encountered between 100 – 200 m bgl.
- In most villages, the average yield varies between 1 to 2 lps.
- High yielding wells are noticed in Gneissic formation.
- Fractures are encountered up to maximum depth in Gneisses.

Collection of well inventory data from a farmer at Kurubarahalli village

Collection of well inventory from a farmer on Sasalu - Agasarahalli road

Measurement of discharge through volumetric method near Bommanahalli thanda village

3.7 GROUND WATER LEVEL

To study the behaviour of ground water in time and space, 52 observation wells were established during September 2011, to monitor the ground water levels on monthly basis. Subsequently, the number of observation wells were increased to 86 for better representation of various aquifers. As the phreatic aquifer is completely desaturated except in Halkurike and surrounding area, borewells fitted with hand pumps for rural water supply were established as key observation wells. Some observation wells were also established outside the boundary of the watershed to have optimum monitoring mechanism. During the course of study, 14 exploratory wells were drilled through outsourcing, which are also added to monitoring list and the final count became 104 observation wells. The locations of observation wells are shown in Fig. 3.46. The month-wise depth to ground water level data of key observation wells are given in Annexure 3.3. The elevation of ground water level data of observation wells from mean sea level is given in Annexure 3.4. The ground water level fluctuation data is given in Annexure 3.5.

Based on ground water level data of all the observation wells, three types of maps are generated

- Depth to ground water level map for each monitoring
- Water table contour map and
- Water table fluctuation map

Depth to ground water level map shows the depth to ground water level at that particular time. Water table contour map shows the water table elevation form mean sea level and gives information on ground water flow direction and gradient. Water table fluctuation map gives information on change in ground water level and hence, change in ground water storage between two different periods of time.

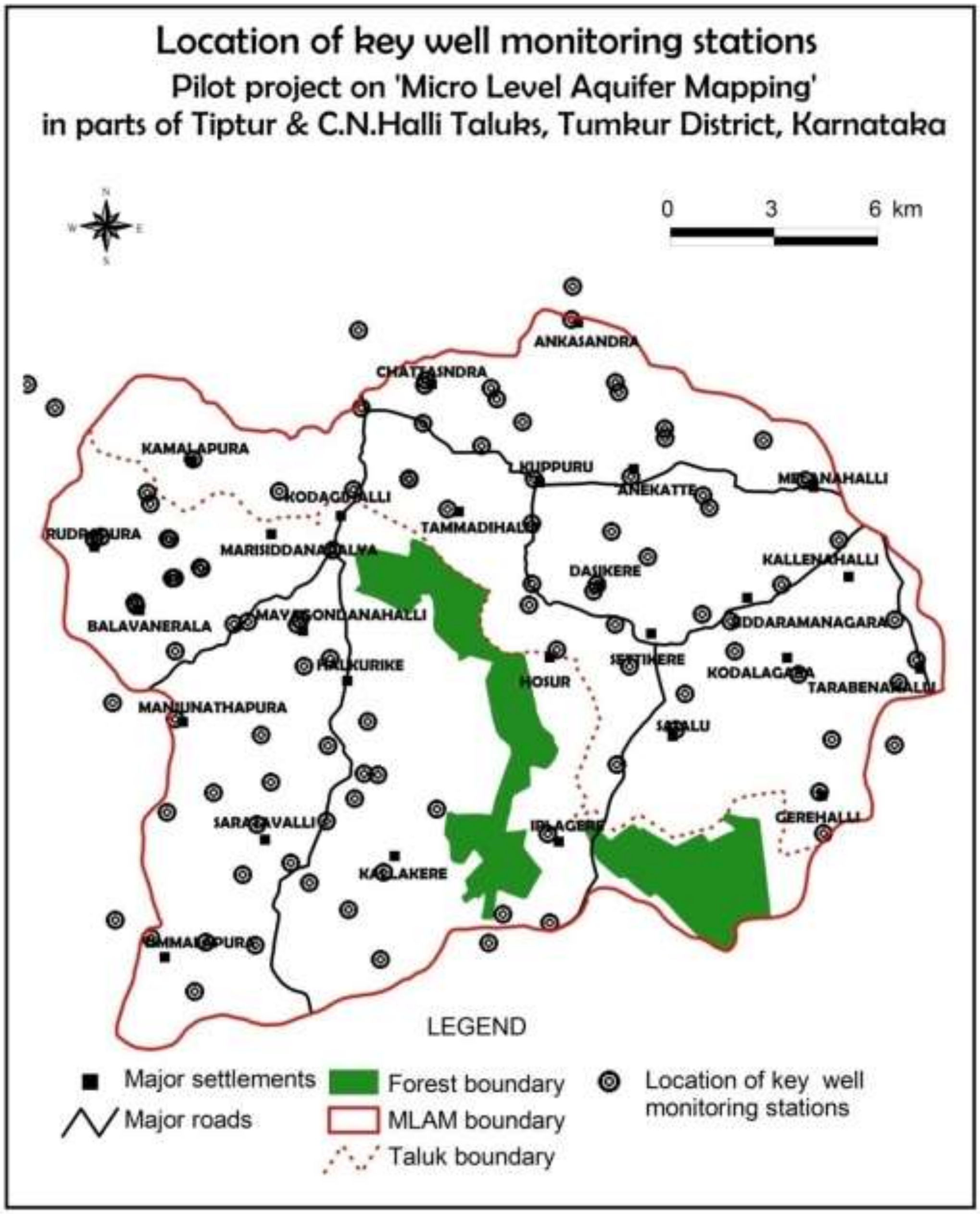


Fig. 3.46: Location of observation wells

3.7.1 Post-monsoon depth to ground water levels

During November 2011, the minimum and the maximum depths to ground water levelare 0.78 and 30.50 m bgl respectively. Major part of the project area is having depth to ground water levelin the rangeof 10 to 20 m bgl. Depth to ground water level between 20 and 30 m bgl is observed in SW part, SE part and in certain isolated patches. Depth to ground water level of more than 30 m bgl is noticed at Bhairanayakanhalli village (Fig. 3.47).

During November 2012, the minimum and the maximum depths to ground water levelare 0.66 and 74.58 m bgl respectively. The major part of the area is having depth to ground water level ranging from 20 to 50 m bgl. The depth to ground water levels of more than 50 m bgl and also less than 20 m bgl are noticed in isolated patches (Fig. 3.48).

During September 2013, the minimum and maximum depth to ground water level is 0.49 m to 88.44 m bgl. The major part of the area is having depth to ground water level ranging from 20 – 50 m bgl. Depth to ground water level of more than 50 m is noticed in SW part of the area in small patches. It is observed that during the post-monsoon period also in general ground water levels have steadily declined from 10 to 20 m bgl during 2011 to 20 to 50 m bgl during 2013 (Fig. 3.49).

3.7.2 Pre-monsoon depth to ground water levels

During May 2012, the minimum and the maximum depths to ground water level are 1.81 to 47.76 m bgl respectively. The major part of the area is having depth to ground water level ranging from 10 to 30 m bgl. Depth to ground water level of more than 30 m bgl is noticed in SW part of the area (Fig. 3.50).

During May 2013, the minimum and the maximum depths to ground water levelare 3.67 to 88.44 m bgl respectively. The major part of the area is having depth to ground water level ranging from 30 to 50 m bgl. Depth to ground water level of more than 50 m bgl is noticed in SW part and SE part of the area (Fig. 3.51).

During April 2014, the minimum and the maximum depths to ground water levelare3.58 to 132.87 m bgl respectively. The major part of the area is having depth to ground water level ranging from 30-50 m bgl. Depth to ground water level of more than 50 m bgl is noticed in SW part, NE part and Northern part of the area (Fig. 3.52). As in the case of pre-monsoon, ground water levels also have declined from 10 to 30 m bgl during May 2012 to 30 to 50 m bgl during April 2014.

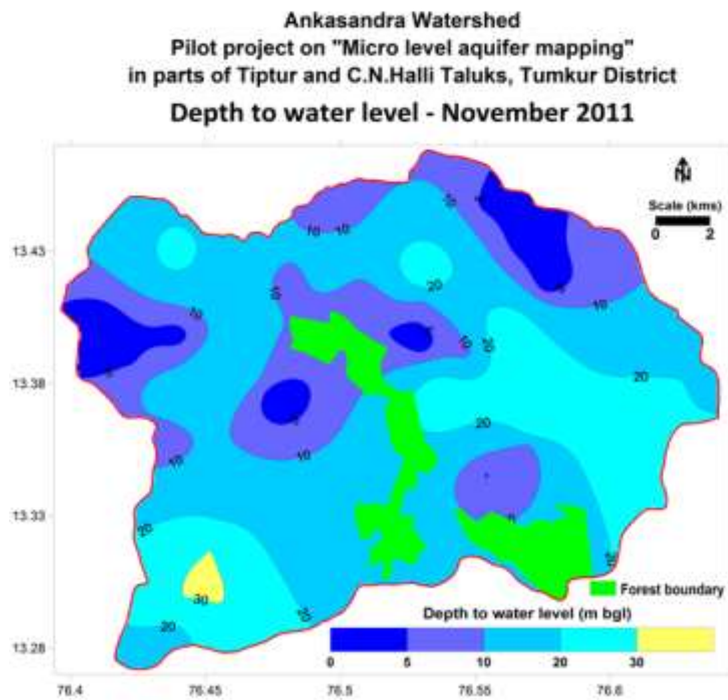


Fig. 3.47: Depth to ground water level map – Nov. 2011

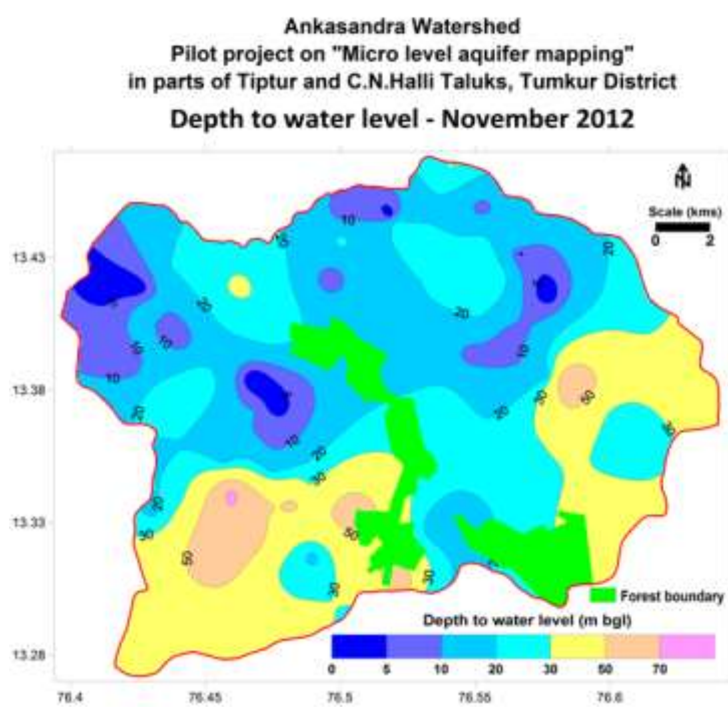


Fig. 3.48: Depth to ground water level map – Nov. 2012

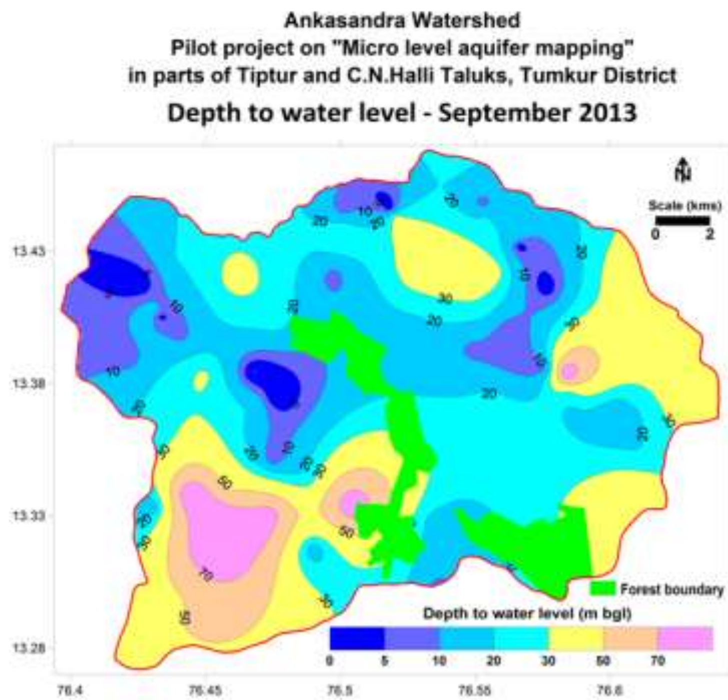


Fig. 3.49: Depth to ground water level map – Sept. 2013

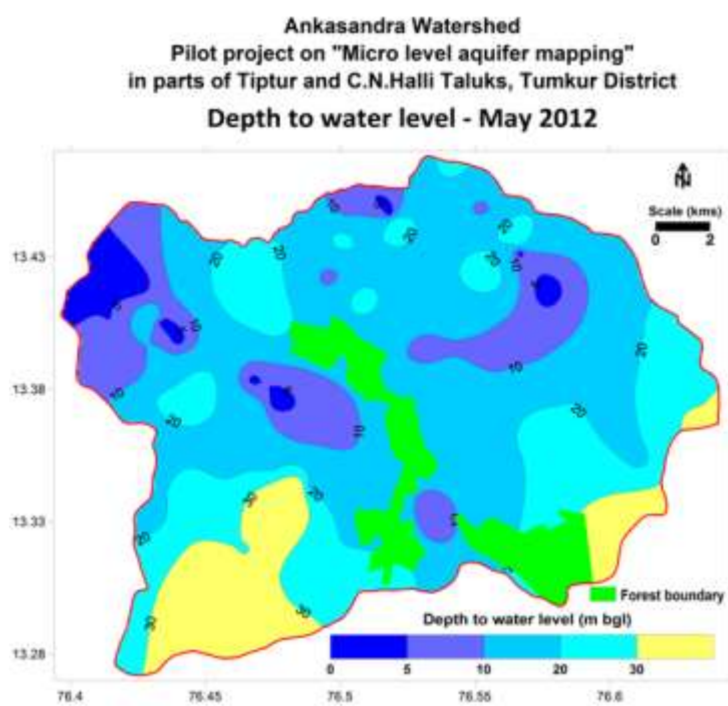


Fig. 3.50: Depth to ground water level map – May 2012

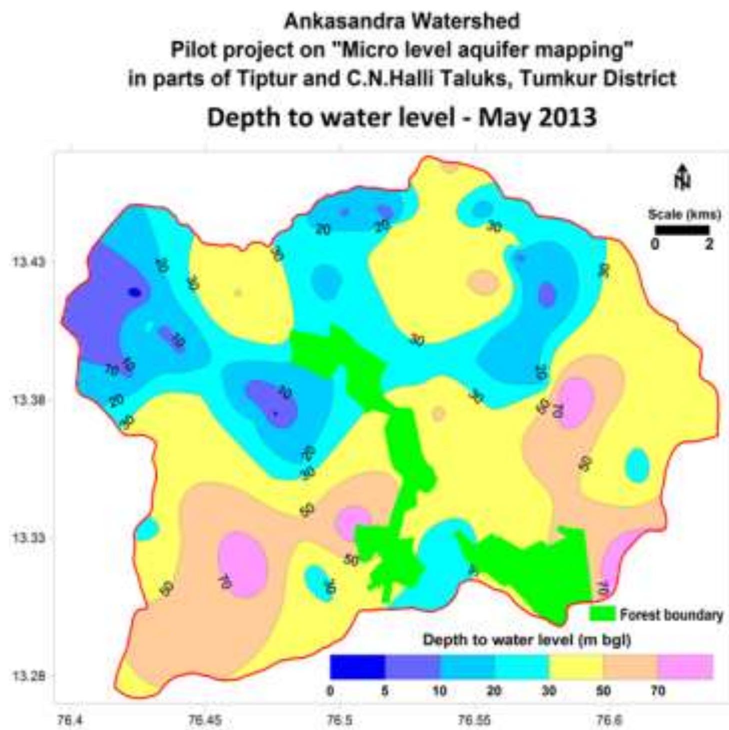


Fig. 3.51: Depth to ground water level map – May 2013

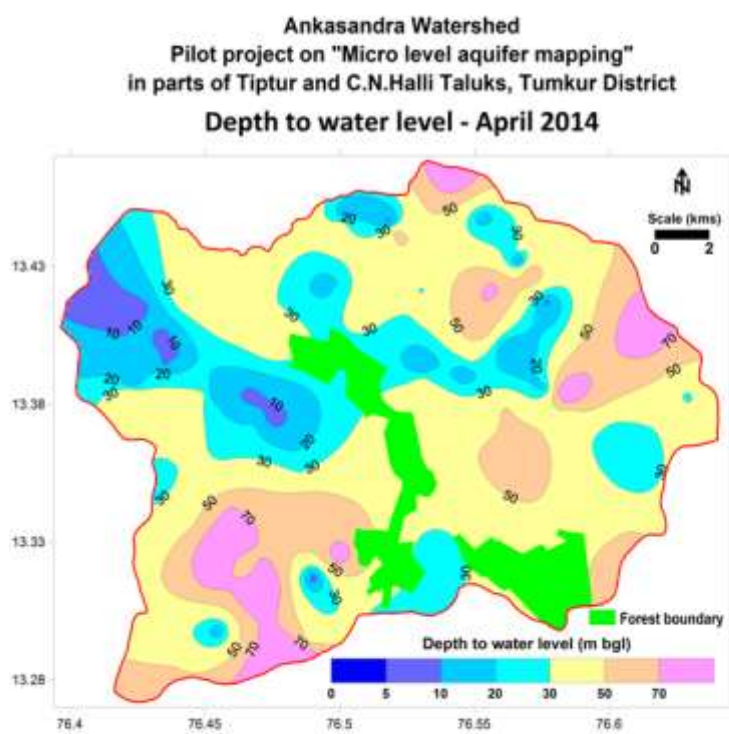


Fig. 3.52: Depth to ground water level map – Apr. 2014

3.7.2 Average depth to ground water level

An attempt is made to know the change in depth to ground water level for the entire area from September 2011 to April 2014.The average depth to ground water level is calculated from the total of all depths to ground water levels of all monitoring stations divided by the number of monitoring stations. This exercise was carried out for all the monitoring months. The average depth to ground water level is given in Table 3.28. Based on average depth to ground water level, hydrograph is generated and shown in Fig 3.53.The average depth to ground water level is 12.8m bgl and 11.5m bgl during September 2011 and November 2011 respectively.

Table 3.28: Month-wise average depth to ground water level

	Sept 11	Nov 11	Jan 12	Feb 12	Apr 12	May 12	June 12	July 12	Aug 12	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	May 13	June 13	July 13	Sept 13	Jan 14	Mar 14	Apr 14
Average DTWL	12.80	11.52	13.10	13.36	14.90	14.75	19.30	18.10	21.54	19.67	20.24	20.37	23.08	25.88	27.97	31.09	27.37	29.47	23.27	30.11	37.56	37.19

During the year 2012, the average depth to ground water level during the months of January, February, April, May, June, July, August, October, November and December are 13.1, 13.3, 14.9, 14.7, 19.3, 18.1, 21.5, 19.6, 20.2 and 20.3 m bgl respectively. It shows that the ground water levels are declining during the period. The steady decline during pre-monsoon and post-monsoon period is due to deficiency of rainfall during the year 2012 and more extraction of ground water for perennial crops like coconut and arecanut.

During the year 2013, the average depth to ground water level during the months of January, February, March, May, June, July, September are 23.0, 25.8, 27.9, 31.0, 27.3, 29.4 and 23.2 m bgl respectively. It shows that the ground water levels are declining upto May 2013 and thereafter increasing (shallow) during September 2013 due to recharge from monsoon rainfall. However, the depth to ground water levels are deeper than 2012.

During the year 2014, the average depth to ground water level for the watershed during the months of January, March and April are 30.1, 37.5 and 37.1 m bgl respectively. It shows that the ground water levels are on the decline upto April 2014.

It is observed that the depths to ground water levels are increasing over a period of time and hence, there is an overall fall in ground water level of about 25 m during September 2011 to April 2014.

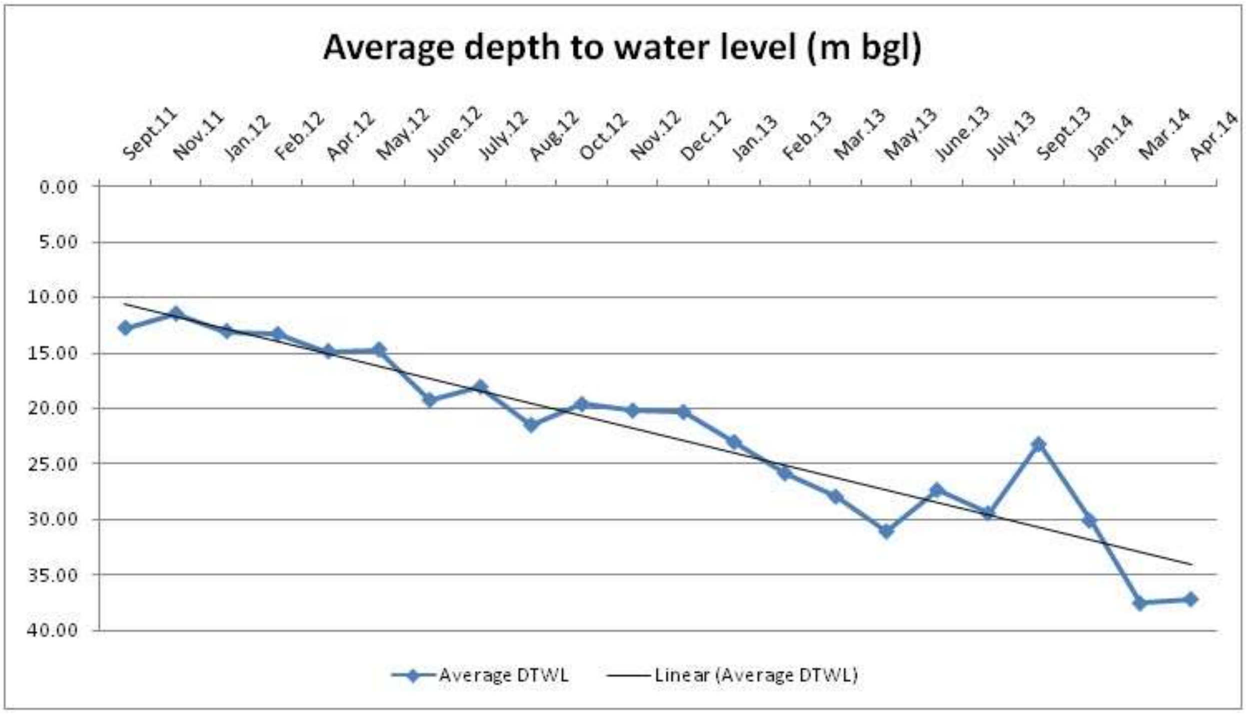


Fig. 3.53: Hydrograph of average depth to ground water level

3.7.3 Analysis of depth to ground water levels with time

An analysis has been made on the number of stations falling in different depth ranges of ground water levels i.e., upto 10, 10-20, 20-30, 30-50, 50-70 and more than 70 m bgl over a period of time from September 2011 to April 2014. The month-wise number of stations falling in different depth ranges is given in the Table 3.29.

Table 3.29: Month-wise number of station falling in different depth ranges

Sl. No.	Months	No. of stations	Ground water level range		Upto 10 m bgl		10 - 20 m bgl		20 - 30 m bgl		30 - 50 m bgl		50 - 70 m bgl		> 70 m bgl	
			Min.	Max.	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%
1	Sept.11	50	0.79	35.86	15	30.00	18	36.00	13	26.00	4	8.00	0	0.00	0	0.00
2	Nov.11	48	0.78	30.5	19	39.58	18	37.50	5	10.42	6	12.50	0	0.00	0	0.00
3	Jan.12	44	2.18	30.5	13	29.55	14	31.82	10	22.73	7	15.91	0	0.00	0	0.00
4	Feb.12	71	0,61	36.44	26	36.62	23	32.39	18	25.35	4	5.63	0	0.00	0	0.00
5	Apr.12	84	1.8	45.41	28	33.33	24	28.57	21	25.00	11	13.10	0	0.00	0	0.00
6	May.12	82	1.81	47.76	24	29.27	26	31.71	19	23.17	13	15.85	0	0.00	0	0.00
7	June.12	95	2.47	90.83	23	24.21	24	25.26	23	24.21	18	18.95	5	5.26	2	1.90
8	July.12	94	1.86	71.69	25	26.60	28	29.79	22	23.40	15	15.96	3	3.19	1	0.94
9	Aug.12	95	2.79	88	22	23.16	20	21.05	24	25.26	22	23.16	2	2.11	5	4.75
10	Oct.12	94	1.73	88	23	24.47	26	27.66	21	22.34	18	19.15	4	4.26	2	1.88
11	Nov.12	92	0.66	74.58	24	26.09	23	25.00	21	22.83	16	17.39	7	7.61	1	0.92
12	Dec.12	93	1.41	72.64	23	24.73	20	21.51	24	25.81	20	21.51	4	4.30	2	1.86
13	Jan.13	91	2.75	75.34	23	25.27	12	13.19	23	25.27	26	28.57	5	5.49	2	1.82
14	Feb.13	92	3.02	88	22	23.91	12	13.04	19	20.65	26	28.26	9	9.78	4	3.68
15	Mar.13	91	3.27	88	21	23.08	11	12.09	18	19.78	25	27.47	11	12.09	5	4.55
16	May.13	88	3.67	88.44	17	19.32	8	9.09	18	20.45	23	26.14	16	18.18	6	5.28
17	June.13	88	2.57	88.44	18	20.45	10	11.36	22	25.00	24	27.27	10	11.36	4	3.52
18	July.13	87	2.85	88.44	15	17.24	11	12.64	20	22.99	25	28.74	11	12.64	5	4.35
19	Sept.13	87	-0.49	88.44	26	29.89	17	19.54	20	22.99	17	19.54	2	2.30	5	4.35
20	Jan.14	98	2.1	100.65	20	20.41	12	12.24	24	24.49	27	27.55	5	5.10	10	9.80
21	Mar.14	95	1.93	110.05	13	13.68	11	11.58	15	15.79	30	31.58	9	9.47	17	16.15
22	Apr.14	104	3.58	132.87	16	15.38	13	12.50	17	16.35	34	32.69	11	10.58	13	13.52

The analysis shows that during September 2011, 30% of stations are having depths to ground water levels less than 10 m bgl, 36% of stations between 10-20 m bgl, 26% of stations between 20-30 m bgl and only 8% of the stations are having depth toground water levels between 30-50 m bgl. No station was having ground water level deeper than 36 m bgl. By the end of April 2014, it is observed that there is a major change in the depth to ground water level scenario in the study area. The number of stations having ground water level upto 10 m bgl gradually decreased from 30% at the beginning of the monitoring to 15% in April 2014 whereas, the number of stations showing deeper ground water levels from 50-70 and more than 70 m bgl increased from nil to 11% and nil to 14% respectively by April 2014 i.e., in more than 25% of the wells, the ground water level have gone down more than 50 m bgl. It indicates the decline inground water levels over the period of time from September 2011 to April 2014.

3.7.4 Depth to water table elevation

During September 2011, the minimum and the maximum water table elevations are 708.36 m amsl at Kuppur and 858.77 m amsl at Bandegate village respectively. The majority of the area is having water table elevation between 750 to 800 m amsl. Water table elevation between 725 to 750 m amsl is noticed in the northern part whereas, more than 800 m amsl is noticed along the southern boundary of the watershed. The water table gradient is about 8.33 m/km at Bandegate village towards north and about 6 m/km near Kupparadoddahalli village towards northeast.

During November 2011, the water table elevation ranges from 708.36 m amsl at Kuppur to 858.43 m amsl at Bandegate village. The majority of the area is having water table elevation between 750 to 800 m amsl. Water table elevation between 725 to 750 m amsl is noticed in the northern part whereas, more than 800 m amsl is noticed along the southern boundary of the watershed. The water table gradient is about 8.33 m/km at Bandegate village towards north and about 6 m/km near Kupparadoddahalli village towards northeast (Fig. 3.54).

During May 2012, the water table elevation ranges from 703.18 m amsl at Ankasandra to 865.25 m amsl at Bandegate village. The majority of the area is having water table elevation between 725 to 800 m amsl. Water table elevation of less than 725 m amsl is noticed near Ankasandra village whereas, more than 800 m amsl is noticed along the southern boundary of the watershed. The water table gradient is about 9 m/km at Bandegate village towards north and about 6.48 m/km near Kupparadoddahalli village towards northeast (Fig. 3.55).

During November 2012, the water table elevation ranges from 696.41 m amsl at Ankasandra to 856.17 m amsl at Bandegate village. The majority of the area is having water table elevation between 725 to 800 m amsl. Water table elevation of less than 725 m amsl is noticed in the northern part in a very small area whereas, more than 800 m amsl is noticed along the southern boundary of the watershed over a small area. The water table gradient is about 8.88 m/km at Bandegate village towards north and about 6.4 m/km near Kupparadoddahalli village towards northeast (Fig. 3.56).

During May 2013, the water table elevation ranges from 672.36 m amsl at Ankasandra to 852.62 m amsl at Kaval village. The water table elevation map shows that majority of the area is having water table elevation between 725 to 775 m amsl. Water table elevation of less than 725 m amsl is noticed near Ankasandra village whereas, more than 775 m amsl is noticed mostly along the southern boundary of the watershed. The water table gradient is about 10 m/km at Bandegate village towards north and about 7.2 m/km near Kupparadoddahalli village towards northeast (Fig. 3.57).

During September 2013, the water table elevation ranges from 695.86 m amsl at Kuppuru to 868.28 m amsl at Bandegate village. The water table elevation map shows that majority of the area is having water table elevation between 725 to 775 m amsl. Water table elevation less than 725 m amsl is noticed near Ankasandra village and also around Sarathavalli village. More than 775 m amsl is noticed mostly along the southern and western boundary of the watershed. The water table gradient is about 9.55 m/km at Bandegate village towards north and about 6.88 m/km near Kupparadoddahalli village towards northeast (Fig. 3.58).

During April 2014, the water table elevation ranges from 631.06 m amsl at Ankasandra to 853.58 m amsl at Kaval village. The majority of the area is having water table elevation between 700 to 775 m amsl. Water table elevation less than 700 m amsl is noticed near Ankasandra village whereas, more than 775 m amsl is noticed mostly along the southern, south eastern and western boundary of the watershed. The water table gradient is about 12.33 m/km at Bandegate towards north and about 8.88 m/km near Kupparadoddahalli towards northeast (Fig. 3.59). Initially the water table gradient was between 6 to 8m/km during 2011.Subsequently, water table gradient varied between 8 to 10m/km.

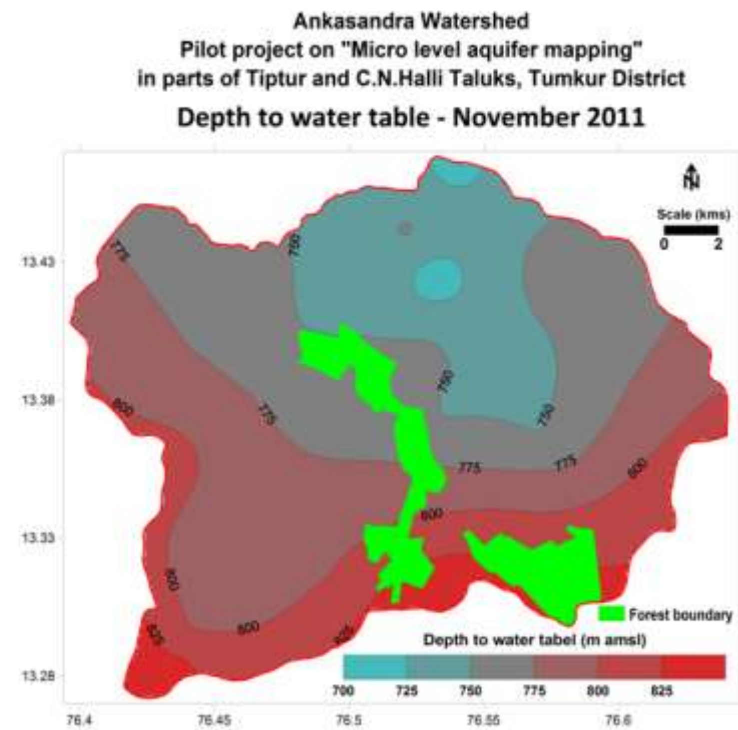


Fig. 3.54: Water table elevation contour map – Nov. 2011

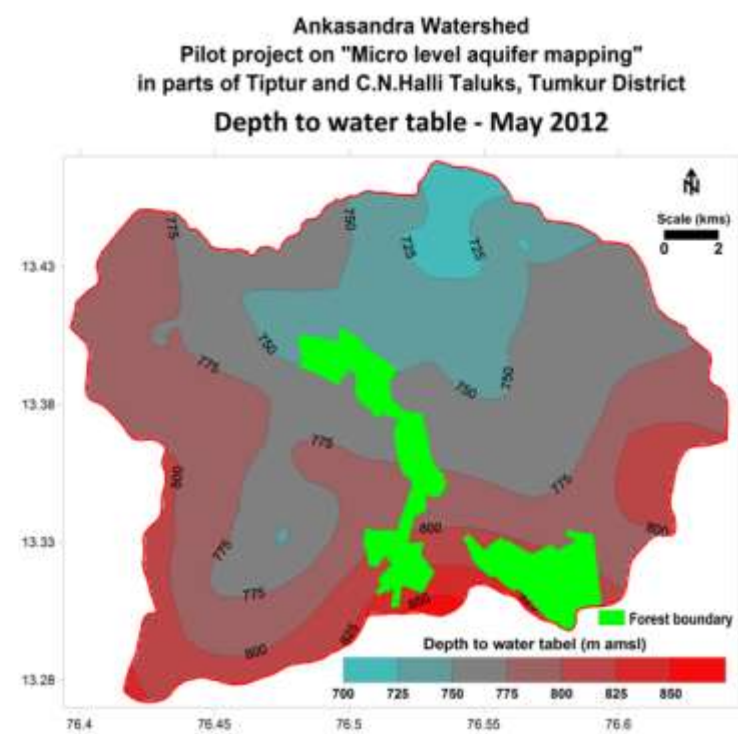


Fig. 3.55: Water table elevation contour map – May 2012

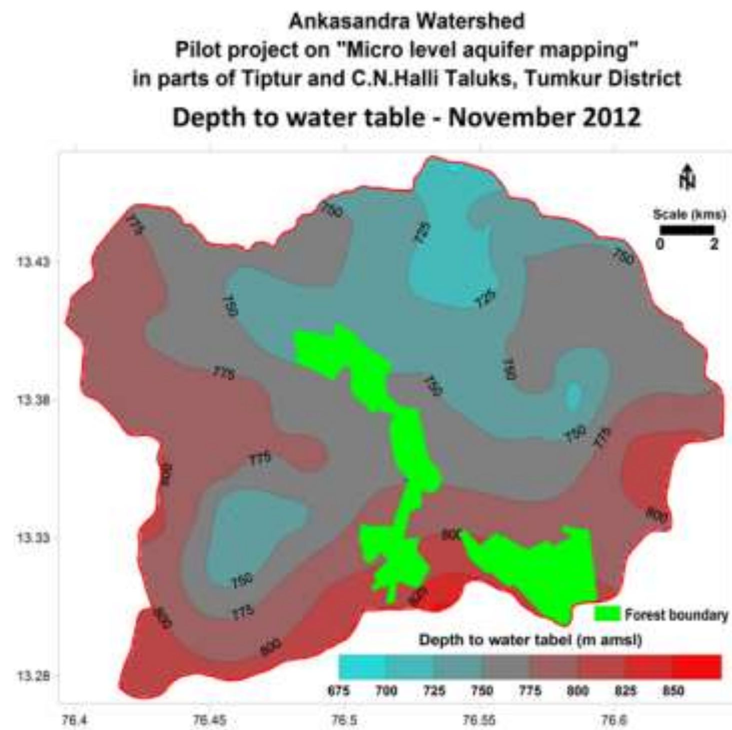


Fig. 3.56: Water table elevation contour map – Nov. 2012

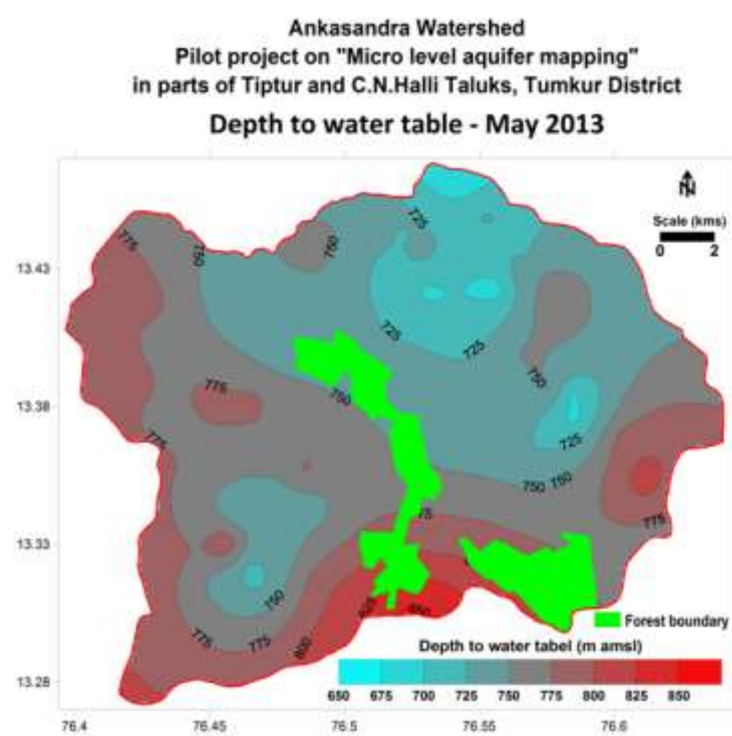


Fig. 3.57: Water table elevation contour map – May 2013

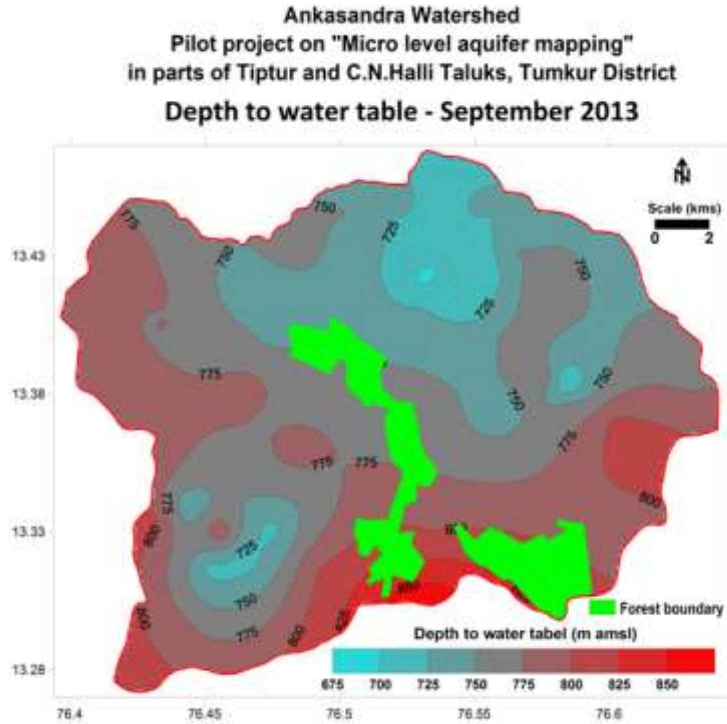


Fig. 3.58: Water table elevation contour map – Sept. 2013

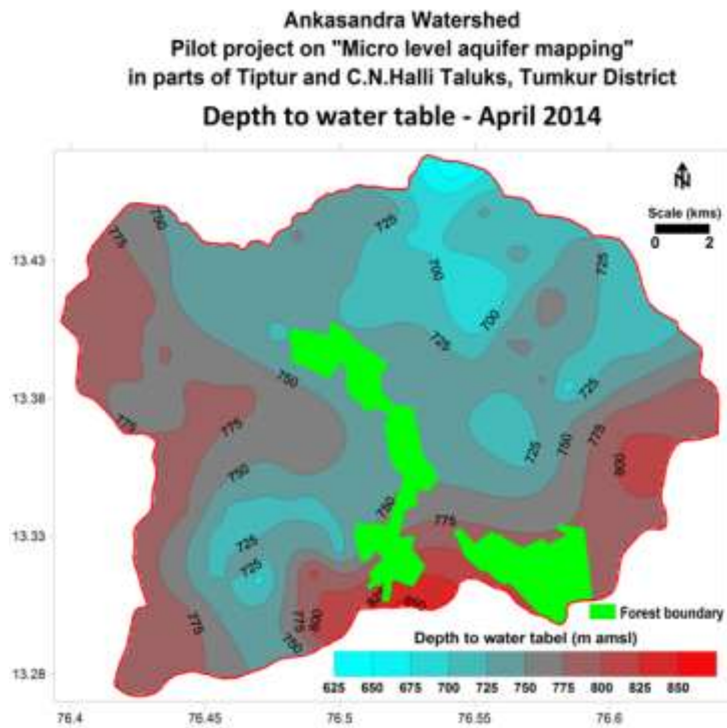


Fig. 3.59: Water table elevation contour map – Apr. 2014

3.7.5 Water table fluctuation (WTF)

The water table represents the ground water reservoir level and any change in it represents change in the ground water storage. A decline in water table represents ground water abstraction in excess of recharge. A rise in water table represents ground water increment in excess of abstraction. Most ground water assessment studies involve correlation of water table fluctuations with climatic elements such as rainfall, and manmade causes like application of irrigation water, artificial recharge, withdrawals from wells etc. Primarily WTF is governed by Specific yield/Storativity of aquifer in the zone of water table fluctuation. The WTF for selected months is given below.

3.7.5.1 Water table fluctuation – May 2012 vs. November 2012

WTF is arrived after deducting ground water level data of observation wells of November 2012 from May 2012. It shows that fall of water table in most of the area. It is due to deficiency of rainfall during 2012.The fall of water table is mostly in the range of 0 – 10 m and in isolated patches from 10 – 20 m and occasionally more than 20 m. More than 20 m fall is observed at Alur, Choulahalli, Chuganahalli, Harisamudra gate and Kaval villages only. Fall of 10 – 20 m range is observed at Laxmanapura and Manakikere villages. The rise of water table is observed in small isolated patches and mostly in the range of 0 to 5 m and occasionally from 5 - 10 m. The rise of water table is noticed in small isolated areas in west central, northern and north eastern part of the study area. The map showing WTF May 2012 vs. November 2012 is shown in (Fig. 3.60).

3.7.5.2 Water table fluctuation – May 2013 vs. September 2013

WTF is arrived after deducting ground water level data of observation wells of September 2013 from May 2013. The data shows mostly rise of water table in majority of the area. It is due to good monsoon during 2013. The rise of water table is mostly in the range of 0 – 10 m and 10 – 20 m and more than 20 m is noticed in isolated patches at Chuganahalli, Hosur, Ankasandra, Bairapura, Kodalgara, Somalapura villages, etc. Rise of water table between 10 - 20 m is observed in isolated patches. Fall of water table mostly in the range of 0-10 m is observed at Alur, Huralahalli and Nelagondanahalli villages. The map showing WTF is shown in Fig. 3.61.

3.7.5.3 Water table fluctuation – September 2013 vs. April 2014

WTF is arrived after deducting ground water level data of observation wells of April 2014 from September 2013. The data shows mostly fall of water table in most of the area. The fall of water table is mostly in the range of 0 – 20 m and more than 20 m is noticed in isolated patches at Anekatte, Ankasandra, Bhairapura, Chattasandra, Choulahalli, Dasanakatte, Hesarahalli, Hosur, Laxmanapura, Madihalli, Melanahalli, Somalapura, Virupakshapura villages, etc. Rise of water table between 0 - 10 m and more than 10 m is also observed at very small area at Harisamudra gate, Nelagondanahalli, Timmarayanahalli and Vasudevarahalli villages. The map showing WTF is presented in Fig. 3.62.

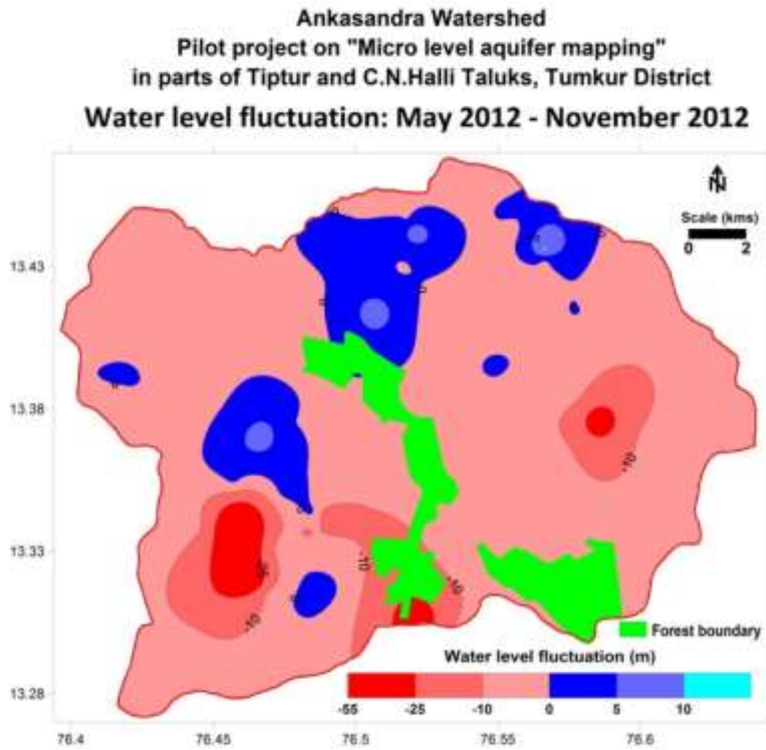


Fig. 3.60: Water table fluctuation map

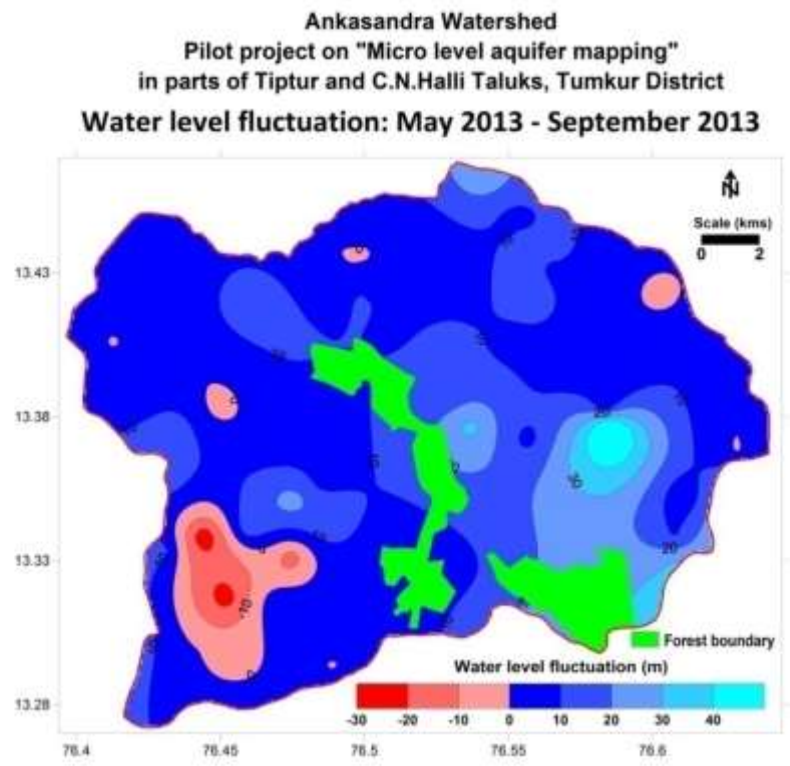


Fig. 3.61: Water table fluctuation map: May 2013 – September 2013

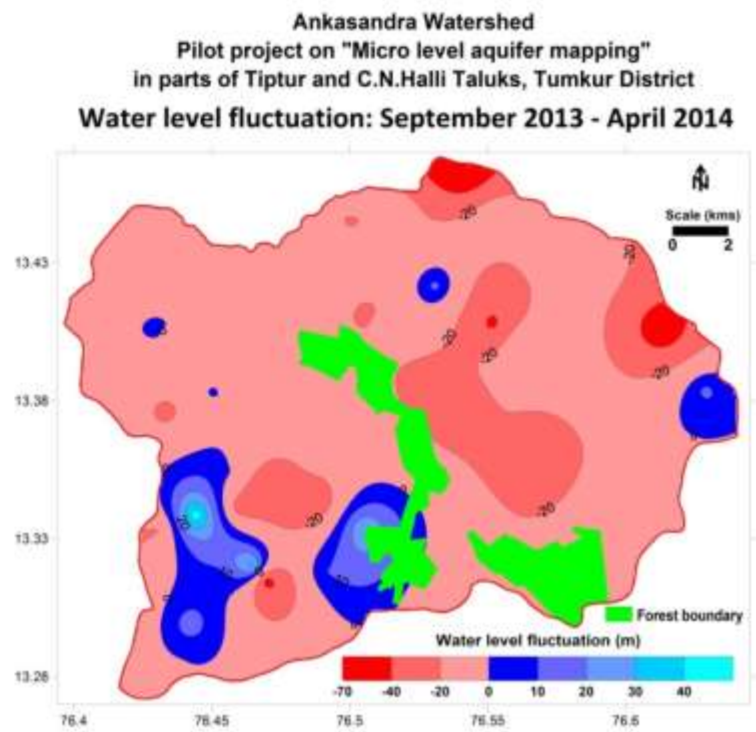


Fig. 3.62: Water table fluctuation map: May 2013 – September 2013

3.7.6 Hydrographs

The ground water level data collected for each well is utilised to draw hydrographs depicting ground water level with respect to time. Mostly ground water levels are declining continuously in the area. The steep declining trends are noticed at Alur villages where the ground water level decline from 30 to 90 m in two and half years. Similarly steep decline are noticed at Ankasandra (10 to 90 m), Kupparadoddahalli (20 to 70 m), Sarathavalli (10 to 90 m), Siddaramanagara (70 to 100 m), Khaimara junction (10 to 35 m) villages. At Halkurike, Mayagondanahalli, Bandegate, and Agasarahalli villages no changes in ground water levels are observed. The selected hydrographs are shown in Fig. 3.63.

Fig. 3.63: Hydrographs of selected stations

The typical dug well at B.Hosahalli village

Measurement of ground water level in dug well at Halkurike village

Measurement of ground water level from hand pump at Karehalli village

Measurement of ground water level in exploratory well at Huchanahatti EW site

3.8 WATER QUALITY

The chemical composition of ground water is derived from different sources and the relationship of ground water composition to source rock type is well known. Human activities may modify water composition extensively through direct effects of pollution and indirect results of ground water development.

3.8.1 Relation of ground water quality to Lithology

The study area is underlain by Granites, Gneisses and Schistose rocks which are occasionally intruded by dolerite dykes. As already mentioned, Gneisses, Schists and Granites are the predominant rock types in the area. Granite is a rock rich in quartz and having a large proportion of feldspar of which more than two-thirds of the potassium or sodium type. Gneiss and Schist resulted form heat and pressure that do not completely reorganize the initial rock. Ground water from such formations generally can be expected to be low in solute concentrations.

3.8.2 Hydrochemistry in the study area

To study the chemical quality of ground water, 52 samples were collected during September 2011 and 73 during May 2012. The locations of water samples collected are shown in Fig. 3.64 and Fig 3.65 respectively. The data is given in Annexure 3.6 and 3.7 respectively.

During September 2011, out of 52 samples, forty five are collected from Gneisses, six from Schists and one sample from Granites. During May 2012, out of 73 samples sixty four are collected from Gneisses, eight from Schists and one sample from Granites.

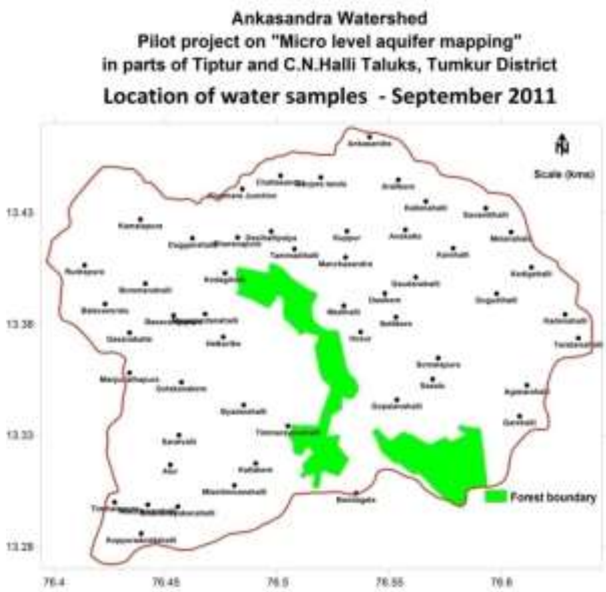


Fig. 3.64: Location of water samples collected during Sept. 2011

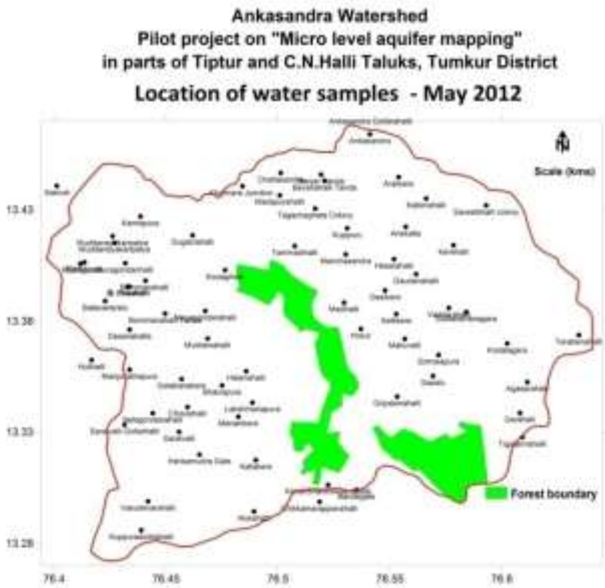


Fig. 3.65: Location of water samples collected during May 2012

Collection of water samples from key wells for quality analysis

3.8.2.1 Ground water quality in Granite formation

Only one sample is collected from Granite formation from Bandegate village. The analytical results show that pH, Calcium, Magnesium, total hardness chloride, nitrate, sulphate and fluoride are within acceptable limits. The EC is within permissible limits. The concentration of iron is beyond acceptable limits. Hence, ground water is mostly suitable for drinking, irrigation and industrial needs.

3.8.2.2 Ground water quality in Schistose formation

Six samples collected are from Schistose formation in the area. The analytical results show that pH, sulphate, zinc and copper are within acceptable limits in all the samples. The remaining parameters are mostly within acceptable limits and some are within permissible limits. In some samples, the Total Hardness (2 samples), magnesium (3 samples) and nitrate (2 samples) are found to be more than permissible limits. Iron concentration is beyond acceptable limits in 3 samples. Hence, ground water in general is suitable for drinking, irrigation and industrial needs.

The summarized results of chemical analysis of all the water samples collected during September 2011 and May 2012 along with Indian standard - Drinking Water Specification (IS 10500:2012)are given in Table 3.30.

Table 3.30: Chemical parameter wise range of concentrations along with IS 10500:2012

Sl. No.	Parameter	Range of concentrations		IS 10500:2012	
		Sept. 2011	May-12	Acceptable limit	Permissible limit*
1	pH	7.2 - 8.5	7.6 - 8.9	6.5 - 8.5	N.R.
2	EC	630 - 2570	420 - 4440	750	3000
3	TH	130 - 750	100 - 1490	200	600
4	Ca	12 - 200	12 - 156	75	200
5	Mg	2 - 138	2 - 267	30	100
6	Na	58 - 265	29 - 391	---	---
7	K	1.6 - 30.5	1.9 - 101	----	---
8	CO3	0 - 15	0 - 39	----	---
9	HCO3	104 - 616	91 - 384	----	----
10	Cl	28 - 454	28 - 1228	250	1000
11	NO3	3 - 190	10 - 100	45	N.R.
12	S04	14 - 180	10 - 244	200	400
13	F	0.3 - 1.6	0.13 - 1.42	1	1.5
14	P04	---	0.005 - 0.43	---	---
15	B	---	0.01 - 0.52	0.5	1
Heavy metals					
1	Zn	0.0001 - 8.03	---	5	15
2	Cu	0.0001 - 0.032	----	0.05	1.5
3	Ni	0.0001 - 0.504	---	----	---
4	Fe	0.14 - 5.4	---	0.3	N.R.

Note: EC in µS/cm-25°C and all other concentrations are in mg/l except pH.
*N.R.=No relaxation in the absence of alternate source.

3.8.3 Suitability of ground water for domestic purpose

The chemical parameter wise suitability of ground water for drinking purpose as per IS 10500:2012 is given below

3.8.3.1 pH

During September 2011, the pH of ground water ranged from 7.2 to 8.5 which indicates that the ground water is of alkaline type and well within acceptable limit(6.5-8.5) and hence, suitable for domestic use.

During May 2012, the pH of ground water ranged from 7.6 to 8.9 which indicates that the ground water is of alkaline type and mostly within ISI standard of 6.5 - 8.5 and hence, mostly suitable for domestic use. Higher concentration of pH of more than 8.5 is observed at Balavaneralu, Dasikere, Dugganahalli, Gopalanhalli, Hulihalli and Manakikere villages.

3.8.3.2 Electrical Conductivity (EC)

The acceptable and permissible limit for EC is 750 & 3000 µS/cm – 25 °C respectively.The EC of ground water ranges from 630 - 2570 µS/cm – 25 °C for the samples collected duringSeptember 2011 which indicates that the ground water is within permissible limit of 3000 µS/cm and hence, suitable for domestic use.

During May 2012, the EC of ground water ranged from 420 - 4440 µS/cm – 25 °C which indicates that the ground water is mostly within permissible limits and generally suitable for domestic use. Higher concentration of EC more than 3000 µS/cm – 25 °C is observed at B. Hosahalli village only. The distribution of EC is shown in Fig. 3.66.

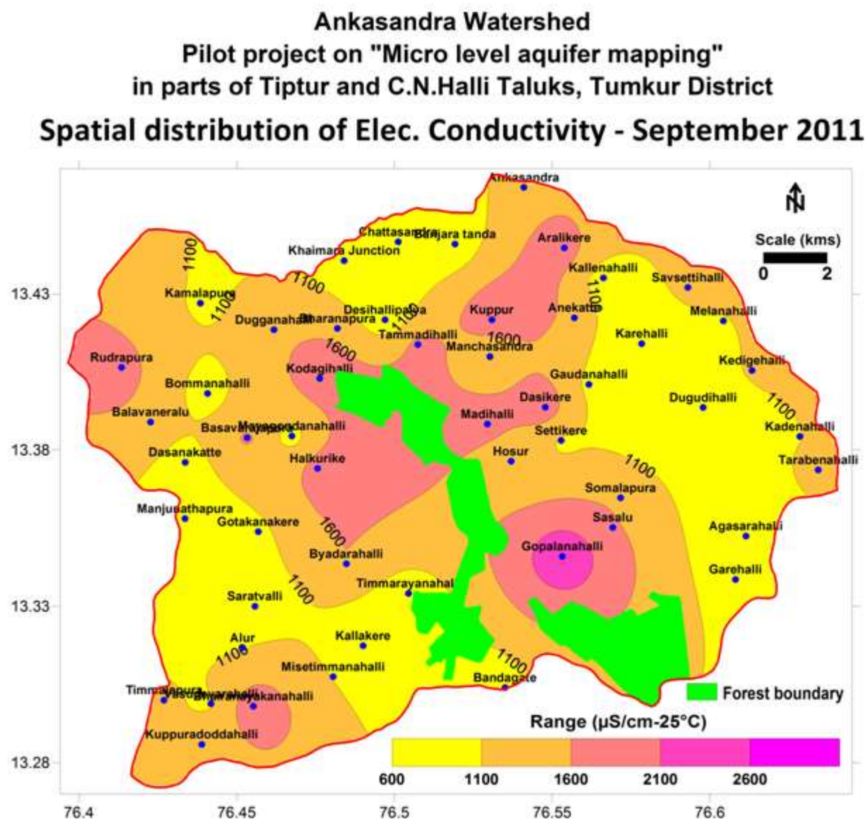


Fig. 3.66: Spatial distribution of EC (Sept. 2011)

3.8.3.3 Total hardness (TH)

Hardness is an important criterion for determining usability of water for domestic, drinking and industrial supplies. Based on the concentration of TH, the waters are classified as soft (0 - 50 mg/l), moderately hard (50 – 100 mg/l), hard (100 - 300 mg/l) and very hard if more than 300 mg/l. The acceptable and the permissible limits for TH are 200 and 600 mg/l respectively.

TH of ground water ranged from 130 - 750 mg/l (September 2011) which indicates that the ground water samples fall in hard to very hard type and hence, mostly suitable for domestic use. High concentrations of TH more than 600 mg/l are noticed at Bhairanayakanhalli, Kuppuru, Aralikere, Madihalli and Gopalanhalli villages.

During May 2012, the TH of ground water ranged from 100 - 1490 mg/l which indicates that the ground water samples falls in hard to very hard type and hence, mostly suitable for domestic use. High concentrations of TH more than 600 mg/l are noticed at Hosahalli (1490 mg/l) and Sasival (630 mg/l) villages only.

3.8.3.4 Calcium

The acceptable and the permissible limits for calcium are 75 and 200 mg/l respectively. The concentration of calcium in ground water ranged from 12 - 200 mg/l (September 2011) whereas, during May 2012, the concentration of Calcium in ground water ranges from 12 - 156 mg/l respectively. During both the periods the ground water is within the permissible limit and suitable for domestic use.

3.8.3.5 Magnesium

The acceptable and the permissible limits for magnesium are 30 and 100 mg/l respectively. During September 2011, the concentration of Magnesium in ground water ranged from 2 to 138 mg/l and mostly suitable for domestic use. Higher concentrations of Magnesium beyond permissible limits are noticed at Kuppuru, Kodigehalli, Madihalli and Gopalanhalli villages.

During May 2012, the concentration of Magnesium in ground water ranged from 2 to 267 mg/l and mostly within the permissible limit and suitable for domestic use. Higher concentrations beyond permissible limits are noticed at B.Hosahalli village only.

3.8.3.6 Sodium

There are no acceptable and permissible limits for sodium concentration. During September 2011, the concentration of Sodium in ground water ranged from 58 - 265 mg/l. During May 2012, the concentration of Sodium ranges from 100 - 1490 mg/l.

3.8.3.7 Potassium

Acceptable and permissible limits for potassium concentration are not fixed. During September 2011, the concentration of potassium ranged from 1.6 - 30.5 mg/l. During May 2012, the concentration of potassium ranges from 1.9 - 101 mg/l.

3.8.3.8 Carbonate and Bicarbonate

There are no acceptable and permissible limits for carbonate and bicarbonate concentrations. During September 2011, the concentration of carbonate ranged from 0 - 15 mg/l. During May 2012, its concentration ranges from 0 - 39 mg/l. During September 2011, the concentration of Bicarbonate ranges from 104 - 616 mg/l. During May 2012, the concentration of Bicarbonate ranges from 91 - 384 mg/l.

3.8.3.9 Chloride

The acceptable and the permissible limits for chloride are 250 and 1000 mg/l respectively. During September 2011, the concentration of chloride in ground water ranged from 28 – 454 mg/l during May 2012its concentration ranges from 28 - 1228 mg/l. During both the periods it is found to be mostly within the permissible limit and suitable for domestic use. Higher concentration of chloride beyond permissible limits is noticed at B.Hosahalli village only.

3.8.3.10 Nitrate

The acceptable limit for nitrate is 45 mg/l and there is no relaxation for permissible limit.During September 2011, the concentration of nitrate in ground water ranged from 3 - 190 mg/l and mostly suitable for domestic use. Higher concentrations of nitrate beyond acceptable limits are noticed at Kupparadoddahalli, Bairanayakanahalli, Dugganahalli, Anekatte, Aralikere, Ankasandra, Dasikere, Savsettihalli, Sasalu and Gopalanhalli villages.

During May 2012, the concentration of nitrate ranged from 10 - 100 mg/l and mostly within the acceptable limit and suitable for domestic use. Higher concentration of nitrate beyond acceptable limit are noticed at B.Hosahalli, Balavaneralu, Banjar thanda, Bevanahalli thanda, Chattasandra, Dasanakatte, Dasikere, Hosur, Hulihalli, Kamalapura, Kupparadoddahalli, Madapurahatti, Madihalli, Mayagondanahalli, Rudrapura, Settikere, and Vasudevarahalli villages. Higher concentration of nitrate is mostly due to domestic pollution. The distribution of nitrate is shown in Fig. 3.67.

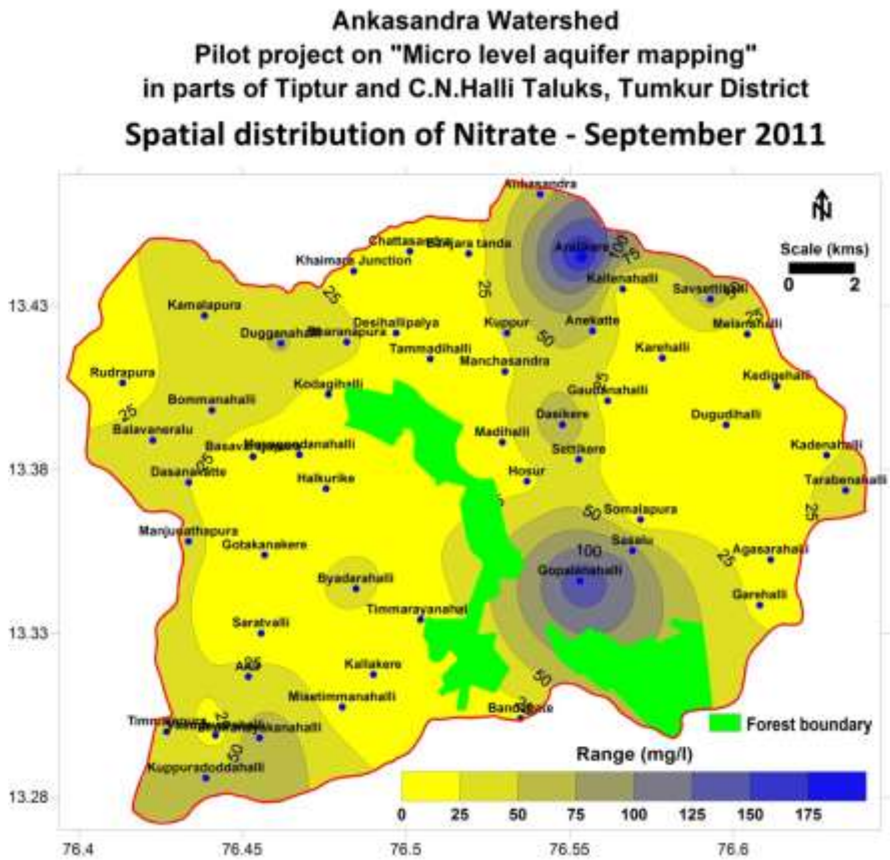


Fig. 3.67: Spatial distribution of Nitrate (Sept. 2011)

3.8.3.11 Sulphate

The acceptable and the permissible limits for sulphate are 200 and 400 mg/l respectively. During September 2011, the concentration of sulphate in ground water ranged from 14 to 180 mg/l and is within the acceptable limit. During May 2012, the concentration of sulphate ranged from 10 - 244 mg/l and hence, within the permissible limit.

3.8.3.12 **Fluoride**

The acceptable and the permissible limits for Fluoride are 1 and 1.5 mg/l respectively. During September 2011, the concentration of Fluoride in ground water ranged from 0.3 to 1.6 mg/l and hence, mostly within the permissible limit. Higher concentrations of Fluoride beyond permissible limit are noticed at Banjarathanda village only. During May 2012, the concentration of Fluoride ranged from 0.13 - 1.42 mg/l and hence, within the permissible limit and suitable for drinking purpose.

3.8.3.13 Phosphate

There are no acceptable and the permissible limits of phosphorous concentration. During May 2012, the concentration of Phosphorous ranged from 0.005 - 0.43 mg/l.

3.8.3.14 Boron

The acceptable and the permissible limits for Boron are 0.5 and 1.0 mg/l respectively. During May 2012, the concentration of Boron in ground water ranged from 0.01 - 0.52 mg/l and hence, within the permissible limit.

3.8.3.15 Conclusion

From the above study it is found that the ground water is generally suitable for drinking purpose except at few isolated locations where the concentration of nitrate is higher than acceptable limit and some areas the concentration of iron is beyond acceptable limit.

3.8.4 Heavy metals

Heavy metal concentrations of Zinc, Copper, Nickel and Iron were also analysed for 52 samples of September 2011 and the details are given below.

3.8.4.1 Zinc

The acceptable and the permissible limits for Zinc are 5 and 15 mg/l respectively. During September 2011, the concentration of Zinc in ground water ranged from 0.0001 - 8.03 mg/l and hence, within permissible limit.

3.8.4.2 Copper

The acceptable and the permissible limits for copper are 0.05 and 1.5 mg/l respectively. The concentration of copper in ground water ranged from 0.0001 - 0.032 mg/l and lies within acceptable limit.

3.8.4.3 Nickel

There are no standards for Nickel concentration. The concentration of nickel in ground water ranges from 0.0001 - 0.504 mg/l.

3.8.4.4 Iron

The acceptable limit for iron is 0.3 mg/l and there is no relaxation for permissible limit. The concentration of iron ranged from 0.14 to 5.4 mg/l. The higher concentrations beyond acceptable limit occur at many places in the study area. It may be due to the presence of large number of dolerite dykes in the area. The distribution of iron is shown in Fig. 3.68.

From the above study it is found that, the concentration of heavy metals like zinc, copper and nickel are in the permissible limits. However, the concentration of iron is beyond acceptable limit in most parts of the study area. It may be due the presence of banded ferruginous quartzite as linear patches in the area.

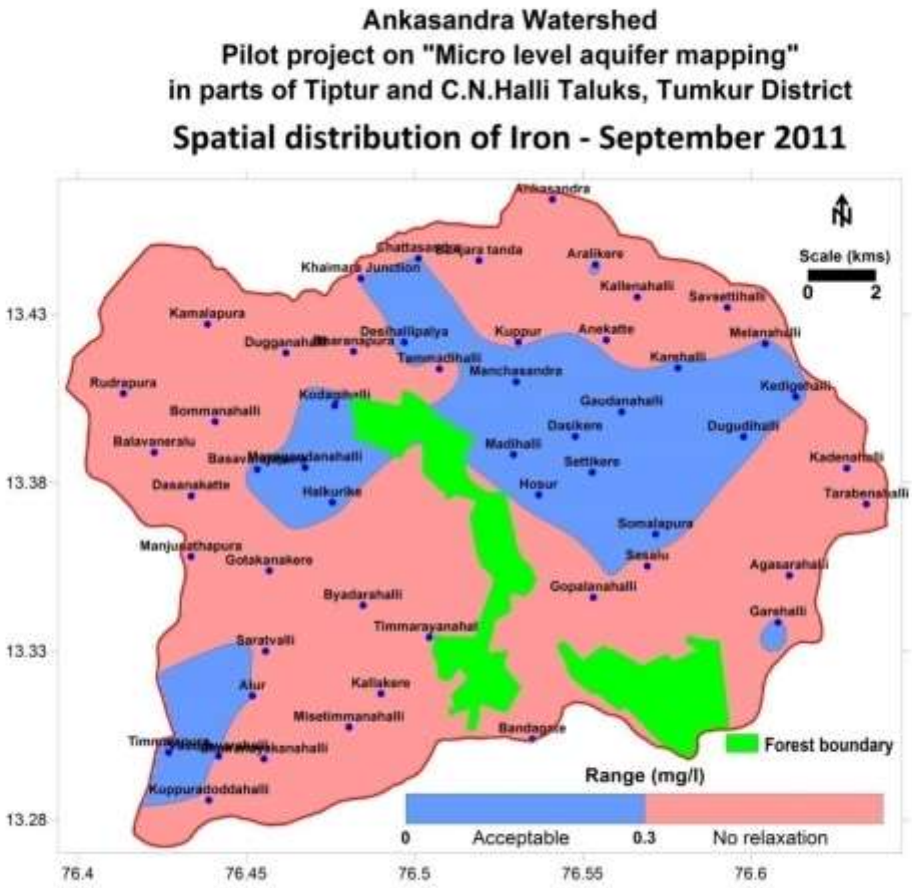


Fig. 3.68: Spatial distribution of Iron (Sept. 2011)

3.8.5 Suitability of ground water for irrigation

The chemical quality of ground water is essential factor to be considered in evaluating its suitability for irrigation use. Electrical conductivity (EC), Percent Sodium (%Na), Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are considered for the determination of suitability of water for irrigation purpose. The computed values of percent Sodium, SAR and RSC are given in Table 3.31.

Table 3.31: Computed values of EC, percent sodium, SAR and RSC

Sample Id.	Location	EC (µS/cm-25°C)	Percent Sodium	SAR	RSC
1	Kuppuradoddahalli	1230	36	3.05	-0.13
2	Timmalapura	1180	37	3.05	-0.86
3	Vasudevarahalli	1050	41	3.04	0.12
4	Bhairanayakanahalli	1970	32	3.26	-7.74
5	Alur	1090	45	3.56	-0.49
6	Saratvalli	800	55	4.44	0.19
7	Halkurike	1860	63	8.79	-0.43
8	Mayagondanahalli	850	51	4.00	0.44
9	Basavarajapura	1700	34	3.28	-4.37
10	Bommanahalli	870	51	3.61	1.09
11	Balavaneralu	1430	41	3.82	-1.06
12	Rudrapura	1820	64	9.12	3.71
13	Kamalapura	1020	31	2.37	-0.47
14	Dugganahalli	1460	26	2.25	-3.02
15	Bharanapura	1480	33	3.03	-1.15
16	Khaimara Junction	830	40	2.80	0.80
17	Chattasandra	910	49	4.05	-2.52
18	Banjara thanda	690	56	4.25	2.34
19	Kuppur	2070	32	3.51	-10.11
20	Anekatte	1480	52	5.65	-0.61
21	Aralikere	1870	34	3.36	-10.39
22	Ankasandra	1320	44	4.10	-3.89
23	Kallenahalli	820	46	3.39	0.87
24	Karehalli	630	43	2.67	0.94
25	Desihallipalya	690	47	3.17	0.90
26	Kodagihalli	1940	38	4.17	-6.07
27	Tammadihalli	1740	61	7.91	-0.70
28	Manchasandra	1030	53	4.93	-2.49
29	Madihalli	1860	19	1.82	-7.28
30	Dasikere	1960	47	5.61	-1.40
31	Settikere	1030	51	4.54	-2.10
32	Gaudanahalli	970	59	5.33	-1.86

Sample Id.	Location	EC (µS/cm-25°C)	Percent Sodium	SAR	RSC
33	Hosur	1070	34	2.64	1.33
34	Somalapura	1490	40	3.81	-3.55
35	Dugudihalli	760	42	2.82	-2.69
36	Kedigehalli	1160	53	5.00	2.15
37	Melanahalli	1070	61	6.24	-1.09
38	Savsettihalli	1260	55	5.70	0.85
39	Kadenahalli	1080	59	5.98	-0.58
40	Tarabenahalli	1290	60	6.60	-1.49
41	Agasarahalli	650	57	4.24	-0.27
42	Garehalli	850	38	2.74	-1.60
43	Sasalu	1670	51	5.34	-3.13
44	Gopalanahalli	2570	43	5.42	-6.07
45	Bandegate	860	53	4.52	-0.10
46	Misetimmanahalli	1080	53	4.76	1.73
47	Kallakere	740	57	4.45	2.65
48	Timmarayanahalli	780	47	3.43	0.29
49	Byadarahalli	1600	66	8.62	2.52
50	Gotakanakere	970	71	8.10	0.20
51	Manjunathapura	840	54	4.46	-0.20
52	Dasanakatte	900	71	7.69	0.21

3.8.5.1 Electrical Conductivity

Based on the values of EC, ground waters are categorized into excellent, good, permissible, doubtful and unsuitable for irrigation if EC is lesser than 250, 250 - 750, 750 - 2000, 2000 - 3000 and more than 3000 µS/cm at 25 °C respectively. In the study area, out of 52 samples, no sample falls under excellent category. Five samples fall under good category, forty five samples fall in permissible category and the remaining two samples fall in doubtful category. The EC more than 2000 µS/cm was noticed at Kuppur and Gopalanhalli villages (Annexure 3.7).

During summer season, the EC has decreased in majority of the samples when compared to previous year post monsoon. It implies that the waters of more areas will move towards permissible and good category and more suitable for drinking and irrigation purposes. The concentration of other chemical parameters like calcium, Bicarbonate and Fluoride also decreased in summer season and hence more suitable for drinking and irrigation purposes.

3.8.5.2 Sodium hazard

Sodium concentration is very important in classifying irrigation water because; sodium by process of Base Exchange replaces calcium in the soil thereby reduces the permeability of soil which has greater effect on plant growth. Sodium content in chemical analysis is reported as percent sodium which is determined by -

$$\text{Percent sodium} = \frac{\text{Na} + \text{K}}{\text{Ca} + \text{Mg} + \text{Na} + \text{K}} \times 100$$

Where, all ionic concentrations are expressed in equivalent per million (epm).

The water is classified as excellent, good, permissible, doubtful and unsuitable if the Percent Sodium is < 20, 20 - 40, 40 - 60, 60 - 80 and > 80 respectively.

In the study area, out of 52 samples, only one sample falls under excellent category, 14 samples fall under good category, 30 samples fall under permissible category and the remaining seven samples fall under doubtful category (Table 3.31).

3.8.5.3 Sodium Adsorption Ratio (SAR)

The relative activity of sodium ion in the exchange reaction with soil is expressed in terms of a ratio known as Sodium Adsorption Ratio (SAR) which is determined by

$SAR = Na / \sqrt{((Ca+Mg)/2)}$

Where, all ionic concentrations are expressed in epm.

The water is classified as excellent, good, fair and poor if the SAR is < 10, 10 - 18, 18 - 26 and > 26 respectively. The SAR reveals that all 52 samples fall in excellent category.

3.8.5.4 Wilcox diagram

In order to determine suitability of class of water for irrigation purpose, Wilcox (1948 & 1955) proposed a diagram in which percent sodium is to be plotted against electrical conductivity. Wilcox diagram is prepared and presented in Fig. 3.69. The diagram reveals that five samples fall in excellent to good (Class - I), thirty eight samples fall in good to permissible (Class - II), seven samples fall in permissible to doubtful (Class - III) and only two samples fall in doubtful to unsuitable (Class - IV) category.

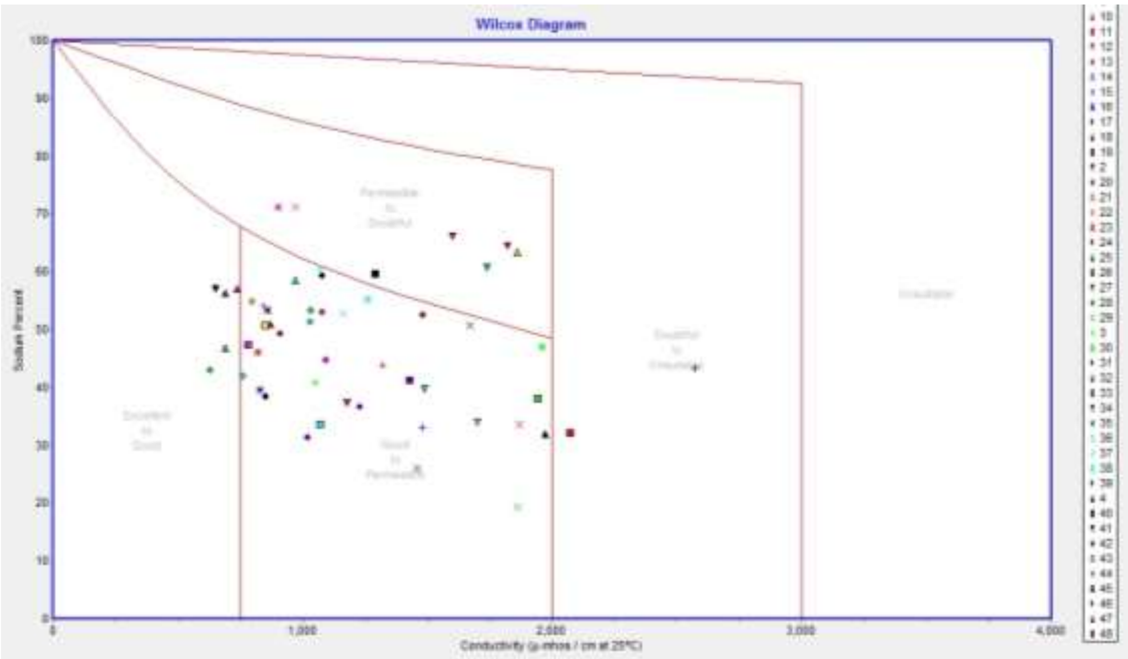


Fig. 3.69: Classification of irrigation water quality with respect to EC and Percent Sodium (Wilcox's diagram)

3.8.5.5 US Salinity diagram

The US Salinity Laboratory staff (1954) has constructed a diagram for classification of irrigation water with reference to SAR as an index for sodium hazard 'S' and EC as an index of salinity hazard 'C'. The sodium hazard is classified into low (S1), medium (S2), high (S3) and very high (S4) whereas, salinity hazard is classified into low (C1), medium, (C2), high (C3) and very high (C4). In this diagram, the values of SAR are plotted on arithmetic scale against EC on log scale and different classes of water have been marked and presented in Fig. 3.70. From the figure it is concluded that, forty one samples fall in C3S1 category (High salinity - Low sodium hazard), five samples each fall in C3S2 (High salinity – Medium sodium hazard) and C2S1 (Medium salinity – Low sodium hazard) categories and one sample fall in C4S2 (Very high salinity – Medium sodium hazard) category.

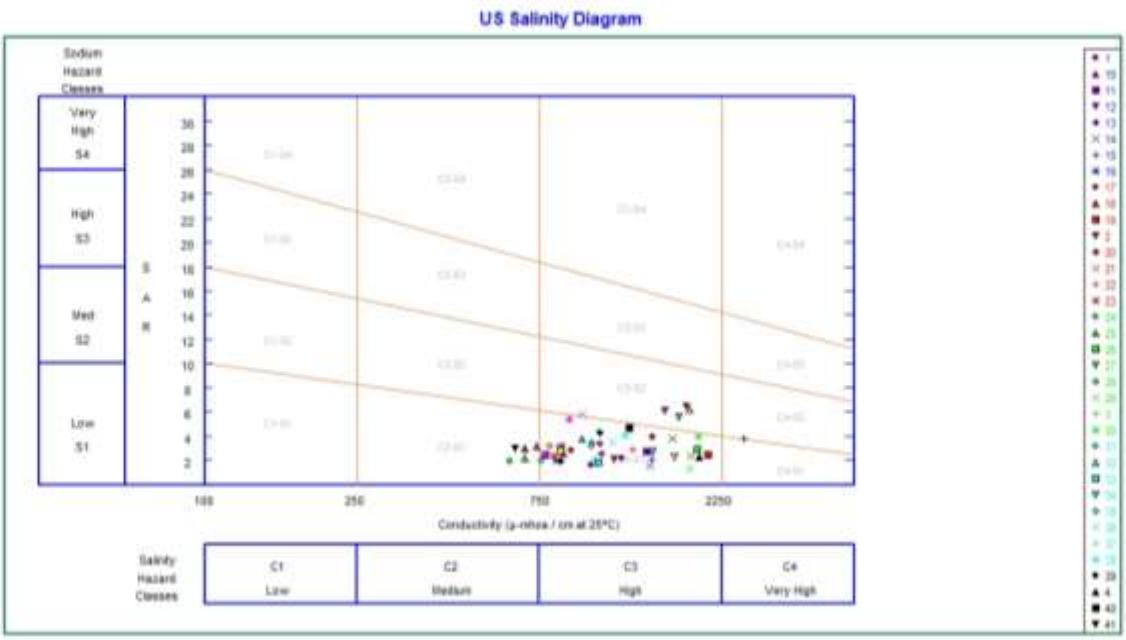


Fig. 3.70: Classification of irrigation water quality with respect to Salinity hazard and Sodium hazard (USSL diagram)

3.8.4.6 Bicarbonate hazard

The Bi-carbonate concentration of water has been suggested as additional criterion to study the suitability of ground water for irrigation purpose. If the water contains high concentration of bicarbonate ion, there is a tendency of calcium and magnesium ions to precipitate as carbonates. The convenient way of expressing values of the water in terms of Residual Sodium Carbonate (RSC) is as follows.

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

Where all the ionic concentrations are expressed in epm

On the basis of RSC, ground waters are divided into three categories viz., safe, marginal and unsuitable if RSC is < 1.25, 1.25 - 2.5 and > 2.5 respectively and shown in Table 3.32. It shows that out of 52 samples, 45 samples fall in safe category, 4 samples in marginal and 3 samples in unsuitable category.

Ground waters in the study area are generally alkaline in nature and the pH varies from 7.2 to 8.5. The concentration of EC varies from 630 to 2570 µS/cm-25 °C and mostly suitable for irrigations purposes. According to percent sodium, two percent samples fall in excellent category, twenty seven percent samples fall in good category, fifty eight percent samples fall in permissible category and thirteen percent samples fall in doubtful category. According to Sodium Adsorption Ratio all the samples fall in excellent category. As per RSC, eighty six percent samples fall in safe category, eight percent in marginal category and six percent in unsuitable category. From the above discussion on chemical quality of ground waters, it is concluded that ground water in the study area in general, is suitable for irrigation purpose. The high values of certain chemical constituents at certain locations are highly localized in nature.

Table 3.32: Classification of irrigation water

Parameter	Min.	Max.	Category	No. of Samples	% of samples	Water Class
EC (µS/cm-25°C)	630	2570	< 250	-	-	Excellent
			250 - 750	5	10	Good
			750 - 2000	45	87	Permissible
			2000 - 3000	2	4	Doubtful
			> 3000	-	-	Unsuitable
Percent Sodium	19	71	< 20	1	2	Excellent
			20 - 40	14	27	Good
			40 - 60	30	58	Permissible
			60 - 80	7	13	Doubtful
			> 80	-	-	Unsuitable
SAR	1.82	9.12	< 10	52	100	Excellent
			10 - 18	-	-	Good
			18 - 26	-	-	Fair
			> 26	-	-	Poor
RSC	-10.39	3.71	< 1.25	45	87	Safe
			1.25 - 2.5	4	8	Marginal
			> 2.5	3	6	Unsuitable

3.8.6 Seasonal variation of ground water quality

The season wise variation in ground water quality is analysed based on the quality of ground water in September 2011 and May 2012. Among the 52 water samples of September 2011 and 73 samples of May 2012, 35 common locations were considered for analysis. The seasonal variation of ground water quality is given in Annexure 3.8. The parameter wise variation is given below.

3.8.6.1 pH

When compared September 2011 with May 2012 results, out of 35 samples, the pH decreased in 2 samples and increased in 31 samples and there is no change in 2 samples. It shows that, that pH values are more in summer season when compared to winter season.

3.8.6.2 Electrical Conductivity (EC)

When compared September 2011 with May 2012 results, out of 35 samples, the EC decreased in 22 samples and increased in 12 samples and there is no change in 1 sample. It shows that, that EC values are mostly less in summer season when compared to winter season.

3.8.6.3 Total hardness (TH)

When compared September 2011 with May 2012 results, out of 35 samples, the TH decreased in 7 samples and increased in 25 samples and there is no change in 3 samples. It shows that that, TH values are mostly more in summer season when compared to winter season.

3.8.6.4 Calcium

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of Calcium decreased in 25 samples and increased in 8 samples and there is no change in 2 samples. It shows that that, the concentration of calcium decreased in summer season when compared to winter season.

3.8.6.5 Magnesium

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of Magnesium decreased in 7 samples and increased in 25samples and there is no change in 3 samples. The concentration of calcium increased in summer season when compared to winter season.

3.8.6.6 Sodium

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of sodium decreased in 20 samples and increased in 15 samples. It reflects the mixed trend of sodium concentration with season.

3.8.6.7 Potassium

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of potassium decreased in 18 samples and increased in 16 samples and there is no change in 1 sample. It reflects the mixed trend of potassium concentration with season.

3.8.6.8 Carbonate

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of carbonate decreased in 1 sample and increased in 11 samples and there is no change in 23 samples. From the analysis, it is found that that, the concentration of carbonate is showing increasing trend because of increase in pH during summer season. If the pH increases more than 8.2, carbonate will exist.

3.8.6.9 Bicarbonate

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of bicarbonate decreased in 25 samples and increased in 10 samples. It shows that that the concentration of bicarbonate mostly decreased because of its conversion to carbonate in summer season.

3.8.6.10 Chloride

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of chloride decreased in 17 samples and increased in 18 samples. It shows that, the concentration of chloride showing mixed trend with season.

3.8.6.11 Nitrate

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of nitrate decreased in 10 samples and increased in 24 samples and there is no change in 1 sample. It shows that that, the concentration of nitrate is showing increased trend in summer season.

3.8.6.12 Sulphate

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of sulphate decreased in 19 samples and increased in 14samples and there is no change in 2 samples. From the analysis, it shows that that the concentration of sulphate is showing mixed trend with season.

3.8.6.13 Fluoride

When compared September 2011 with May 2012 results, out of 35 samples, the concentration of fluoride decreased in 32 samples and increased in 3 samples only. It reflects that, the concentration of fluoride decreases in summer season.

3.8.7 Radioactive elements

Radioactivity is the release of energy and energetic particles by changes occurring within atomic or nuclear structures. Certain arrangements within these structures are inherently unstable and spontaneously break down to form more stable arrangements. Usually, for radioactive elements, the decay is expressed as a 'half–life', which is the length of time required for half the quantity present at time zero to disintegrate. The radioactive energy is released in various ways. The three types of radiations of principal interest in natural water chemistry are (i) alpha radiation, consisting of positively charged helium nuclei, (ii) beta radiation consisting of electrons or positrons and (iii) gamma radiation consisting of electromagnetic wave-type energy similar to X-rays. Radioactivity in water is produced principally by dissolved constituents.

3.8.7.1 Radon in ground water

The Radium isotopes 223, 224 and 226 decay to produce isotopes of radon, an alpha emitting noble gas. Radon - 222 produced in the decay of radium - 226 has a half-life of 3.8 days and is the only radon isotope of importance in the environment, as the other radon isotopes have half –lifeless than a minute. Radon is soluble in water and also can be transported in the gaseous phase. Small amounts present in atmosphere and large quantities occur in gases below the land surface. Many ground waters contain readily detectable quantities of radon. Radon - 222 decays through a series of short lived daughters to lead - 201, which has a half-life of 21.8 years. Indian Standard- drinking water specification (IS 10500:2012) does not specify any acceptable and permissible ranges for radon. However, US Environmental Protection Agency (EPA) in 1991 proposed a Maximum concentration level (MCL) of 11.1 Bq/l for public water supply.

3.8.7.2 Radon concentration in the area

Radon concentrations in ground water of borewells are studied at 17 locations in the area. The depth of borewells ranges from 73 to 195 m. The depth of casing in borewells ranges from 6 to 24 m. The depth of fractures encountered ranges from 15 to 126 m. The study revealed the concentration of radon ranges from 5.86 Bq/l (at Banasankarinagar in Schist) to 231 Bq/l (at Kadenahalli in Gneisses formation). As per the US Standards, except Banasankarinagar village, the concentration of radon exceeds the maximum concentration level. The Radon concentration in ground water in the study area is given in Table 3.33.

Table 3.33: Radon concentration in ground water in study area

Sl. No.	Name of the station	Total depth of Bore well (m)	Depth of fracture/ aquifer (m)	Depth of casing/ weathered thickness (m)	Radon Bq / l	Forma-tion
1	Bhairapura	90	54	12	160	Gneisses
2	H.Bhairapura	120	36	12	57	Gneisses
3	Gattikinkere-I	105	84	12	44	Gneisses
4	Gattikinkere-II	73	24	12	46	Gneisses
5	Dasanakatte	180	90	12	118	Gneisses
6	Manikinkere/ Huralihalli	135	45	18	53	Gneisses
7	Vaderahalli	150	126	12	57	Gneisses
8	Siddaramnagar	120	75	06	86	Gneisses
9	Dugadihalli	195	75	12	37	Gneisses
10	Kedegehalli	150	105	12	49	Gneisses
11	Gowdanahalli	130	72	09	76	Gneisses
12	Heserehalli	105	60	24	56	Gneisses
13	Kodagehalli	135	60	24	29	Schists
14	Banashankari nagar	126	72	12	5.86	Schists
15	Sasalu	90	90	24	76	Gneisses
16	Tharabenahalli	165	15	15	135	Gneisses
17	Kadenahalli	105	24	12	231	Gneisses

Collection of fresh water samples at an agriculture pumping well near Siddaramanagara village

Radon analysis of water samples

3.8.8 Ground water pollution

Pollution is the process of induction to ground water of objectionable matter or property arising from human activity and thereby changing its physical, chemical or other properties as to render it unfit or less fit for drinking, irrigation or other uses. In the study area, the ground water is subjected to both geogenic and anthropogenic pollution. High concentration of iron at most places beyond acceptable limit (0.3 mg/l) is mainly due to geogenic pollution. High concentration of nitrate at certain places beyond acceptable limit (45 mg/l) is due to human activity and it is highly localized in and around village habitations.

3.9 RECHARGE PARAMETERS

The dynamic ground water resources of the study area which is part of 4D3D8 watershed is computed based on Ground Water Estimation Methodology 1997 (GEM 97) as on 31.3.2014.The GEM-97 is an improvement version over the GEC-84 taking into consideration of many ground water aspects based on field investigations. The major improvement over GEC 1984 is that the watershed is taken as assessment unit and then appropriated for administrative units. Sub-areas viz. hilly area is excluded, poor quality areas as per local standards separately dealt with and the rest of the area is classified as command and non-command for ground water assessment.

Season wise ground water resource assessment is done for each sub-area. For monsoon recharge, post-monsoon ground water levels is taken after a month of cessation,thereby ensuring that, base flow after monsoon, not utilised for development, is avoided during estimation.

Methodology has been provided for determination of specific yield based on ground water balance approach in dry season for non-command area in hardrock terrain. Norm for return flow from irrigation is based on type of source, type of crop and depth to water table. Categorisation is based on stage of development and long term trend in pre-& post monsoon ground water levels. Allocation for domestic and industrial use is more realistic based on population density and relative load on ground water for the purposes.

3.9.1 Data collection and compilation

The following data were collected during the field work and from various State Govt. Departments. viz. daily rainfall data for 4 years (2010-2013), infiltration rates of soil, inventory of borewells for unit draft, aquifer information, quality etc., area under ground water irrigation, well census, details pertaining to tanks, cropping pattern, command and non-command area, population growth, watershed, geology, soil, hilly area, location of observation wells, rain gauge stations and taluk boundaries were digitised. The periodical ground water level data collected from observation wells established by CGWB and also from DMG, Govt. of Karnataka were processed and mean ground water level fluctuation and trends were estimated.

3.9.2 Ground Water Assessment

There is no command area in the watershed. Similarly, there is no mappable poor quality area in the watershed. The areas having slope of more than 20% are supposed to have very quick run off and little recharge to ground water. Similarly, areas having massive rock exposures are also not suitable for augmenting recharge to ground water. Hence, an area of about 2546 ha is excluded for recharge calculations and an area of 34954 ha is considered for ground water recharge.

3.9.3 Computation of Ground water Resources

The dynamic groundwater resource of the watershed is assessed as on March 2014.

3.9.4 Ground Water Recharge

For the purpose of evaluation of ground water recharge, rainfall infiltration method is followed. The average amount of rainfall received during the year 2013-14 is 632 mm after making the average of all influencing rain gauge stations. The rainfall infiltration factor is taken as 10% in the study area because the farmers have constructed farm bunds to collect rainwater at most of the places.

The ground water recharge is calculated as, Area * 10% of Rainfall (m)

=34954 ha * 63.2/1000 = 2209 ha.m

Recharge from return flow from irrigation is negligible as most of the farmers are practicing drip irrigation. Recharge from minor irrigation tanks is also negligible as the tanks are not receiving any inflows.

3.10 DISCHARGE PARAMETERS

3.10.1 Natural Discharge

GEM-97 accounts for natural discharge like base flow and evapo-transpiration from groundwater source as 5% & 10% of annual recharge in case of recharge calculated by WTF method and RIF method respectively. In the study area, it is taken as 10% as transpiration from coconut trees is high in the area. Therefore, the natural discharge is 220.9 ha.m and the net ground water availability is 1988.1 ha.m (19.88 MCM)

3.10.2 Ground water draft for domestic and industrial purpose

The area is predominantly rural with a density of 180 persons per sq.km. There are about 67,357 persons and some coconut based industries in the area. It is observed that the population is stagnated over a decade (2001-2011) due migration of people to nearby urban areas like Tiptur, C.N.Halli or to Bangalore mostly for finding employment. The domestic and industrial demands are calculated as 100 liters per day/person for 365 days which works out to 246 ha.m.

3.10.3 Ground water draft for irrigation purpose

The preference for different type of groundwater abstraction structure has changed over the years. In the past, the dug wells are preferred structures. Over a period of time, the number of dug wells increased and ground water draft increased which resulted in lowering of the ground water levels. Over a period of time, the dug wells replaced by borewells and finally led to drying up of the phreatic aquifer.

The groundwater draft figures were assessed based on unit draft method. More than 900 borewells were inventoried to know the aquifer disposition, yield, quality etc. The field study indicates that, most of the farmers are growing perennial crops like coconut and areacanut under ground water irrigation. Majority of the farmers are practicing drip irrigation, as the state Government is providing subsidy up to 90% to the farmers. The power availability in the study area is only limited hours which was recently increased to 6 hours/day from earlier 3 hrs/ day. It is reported that there are 295 pumping days in a year.

Unit draft of borewells was arrived based on the inventory of borewells in different formations and also after interaction with farmers. Granite formation occupies small area and is mostly undulating and massive in nature. Schist formation is mostly in hilly areas with less accessibility. Gneiss is the dominant formation for draft point of view. The formation wise unit draft of borewells and the total draft for irrigation is given in the Table 3.34.

Table 3.34: Formation wise unit draft and total draft for borewells

Formation	Area (sq.km)	No of bore wells	Unit Draft (2013-14) (Ha.m/Annum)	Total draft (ha.m)
Gneiss	270	3500	0. 9558	3345.30
Granite	11	60	0. 7168	43.00
Schist	94	200	0. 4779	95.58
			Total draft for irrigation	**3483.88**

It is also observed that, there is reduction in unit draft recently because of mutual interference due to unscientific growth of borewells without spacing norms, over exploitation and below normal rainfall. The total ground water draft for irrigation and domestic needs is 3729.88 ha.m.

3.10.4 Categorisation of watershed

The net annual groundwater availability as on March 2014 for the watershed is 1992.2 ha.m while, the gross annual draft is 3773.08 ha.m and the net available for future development is nil. The stage of groundwater development in the watershed is 187% and the watershed is categorised as **"Over exploited"**. The salient features of the groundwater resources of the watershed as on March, 2014 is presented in Table 3.35.

Table 3.35: Ground Water Resources of the study area on March 2014

Particulars	As on 31-3-2014
Net Annual Ground water Availability (ha.m)	1988.1
Existing Ground water draft for Irrigation (ha.m)	3483.88
Existing Ground water draft for domestic and Industrial water supply (ha.m)	246.00
Total ground water draft for irrigation and domestic needs	3729.88
Provision for domestic and industrial requirement supply for 2025	250.00
Net annual ground water availability for future irrigation development (ha.m)	Nil
Stage of Ground water development (%)	187.61%

3.10.5 In-storage ground water resources estimation

The in-storage ground water resources estimation has been calculated for the studyarea. The total dynamic ground water resources calculated as 2510 ha.m and in-storage fresh ground water resources for phreatic and fractured aquifers are calculated as 12685 and 11937 ha.m respectively. The total ground water resources for the entire study area is 27132 ha.m (Table 3.36).

Table 3.36: Calculation of In-storage ground water resources estimation

1	Total geographical area	37500	ha
2	Hilly area	2935	ha
3	Non-command area	34565	ha
4	Average depth upto which aquifer is commonly developed	200	m
5	Average pre-monsoon water level from dugwells (Apr. 2014)	8.98	m bgl
6	Total depth of weathered zone	27.33	m bgl
7	Productive zone below pre-monsoon WL (phreatic zone)	18.35	m
8	Productive zone below pre-monsoon WL (fractured zone)	172.67	m
9	Average Spe. Yield considered for pheratic zone	0.02	%
10	Average Spe. Yield considered for fractured zone (10% of pheratic value)	0.002	%
11	**Total fresh ground water resources:-**		
12	**a) Dynamic ground water resources**	**2510**	ham
13	**b) In-storage fresh ground water resources (static):-**		
14	(i) Phreatic	**12685**	ham
15	(ii) Fractured	**11937**	ham
17	**Total Ground water resources of the study area**	**27132**	ham

3.11 EXISTING GROUND WATER SCENARIO

Ground water is under severe stress in the study areaas the present stage of ground water development is 187%. The average depth to ground water level during the last two-and-half years has declined down to the depth of 35 m bgl from 11 m bgl. It is noticed that the depth to ground water levels are more than 100 m bgl at Huchanahatti, Sarathavalli, Ankasandra villages. The yield from borewells has also decreased from 2 to 3 lps to 1 to 1.5 lps generally, which has resulted in lesser availability of water to perennial crops like coconut. Most of the shallow borewells are dried-up due to lowering of water table. In most cases, the tanks are not receiving any inflows and hence, no scope for additional recharge to the ground water.

Dry dug well at Siddaramanagara village

Dry tank near Tammadihalli village

Major check dam near Ankasandra village in a state of dry condition

Construction plot-wise bunds near Gerehalli – Agasarahalli village road

4.0 DATA INTEGRARATION

4.1 INTEGRATION OF DATA FROM CONVENTIONAL AND ADVANCED TECHNIQUES

In order to achieve one of the main objectives of mapping the principal aquifer, we established an approach for translating the geophysical results into the hydrogeological models through the steps as follows:

i. SkyTEM results are calibrated against the drilling lighologs, ground geophysical results and then integrated lithological logsareprepared for selected sites.
ii. Equivalent litho-units of the integrated logs are converted into principal litho-units as proxy of principal aquifer and aquitard.
iii. The principal lithologs are imported to the Arhus Workbench and incorporated with the individual sections prepared at each 2 km X 2 km gridline.
iv. The principal litho-facies are interpolated and extrapolated along the SkyTEM sections using the calibrated resistivity values.
v. Based on the hydrostratigraphy, the principal lithological units are finally attributed into principal aquifer, bedrocks.

Lithological layer boundaries are prepared for all possible SCI model separated ~25m from each other along the grid lines. This is followed by gridding using the krigging interpolation scheme. Of course, the interpolation has averaged out some of the sharp anomalies indicating smooth variation. In order to retain the small-scale variation, it is desired to do the digitization and demarcation of lithological boundaries for all the flight lines.

4.2 VALUE ADDITION FROM GEOPHYSICAL STUDIES

With the results from the SkyTEM survey, a first order understanding of the SkyTEM responses with the ground geophysics (i.e. ERT, VES), exploratory well lithologs and aquifers encountered was made at all the drilling sites. This attempt is made to validate the efficacy of newly inducted SkyTEM tool in aquifer mapping.

Table 4.1: CGWB exploratory well details in Ankasandra watershed area

SiteName	Lat	Long	Well depth (m)	Well dia	Zone stapped (m)	Disch-arge (lps)	SWL (m bgl)
Sarathvalli	13.3276	76.4558	200	6”	99.50-102, 186.0-188.0	2.91	80.10
Balavanerlu	13.3837	76.4222	200	-do-	60.35-61.35, 66.0-67.0, 154.97-155.97	1.79	32.21
BommanahalliThanda	13.3814	76.4470	200	-do-	192.0-193.0	0.08	31.33
Bharanapura	13.4180	76.4791	200	-do-	134.88-135.88, 178.84-179.84	0.59	22.54
Hossur	76.4437	76.4437	200	-do-	191-192	1.22	12.97
MadhapurahattuThanda	76.4999	13.4374	200	-do-	68.0-69.0, 88.0-89.0, 109.78-112.40	0.08	28.83
Navule	76.5710	13.4272	200	-do-	150.0-151.0, 159.0-160.0, 185.5-186.5	4.36	25.57
Ankasandra	76.5423	13.4631	200	-do-	100.0-101.0	4.36	20.42
Huchanahatti	76.4844	13.2858	189.36	-do-	170.60-171.60, 185.20-186.20	4.36	45.72
Adinayakanahalli	76.4994	13.3245	200	-do-	189.0-190.50, 198.0-199.0	3.84	49.47
Shettikere	76.5620	13.3781	200	-do-	82.0-83.0	1.79	25.66
Sasalu	76.5687	13.3563	181	-do-	54.0-56.0, 77.0-78.0, 96.0-97.0, 111.0-112.0, 128.0-129.0, 143.0-144.0, 161.0-162.0	5.54	24
Madhihalli	76.5291	13.3883	200	-do-	171.0-172.0	0.22	13.39
Tarabenahalli	76.6291	13.3679	200	-do-	77.0-78.0, 161.0-162.0	0.59	34

High reservations were kept while analysing by keeping in mind that complexity of hardrock terrain in general and specially with such a pilot study area having high tectonic implications with over-exploited conditions. Such attempt is made with an aim of developing a strategy model for aquifer mapping over other similar hardrock terrains. In order to visualize the response of SkyTEM, a profile line of 1 km length was chosen in which the exploratory well is located and the inferences were drawn at selected sites.

CGWB, SWR, Bangalore has drilled 14 exploratory wells in the study area up to a depth of 200 m bgl covering the entire watershed area. The details on locations and aquifer depth ranges with yield are presented in Table 4.1. Although, all the exploratory well sites have been analysed for validation, few representative sites have been discussed in detail for the presentation. The wells selected for discussion are expected to cover the four directional segments and the centre of the area.

As a first order comparison with the litholog; drill time log and aquifer depth details, the geophysical results from ground and airborne surveys were collated together along with the control site information and analysed for site specific correlation. The ground surveys, though conducted at nearest feasible location, the interpreted results were taken into consideration for correlation with litho-information. Due to the presence of habitations, even the SkyTEM results of the nearest fly-line data is considered for analysis. Keeping this in mind, an attempt has been made to analyse the geophysical survey response in terms of litho-information. The results of ERT, VES, GTEM and SkyTEM are presented in a graphical mode along with litholog and drill time log in Fig. 4.1.

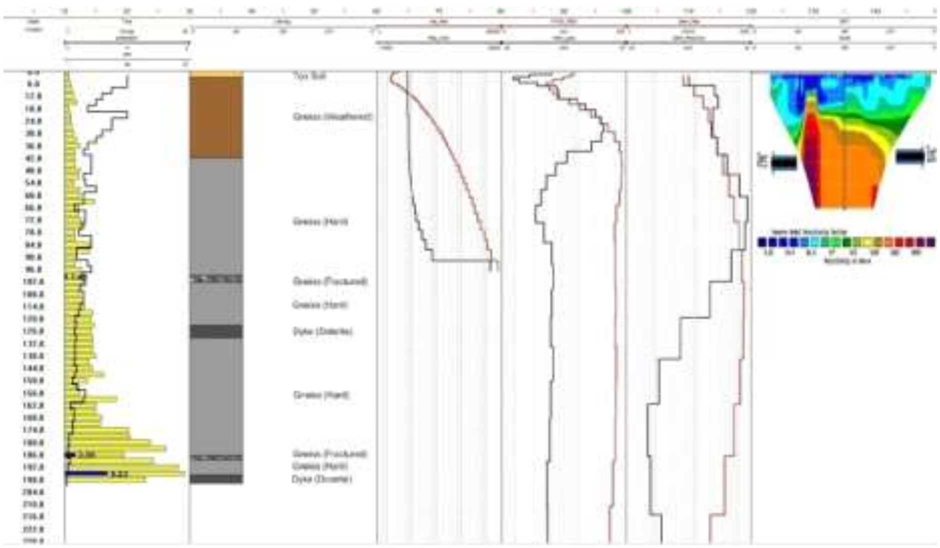


Fig. 4.1: Comparisons of geophysical interpretated results with litholog and drill time log of borehole at Sarathavalli

The fracture associated aquifer at two different depths and the reported occurrence of intrusive rock of the same nature are the interesting features to be traced in geophysical survey results. Due to the natural limitation detection of thin conducting layers at depths by geophysical surveys, a new interpretation technique was developed with gradient/slope analysis of geophysical data generated. The gradient behaviour was supplemented with the geophysical results while correlating with or identifying the interesting targets. The gradient profile has been plotted in black color for respective geophysical tool results and presented in the same figure.

The ERT imaging which was carried out perpendicular to the VES alignment indicating the presence of an intrusive body at shallow level onwards (15-20 m) west of the borewell location. Due to paucity of space, the conducted ERT gave rise to the information upto a depth of 91 m only. Similarly, the VES results also seem to be un-utilizable in the present site correlation. Whereas, the SkyTEM mean resistivity depth profile along with gradient depth profile indicated the aquifer and dyke depth signatures as the information available by SkyTEM is upto a depth of 200 m.

The occurrence of aquifer in the fracture zone just above the intrusive at both depth ranges point out that the intrusion process of dolerite might have induced fracturing in the basement making the zone above to form a good aquifer zone. For rest of the sites,comparison images are shown in Appendix.

Validation of the heliborne and surface geophysical data with the drilling log results has been done on the WellCAD platform using the evaluation version. This provides excellent platform for data validation and integration. Finally, we have integrated all sorts of available information from heliborne, surface and drilling logs and prepared composite and integrated litholog upto 150 m depth instead of targeted depth of 200 m.

A typical example of Sasalu (Fig. 4.2) is discussed as an example. The rest are given in Appendix. As none of the drilled wells were logged by geophysical probes, the calibration, validation and integration were managed using drill time record and the penetration rate in addition to the litholog prepared by CGWB based on the hand specimen at every 3 m depths interval. To avoid the effect of principle of equivalence, smooth layer model of the VES as well as HeliTEM is utilized to demarcate the lithological boundaries; it is preferred to take the first derivative of smooth resistivity model. The ERT 2D model is also used maintaining the vertical scale with common reference.

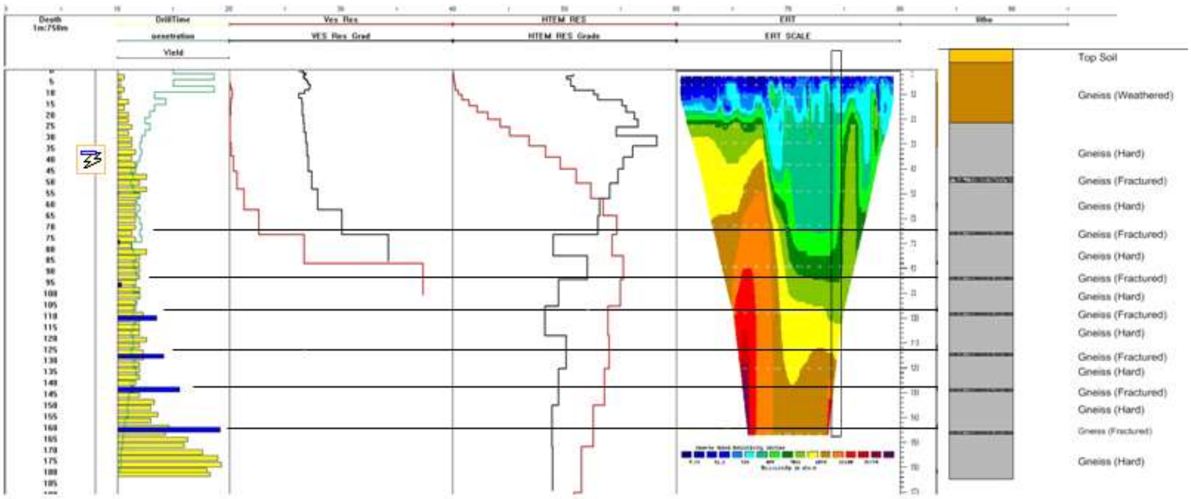


Fig. 4.2: Data integration and Validation of CGWB drilled well at Sasalu village

The top 10 m showing high penetration rate (PR) is an indicative of soft formation, which given as top soil in CGWB litholog. The measured resistivity by VES, SkyTEM and ERT are also found low in the range of 10-20 Ohm.m. There is sharp change of the grade of the VES and HTEM revealing encountering the litho-interface. There is another sharp change at around 15 m, which reveals increase in the compactness of the rock matrix. Though the drilling log shows encountering the ~30 m, the PR and HTEM-RES_Grade found change at 35 m, which is within the agreement limit. As per the drilling record, first moisture encountered at 54-56 m depth below ground has also been found responded by the HTEM-RES Grade.

There are six sets of fractures encountered at respectively 77-7, 96-97, 111-112, 128-129, 143-144 and 161-162 m depths. The corresponding cumulative well discharges (i.e. yield) with depths are also given in blue color. The fractures at 111-112 and 161-161 are the major contributor of the ground water discharge, which showed significant increase in yield. The SkyTEM resistivity and its first derivative shown respectively as HTEM-RES and HTEM-RES_Grade reveal down-to-one correspondence. The HTEM-RES result below 150 m in the present case loses its sensitivity and hence, may not be taken for interpretation. The strong correspondence of various litho-interfaces including the potential fracture encountered at 111 m depth with SkyTEM result does validate to the HeliTEM results. Strong correlation of the HTEM at shallow level validates the contribution of the low moment data. This is very important from the point of mapping the weathering profile, which is hardly 10-20 m thick.

4.3 EFFICACY OF VARIOUS GEOPHYSICAL TECHNIQUES FOR DIFFERENT HYDROGEOLOGICAL TERRAIN

Elevation of the all principal lithological layers along with the ground elevation at each grid intersection points. 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 layers show inter connectivity between exploited aquifer and productive aquifer-I and II. Such sites can be used for constructing percolation tank for development of ground water resources.

4.4 PROTOCOL FOR GEOPHYSICAL INVESTIGATIONS IN AQUIFER MAPPING

Based on the above methodology, HeliTEM results have been taken along a cross section running in NE-SW direction passing through Sarathavalli, Madihalli and Navule (Fig. 4.3). The weathered profile which is supposed to constitute the main aquifer is presently exploited. This weathered zone could be called as exploited aquifer. Due to over-exploitation, water is confined to the fissured zone and hence, is termed as Fissured aquifer. Resistivity of 100-3000 Ohm.m is marked as fissured aquifer. The fissured principal aquifer though shown as a single layer indicates the presence of multiple fractures within the depth range.

It is important to note that the low resistivity within the Schist belt is due to presence of conductive minerals and need not to be mistaken as aquifer unless otherwise a targeted drilling is done. This example has shown an art of translating the geophysical result into the hydrogeological model. The remaining sections given at every 2 km grid in NS and EW direction can be translated.

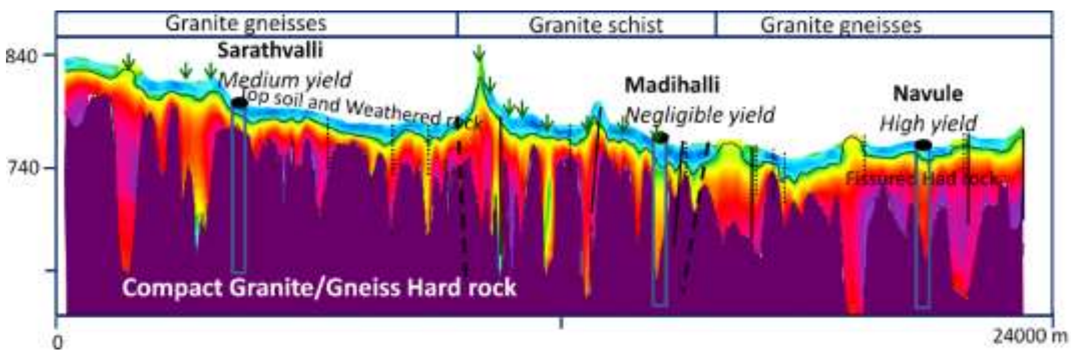


Fig. 4.3: HeliTEM result along with the well yield and litholog (upper); translated into hydrogeological model (lower)

The cross sections shown in Fig. 4.4 and 4.5 are prepared on the basis of SkyTEM results in SW-NE direction running across the geological strike direction. The sections depicted a simple three layered hydrogeological strike direction. These sections depicted a simple three layered hydrogeological layering. The top thin layer which represents the weathered zone varies in thickness from 8-40 m which is already over exploited. The second layer represents the fissured zone and its thickness varying from few meters to 100-200 m at photo-lineament areas. The bottom most layer is the stress basement with high resistivity. In the present case, these two layers are acting as aquifer zones.

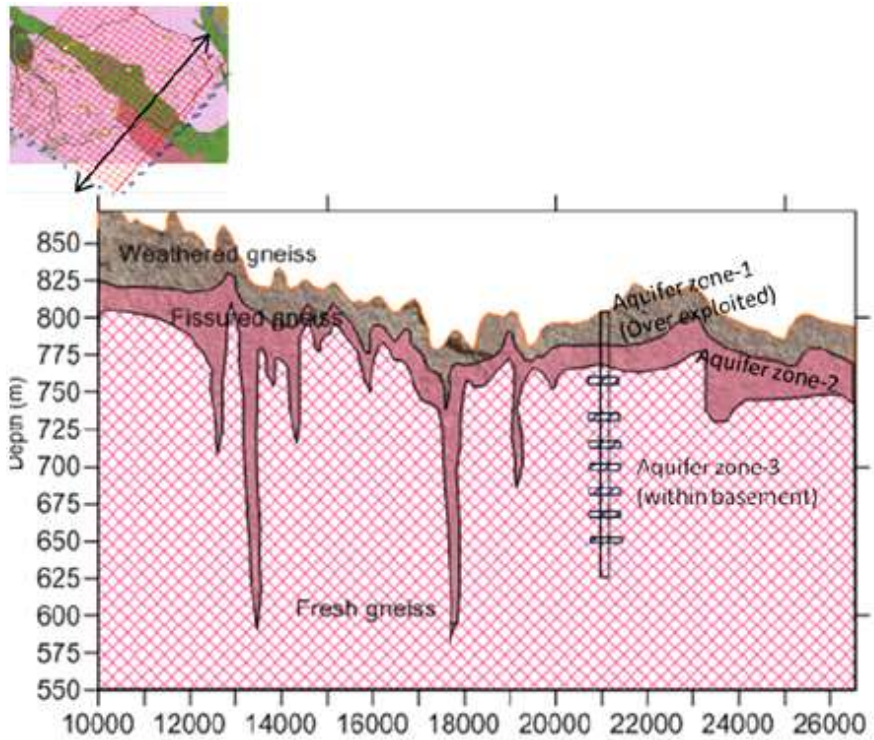


Fig. 4.4: Hydrogeological section along profile-II containing surface exploited aquifer zone-1 (weathered zone), Aquifer zone-2 (semi-weathered/fissured zone), aquifer zone-3 (hardrock)

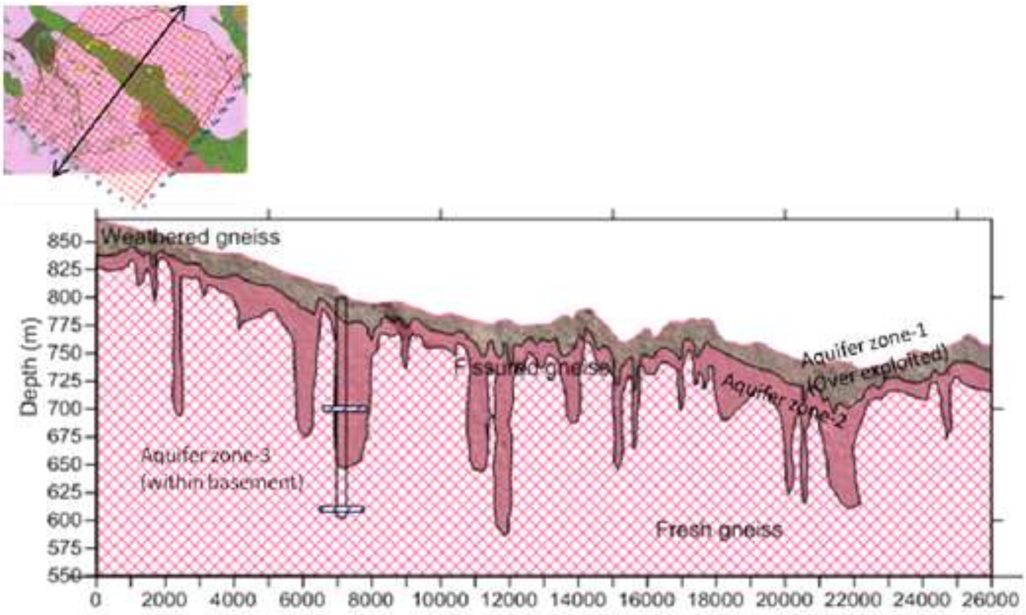


Fig. 4.5: Hydrogeological section along profile-III containing surface exploited aquifer zone-1 (weathered zone), Aquifer zone-2 (semi-weathered/fissured zone), aquifer zone-3 (hardrock)

4.5 THREE-DIMENSIONALRESISTIVITYSECTION

Based on SkyTEM data, the aquifer disposition in the form of 3-D map by slicing, the two vertical sections of 130 m thickness in the E-W and NE-SW directions are prepared. Since aquifer system is limited within the upper one-third to one-fourth 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 130 m depth maximum. As usual depth to bed rock is found deepening at depressions and lineaments and almost in the same.

Based on the results of ERT, TDEM, VES and GRP, the following additional information has been obtained:

- The ERT has revealed the weathered zone thickness and depth to bed rock and the possibilities of the occurrences of fracture zones.
- TDEM technique has been useful to the extent of determination of weathered layer thickness in hardrock areas.
- GRP could be useful in detection of fractures and needs to be carried out across the major lineament.
- The GRP supplemented with VES must form the key technique in the hardrock terrain for the delineation of water bearing fractures.

Findings of Heliborne Surveys:

The area is quite complex with rapid hydrogeological variations. Ground water is mostly occurring in the deeper thin fracture zones which make its detection by HeliTEM survey a challenge. The combination of heliborne magnetic and electromagnetic results and the geological information helped in identifying several buried linear structures which control the ground water occurrences in fracture zones. These regional structures could neither be picked up through satellite imageries nor through surface mapping. Locations with favourable TEM signatures along these magnetic lineaments could prove to be successful drilling sites. Mostly the high yielding wells are found to be falling in the areas near these lineaments or the contact of Granite, Gneisses and Schist.

It has shown even more than 200 m depth of investigation over buried lineaments identified by HeliMAG. While the HeliMAG results could be used to identify area in proximity of structures, the HeliTEM results could be used as follow-up in those areas to pinpoint sites and characterize their hydrogeological suitability for water well drilling. A comparative performance of VES, ERT, GRP, G-TEM and SkyTEM revealed that SkyTEM survey with dense and high quality data has added great value in mapping the sub-surface that revealed several features of high significance in terms of ground water occurrence and dynamics and hence aquifer mapping. The major SkyTEM findings in the area as follows:

- A number of NW-SE, NE-SW and N-S faults, and dykes manifested as magnetic lineaments have been identified which are not picked up in satellite imageries.
- The potential ground water zones are inferred from magnetic lineaments.
- The magnetic lineaments in E-W and NE-SW directions are more suitable as revealed by the high yielding well at Navule.
- The dip of the fault plane could be inferred. The areas in proximity of the fault in down dip direction hold better ground water potentiality.
- The contact between Granite, Gneiss and Schist is precisely delineated. The successful well can be located near the contact preferable on Gneiss in the NE part.
- The weathered and weathered-fracture zones have been delineated. The thickness of weathered rock is roughly 20-40 m.
- Precise dry and saturated weathered zone map and hydrogeologically sensitive structural map can be prepared from the combination of HeliTEM and HeliMAG.
- Lineaments are inferred by HeliMAG results.
- The depth of weathering and fracture occurrences is significantly high along the

lineaments and also the degree of variability is high indicating that the lineaments are not equally potential for ground water at all the places and location wise analysis is important.

- A methodology has been established to translate the geophysical data into hydrogeological model that has been successfully employed.

4.6 VIEWS ON THE SURVEYS CARRIED OUT BY NGRI

CGWB and NGRI entered into a Contract Agreement in May 2012 for carrying out Aquifer Characterization using Advance Geophysical Techniques in representative hydrogeological terrains.

4.6.1 Vertical electrical soundings

Out of 60 VES carried out, 15 VES have AB/2 less than 200 m, 21 have AB/2 200 m and the remaining 24 is more than 200 m with maximum AB/2 of 360 m. The resistivity ranges for different litho units and hydrogeological conditions is given below in Table 4.2.

Table 4.2: Resistivity ranges for different litho units and hydrogeological conditions.

Lithological Unit	Resistivity Range (Ohm-m)	Hydrogeological conditions
Surface layer	4-1635	Higher resistivity indicate dry condition
Weathered Gneiss	15-80	Saturated, lower limit of resistivity indicates higher clay content leading to less permeability
Weathered Schist	4-60	Saturated, lower limit of resistivity indicates higher clay content leading to less permeability
Semi-weathered Schist	100-160	Saturation is expected
Semi-weathered Gneiss	120-300	Saturation is expected, higher limit indicates less saturation to dryness
Jointed & fractured Gneiss	300-800	Saturation only in fracture zones and joints, higher resistivity indicate dryness
Hard compact rock	>1500	Very little possibility of saturated yielding fractures

It is observed that the resistivity ranges overlap for different litho units. The resistivity values established for different litho-units have been used for deducing the hydrogeological conditions from VES interpretation.

Comment:

i. VES results have been given only as layers. Within the compact hardrock, the resistivity is shown as very high.

4.6.2 GTEM

GTEM were carried out at 26 locations to delineate sub-surface layer parameters and fractures. It is found that GTEM techniques can be helpful to delineate first two layers namely weathered and semi-weathered zones. More noise is reported after these zones and data is not interpretable. At some of the GTEM locations, VES were also carried out for correlation. However, the results of GTEM and VES are not very well correlated in this hardrock area.

4.6.3 Electrical resistivity tomography (ERT)

ERT were carried out at 32 places with a total of 15.6 line km in the area. In 30 places out of 32, the depth of investigation is 91.2m or less. The depth of investigation is 115 m and 165 m only at two locations.

Comment:

ERT surveys revealed the vertical and lateral extent of subsurface lithology, weathered zone thickness and variation in depth to bed rock. The studies have not revealed the fractured depths precisely and indicated only possibility of fracture zone at deeper levels.

4.6.4 SkyTEM Survey

SKYTEM surveys were carried out with a line spacing of 150 m having 171 fly lines in NE-SW direction. Total flown line km works out to be 2909 of which 2843 line km data is accepted for processing. The average flight speed of the helicopter was 17 m/sec with an average flight altitude of 35 m above ground.

Findings:

The study was aimed at to infer low resistivity deeper zones associated with lineaments (fractures) through Generalized Depth of Investigation (GDI) of HeliTEM as the ground water levels are deep in the area. The GDI is a newly used concept as fracture zones filled with water produced sufficiently deep inductive environment and hence, deep information are obtained. The places over compact resistive zones without any significant fracture zone will have shallow GDI limited to the bottom of weathered zone. The depth sensitivity of HeliTEM in terms of GDI can be used to identify the deeper fracture zones. Once the fracture zone is identified and demarcated laterally, the HeliTEM soundings in that zone can be further studied to define the possible depth zone of the occurrence of fractures. It may not be possible to identify the deeper thin fractures but, the zones where such fractures can occur can be defined. In the present area, a significant observation is that the maximum GDI is 360 m i.e. there is a possibility of encountering conductive fracture zone upto 360 m depth. Further, fracturing zones occurring at depths beyond 100 to 150 m can be detected if thin fractures area significantly high yielding indicating a larger geometry and conductivity contrast. The resistivity ranges are upto 300 Ohm.m for weathered formation, 300 to 2000 Ohm.m for fissured formation and more than 2000 Ohm.m for fresh Gneiss/Schist.

The heterogeneity and complexity are characteristics features of the hardrocks. All these integrated geophysical surveys have expressed these complexities in term of geophysical properties of hardrock. The SkyTEM results have indicated the general depth of occurrence of water bearing zones.

4.6.5 GRP

The studies were carried out to pinpoint sites for exploration. At Sasalu site, the technique has helped to identify the potential zones and VES and ERT techniques are used to confirm the fracture depths. This has clearly illustrated the efficacy of applications of combined geophysical techniques like GRP, VES and ERT for ground water studies.

At Adinayakanahalli site, the GRP technique indicates that, the technique is useful for identification of deep fractures. Generally, it is concluded that GRP technique is useful to confirm and to identify the fracture depths with the help of other techniques such as VES and ERT. Hence, the limitation in these technique needs to be confirmed i.e., GRP alone does not give the clear cut confirmation of presence of fracture zone.

4.6.6Efficacy of various types of geophysical surveys

The efficacy of various types of geophysical surveys carried out by NGRI is given in the following table.

Table 4.3: Efficacy of various types of geophysical surveys

Sl no	GP Survey	Targeted depth	General Depth of Investigation (GDI) by NGRI	Remarks
1	VES	AB/2=500m	Mostly AB/2=200 m	Indicated weathered and semi-weathered zone.
2	GroundTEM	200 m	~ 30 m	Useful only for delineation of weathered and semi-weathered zone (i.e. Shallow zone).
3	ERT	200 m	Mostly 92 m	To delineate deep seated fracture, it is required 120 channel of ERT in hardrock areas.
4	SKYTEM	200 m	360 m	The SkyTEM results indicated the GDI and possibilities of encountering conductive zones upto a depth of 360 m. It is indicated that fracture zone occurring upto 100 m depth can be mapped with adequate accuracy. The fracture zone occurring beyond the depth of 100 m can be detected if there are significantly high yielding zones.

4.7 MAJOR FINDINGS

In the project area, CGWB has carried out 125 VES initially to decipher the sub-surface geo-electric layers. The raw data is shared with NGRI. Based on hydrogeological data supplemented by VES results, 14 exploratory wells were drilled. All the wells were also geophysically logged.

In tune with these works, NGRI has also carried out 60 VES, 26 Ground Time Domain Electro Magnetic (Ground TEM), 32 number (15.6 line km) of 2D ERT resistivity imaging, 2909 line kilometer of HeliTEM, and 37 Ground Resistivity Profile (GRP) to delineate weathered, fractured and depth to basement (massive formation). Studies revealed that deep fractures play a major role for occurrence of ground water in thin hardrock terrain. Initially, NGRI made an attempt to delineate fractures using integrated ground water geophysical techniques like VES, ERT, GTEM and GRP. From the results, it is observed that GRP technique could be useful for the qualitative delineation of fractures and their orientation whereas, VES and ERT can be helpful in deciphering both the weathered zone and fracture depth. Based on the results of GRP, VES and ERT surveys the following information has been obtained;

- The GRP surveys with close spacing could help in identifying the orientation of the conductive formations. This technique will work effectively at lineament sites. The GRP lows are observed as fractures and these fractures are confirmed by the drilling borehole at Sasalu village.
- The VES also picked up fractures at GRP lows (i.e., at Sasalu village and few nearby CGWB wells) whereas, the ERT has given idea about the lithology. Further, the VES with close spacing is a good technique to detect thin fractures in granitic area.
- The GRP supplemented with VES technique forms the key in the hardrock terrain for the delineation of water bearing fractures.

Comments:

The combination of heliborne magnetic and electro-magnetic surveys employed in pilot project area have helped in deciphering weathered and semi-weathered zones which are restricted to shallow depths (up to 60 m bgl). Further, it is indicated that, thin structures could neither be picked up through satellite imageries nor through surface mapping. However, these signatures are newly traced ones as per the interpretation and need to be checked and validated in field. Specific depth of occurrence of fractures is also not indicated and only relative and general description of sub-surface conditions is interpreted. The general depth of investigation (GDI) by SkyTEM is upto 360 m bgl. The fracture zones occurring beyond the depth of 100 m bgl can only be detected if the fracture zones are high yielding. Further, the sites recommended based upon the SkyTEM results also need to be tested by drilling to prove the applicability of SkyTEM technique in hardrock terrain.

5.0 GENERATION OF AQUIFER MAP

5.1 AQUIFER DISPOSITION

5.1.1 Aquifer disposition through borewell inventory

To understand the aquifer disposition and its yield, borewell inventory was carried out at 955 locations. The depth of casing gives information on depth of weathering and in most villages it is about 10 – 20 m bgl. The depth of weathering is 20 to 30 m bgl and rarely 30 to 40 m.More than 40 m weathering is noticed in selected villages like Navule and Tigalanhalli.

In hardrocks, fractures are the repositories of ground water at deeper depths. The occurrence of productive fractures is very important for successful borewell. Based on the data collected, village-wise and depth-wise distribution of fractures is presented in Fig.5.1. Depth-wise availability of fractures at various villages is given in Table 5.1. The data analysis reveals that, shallow fractures are occurring at Bhairapura, Kantalagere, Mallidevihalli and Mayagondanahalli villages. Deep fractures up to 250 m depth are occurring in Agasarahalli, Ajjehalli, Bhairanayakanahalli, Chaulihalli, Chikkenahalli, Dabbeghatta, Madihalli, Garehalli, Kallakere, Kodagihalli, Kodalgara, Manakikere, Manchasandra, Manjunathapura, Settikere, Tammadahalli, Tigalanahalli, Timmalapura villages. In most of the villages fractures are restricted to 200 m depth.

Table 5.1: Depth-wise occurrence of fractures

Occurrence of fracture at different depths					
Sl. No.	Upto 50 m bgl	Upto 100 m bgl	Upto 150 m bgl	Upto 200 m bgl	Upto 250 m bgl
1	Bhairapura	Abhujihalli	Adinayakanahalli	Anekatte	Agasarahalli
2	Kantalagere	Bete Ranganahalli	Alur	Ankasandra	Ajjenahalli
3	Mallidevihalli	Bevinahalli	Arlikere	Bachihalli	Bhairanayakanahalli
4	Mayagondanahalli	Dasanakatte	Ballenahalli	Banjara thanda	Chaulihalli
5		Doddakatte	Baluvanerlu	Basaveshwarapura	Chikkenahalli
6		Dugudihalli	Bennayakanahalli	Benakanakatte	Dabbeghatta
7		Gatakanakere	Bommanahalli	Byadarahalli	Dasihalli
8		Gollarahatti-Bhairanayakanahatti	Chattasandra	Chaudlapura	Gerehalli
9		Halenahalli	Chunganahalli	Gollarahatti-Harisamudra	Hurlihalli
10		Halkurike kaval	Dasihalli palya	Gollarahatti-Timmalapura	Kallakere
11		Harachanahalli	Dibbadahalli	Hesarahalli	Kedagihalli
12		Paragondanahalli	Dugganahalli	Irlagere	Kodalgara
13		Rangapura	Gopalanahalli	Kamalapura	Kurubarahalli_2
14		Siddaramanagara	Gowdanakatte	Kodagihalli	Manakikere

Occurrence of fracture at different depths					
Sl. No.	Upto 50 m bgl	Upto 100 m bgl	Upto 150 m bgl	Upto 200 m bgl	Upto 250 m bgl
15		Suragondanahalli	Halkurike	Kugihalla	Manchasandra
16		Timmarayanahalli	Harisamudra	Kurubarahalli_1	Manjunathapura
17			Jakkanahalli	Madapura	Settikere
18			Kadenahalli_1	Makuvalli	Tammadihalli
19			Kallenahalli	Misetimmanahalli	Tigalanahalli
20			Kibbanahalli	Muddenahalli	Timmalapura
21			Kuppuru	Navule	
22			Lakshmanapura	Nelagondanahalli	
23			Madihalli	Pinnenahalli	
24			Marasandra	Rudrapura	
25			Ramashettihalli	Sarathavalli	
26			Shavigehalli	Sasalu	
27			Yerehalli	Savsettihalli	
28				Suleman palya	
29				Tarabenahalli	
30				Upparahalli	
31				Vaderahalli_1	
32				Vaderahalli_2	
33				Vittlapura	

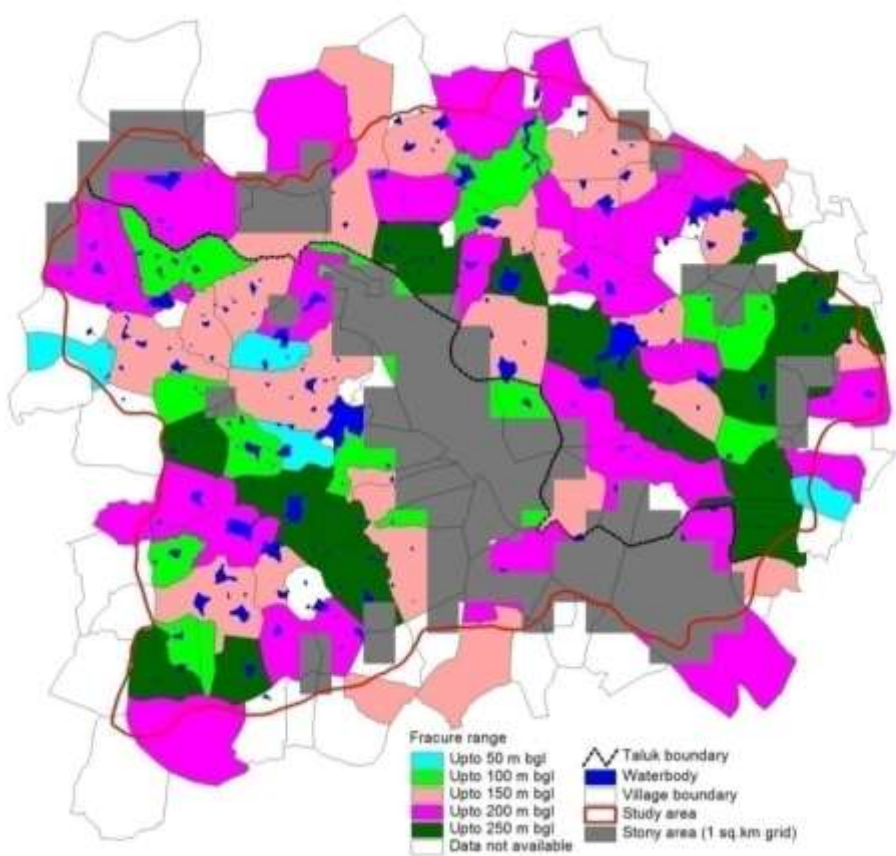


Fig. 5.1: Village-wise occurrence of fractures

The analysis of depth vs. fractures encountered shows that 40% of fractures are falling in the depth range of 100 – 150 m followed by 28% of fractures are falling in the depth range of 150-200 m. Another 22% of fractures are falling in the depth range of 50 - 100 m. Very negligible percentage of fractures are falling in the depth ranges of 0 – 50 m, 201 - 250 m and more than 250 m depth. It reflects that most of the fractures are falling in 100 – 200 m depth range. The analysis of depth vs. fractures is shown in Table 5.2 and pictorially shown in Figs. 5.2 and Fig. 5.3.

Table 5.2: Analysis of depth vs. fractures

Analysis of Depth vs. Fracture						
Depth drilled (m bgl)	**Casing range (m bgl)**	**No. of fractures**	**No. of villages covered**	**No. of failed wells**	**No. of wells Inventoried**	**Fractures (%)**
0 - 50	**3.05 - 18.29**	**27**	**13**	**-**	**27**	**3**
50 - 100	**6.10 - 36.58**	**234**	**49**	**-**	**210**	**22**
100 - 150	**6.10 - 36.58**	**437**	**70**	**1**	**386**	**40**
150 - 200	**6.10 - 36.58**	**311**	**76**	**5**	**265**	**28**
201 - 250	**6.10 - 42.67**	**74**	**37**	**3**	**59**	**6**
250 - 280.42	**3.05 - 36.58**	**6**	**8**	**1**	**8**	**1**
				Total	**955**	**100**

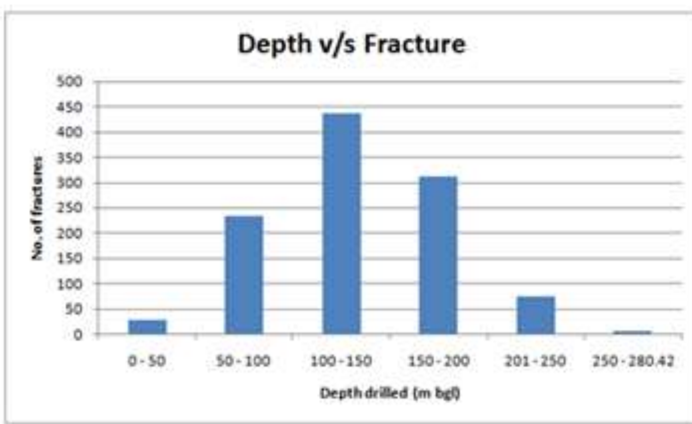


Fig. 5.2: Analysis of depth vs. fractures (scale bar)

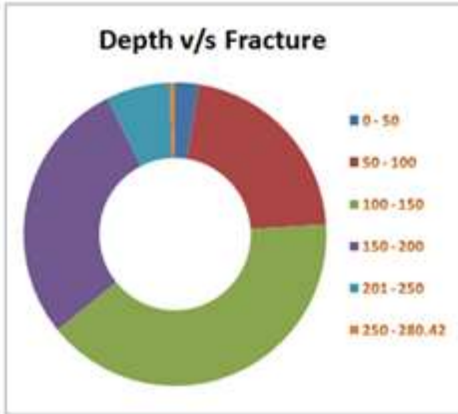


Fig. 5.3: Analysis of depth vs. fractures (pie diagram)

An analysis of depth vs. yield shows that 0 - 50 m depth range is giving yield range of 0.5 to 2 lps, 50 – 100 m depth range is giving yield range of 0.5 to 2 lps , 100 - 150 m depth range is giving yield range of 0.5 to 3 lps, 150 - 200 m depth range is giving yield range of 0.5 to 2 lps, 201 - 250 m depth range is giving yield range of 0.5 to 2 lps and more than 250 m depth range is giving yield range of 0.5 to 1 lps. It is observed that the most of potential fractures are found within depth range of 100 - 150 m. The analysis of depth vs. yield is given in Table 5.3.

Table 5.3: Analysis of depth vs. yield

Depth drilled (m bgl)	Yield (lps)
0 - 50	0.5 - 2
50 - 100	0.5 - 2
100 - 150	0.5 - 3
150 - 200	0.5 - 2
201 - 250	0.5 - 2
250 - 280.42	0.5 - 1

Based on the inventory of borewells, an analysis of village wise distribution of yield is carried out. It shows that majority of the villages are giving yield up to 1.5 lps followed by up to 1 and 2 lps. Very limited villages are yielding up to 3 lps. Village wise distribution of yield of borewells is given in Table 5.4 shown in Fig. 5.4.

Table 5.4: Village-wise distribution of yield

Village-wise yield analysis					
Sl.No.	**Upto 1 lps**	**Upto 1.5 lps**	**Upto 2 lps**	**Up to 2.5 lps**	**Up to 3 lps**
1	Adinayakanahalli	Abhujihalli	Agasarahalli	Chaudlapura	Alur
2	Bachihalli	Ajjenahalli	Ballenahalli		
3	Banjara thanda	Anekatte	Bevinahalli		
4	Bete Ranganahalli	Ankasandra	Bhairapura		
5	Byadarahalli	Arlikere	Chattasandra		
6	Chikkenahalli	Baluvanerlu	Dasihalli palya		
7	Dasanakatte	Basaveshwarapura	Gollarahatti-Harisamudra		
8	Doddakatte	Benakanakatte	Halkurike kaval		
9	Dugganahalli	Bennayakanahalli	Harachanahalli		
10	Dugudihalli	Bhairanayakanahalli	Harisamudra		
11	Gollarahatti-Timmalapura	Bommanahalli	Hurlihalli		
12	Kantalagere	Chaulihalli	Kallenahalli		
13	Kugihalla	Chunganahalli	Kibbanahalli		
14	Lakshmanapura	Dabbeghatta	Kuppuru		
15	Mallidevihalli	Dasihalli	Manakikere		
16	Manjunathapura	Dibbadahalli	Manchasandra		
17	Mayagondanahalli	Gatakanakere	Marasandra		
18	Misetimmanahalli	Gerehalli	Navule		
19	Paragondanahalli	Gollarahatti-Bhairanayakanahatti	Sarathavalli		
20	Pinnenahalli	Gopalanahalli	Tammadihalli		
21	Ramashettihalli	Gowdanakatte	Tarabenahalli		
22	Shavigehalli	Halenahalli			
23	Siddaramanagara	Halkurike			
24	Tigalanahalli	Hesarahalli			
25	Timmarayanahalli	Irlagere			
26	Vaderahalli_2	Jakkanahalli			
27	Vittlapura	Kadenahalli_1			
28		Kallakere			
29		Kamalapura			
30		Kedagihalli			
31		Kodagihalli			
32		Kodalgara			
33		Kurubarahalli_1			
34		Kurubarahalli_2			
35		Madapura			
36		Madihalli			
37		Makuvalli			
38		Muddenahalli			
39		Nelagondanahalli			
40		Rangapura			
41		Rudrapura			
42		Sasalu			
43		Savsettihalli			
44		Settikere			
45		Suleman palya			

Village-wise yield analysis					
Sl.No.	**Upto 1 lps**	**Upto 1.5 lps**	**Upto 2 lps**	**Up to 2.5 lps**	**Up to 3 lps**
46		Suragondanahalli			
47		Timmalapura			
48		Upparahalli			
49		Vaderahalli_1			
50		Yerehalli			

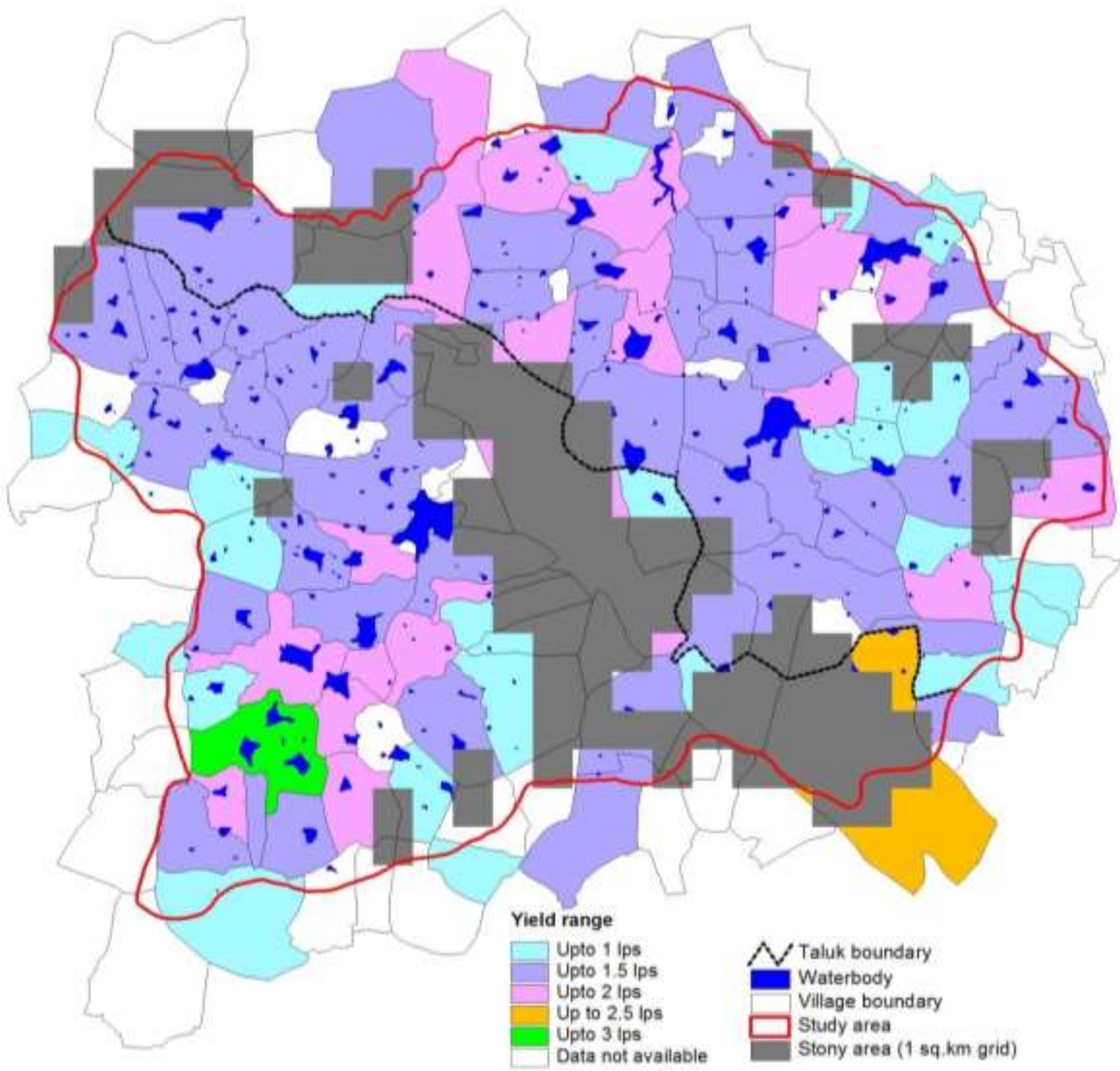


Fig. 5.4: Village-wise distribution of yield

An analysis is also done for aquifer-wise distribution of inventoried borewells. It shows that out of 955 wellsinventoried, 858 (90%) wells are in Gneisses, followed by 95 (10%) in Schist and only two wells in Granite formation.

Conclusions

- The depth of weathering in general is 10 – 20 m only and lesser in granitic formation.
- Most of the fractures are encountered between 100 – 200 m bgl.
- In most villages, the average yield varies between 1 and 2 lps.
- High yielding wells are noticed in Gneissic formation.
- Fractures encountered up to maximum depth in Gneisses.

Note: It is observed that most of the farmers are not lowering the casing pipe up to massive formation. Hence, the thickness of weathering is higher than the length of casing lowered.

5.1.2 Aquifer disposition based on exploratory wells through ROCKWORKS software

The geotechnical software, ROCKWORKS15 was utilized for the analysis of the 21 exploratory wells drilled under VRBP, outsourced wells drilled during AAP 2004-05 and during AAP 2013-14 under pilot project on aquifer mapping. The software requires basic details of exploratory wells like coordinates, elevation, total depth drilled and casing length lowered. Then depth-wise lithology data, stratigraphy data, fracture depth, drilling discharge, etc., for each exploratory well is given. The format of database required for the software is given in Table 5.5 to 5.9. Then the data base is to be imported into Rockworks software (Fig. 5.5). The software gives outputs viz. Distribution of exploratory wells (Fig. 5.6), general topography based on elevation (Fig 5.7), 2D single well strip log data for each well, 2D multi-well strip log data of wells, 3D multi-well strip log data of wells, 3D lithology models, volumes of individual lithology masses, lithology profiles, lithology cross-sections, fence diagrams, discharge data models and fracture data models through interpolation technique.

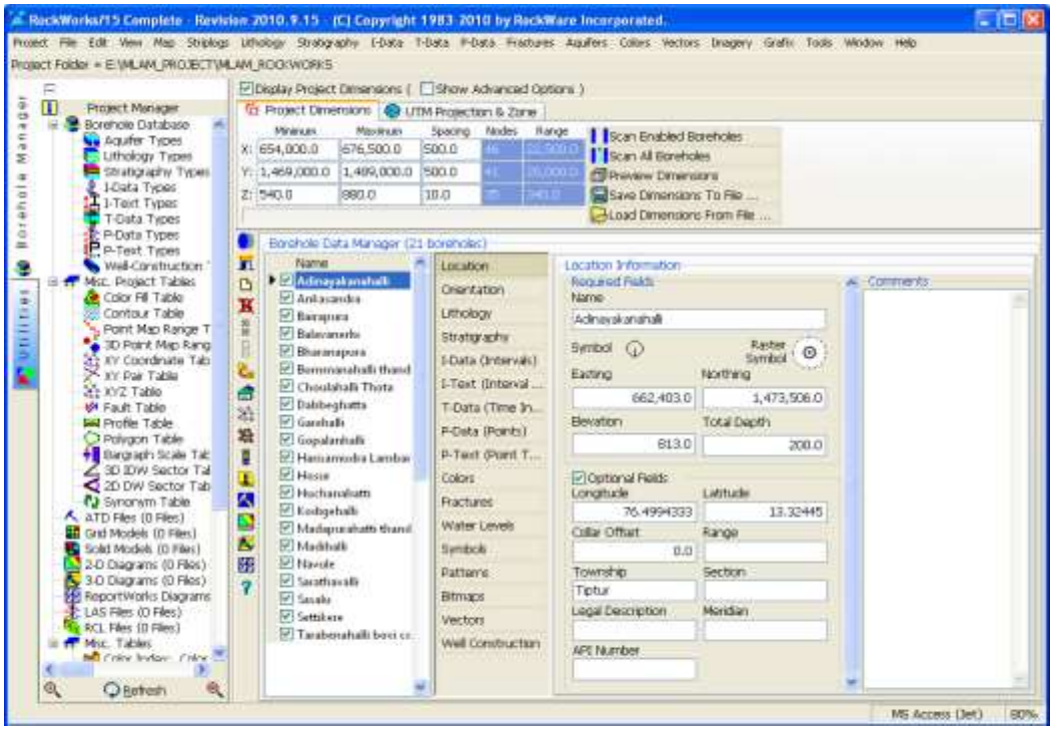


Fig. 5.5: Importing of exploratory wells to Rockworks software

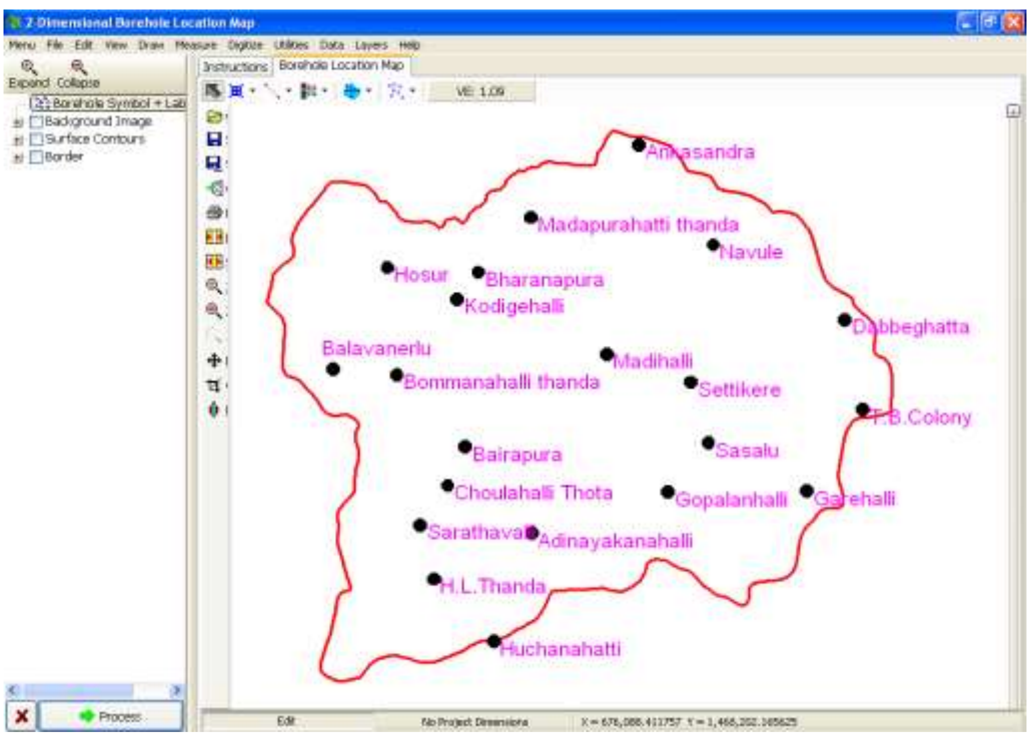


Fig. 5.6: Location of exploratory borewells (Rockworks)

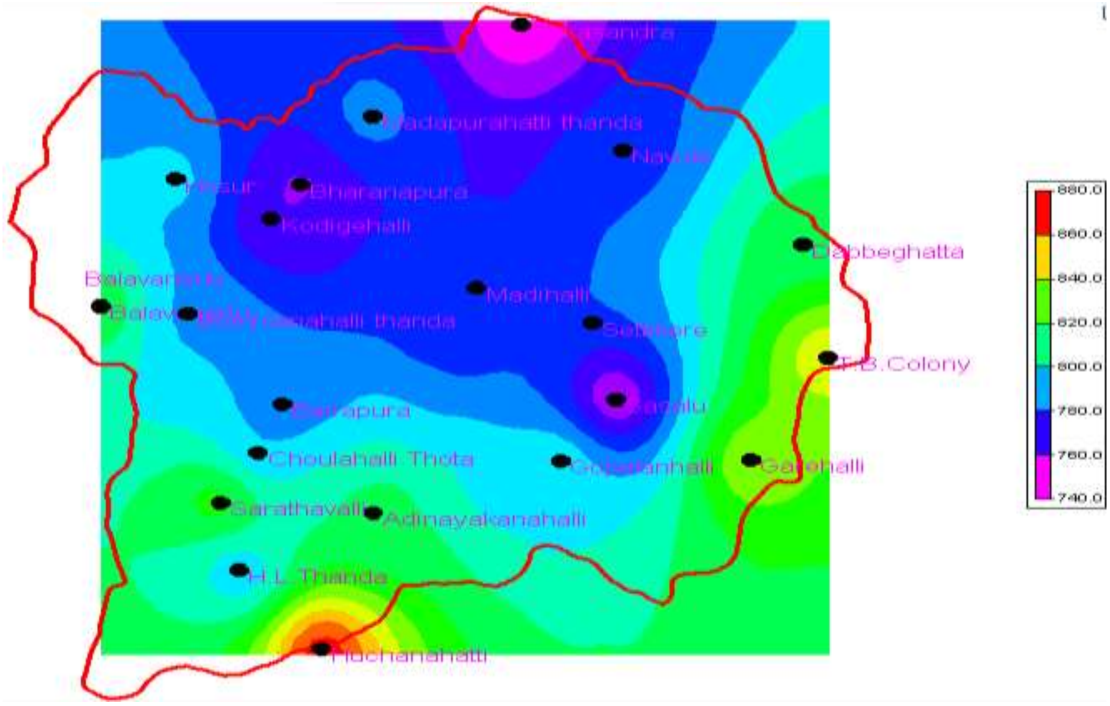


Fig. 5.7: General topography based on elevation

Table 5.5: Format of exploratory well details for Rockworks output.

Sl. No.	EW site	Taluk	Longitude	Latitude	Easting	Northing	Elevation	Total depth	Casing
1	Bairapura	Tiptur	76.47361	13.35556	659586	1476930	781	46.50	4
2	Choulahalli Thota	Tiptur	76.46670	13.34170	658846	1475393	790	200	10.36
3	Dabbeghatta	C.N.Halli	76.62220	13.40000	675649	1481947	816	200	17
4	Garehalli	C.N.Halli	76.60694	13.33889	674040	1475176	838.93	40.50	31
5	Gopalanhalli	C.N.Halli	76.55278	13.33889	668172	1475139	797.79	51	2.6
6	H.L.Thanda	Tiptur	76.46110	13.30830	658261	1471694	790	200	14
7	Kodigehalli	Tiptur	76.47083	13.40833	659250	1482767	758.69	90	3.9
8	Sarathavalli	Tiptur	76.45583	13.32758	657678	1473824	828	200	44.70
9	Balavanerlu	Tiptur	76.42222	13.38367	654002	1480007	821	200	25.50
10	Bommanahalli thanda	Tiptur	76.44703	13.38142	656690	1479774	787	200	24.17
11	Bharanapura	C.N.Halli	76.47914	13.41797	660143	1483838	757	200	34.20
12	Hosur	C.N.Halli	76.44367	13.41983	656301	1484021	794	200	30.68
13	Madapurahatti thanda	C.N.Halli	76.49990	13.43742	662378	1486003	785	200	51.62
14	Navule	C.N.Halli	76.57100	13.42721	670084	1484922	775	200	34.92
15	Ankasandra	C.N.Halli	76.54227	13.46306	666948	1488868	742	200	18.42
16	Huchanahatti	Tiptur	76.48442	13.28583	660802	1469224	879	189.63	24.00
17	Adinayakanahalli	Tiptur	76.49943	13.32445	662403	1473506	813	200	37.96
18	Settikere	C.N.Halli	76.56196	13.37811	669140	1479484	790	200	38.18
19	Sasalu	C.N.Halli	76.56867	13.35631	669881	1477076	749	181	32.02
20	Madihalli	C.N.Halli	76.52911	13.38828	665575	1480586	774	200	42.00
21	T.B.Colony	C.N.Halli	76.62906	13.36789	676415	1478400	849	200	45.20

Table 5.6: Format of lithology data details for Rockworks output

EW site	Depth1	Depth2	Lithology
Bairapura	0	0.8	Top soil
Bairapura	0.8	4	Gneiss - weathered
Bairapura	4	18	Gneiss - massive
Bairapura	18	19	Gneiss - fractured
Bairapura	19	22	Gneiss - massive
Bairapura	22	24	Gneiss - fractured
Bairapura	24	25	Gneiss - massive
Bairapura	25	26	Gneiss - fractured
Bairapura	26	28	Gneiss - massive
Bairapura	28	30	Gneiss - fractured
Bairapura	30	46.5	Gneiss - massive
Choulahalli Thota	0	2	Top soil
Choulahalli Thota	2	10.36	Gneiss - weathered
Choulahalli Thota	10.36	200	Gneiss - massive
Dabbeghatta	0	2	Top soil
Dabbeghatta	2	17	Gneiss - weathered
Dabbeghatta	17	95	Gneiss - massive
Dabbeghatta	95	96	Gneiss - fractured
Dabbeghatta	96	120	Gneiss - massive
Dabbeghatta	120	121	Gneiss - fractured
Dabbeghatta	121	165	Gneiss - massive
Dabbeghatta	165	166	Gneiss - fractured
Dabbeghatta	166	200	Gneiss - massive

Table 5.7: Format of stratigraphy data details for Rockworks output

EW site	Depth1	Depth2	Stratigraphy
Bairapura	0	0.8	Top soil
Bairapura	0.8	46.5	Gneiss
Choulahalli Thota	0	2	Top soil
Choulahalli Thota	2	200	Gneiss
Dabbeghatta	0	2	Top soil
Dabbeghatta	2	200	Gneiss
Garehalli	0	1	Top soil
Garehalli	1	40.5	Gneiss
Gopalanhalli	0	0.4	Top soil
Gopalanhalli	0.4	51	Schist
H.L.Thanda	0	1	Top soil
H.L.Thanda	1	200	Gneiss
Kodigehalli	0	1.5	Top soil
Kodigehalli	1.5	90	Schist
Sarathavalli	0	3	Top soil
Sarathavalli	3	123	Gneiss
Sarathavalli	123	129	Dyke - dolerite
Sarathavalli	129	195.23	Gneiss
Sarathavalli	195.23	200	Gneiss

Table 5.8: Format of fracture depth data details for Rockworks output

EW site	Date	Depth1	Depth2	Aquifer
Bairapura	29-12-1977	18	19	Aquifer 1
Bairapura	29-12-1977	20	24	Aquifer 2
Bairapura	29-12-1977	25	26	Aquifer 3
Bairapura	29-12-1977	28	30	Aquifer 4
Dabbeghatta	25-03-2005	95	96	Aquifer 1
Dabbeghatta	25-03-2005	120	121	Aquifer 2
Dabbeghatta	25-03-2005	165	166	Aquifer 3
Garehalli	21-11-1977	31	32	Aquifer 1
Garehalli	21-11-1977	37	38	Aquifer 2
Garehalli	21-11-1977	39	40	Aquifer 3
Gopalanhalli	02-12-1977	13	14	Aquifer 1
Gopalanhalli	02-12-1977	16	20	Aquifer 2
Gopalanhalli	02-12-1977	41	42	Aquifer 3
H.L.Thanda	10-03-2005	60	61	Aquifer 1
H.L.Thanda	10-03-2005	156	157	Aquifer 2
Kodigehalli	16-12-1977	11	12	Aquifer 1
Kodigehalli	16-12-1977	18	20	Aquifer 2
Kodigehalli	16-12-1977	28	29	Aquifer 3
Kodigehalli	16-12-1977	81	82	Aquifer 4
Sarathavalli	12-08-2013	99.5	102	Aquifer 1
Sarathavalli	12-08-2013	186	188	Aquifer 2

Table 5.9: Format of drilling discharge details for Rockworks output

EW site	Type	Depth1	Depth2	Value(lps)
Bairapura	Discharge	18	19	0.05
Bairapura	Discharge	20	24	0.18
Bairapura	Discharge	25	26	0.08
Bairapura	Discharge	28	30	0.4
Dabbeghatta	Discharge	95	96	2.13
Dabbeghatta	Discharge	120	121	2.91
Dabbeghatta	Discharge	165	166	4.36
Garehalli	Discharge	31	32	0.33
Garehalli	Discharge	37	38	0.67
Garehalli	Discharge	39	40	0.25
Gopalanhalli	Discharge	13	14	0.42
Gopalanhalli	Discharge	16	20	1.24
Gopalanhalli	Discharge	41	42	0.84
H.L.Thanda	Discharge	60	61	0.5
H.L.Thanda	Discharge	156	157	1.2
Kodigehalli	Discharge	11	12	0.05
Kodigehalli	Discharge	18	20	0.13
Kodigehalli	Discharge	28	29	0.94
Kodigehalli	Discharge	81	82	0.17
Sarathavalli	Discharge	99.5	102	1.49
Sarathavalli	Discharge	186	188	2.91

A 2D single well strip log gives vertical information of lithology consisting of soils, highly weathered, weathered, massive formations with fractures and massive formation at a particular site. The 2D single well strip log data of Adinayakanahalli, Sasalu, Bharanapura and Hosur is shown is Fig. 5.8. The 2D multi-well strip log data of wells drilled under VRBP and Outsourcing (AAP 2003-04) along with elevations is generated using software and given in Fig. 5.9.

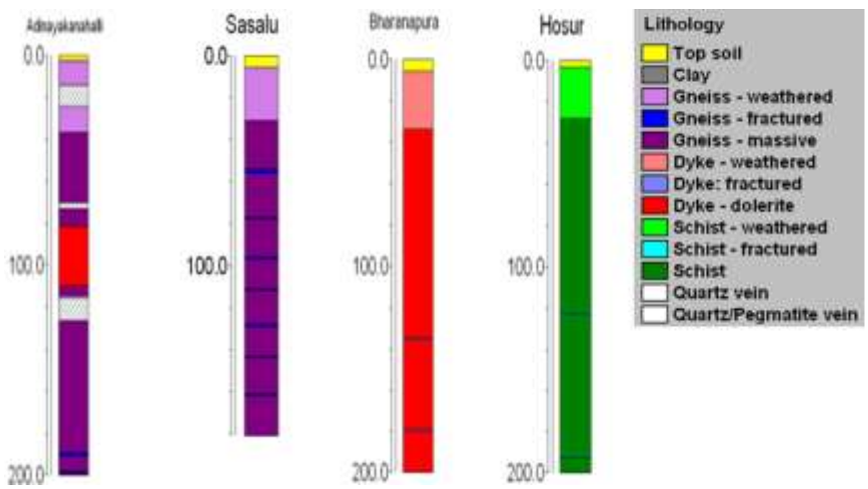


Fig. 5.8: 2D-single well strip log data

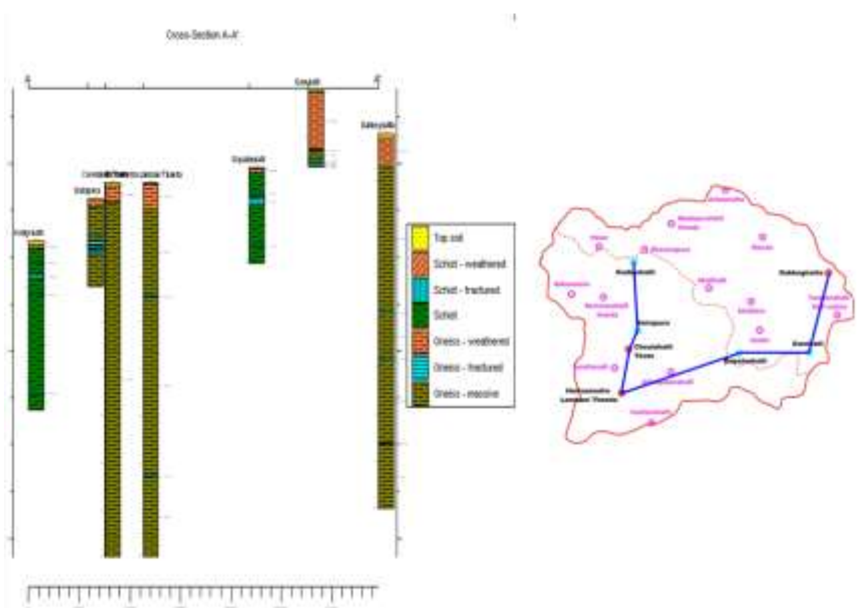


Fig. 5.9: 2D-multi well strip log data

The 3D multi-well strip log data of all the 21 exploratory wells is generated and shown in Fig. 5.10 where, the figures show that the wells are showing difference in elevation and vertical information on soil, thickness of weathering, fractures/massive formations at each well. The 3D lithology models developed using the software is shown in Fig. 5.11. The 3D lithology model shows the distribution of various formations in space with depth. The lithology model shows the volumes of various formations.

The volume of individual lithology masses is generated and shown in Fig. 5.12. It shows that, the Gneiss formation has greater mass than other formations. The lithology profile along NW-SE direction is prepared and is shown in Fig. 5.13. It is found that, the Gneiss formation is dominating in the lithology profiles followed by Schists and Granite.

The three lithology cross-sections generated viz., over the entire area covering maximum number of wells, north-south and east-west directions are shown in Fig. 5.14. It shows that, Gneiss is the dominant formation andoccasionally Schist formation which are intruded by dolerite dykes. Four fence diagrams generated along various directions and shown in Fig.5.15. They show the distribution of various formations.

The four discharge data models were generated for 7 exploratory wells drilled under VRBP and through outsourcing (AAP 2003-04) which are shown in Fig. 5.16. The models show the variation of discharge (lps) at various locations with depth. Three fracture data models generated along different directions are shown in Fig. 5.17.   These models show the direction of fractures.

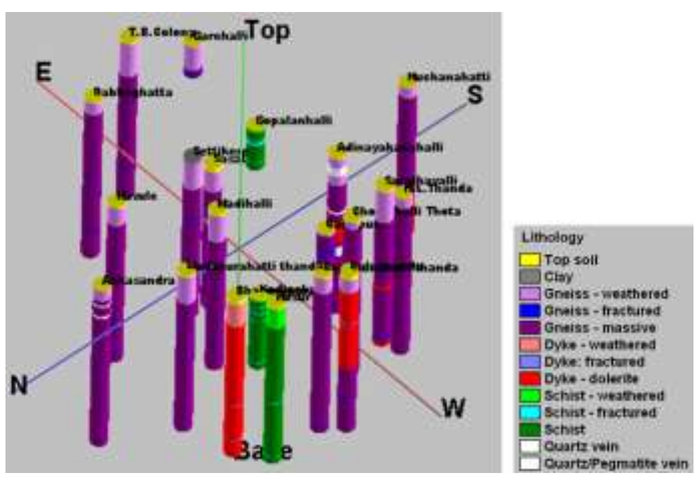


Fig. 5.10: 3D-multi well strip log data

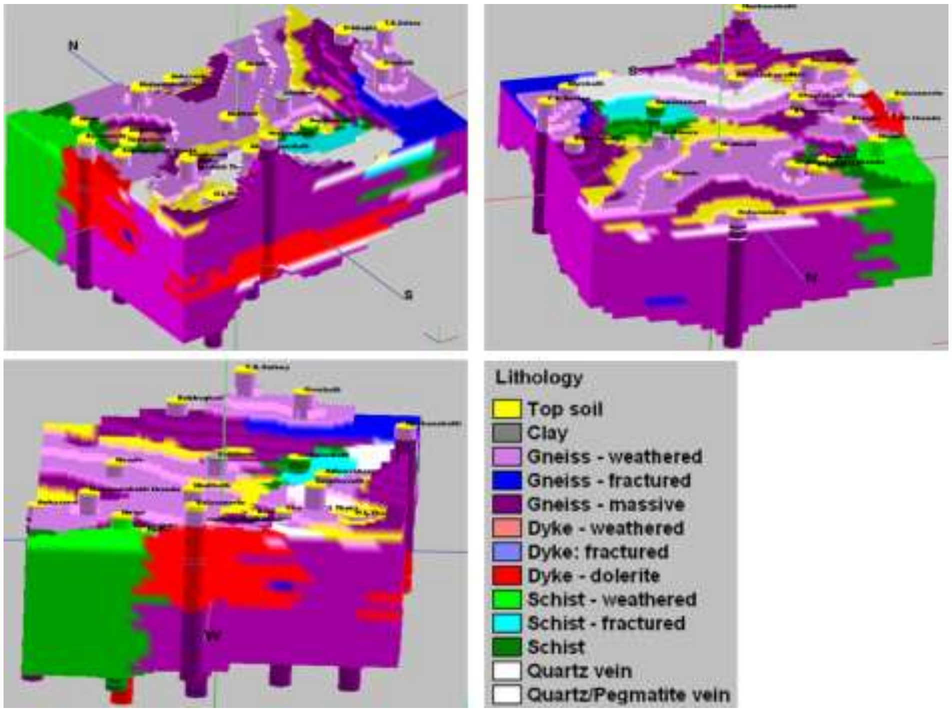


Fig. 5.11: 3D-litholog models

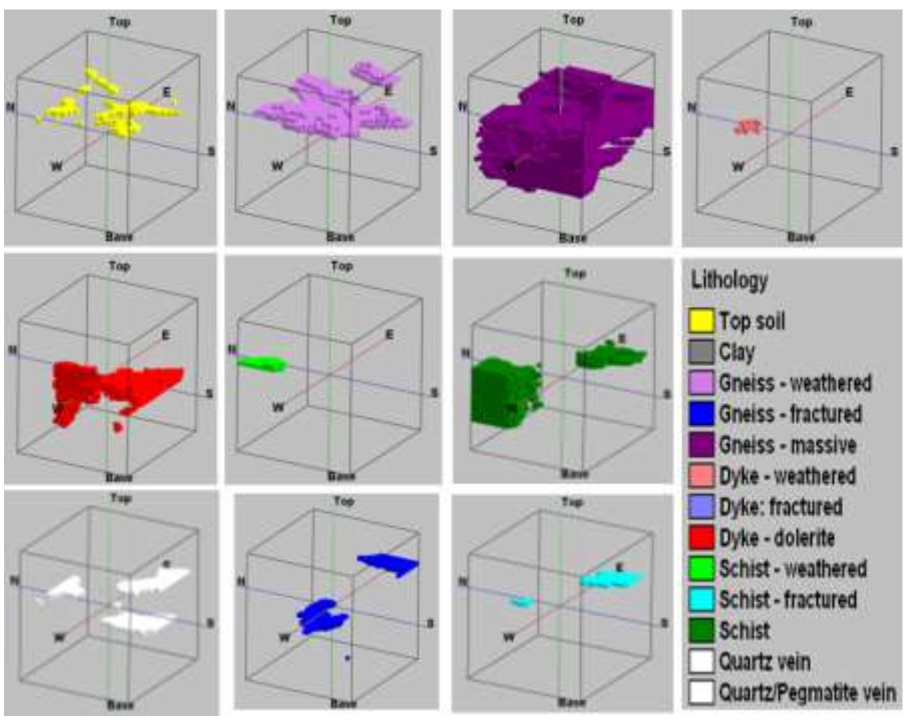


Fig. 5.12: Volumes of individual lithology models

Fig. 5.13: Lithology profiles

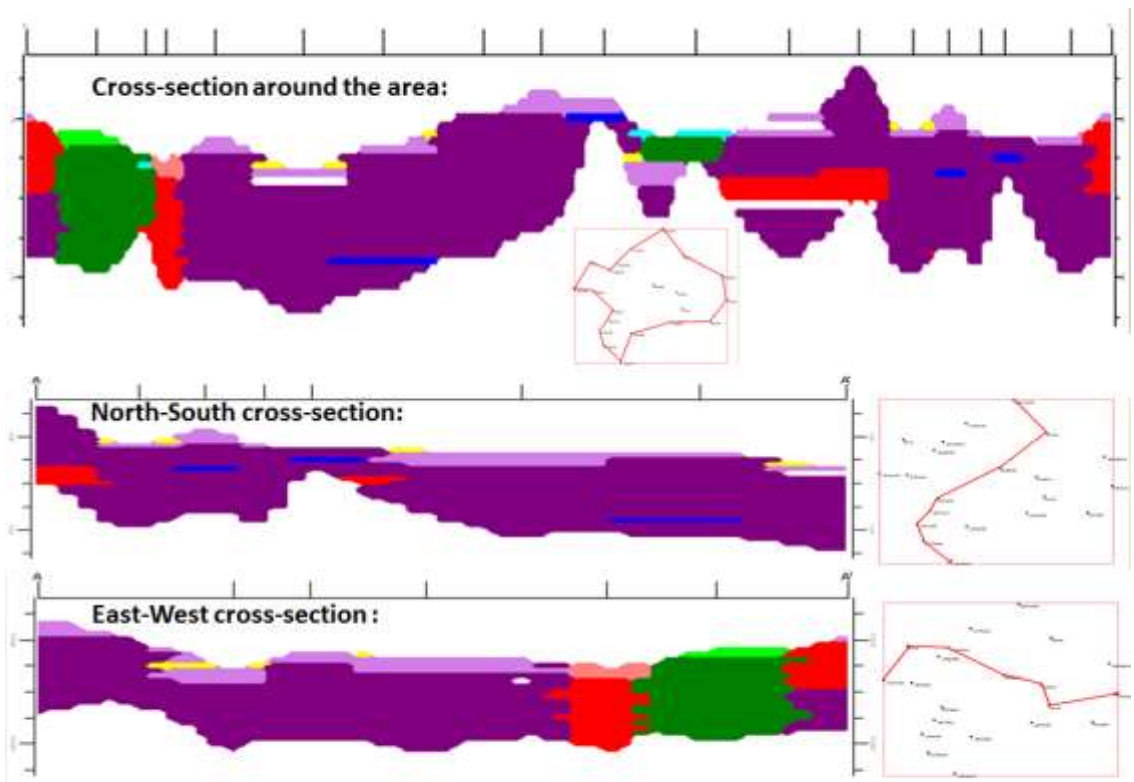


Fig. 5.14: Lithology cross-sections

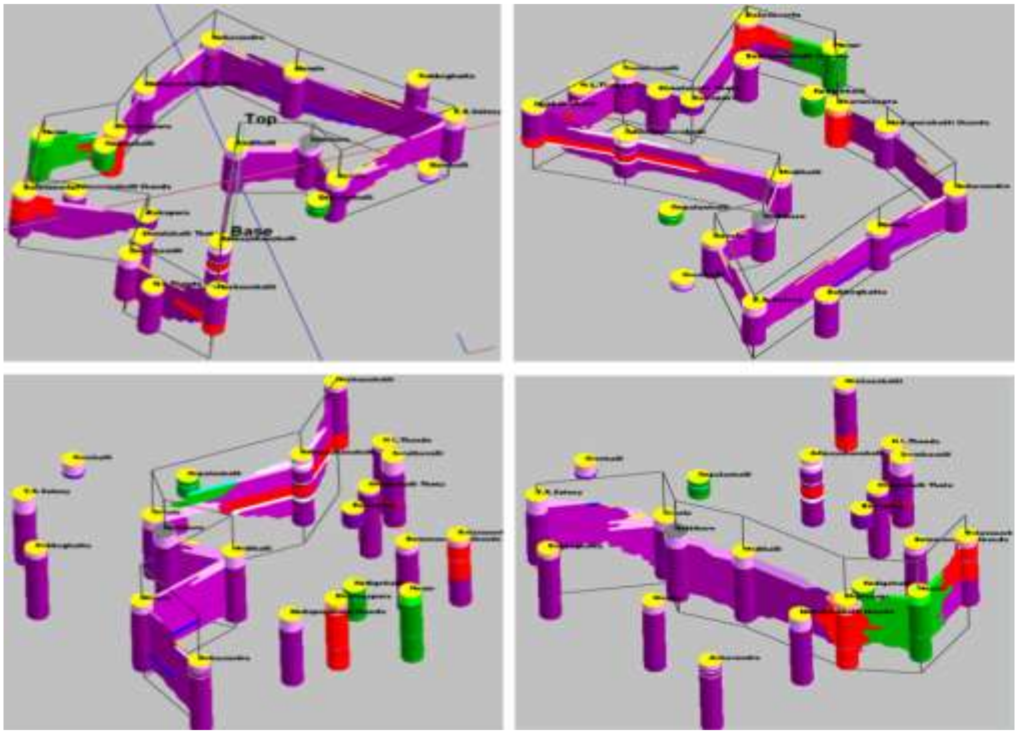


Fig. 5.15: Fence diagrams

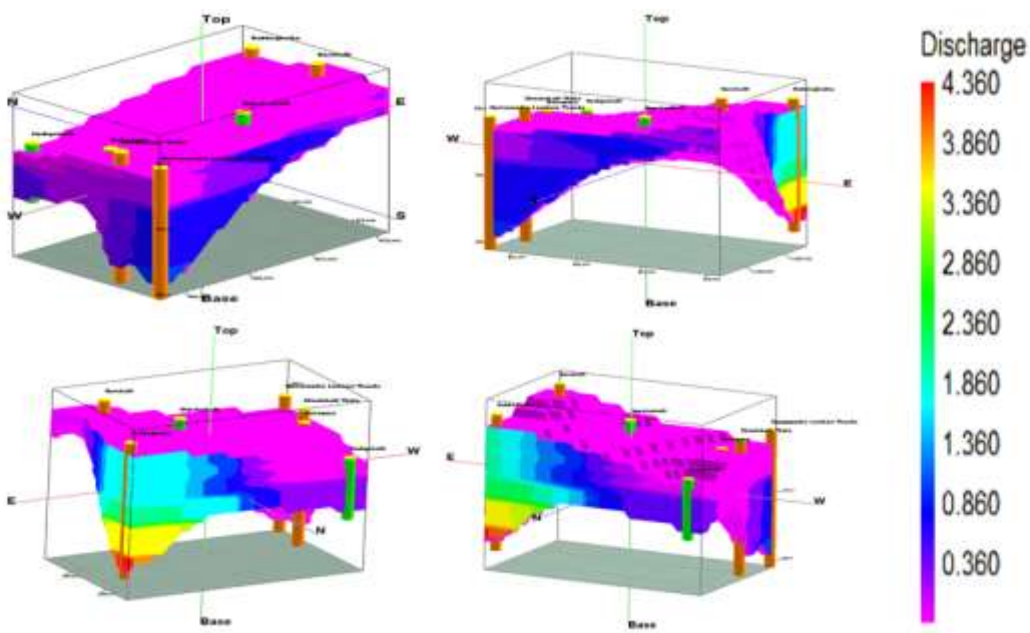


Fig. 5.16: Discharge data models

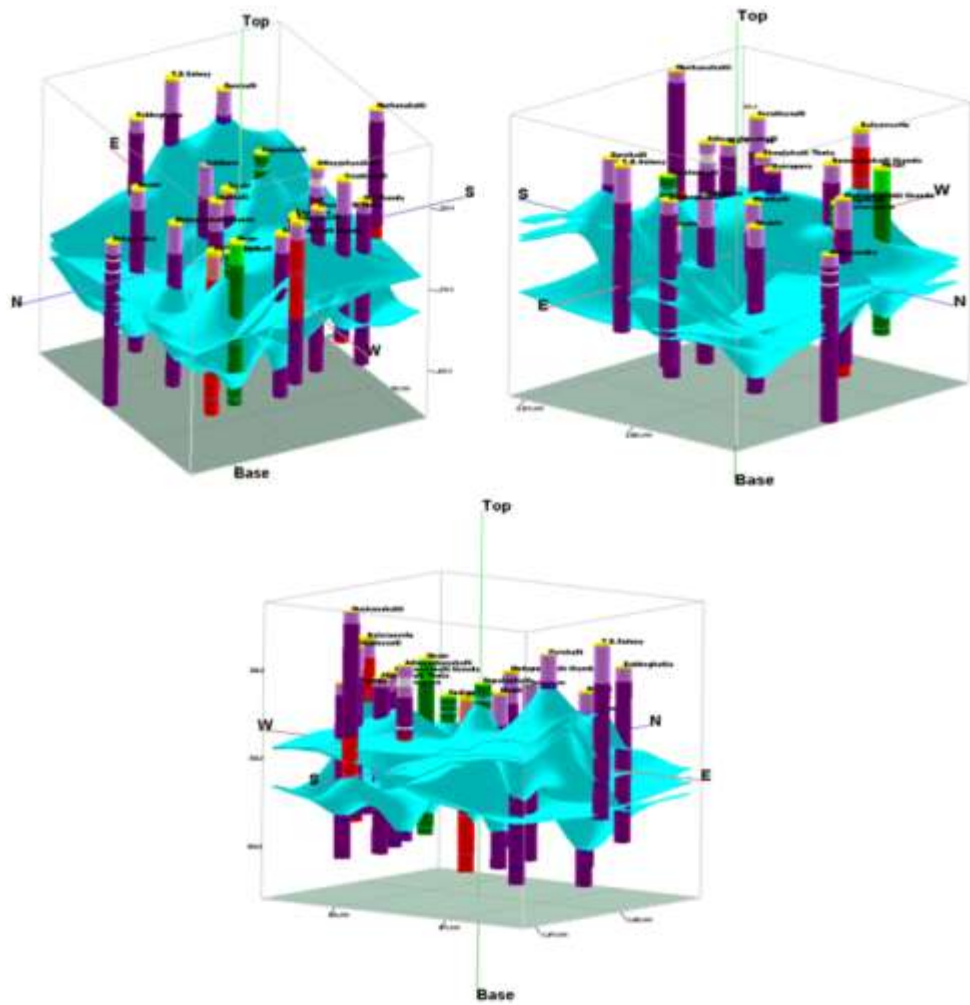


Fig. 5.17: Fracture data models

5.1.2 Aquifer disposition based on Geophysical Surveys including SKYTEM

Based on SkyTEM data, the aquifer disposition in the form of 3-D map by slicing, the two vertical sections of 130 m thickness in the E-W and NE-SW directions are prepared. Since the 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 130 m depth maximum. As usual, depth to bedrock is found deepening at depressions and lineaments and almost in the same NE-SW direction coinciding with the bedrock topography. The SkyTEM 3D map is shown in Fig. 5.18.

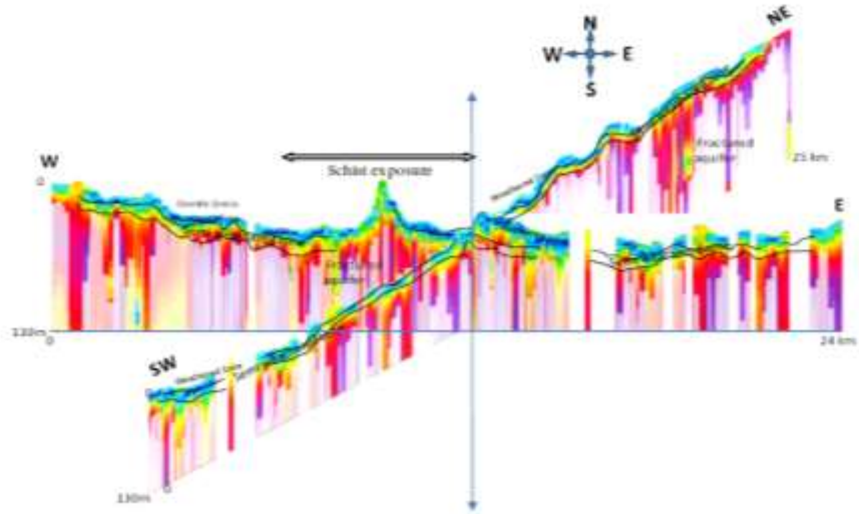


Fig. 5.18: Three- dimensional aquifer section represented by E-W and NE-SW profiles of 130 m thickness (NGRI)

5.2 AQUIFER CHARACTERIZATION

5.2.1 Long duration pumping test

Long duration pumping tests were carried out at six sites located at Sarathavalli, Huchanahatti, Adinayakanhalli, Settikere, Sasalu, and Balavaneralu villages for 250 to 1000 minutes duration. The tests revealed that the specific capacity of the formation ranges from 14.41 lpm/m drawdown at Settikere to 61.97 lpm/m drawdown at Sarathavalli indicating a good capacity of the formation. The 'T' values of the aquifer are moderate and ranges from 13.03 to 33.64 m^2/day.

5.2.1 Short duration pumping test

Short duration tests were carried out at three sites located at Balavaneralu, Hosur and Ankasandra sites for 12 to 60 minutes duration. The test at Ankasandra site was stopped after 12 minutes of pumping because of heavy drawdown of 47.97 m at one lps pumping. The test at Hosur site was also stopped after 30 minutes of pumping because of heavy drawdown of 45.21 m at one lps pumping. The tests revealed that the specific capacity of the formation ranges from 1.25 lpm/m drawdown at Ankasandra to 2.47 lpm/m drawdown at Balavaneralu which indicate very low capacity of the formation. The 'T' of the aquifer is low, ranging from 0.46 to 1.43 m^2/day.

5.2.2 Analysis of Slug test

Slug tests were carried out at five sites where the drilling discharges are less than one lps, located at Bommanahalli thanda, Bharanapura, Madapurahatti thanda, Madihalli and T.B.Colony sites. The slug tests revealed the Transmissivity (T) of the formation in the range of 0.0704 to 8.667 m^2/day. The hydraulic conductivity ranges from 0.0104 to 0.05378 m/day.

5.2.3. Permeability of the formation

The Transmissivity of the formations divided by the saturated thickness of the formation gives permeability of the aquifer. The permeability values of the formations at 14 exploratory locations are calculated and given in Table 5.10 and maps showing values of the formation are given in Fig. 5.15. The permeability values range from 0.00037 m/day at Madihalli village to 0.86 m/day at Navule village.

Table 5.10: Format of drilling discharge details for Rockworks output

Sl. No.	Site name	T (m2/day)	Saturated thickness (m)	Permeability (m/day)	Wells	Latitude	Longitude
1	Sarathvalli	37.29	105.45	0.353627312	New well	13.32758	76.45583
2	Balavaneralu	1.09	171.12	0.006369799	New well	13.38367	76.42222
3	Bommanahalli thanda	0.174	168.67	0.0010316	New well	13.38142	76.44703
4	Bharanapura	2.158	179.46	0.012024964	New well	13.41797	76.47914
5	Hosur	0.55	184.23	0.002985399	New well	13.41983	76.44367
6	Madapurahatti thanda	8.667	171.17	0.050633873	New well	13.43742	76.49990
7	Navule	136.08	156.7	0.868410976	New well	13.42721	76.57100
8	Ankasandra	0.34	105.2	0.003231939	New well	13.46306	76.54227
9	Huchanahatti	33.78	59.32	0.56945381	New well	13.28583	76.48442
10	Adinayakanhalli	19.9	150.54	0.13219078	New well	13.32445	76.49943
11	Settikere	19.28	177.1	0.108865048	New well	13.37811	76.56196
12	Sasalu	79.62	159.65	0.498715941	New well	13.35631	76.56867
13	Madihalli	0.0704	186.61	0.000377257	New well	13.38828	76.52911
14	T.B.Colony	0.9175	166	0.005527108	New well	13.36789	76.62906
15	Bairapura	1.002	46.2	0.021688312	Old well	76.47361	13.35556
16	Kodigahalli	16.29	85.72	0.190037331	Old well	76.47083	13.40833
17	Gopalanhalli	21.31	43.41	0.490900714	Old well	76.55278	13.33889
18	Garehalli	22.58	29.64	0.761808367	Old well	76.60694	13.33889

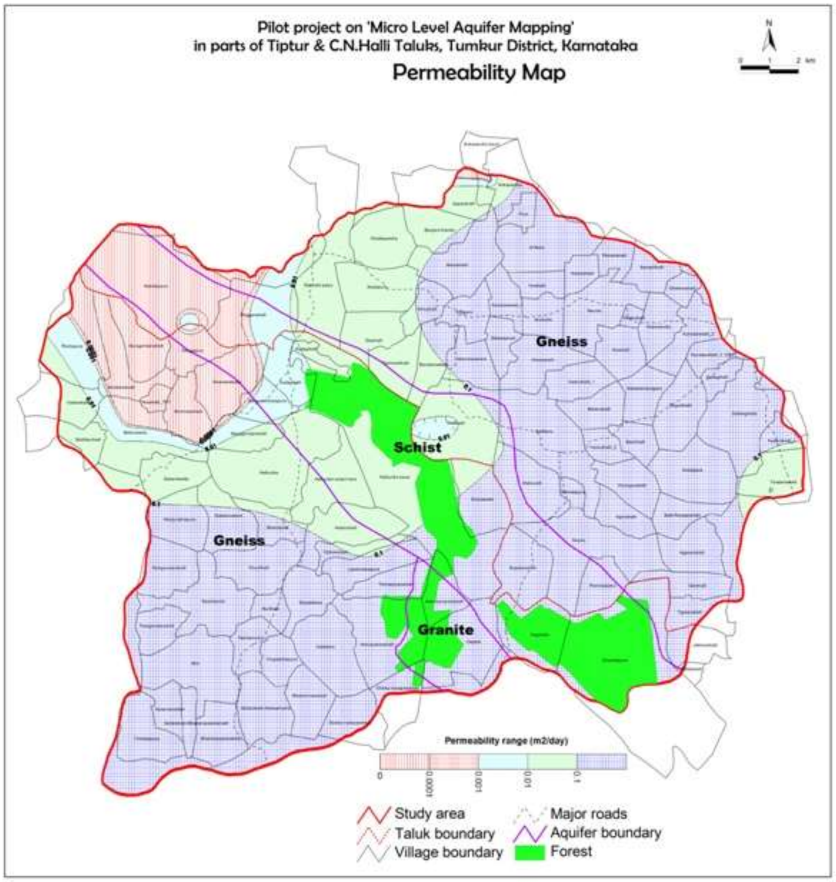


Fig. 5.19: Permeability map

5.2.3. Characterisation of Aquifers

The area has both phreatic and fractured aquifer system. However, presently the phreatic aquifer is desaturated because of over-exploitation of ground water in most part of the study area. The occurrence and movement of ground water is mostly restricted to fracture zones. The depths to ground water levels have declined over a period of time and presently it is more than 100 m bgl at certain locations.

During May 2013, the major part of the area is having depth to ground water level ranging from 30 to 50 m bgl. Depth to ground water level of more than 50 m is noticed in SW part and SE part of the area (Fig. 3.51) and during September 2013, the majority of the area is having depth to ground water level ranging from 20 – 50 m bgl. Depth to ground water level of more than 50 m is noticed in SW part of the area in small patches (Fig. 5.20 and 5.21). With respect to ground water quality, the area is mostly suitable for drinking, domestic and irrigation purposes. However, the concentration of iron is beyond acceptable limits in many places, but however mostly within 1 ppm (Fig. 5.22).

An attempt is made to prepare the 3D aquifer disposition and Aquifer map for the area based on the results of exploratory wells. It reveals that the depth of weathering varies from 18 to 52 m bgl. The fractures were encountered at various depths and deepest fracture is observed at a depth of 193 m bgl in Bommanahalli thanda village. The various lithologies encountered during drilling were also analysed and presented in aquifer 3D disposition (Fig. 5.23). The aquifer map is also prepared and presented. Three cross sections viz., East-West, North-East and South-West directions are prepared and an attempt is made to study the cross-sectional lithology in these directions (Fig. 5.24). These maps are indicating the sub-surface disposition of aquifer. The weathered profile ranges between 18 to 52 m bgl which is desaturated due to over-exploitation of ground water. The occurrence of groundwater is restricted only to fractured zones. At present, the ground water levels are considerably deep. The most frequent depth to ground water level range is 40 to 60 m bgl. However, there are pockets where the ground water levels are more than 100 m bgl.

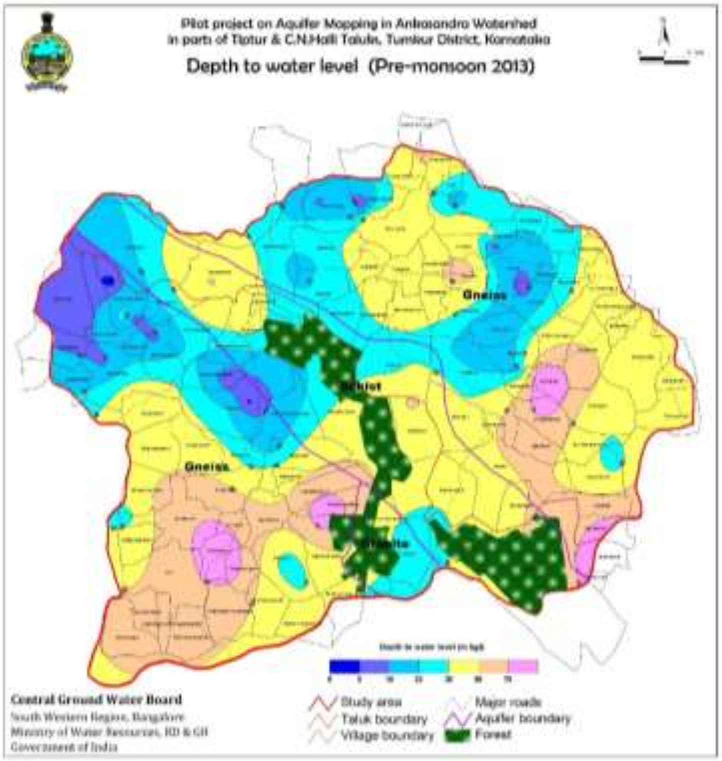


Fig. 5.20: Aquifer characterisation – Depth to ground water level (Pre-monsoon 2013)

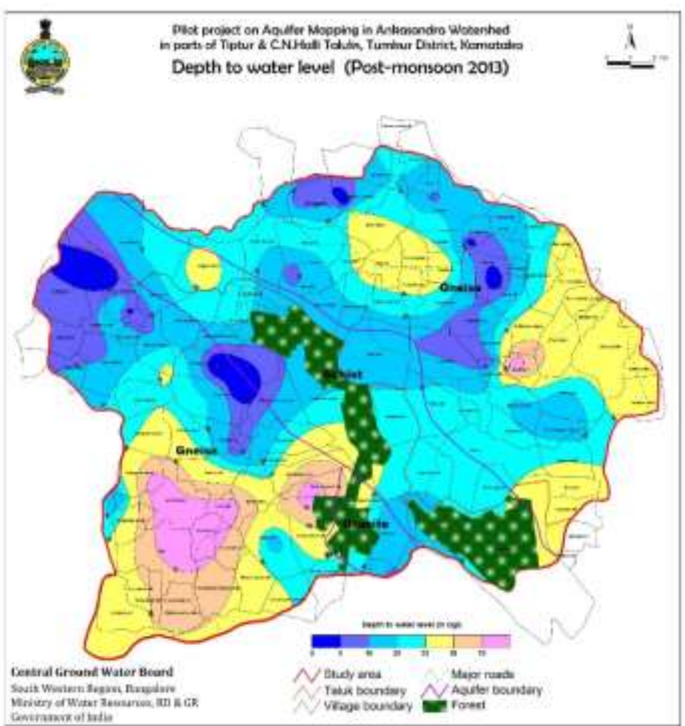


Fig. 5.21: Aquifer characterisation – Depth to ground water level (Post-monsoon 2013)

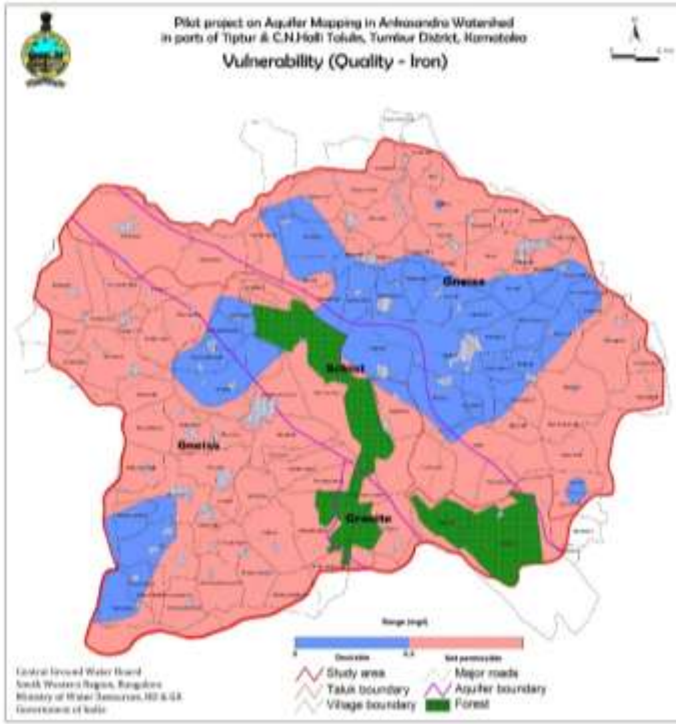


Fig. 5.22: Aquifer characterisation – Water quality (Iron)

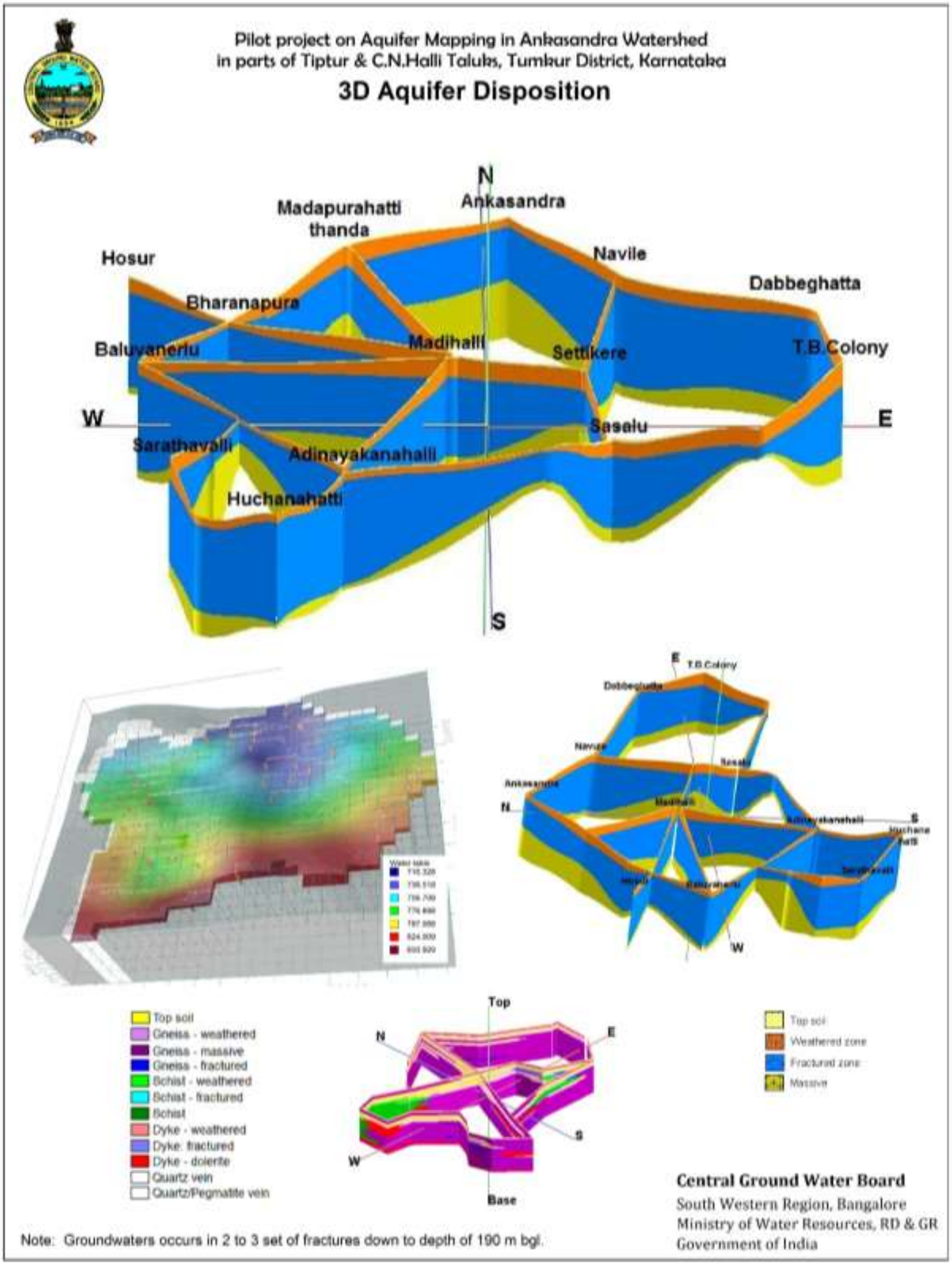
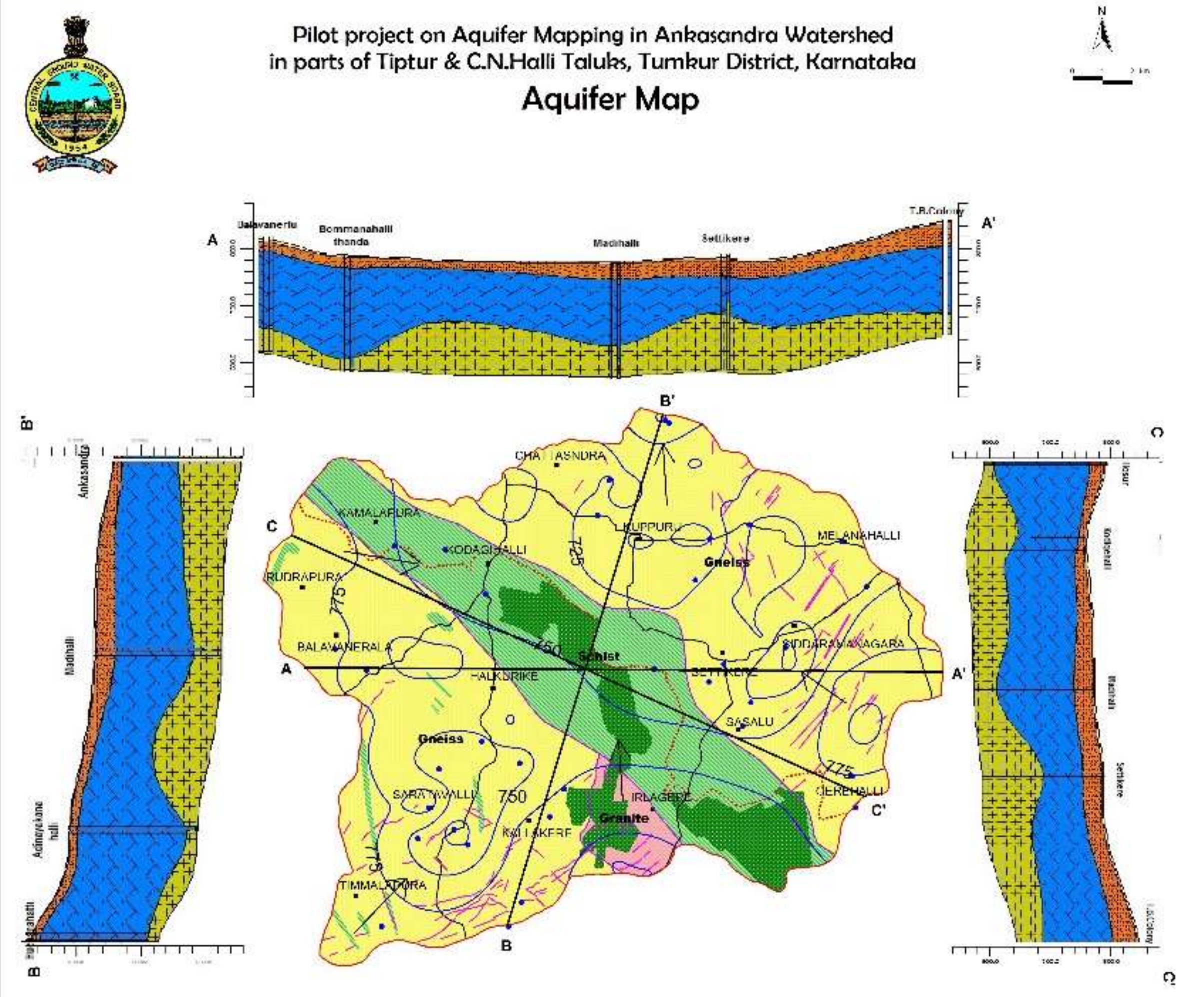


Fig. 5.23: Aquifer characterisation – 3D Aquifer Disposition



Aquifer Characterization

Aquifer	Prominent Lithology	Depth Range of Occurrence of fractures (m bgl)	Thickness Range (m)	Range of Yield Potential (Cu.m /Day)	Range of Storage Characteristics (Sy %)	Range of Permeability (m/day)	Suitability for Irrigation	Suitability for Domestic Purposes	Remarks
Aquifer I	Gneiss, Schist and Granite	44-190	0-190*	2 to 36	0.1 to 1	0.00038 to 0.86841	Yes	Yes	* The ground water in hard rocks exists within the fractures and 2 or 3 set of fractures are likely to be encountered upto 190 m bgl.

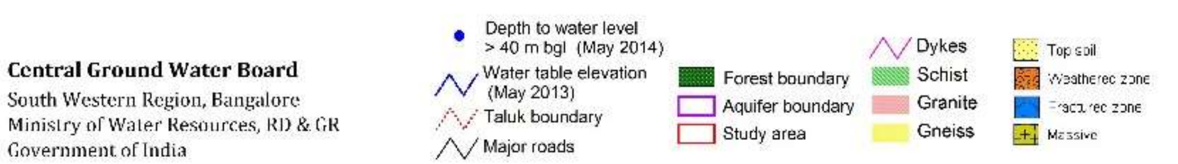


Fig. 5.24: Aquifer characterisation – Aquifer map

6.0 AQUIFER RESPONSE MODEL AND AQUIFER MANAGEMENT FORMULATION

6.1 AQUIFER RESPONSE MODEL

To understand the aquifer dynamics and to assess the ground water potential for effective management of the groundwater resources in the watershed, a groundwater flow model study has been taken up.

Integrated hydrogeological, geophysical, hydrological and hydrochemical studies carried out by CGWB have been considered for the model conceptualization, model design, calibration, simulations, predictive analysis and planning of strategies for ground water management plan.

6.1.1 Numerical Model Design

The steps in Numerical Model Design include design of the grid, setting boundary and initial condition, preliminary selection of values for the aquifer parameters and hydrologic stresses (Anderson and Woessner, 2002).

6.1.2 Methodology

The modelling protocol adopted for the current study is presented in the following Fig. 6.1

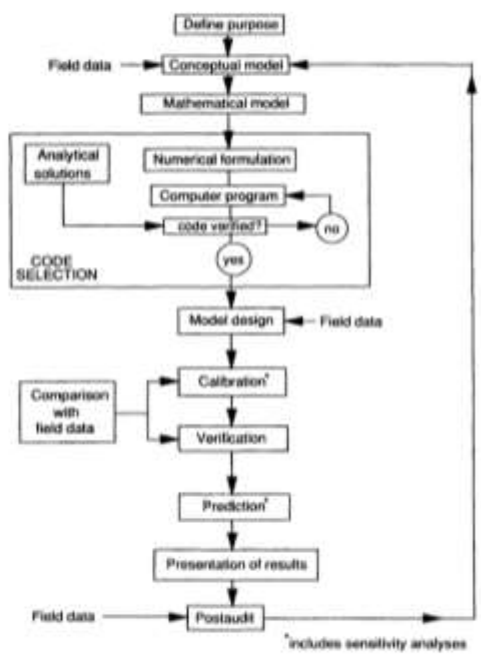


Fig. 6.1: Modelling Protocol by Mary P.Anderson & William W.Woessner

6.1.3 Visual MODFLOW

MODFLOW is a versatile code to simulate groundwater flow in multi-layered porous aquifer. The model simulates flow in three dimensions using a block centred finite difference approach. The groundwater flow in the aquifer may be simulated as confined/unconfined or the combination of both. MODFLOW consists of a major program and a number of sub-routines called modules. These modules are grouped in various packages viz. basic, river, recharge, block centred flow, evapotranspiration, wells, general heads boundaries, drain.

MODFLOW is a computer program that numerically solves the three-dimensional ground-water flow equation for a porous medium by using a finite-difference method (Waterloo Hydrogeologic Inc. 2006). In the finite difference method (FDM), a continuous medium is replaced by a discrete set of points called nodes and various hydrogeological parameters are assigned to each of these nodes.

6.1.4 Conceptualisation of model

To design and to conceptualise ground water flow model of the area, following points are considered. A figure showing the 2D conceptual model of the area is prepared and presented as Fig. 6.2

- The model area is underlain by Archaean group of rocks which includes mostly Gneisses, Schists and Granites etc. which are hardrocks and devoid of primary porosity. Large numbers of dolerite dykes are observed in the south western part of the study area.
- These rocks are subjected to weathering near the surface and the depth of weathering varies from negligible to as high as around 40 m.
- Ground water occurs and moves in weathered residuum as phreatic aquifer in most part of the study area. Most of the southern part of the watershed the phreatic aquifer is desaturated and the ground water occurs in fractured aquifer, where the thickness of the fractures (aquifer) is around a few centimetres.
- Ground water contour map shows that flow of ground water is towards south-west to north-east and south-east to north-east.
- The depth of weathering ranges from 20 to 30 m bgl and rarely 30 to 40 m bgl.

- Fractures are encountered in the study area up to 200 m depth.

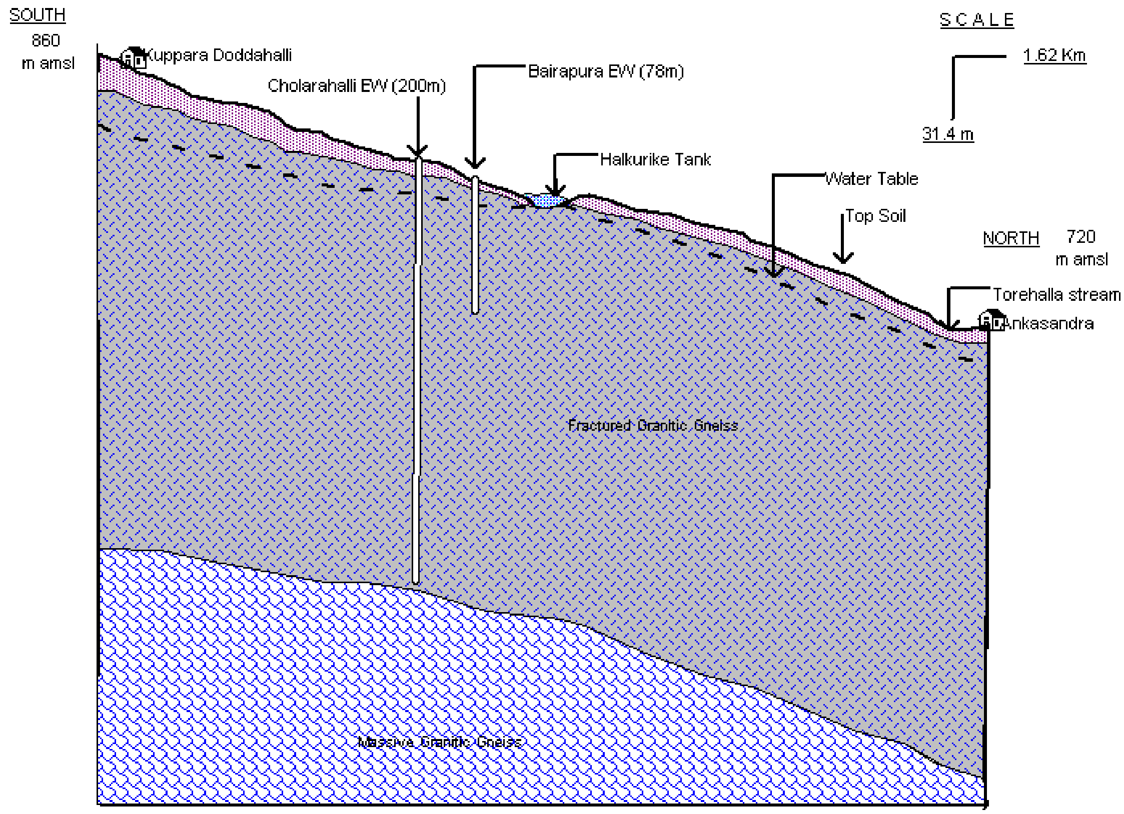


Fig. 6.2: 2 D Conceptual model of the area

6.1.5 Grid design

The area measures a distance of 28 km along east to west and 23 km along north to south at its longest points. The grid size of the model is one kilometre vs. one kilometre. The model area consists of 644 grids. The grids which are outside the model area are demarcated as inactive grids and inside as active grids. A total of 436 active grids and 208 inactive grids are available in the model area. The design of the model area constructed is given as Fig. 6.3.

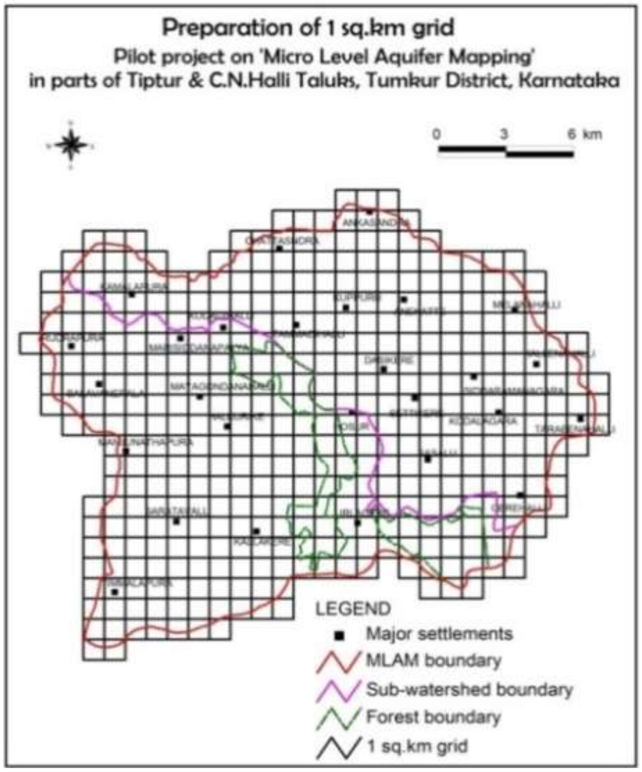


Fig. 6.3: Model area design

6.1.6 Assumptions used in conceptual model

- Weathered part of the aquifer and the fracturedpart are considered as porous and homogeneous one layer
- All the four directions of the model area are considered as no flow boundary except one small patch where ground water flux is observed through water table elevation maps and assigned as 'variable head' boundary .
- Ground water draft is more or less constant throughout the year, as the majority of the area is grown with perennial crops like coconut and areacanut plantations.
- Draft in the area is distributed based on the well density of each grid with unit draft of each formation. The ground water recharge is considered as 12% of rainfall in valley-fill zones, 10% in plains, 6% in pediment zones and 0% i.e. no recharge in hilly areas, where the slope of the area is more than 20%.
- Evapotranspiration is not assigned because of deep ground water level condition in the model area.

6.1.7 Geometry and boundary condition

The weathered portion in major part of the area is desaturated due to over exploitation of the ground water and most of the dug wells and shallow borewells are dry. Presently, ground water development is mostly through borewells down to depth of about 200m. The phreatic aquifer is dry, hence, entire phreatic as well as fractured aquifer in the area is considered as **single layer aquifer** system.

The top of the aquifer is picked up from the reduced levels measured for key observation wells, exploratory wells and well inventory locations. The bottom of the aquifer is considered as 600m amsl uniformly for entire area.

Based on the ground water flow pattern and field observations it is decided that, the southern part of the study area is considered as 'no flow' boundary which is a major basin divide between river Krishna and Cauvery and one grid is left open to study the ground water flux across the boundary. The eastern and western parts of the area are watershed boundaries and are also considered as 'no flow' boundary. Three grids at northern boundary are considered flux boundary from where the water very rarely flows in/out of the watershed. Hence, it was modelled as variable head boundary. The boundary conditions defined in the model are presented in Fig. 6.4.

Fig. 6.4: Model design; active grids, inactive grids and single layer and boundary conditions

6.1.8 Aquifer parameters

The aquifer parameters viz. Hydraulic conductivity 'K' (m/day), Specific yield (Sy) and Specific storage (Ss) values were assigned based on the aquifer performance test analysis data.

6.1.8.1 Conductivity

Transmissivity (T) values derived from the Aquifer Performance Tests conducted on exploratory wells are used to calculate the conductivity values. The conductivity values in the area ranges from 0.003 to 0.868 m/day. In the model, 'K' values along x and y direction has same values and along the z direction as $1/10^{th}$ of the values derived and entered (Table 6.1) as point data and the software has interpolated as zone-wise as shown in Fig. 6.5.

Id	EW sites	Northing	Easting	Kx	Ky	Kz
1	Hosur EW	656301	1484021	0.0030	0.0030	0.000299
2	Balavanerlu EW	654002	1480007	0.0064	0.0064	0.000637
3	Settikere EW	669140	1479484	0.1089	0.1089	0.010892
4	Sarathavalli EW	657678	1473824	0.3536	0.3536	0.035363
5	Adinayakanahalli EW	662403	1473506	0.1322	0.1322	0.013219
6	Navule EW	670084	1484922	0.8684	0.8684	0.086841
7	Ankasandra EW	666948	1488868	0.0032	0.0032	0.000323
8	Huchanahatti EW	660802	1469224	0.5635	0.5635	0.056347
9	Sasalu EW	669881	1477076	0.4986	0.4986	0.049859
10	Bairapura	659586	1476930	0.0217	0.0217	0.002169
11	Kodigehalli	659250	1482767	0.1900	0.1900	0.019004
12	Gopalanhalli	668172	1475139	0.4909	0.4909	0.04909
13	Garehalli	674040	1475176	0.7618	0.7618	0.076181

Table 6.1: Conductivity values

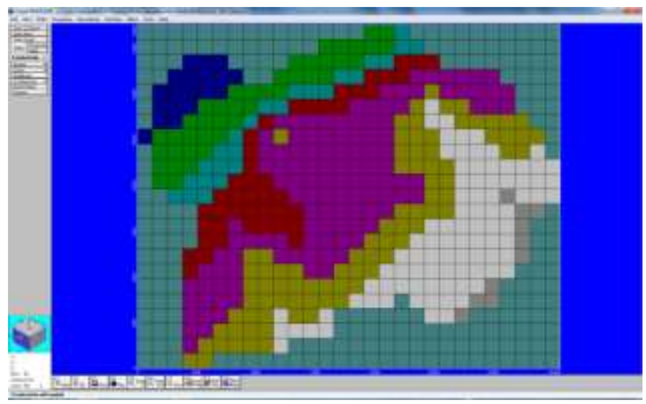
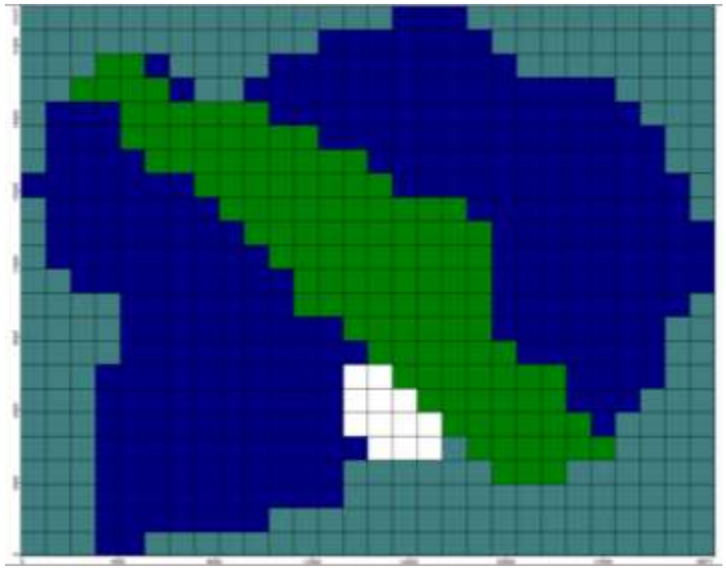


Fig. 6.5: Interpolated zone-wise conductivity

6.1.8.2 Specific storage (Ss)

The standard specific storage (Ss), specific yield (Sy) values available for each formation were assigned to the model. The Ss values assigned for three geological formation viz. Gneiss, Schist and Granite are 0.0001, 0.0001 and 0.0001 respectively. The Sy values assigned for Gneiss, Schist and Granite are 0.01, 0.005 & 0.01 respectively and the model has generated the regions as shown in the Fig. 6.6.



Zone	Colour	Ss (l/m)	Sy	Zone	Colour	Ss (l/m)	Sy	Zone	Colour	Ss (l/m)	Sy
Zone-1		0.0001	0.01	Zone-2		0.0001	0.01	Zone-3		0.0001	0.005

Fig. 6.6: Zone-wise Specific storage & Specific yield values

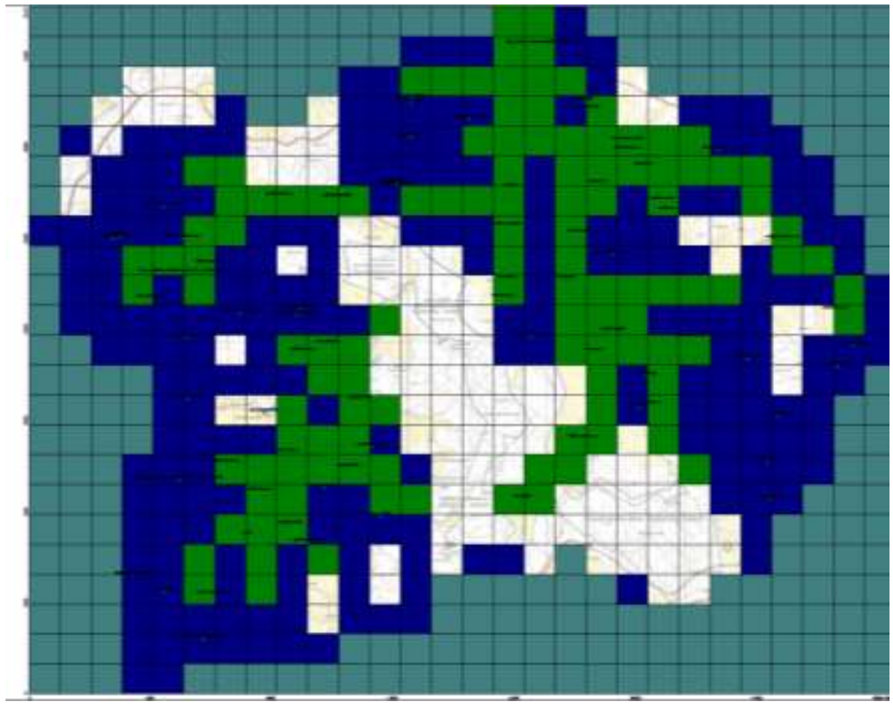
6.1.9 Input output stresses

Input and output stresses acting upon the ground water system in model area are:

- Recharge
- Draft

6.1.9.1 Recharge due to rainfall

As the area lies between two rain gauge stations, the rainfall recharge analysis is carried out for the distribution of recharge values to the model. The normalised values of both the stations were taken up for recharge calculations into the model grids. Initially three zones were considered based on the geomorphology of the area viz. hilly, Pediment, plains and valley fill and data distributed are 0%, 6%, 10% and 12% of the rainfall respectively. The net recharge from all the three zones is 2161 ha.m for the entire model area. The figure showing the distribution of recharge data in the model is given as Fig. 6.7.



Unit	Recharge m/d	grid colou	Unit	Recharge	grid colou	Unit	Recharge	grid colou
Valley fil	0.0003		Plains	0.00015		Hilly / rocl	0.000075	

Fig. 6.7: Recharge values distribution

6.1.9.2 Draft / discharge

Demand for groundwater is increasing year after year in the area. The draft is calculated based on the formation, well density, number of pumping hours, discharge, electrical power consumption/ availability. It was approximated that 3766 ha.m/year of ground water is being withdrawn from the area. It is also observed that there is no return flow from irrigation as farmers are using the drip irrigation system to their plantations. Formation wise well density per grid calculated based on well inventory carried out in the study area which is presented in Table 6.2 and its distribution grid-wise is shown in Fig. 6.8.

Table 6.2: Distribution of GW draft

Vells/Sq.Kr	Granite	Gneiss	Schist
5	98	131	65
10	196	262	131
15	295	393	196
20	393	524	262
30	589	786	393

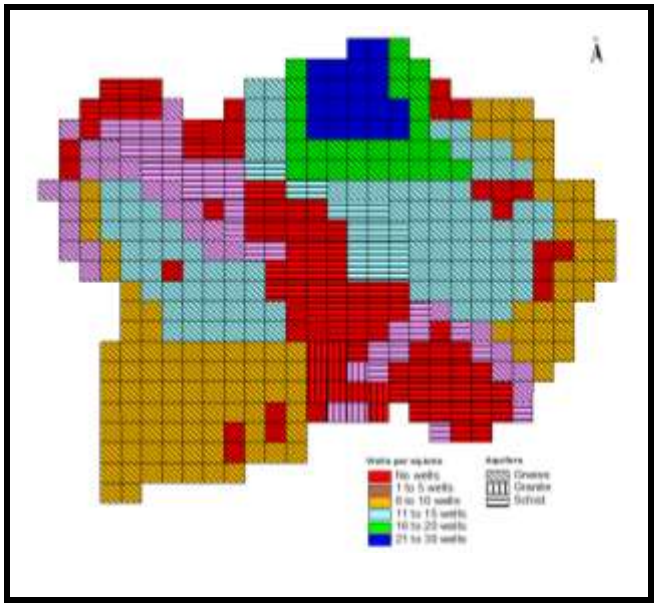


Fig. 6.8: Grid-wise distribution of draft / pumping wells to the model area

6.1.10 Groundwater flow equation

The three-dimensional movement of ground water of constant density through porous earth material may be described by the partial-differential equation. The three-dimensional diffusion equation for flow through porous media is (Rushton and Redshaw 1979):

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)-W=S_s\frac{\partial h}{\partial t}$$

where Kxx, Kyy, and Kzz are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T); h is the potentiometric head (L); W is a volumetric flux per unit volume representing sources and/or sinks of water; SS is the specific storage of the porous material (L-1); and t is time (T).

6.1.11 Model calibration

An important part of any groundwater modelling exercise is the model calibration process. In order for a groundwater model to be used in any type of predictive role, it must be demonstrated that the model can successfully simulate observed aquifer behaviour. Calibration is a process wherein certain parameters of the model such as recharge and hydraulic conductivity are altered in a systematic fashion and the model is repeatedly run until the computed solution matches field-observed values within an acceptable level of accuracy.

The purpose of model calibration is to establish that the model can reproduce field measured heads and flows. Calibration is carried out by trial and error adjustment of parameters or by using an automated parameter estimation code. In this study, trial and error adjustment has been used.

6.1.11.1 Steady state calibration

The aquifer condition of September 2011 is considered as initial condition for the steady state model calibration. The model calibration started by matching the computed and the field ground water level hydrographs. The plots of computed steady state model are shown in Fig. 6.9.

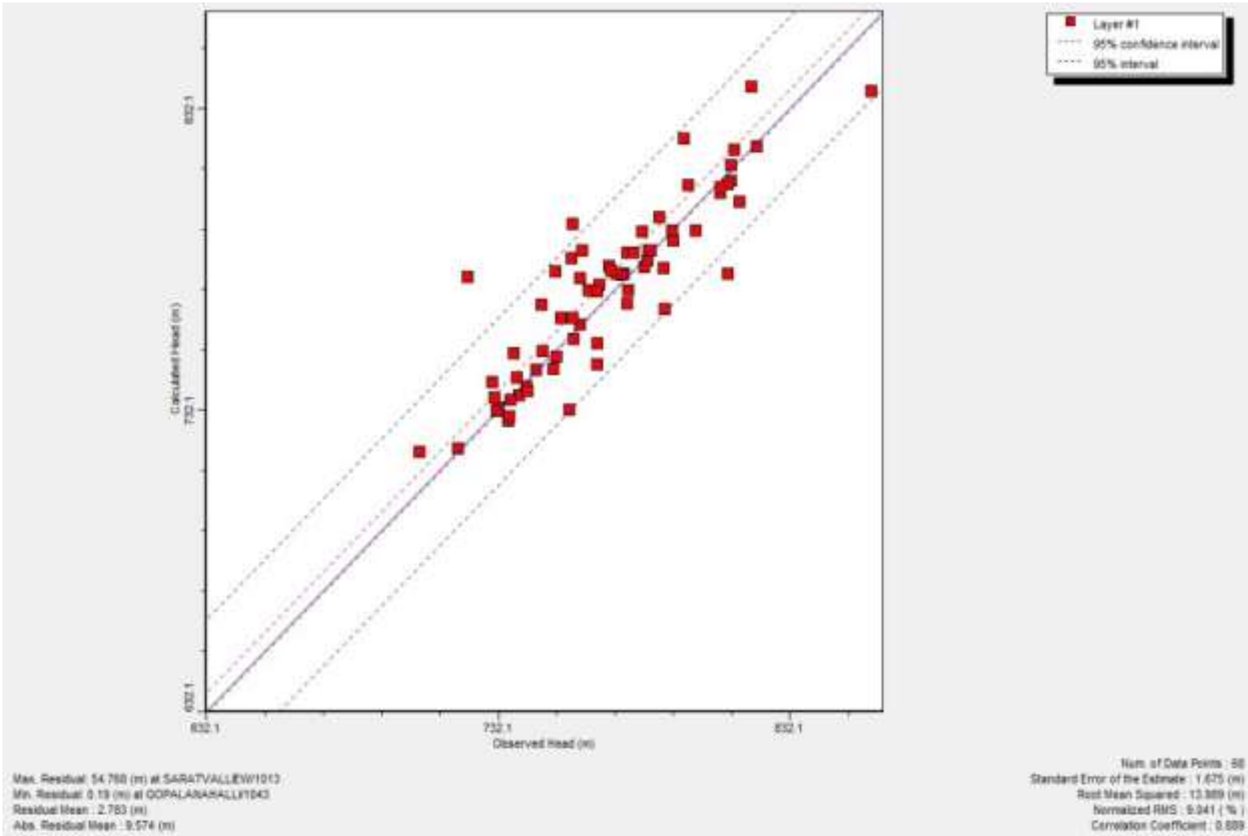


Fig. 6.9: Scattered plot for observed and computed heads for steady state condition

The Recharge and hydraulic conductivity values were slightly modified for each run and brought the model to a nearly matching condition.

6.1.11.2 Model Calibration - Remarks

The calibration was made using 68 observation wells monitored during September 2011. The computed ground water level accuracy was judged by comparing the mean error with mean absolute and Root Mean Squared (RMS) error (Anderson and Woessner, 1992). Mean error is 2.783 m. RMS error is the square root of the sum of the square of the differences between calculated and observed heads, divided by the number of observation wells, which in the present simulation is 13.989 m (Fig. 6.10). The absolute residual mean is 9.764 m. The absolute residual mean measures the average magnitude of the residuals, and therefore, provides a better indication of calibration than the residual mean (Waterloo Hydrogeologic Inc, 2006).Absolute residual Mean values are slightly high because the sampling points are located in varying geomorphic, climatic and hydrogeological setup. These anomalies coupled with interference effect by pumping in the vicinity affecting the residuals. Therefore repeated calibration processes could not improve the Absolute Residual Mean values.

6.1.12 Transient model

In Transient state, head changes with time. Transient state is also called time dependent, unsteady, non-equilibrium, or non-steady state problem.

6.1.12.1 Storage values – transient state

The estimated specific storage, specific yield values available for type areas of the same formation were assigned to the model. These values along with the calibrated specific storage and specific yield have been assigned to the model area. The specific yield and specific storage values are modified slightly for every run till the observed and calculated heads of the outputs plots are reasonably matching. The specific yield and specific storage values given for transient state model are shown in Table 6.3.

Table 6.3: Final set of aquifer parameters arrived through Transient state calibrations.

Zones	Transient state	
	Ss	Sy
Zone-1	0.0001	0.011
Zone-2	0.0001	0.011
Zone-3	0.0001	0.008

6.1.12.2 Discharge inputs

The ground water discharge in the study area is mainly through pumping from the wells. Grid wise calculated ground water draft has been assigned for the study area. The unit ground water draft worked out from the well inventory studies for different months are used to arrive at the pumping estimate of the area.

6.1.12.3 Recharge inputs

Four zones were considered based on the geomorphology of the area viz. hilly, Pediment, plains and valley fill and data distributed are 0%, 6%, 10% and 12% of the rainfall respectively. Monthly recharge values for respective grid representing the geomorphic unit are incorporated into the model area. The transient calibrations and the run are carried out for the period September 2011 to March 2014.

6.1.12.4 Transient state calibrations

The transient state calibrations were carried out and the model was run for the period September 2011 to March 2014.The input and output parameters are modified slightly for every run till the observed and calculated heads of the outputs plots are reasonably matching. The RMS error for the transient state model obtained is 15.14m for 948 days (Fig 6.10).

The plots of observed and interpolated heads for different stress periods are given in Fig. 6.10 and interpolated and graphs of Head Vs Time for selected villages are shown in Fig. 6.11

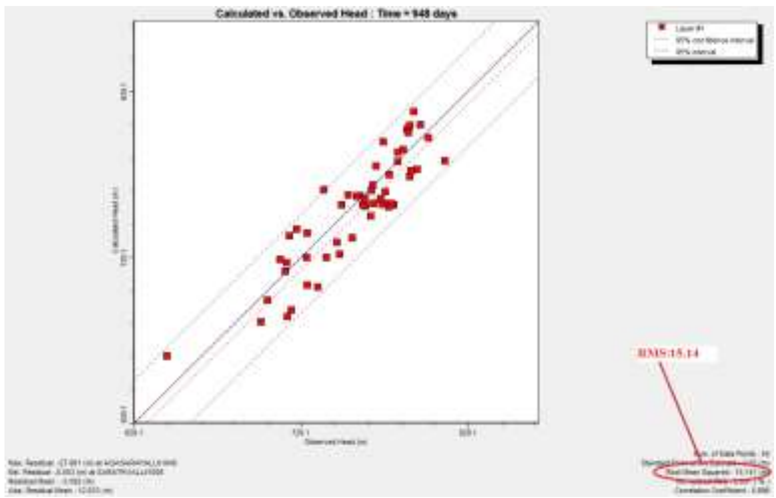


Fig. 6.10: Plot of Calculated Vs observed head of Aquifer for March 2014

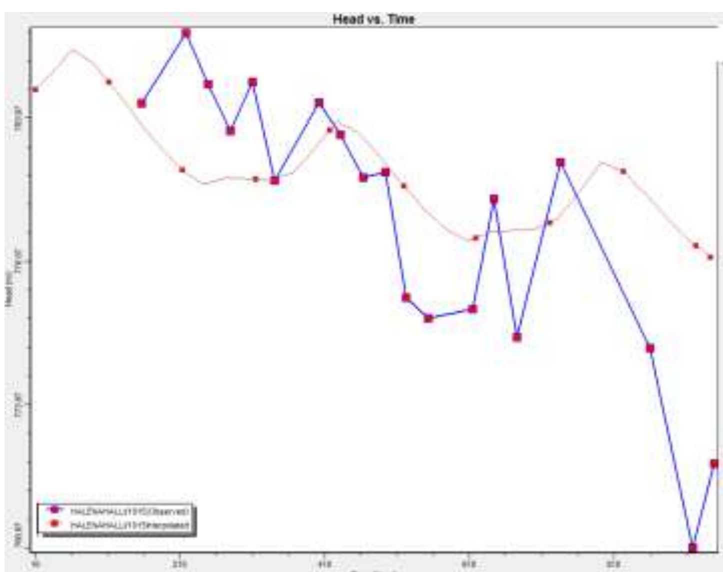


Fig.6.11: Interpolated and observed hydrographs of observation well at Halenahalli

6.1.12.5 Remarks of transient condition

The comparison of computed and observed hydrographs shows only reasonable match as very good match cannot be expected because of the heterogeneity of the aquifer system with rapid change of aquifer parameters at short distances. The present abstraction is only from fractured aquifer and the occurrences of fracture vary both laterally as well as vertically. Apart from the above, the key observation wells are located within the influence of the other irrigation pumping well.

With all these constraints, the model is made to run for transient condition. Out of 67 observation wells monitored for a reasonably long period (27 months), 22 wells show reasonable match. It is observed that, there is a steady decline in the ground water level due to increased abstraction from the aquifer. The interpolated map of ground water flow directions shows the ground water flow towards the watershed lowest point, which drains the entire watershed.

6.1.12.6 Cumulative budget – transient state

The details of flow rates (both inflow to and outflow from the Zone) viz., Storage, Constant Heads, Wells, Drains, Recharge, Lake etc., for each of the stress period are studied. Cumulative budget of ground water for the transient run for different stress period is given in Table 6.4 and the respective graphs in Fig.6.12. The zone budget output table also indicates flows into and out-of the zone, as well as the percent discrepancy between the total in and out.

Table 6.4 Cumulative budget (m^3) of Ground water for the transient run

Time (days)	Inflow	Storage	Constant Head	Wells	Drains	Lake seepage	Recharge	Stream Leakage	General-Head	Total	In - Out
	m^3										
90 days	Infllow	4361253	0	0	0	0	12549882	0	0	16911136	238
	Outflow	10640071	0	6271303	0	0	0	0	0	16911374	
360 days	Inflow	21059104	0	0	0	0	27937208	0	0	48996312	908
	Outflow	18065148	0	30932072	0	0	0	0	0	48997220	
720 dyas	Inflow	36382044	0	0	0	0	54646856	0	0	91028896	1632
	Outflow	30037348	0	60993176	0	0	0	0	0	91030528	
948 days	Inflow	48818668	0	0	0	0	69718656	0	0	118537328	2016
	Outflow	38178552	0	80360792	0	0	0	0	0	118539344	

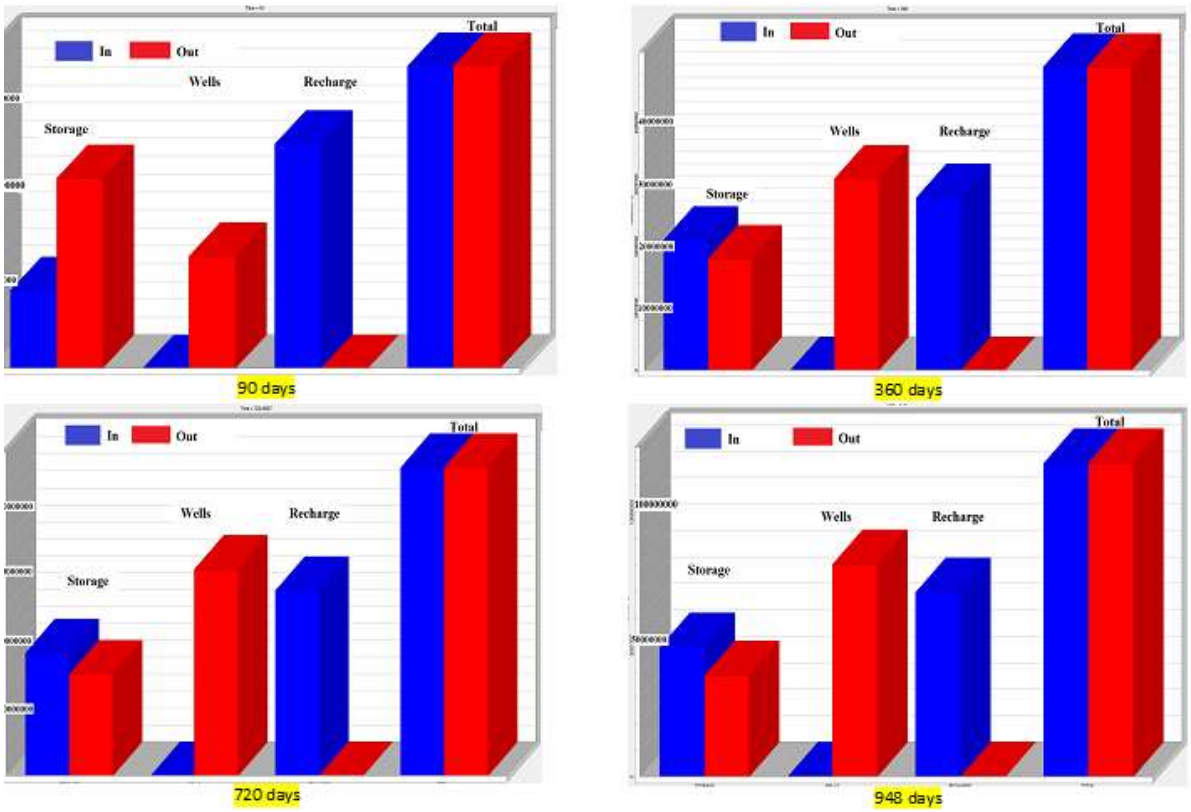


Fig.6.12. Cumulative budget (m^3) of Ground water for the transient run

6.1.12.7 Sensitivity analysis

After the model has been satisfactorily calibrated, sensitivity analyses were performed to determine the model's output to variations (or uncertainties) in physical parameters. Sensitivity analyses identify the factors which affect the variation in the output. These techniques are typically applied iteratively. Sensitivity analysis was applied for hydraulic conductivity and recharge values. The changes in hydraulic conductivity and its sensitivity to change in root mean square (RMS) error and normalised RMS (NRMS) error are studied.

The input hydraulic conductivity values are changed by +10%, -10%, +20% and – 20%. It is observed from the analysis that, the NRMS does not vary above 3% for increase or decrease of K value up to 20%. Hence, the model is not sensitive to aquifer parameter i.e., hydraulic conductivity (Table 6.5).

Table6.5: Sensitivity Analyses for change in Hydraulic conductivity values

Time steps	change in K value	RMS error	Normalised RMS error (%)
61	0	19.81	11.66
	(+)10	22.71	17.67
	(-)10	21.93	14.17
	(+)20	21.92	14.17
	(-)20	21.93	14.17
213	0	20.76	12.7
	(+)10	23.69	16.77
	(-)10	22.67	16.02
	(+)20	22.67	16.03
	(-)20	22.6	16.04
366	0	26.63	16.27
	(+)10	29.09	18.23
	(-)10	27.73	17.4
	(+)20	27.69	17.38
	(-)20	22.78	17.43
626	0	29.18	17.88
	(+)10	33.28	20.49
	(-)10	31.81	19.68
	(+)20	31.76	19.66
	(-)20	31.86	19.62
761	0	29.82	17.49
	(+)10	34.61	21.92
	(-)10	32.66	20.6
	(+)20	22.66	20.49
	(-)20	32.64	20.68
943	0	36.19	16.73
	(+)10	40.66	18.76
	(-)10	39.27	18.1
	(+)20	39.33	18.19
	(-)20	39.26	18.11

The input recharge values were increased by 6%, 10% and 60%. It is observed from the analysis that, the NRMS does not vary from 3 – 6% for increase in recharge value of 6 – 10%. The same is increased to many folds when the recharge values increased to 60%. Hence, from the analyses it is observed that, the model is sensitive to recharge (Table 6.6).

Table.6.6: Sensitivity Analyses for change in Recharge

Time steps	Change in Recharge values	RMS	NRMS (%)
61	0	19.82	11.66
	6% increase	22.04	14.26
	10% increase	22.06	14.26
	60% increase	26.36	17.82
213	0	20.76	12.71
	6% increase	22.16	14.96
	10% increase	22.18	14.76
	60% increase	27.87	18.64
366	0	26.63	16.27
	6% increase	27.91	17.62
	10% increase	28.01	17.68
	60% increase	46.68	29.37
626	0	29.62	17.88
	6% increase	31.33	19.63
	10% increase	32	19.77
	60% increase	63.8	39.37
761	0	29.83	17.49
	6% increase	33.18	20.64
	10% increase	33.4	21.16
	60% increase	81.63	64.66
944	0	36.19	16.74
	6% increase	38.17	17.64
	10% increase	38.46	17.72
	60% increase	97.67	46.73

6.2 AQUIFER MANAGEMENT PLANFORMULATION

Keeping in view of the present stage of ground water development (over-exploited), heterogenic nature of aquifer and erratic rainfall condition, management strategies are developed. Draft and recharge are the only two parameters by altering which the futuristic management strategies/scenarios are predicted from the model.

The model has been calibrated for 31 stress periods (months). The same calibrated model is used for generating the futuristic scenarios of the system. Three times of the calibrated period i.e. for

108 months say **9 years** i.e. up to **March 2023.** Prediction analysis are carried out and presented below in Table 6.7a.

Table.6.7a: Strategies tested for aquifer management plan

Strategy No.	Strategy
I	Model forecast for 9 years considering the present ground water scenario
II	Model forecast -Drought affected years once in 6 years (2016 & 2021)
III	Model forecast -Excessive rainfall years once in 6 years (2017 & 2022)
IV	Model forecast – One percent extra draft for every year
V	Model forecast – Response of aquifer by impounding water to existing tanks

6.2.1 Model forecast for present ground water scenario

The model is studied by simulating the system up to 2023 without changing the aquifer parameters. This scenario (Scenario-1) helps in forecasting the futuristic ground water condition, when the same trend of ground water development is retained. The calibrated aquifer parameters are used to run the system for continued stress periods from April 2014 to March 2023. The Recharge and Draft values for the period September 2011 to March 2014 are also kept unchanged and the model was made to run for 108 stress periods.

6.2.2 Model forecast -Drought affected years once in 6 years

Scenario-2 is predicted the response of the system during the **drought affected years**. Based on the annual rainfall pattern, drought analysis is carried out for Tiptur and C.N.Halli stations for 1901 to 2013. It is observed from the analysis that, incidence of drought in the area is once in 6 years. It is predicting that the 2016 and 2021 are drought years and the rainfall during the said years is likely to be 26% less than the normal rainfall. The recharge to ground water during these years and successive summer season is predicted as 26% less of normal recharge (Table 6.7b). The calculated recharge values are distributed zone wise to the model. The draft for each region is given as the transient model except for 10% extra during non-monsoon periods during the drought years and successive summer season predicting 10% excessive extraction. The model was run for the modified recharge and draft values for the 108 stress periods.

Table 6.7b: Recharge values distributed for drought prediction scenario

	NRF (mm)	25% of NRF	Expected rainfall during drought	12% of RF	10% of RF	6% of RF
Jan.	2.36	0.589167	1.7675	6.8419E-06	5.70161E-06	4.10516E-07
Feb.	5.68	1.419583	4.25875	1.8252E-05	1.52098E-05	1.09511E-06
Mar.	16.23	4.0575	12.1725	4.7119E-05	3.92661E-05	2.82716E-06
Apr.	33.94	8.484583	25.45375	0.00010182	8.48458E-05	6.1089E-06
May.	90.01	22.50333	67.51	0.00026133	0.000217774	1.56797E-05
Jun.	66.57	16.64292	49.92875	0.00019972	0.000166429	1.19829E-05
Jul.	68.98	17.24542	51.73625	0.00020027	0.000166891	1.20162E-05
Aug.	91.58	22.89542	68.68625	0.00026588	0.000221569	1.59529E-05
Sep.	130.39	32.59833	97.795	0.00039118	0.000325983	2.34708E-05
Oct.	141.16	35.28917	105.8675	0.00040981	0.000341508	2.45886E-05
Nov.	40.55	10.13625	30.40875	0.00012164	0.000101363	7.2981E-06
Dec.	7.30	1.825833	5.4775	2.1203E-05	1.76694E-05	1.27219E-06

6.2.3 Model forecast -Excessive rainfall years once in 6 years

Scenario-3 is predicted the response of the system during the excessive rainfall years. Based on the drought analysis for Tiptur and C.N.Halli stations for 1901 to 2013, it is observed incidence of excess of rainfall is once in 6 years. It is predicting that the 2017 and 2022 are excessive rainfall years and the rainfall during the said years is likely to be 26% more than the normal rainfall. The recharge to ground water during these years is predicted as 26% more of normal recharge (Table 6.8). The calculated recharge values are distributed zone wise to the model. The draft for each grid is given as 10% less during monsoon periods for the excess rainfall years. The model was run for the modified recharge and draft values for the 108 stress periods.

Table 6.8: Recharge values distributed for Excess Rainfall years prediction scenario

	NRF (mm)	25% of NRF	Expected rainfall during Excess	12% of RF	10% of RF	6% of RF
Jan.	2.36	0.589166667	2.946	1.14032E-05	9.50269E-06	5.7E-06
Feb.	5.68	1.419583333	7.098	3.04196E-05	2.53497E-05	1.52E-05
Mar.	16.23	4.0575	20.288	7.85323E-05	6.54435E-05	3.93E-05
Apr.	33.94	8.484583333	42.423	0.000169692	0.00014141	8.48E-05
May.	90.01	22.50333333	112.517	0.000435548	0.000362957	0.000218
Jun.	66.57	16.64291667	83.215	0.000332858	0.000277382	0.000166
Jul.	68.98	17.24541667	86.227	0.000333782	0.000278152	0.000167
Aug.	91.58	22.89541667	114.477	0.000443137	0.000369281	0.000222
Sep.	130.39	32.59833333	162.992	0.000651967	0.000543306	0.000326
Oct.	141.16	35.28916667	176.446	0.000683016	0.00056918	0.000342
Nov.	40.55	10.13625	50.681	0.000202725	0.000168938	0.000101
Dec.	7.30	1.825833333	9.129	3.53387E-05	2.94489E-05	1.77E-05

6.2.4 Model forecast – One percent extra draft for every year

Scenario- 4 is based on the additional draft from the system. The system is simulated for one percent of the extra draft for each year on each period. Keeping the recharge component as constant (values derived from the normal rainfall years), the calculated draft values are assigned zone wise for all the grids of the model. The system was made to run for 108 stress periods.

6.2.5 Model forecast – Response of aquifer by impounding water to existing tanks

Scenario- 5 is based on the impounding of water to the existing tanks and its response. Government of Karnataka has already taken up a scheme to fill-up the existing tanks in parts of Tumkur district by diverting canal water from Hemavathi reservoir. The scheme was envisaged to augment ground water recharge for sustainability of borewells which is the main source of drinking water in the area. Part of the pilot project area falls under this scheme.

To study the response of the impounding of water in the existing tanks, this scenario was predicted. The system is simulated for 120 days of impounding water (August to November) in the existing 11 no. of tanks (Fig. 6.13). The quantum of water impounded in these tanks is given in Table 6.9.

Finer grids have been introduced to accommodate the exact size of the tank in the model domain. The system was made to run for 108 stress periods for the said scenario and the output response for selected stress period is given in Table 6.9.

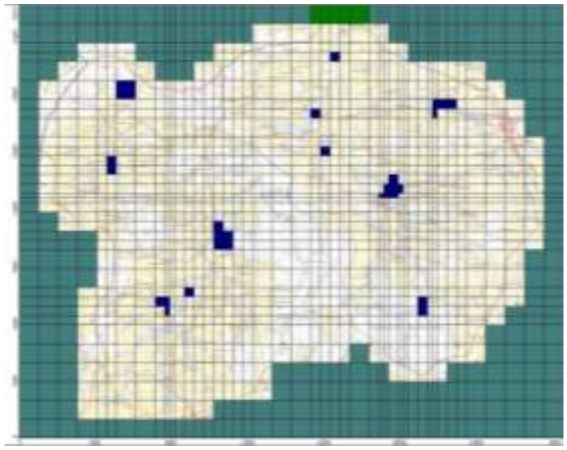


Fig. 6.13: Finer grids and tank locations for impounding water; scenario-IV

Table 6.9: Quantum of water impounded into tanks and its response

Sl. No.	Tank	Area (ha)	Water storage capacity (MCM)	Observation well	Response after 6 yrs of prediction
1	Marasandra	75	1.5	Kallenahalli	7 m rise water level
				Anekatte	4 - 5 m rise water level
2	Sarathavalli	50	1.0	Hurlahalli	3m rise and declining trend arrested
3	Settkere	100	2.0	Dasikere	3-6 m rise observed
4	Chaulihalli	25	0.5	Chaulihalli	1.5 - 2.0 m rise oveserved
				Halenahalli	Impact of two tanks observed
5	Halkurhe	125	2.5	Halenahalli	water level rising reaching to ground level
6	Sasalu Gollarahatti	50	1.0	Sasalu	3.0 -7.0 m rise and decline arrested
7	Bommanahalli	50	1.0	Bommanahalli	4.0- 6.0 m rise
8	Kuppuru	25	0.5	Kuppur	2.0-3.0m rise observed and declining trend

6.2.6 Predictive model results (of proposed management strategies)

The pilot aquifer mapping area model was constructed as a single layer model. The area occupies three principle aquifers viz. Gneissic, Schistose and Granitic formations with more or less similar hydrogeological conditions. The upper phreatic aquifer is completely dry and current ground water extraction is only from the fractured aquifer. Majority of the observation wells shows decline in ground water levels during the project period, which is evident of excessive extraction. The calibrations carried out were reasonably matched with heads of field observation wells in about 68 locations.

Special emphasise is given for generating the “Management Strategies” (futuristic scenarios) in the model area. Five futuristic scenarios based on predictive climatic conditions and ground water developments were tested. All the five prediction scenarios show steep decline of heads in most of the observation locations.

6.2.7 Results of Management strategy-I

The model was made run to 108 stress periods (up to March 2023) without changing the aquifer parameter, recharge and draft. It is observed from the graphs that, there is a steady decline in the ground water level due to increased abstraction from the aquifer. As the area itself categorised as **over exploited** with 187% of ground water stage of development, it is expected that the fall in ground water level is marginal. The decline in heads of the observation wells is noticed up to 80-100 m in the northern part covering villages like Ankasandra, Aralikere Banjara thanda and Chattasandra up to 40 in the western part at Suragondanahalli & Kamalapura villages and southern boundary at Madapurahatti thanda, Chattasandra, Bevinahalli thanda, Saratvalli, Bandegate, Gopalanahalli, etc. villages (Fig. 6.14 and 6.15).

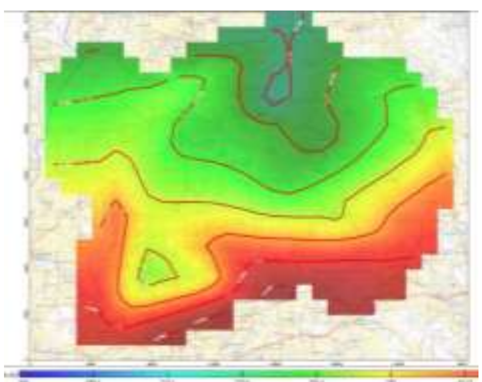


Fig. 6.14 Head Vs. Time

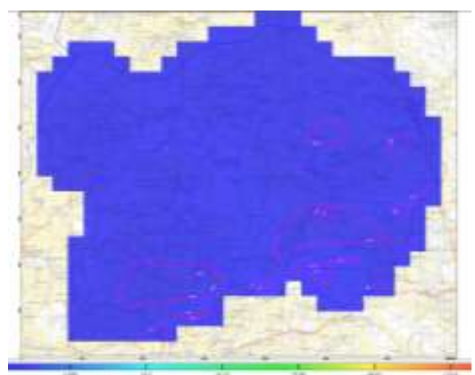


Fig. 6.15 Drawdown Vs. Time

The **scenario-I** cumulative budget estimate illustrates that, the *recharge* to ground water is 27 MCM / year, whereas, the draft is 31 MCM/ year, showing extra drawl of 4 MCM from *storage*.

6.2.8 Results of Management Strategy-II

The model was run for the modified recharge and draft values for the 108 stress periods. It is observed from the graphs that, there is a steady decline in the ground water level due to increased abstraction from the aquifer. During the predicted drought years, there is an extra burden on the system due to 25% less recharge and 10% excessive extraction. These excessive extractions and less recharge periods in the predictive model are clearly noticed in the resultant graphs as well as in the budget estimates generated by the model. The decline in heads of the observation wells is noticed up to 100 m in the northern part covering villages like Ankasandra, Kallenahalli, Kurubarahalli, Kuppur and Banjara thanda, up to 40 in the western and southern boundaries at Kallakere, Virupakshapura, Bevinahalli thanda, Sarathavalli, Bandegate, Gopalanahalli villages, etc (Fig. 6.16 and 6.17).

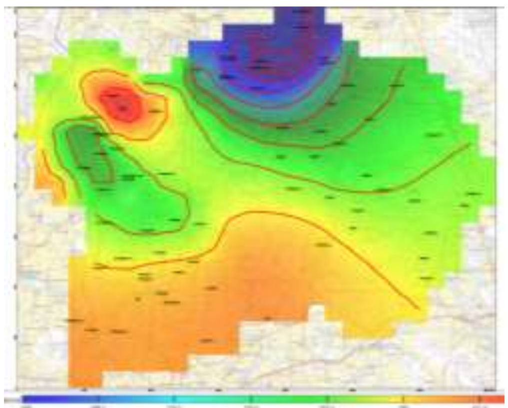


Fig. 6.16 Head Vs. Time

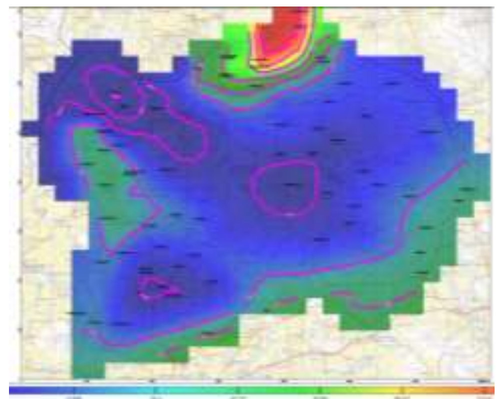
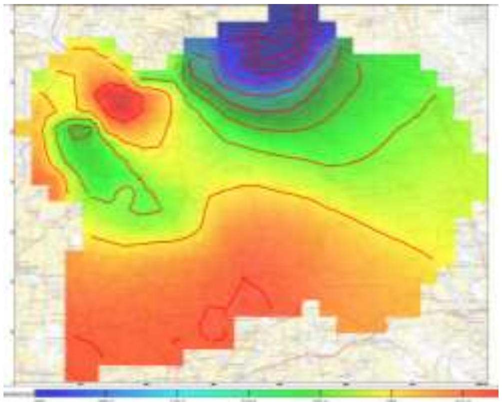


Fig. 6.17 Drawdown Vs. Time

The **scenario-II**, cumulative budget estimate shows that, the recharge to ground water is 25 MCM / year, whereas, the draft is 31 MCM/ year. The difference of volume i.e. 6 MCM of water is being drawn from the storage so as to meet the demands in the area.

6.2.9 Results of Management strategy -III

The current scenario predicted the cumulative recharge to ground water to the tune of 30 MCM and the draft is around 31 MCM for 108 stress periods. It is evident from the budgetary estimates that, during excessive rainfall years (after 33^{rd} & 106^{th} stress periods) the recharge to the ground water is more than the draft and rest of the stress period it follows the normal trend of draft, which is more than the recharge. The continued decline in heads of the observation wells is noticed up to 90-110 m in the northern part covering villages Ankasandra and Aralikere, up to 50m in the North-western (and southern boundary at Madapurahatti thanda, Chattasandra etc. villages). Rise of heads up to 30 m is noticed in the central and north western part covering Alur, Dugganahalli, Kamalapura, Madihalli, Mayagondanahalli etc. villages (Fig. 6.18 and 6.19).



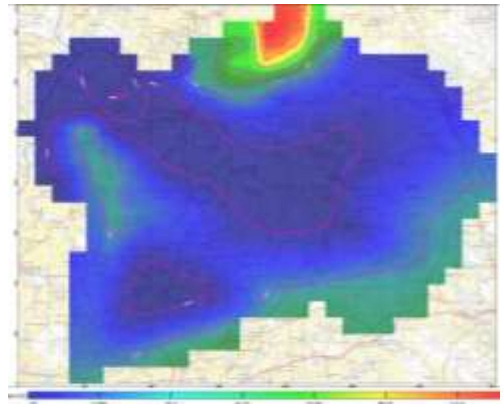
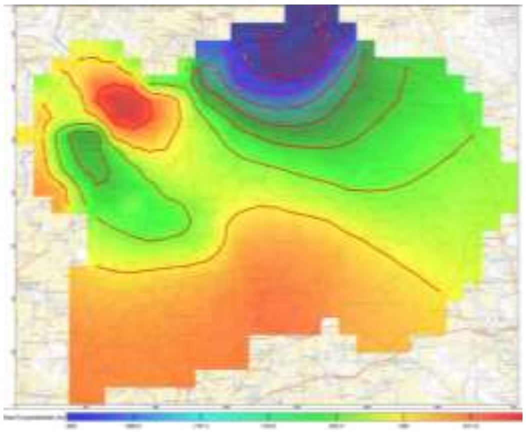


Fig. 6.18 Head Vs. Time **Fig. 6.19 Drawdown Vs. Time**

In scenario-III, cumulative budget estimate shows that, the recharge to ground water is 30 MCM/year, whereas, the draft is 31 MCM/year. These figures clearly indicate that during excessive rainfall years, an extra 3 MCM of water is added to ground water as storage when compared to the 27 MCM during normal scenario (Scenario – I). The difference of 1MCM of water is being drawn from the storage to meet additional demand. The stage of ground water development tends to be 103% in such a scenario.

6.2.10 Results of Management strategy –IV

The aquifer is tested for increasing the draft by 1% for each period is not affecting the ground water heads much. The budgetary estimates show, the cumulative recharge is 26 MCM and the draft is 28 MCM. The decline in heads of the observation wells is noticed up to 100 m in the northern part covering villages Ankasandra, Aralikere, Banjara thanda, Bevinahalli thanda, Chattasandra, Manjunathapura, Tagachigatta colony, Madapurahatti Colony, Sarathavalli, upto 40m in the western and southern boundary at Madapurahatti thanda, Chattasandra, etc. villages (Fig. 6.20 and 6.21).



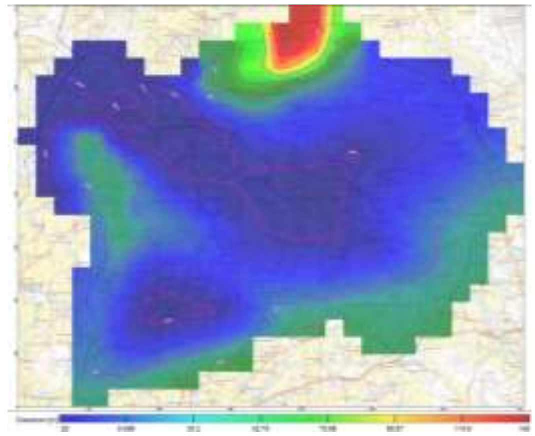


Fig. 6.20 Head Vs. Time **Fig. 6.21 Drawdown Vs. Time**

In Scenario-IV, model predicted "1% extra draft for each year". The cumulative recharge is 28 MCM/year and the draft is 32 MCM/year. These budgetary figures indicate 1 MCM extra draft during this prediction which is being drawn from the storage.

6.2.11 Results of Management Strategy-V

The calibrated model was tested to understand the response of the aquifer to impounding of water in the existing tanks. The figures showing the Head Vs time and Drawdown Vs Time are presented as Fig.6.22 & 6.23 respectively. The 'head vs. time' map generated by the model shows, at the end of predicted period the shallow ground water level area is increased and observed that, the ground water drawdown is significantly arrested in some of the locations. Table 6.10 shows that the area and water storage and the response of the aquifer system to the impounding water. Good response of the aquifer system is observed in Observation wells at Kallenahalli and Anekatte village located 2 & 3 km respectively from the Marasandra tank showing rise in ground water levelranging from 4 to 7m in 6 years. Sasalu and Somalapura villages are located near Sasalu-Gollarahatti tank. The declining trend in the groundwater table is arrested and rise from 3 to 7 m is observed. Bevanahalli village located 2 km from the Kuppuru tank shows 2- 3 m decline in the groundwater level. The responses in the observation wells are shown in the Fig. 6.24.

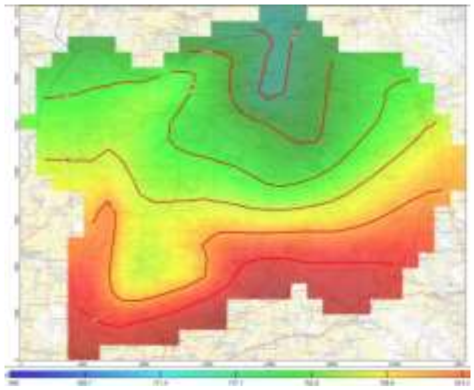


Fig. 6.22 Head Vs. Time

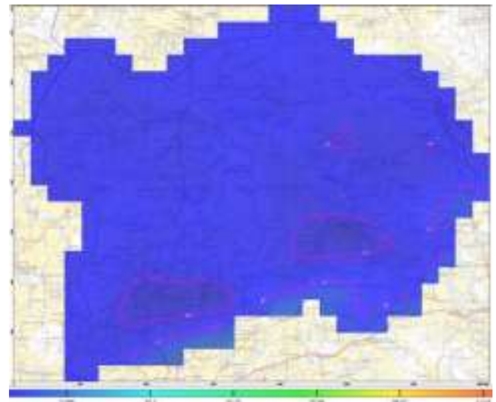
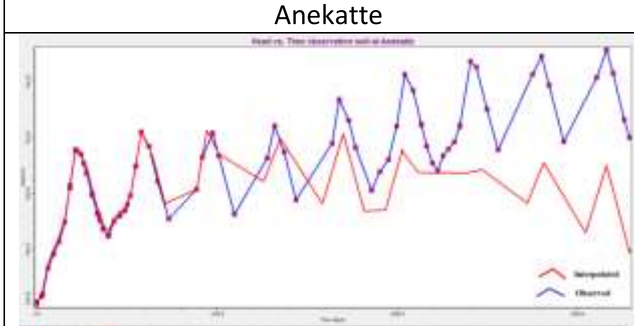
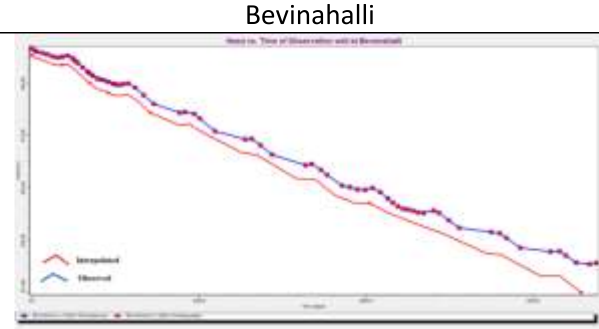
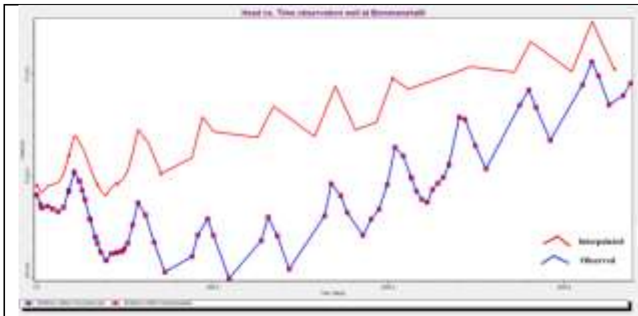
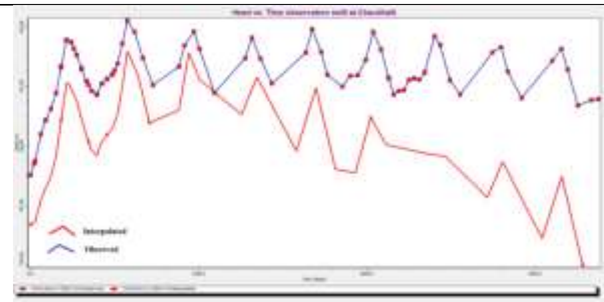


Fig. 6.23 Drawdown Vs. Time

In Scenario-V, the model predicted the response of the aquifer by impounding water in the existing tanks. The cumulative budget indicates that, the rainfall recharge is 27 MCM/year and additional of 3 MCM of recharge is contributed by tanks. The outflow component during this Scenario shows that 29 MCM of water is being withdrawn as draft and 1 MCM/year is out flow from tank (Lake Package).The observation wells located in Anekatte, Kallenahalli, Huralahalli, Chaulihalli, Sasalu and Somalapura show arrest in decline in ground water levels. The wells located in Anekatte, Kallenahalliare only arresting the decline and also are prone to water logging condition. It is also observed that, the wells at Helanahalli and Bommanahalli are prone to water logging after six years of prediction. Based on the model prediction results it is observed that, the regions near the Halkurike tank gets flooded and hence, impounding of water in Halkurike tank may be carried out in alternate years.

Anekatte	Bevinahalli
	
Bommanahalli	Chaulihalli





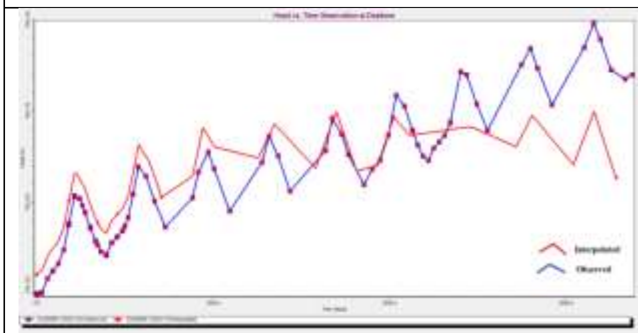
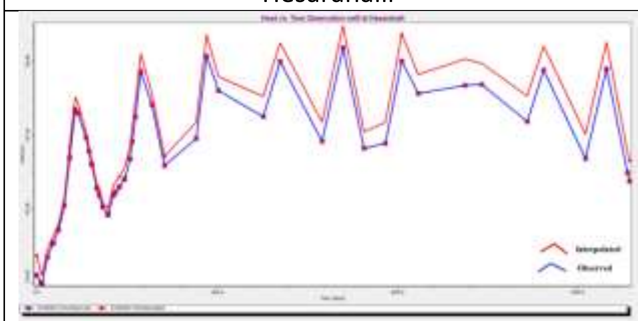
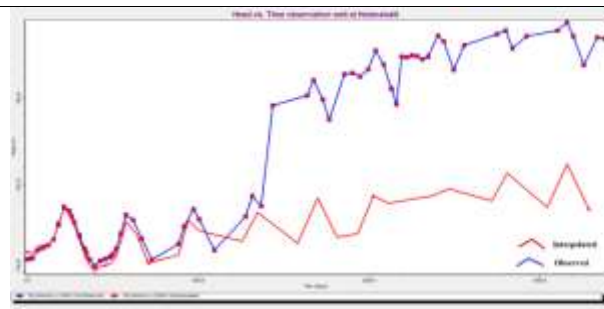
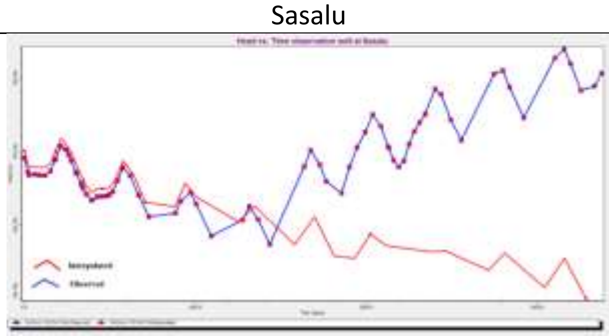
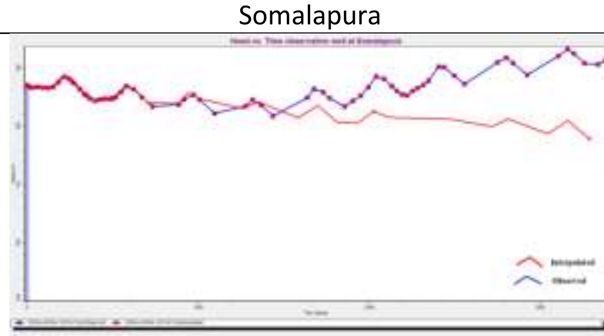
Dasikere	Duggenahalli
	
Hesarahalli	Halenahllli
	
Sasalu	Somalapura
	

Fig. 6.24: Plots of Head Vs Time for selected villages; scenario-IV

Model generated cumulative ground water budget of all scenarios is presented below its corresponding table is given in Table 6.9a.

Scenario-I is tested with unchanged status of recharge and draft conditions prevalent in the area. As per the cumulative budget generated after the model run it is observed that ground water recharge is 27 MCM/year and draft (wells) 31 MCM / year. The overall water budget is balanced by taking in 15 MCM of water from the storage and giving out 12 MCM from the system. This almost coincides with the ground water development trend calculated for the region.

Scenario-II is tested with drought prevalent years during the prediction period (2016 & 2022). Drought is predicted once in 6 years and the reduced recharge is projected during these years against the same draft. After the successful run, the cumulative budget shows that an amount of 25 MCM is getting recharged and 31 MCM draft. This indicates that during the drought affected years the system is taking less 2 MCM when it is compared with projected normal ground water development.

In scenario-III, which made to run with excessive rainfall during the period indicates recharge to the ground water is 30MCM and the draft is 31 MCM/year. It appears that excess recharge of 3 MCM is contributed from the excessive rainfall pattern. The overall draft quantity is unchanged with 31 MCM/year. 45 MCM of water is entering in to the system and 45 MCM is going out from the system, which is maximum utilisation, when compared with other scenarios.

Scenario-IV, model tested with 1% extra draft/year. The cumulative budget shows that an amount of 28 MCM is getting recharged and 32 MCM is draft. This budget indicates that the recharge is continued with the same trend as it is observed during the normal period. An extra 1MCM of draft is observed during this scenario and the system is taking less 2 MCM recharge. This clearly indicates that during such a situation, the extra burden on the system is balanced by withdrawing water from the storage.

In scenario-V, impounding water into existing tanks, the cumulative budget shows that there is extra input into the ground water by means of Lake (ponds) Recharge other than the regular recharge. Lake contributes 3 MCM of water to the system apart from regular 27 MCM of recharge whereas the ground water draft from the system is 29 MCM /year which is less than the regular draft. This indicates that there is less usage of ground water when surface water facilities are available.

Table 6.9a: Cumulative budget of 5 Scenarios

		Scenario-I	Scenario-II	Scenario-III	Scenario-IV	Scenario-V
		MCM				
IN	Storage	15	16	15	15	14
	Constant					
	Wells					
	Drains					
	MNW					
	LAKE					3
	Recharge	27	25	30	28	27
	ET					
	River					
	Stream					
	General-Head					
	Total	**43**	**42**	**45**	**43**	**44**
OUT	Storage	12	11	14	11	14
	Constant					
	Wells	31	31	31	32	29
	Drains					
	MNW					
	LAKE					1
	Recharge					
	ET					
	River					
	Stream					
	General-Head					
	Total	**43**	**42**	**45**	**43**	**44**

6.2.12 Feasible areas for ground water development (along with yield potential/depth of drilling/safe yields etc.)

After carrying out the detailed survey, integration of various data and results of various strategies tested in the groundwater model, following management plans for the study are suggested and represented.

There are7 villages in Tiptur and 9 villages in C.N.Halli taluk are found feasible for ground water development with management practices. The taluk-wise list of villages is given in Table 6.10 and shown in Fig. 6.25. In these villages, it is observed that the sheet rocks are found at many places and the depth of weathering is limited (less than 10m). The well density in these villages is relatively less. The ground water development in the area is comparatively on low key. The existing borewells in the area have encountered poor yielding (1 to 2 lps) fractures. However, further development may prove the existence of potential fractures in these villages.

Further, water remains in Halkurike tank during most part of the year. This helps to augment ground water recharge in the area of influence of the tank. The depth to ground water levels remains shallow in these villages. The general depth range of borewells in these villages is between 150 – 200 m bgl. The safe yields in these villages are about 6000 to 6500 m^3/year per borewell or 0.6 to 0.65 ha.m per year ((1.5 lps X 4 hr/day) X 300 days/year).

Sustainable ground water management including contour bunding, check dams, gully plugs, percolation ponds, etc., are suggested for augmenting ground water resources. Space of 200 m between two productive wells needs to be maintained to avoid mutual interference. Practicing of drip irrigation is to be taken up on larger scale to increase the irrigation efficiency.

Table 6.10: Taluk wise list of villages feasible for ground water development with management practices

Tiptur taluk		
Sl.No.	**Village Name**	**Village code**
1	Balavanerala	T_4
2	Bommanahalli	T_7
3	Halkurike	T_18
4	Halkurike amani kere	T_19
5	Mayagondanahalli	T_35
6	Rudrapura	T_42
7	Suragondanahalli	T_46

C.N.Halli Taluk		
Sl.No.	**Village Name**	**Village code**
1	Aralikere	C_6
2	Chattasndra	C_12
3	Dasihalli	C_16
4	Gaudanahalli	C_20
5	Kallenahalli	C_25
6	Karehalli	C_27
7	Madihalli_CNH	C_35
8	Mallenahalli	C_37
9	Upparahalli	C_55

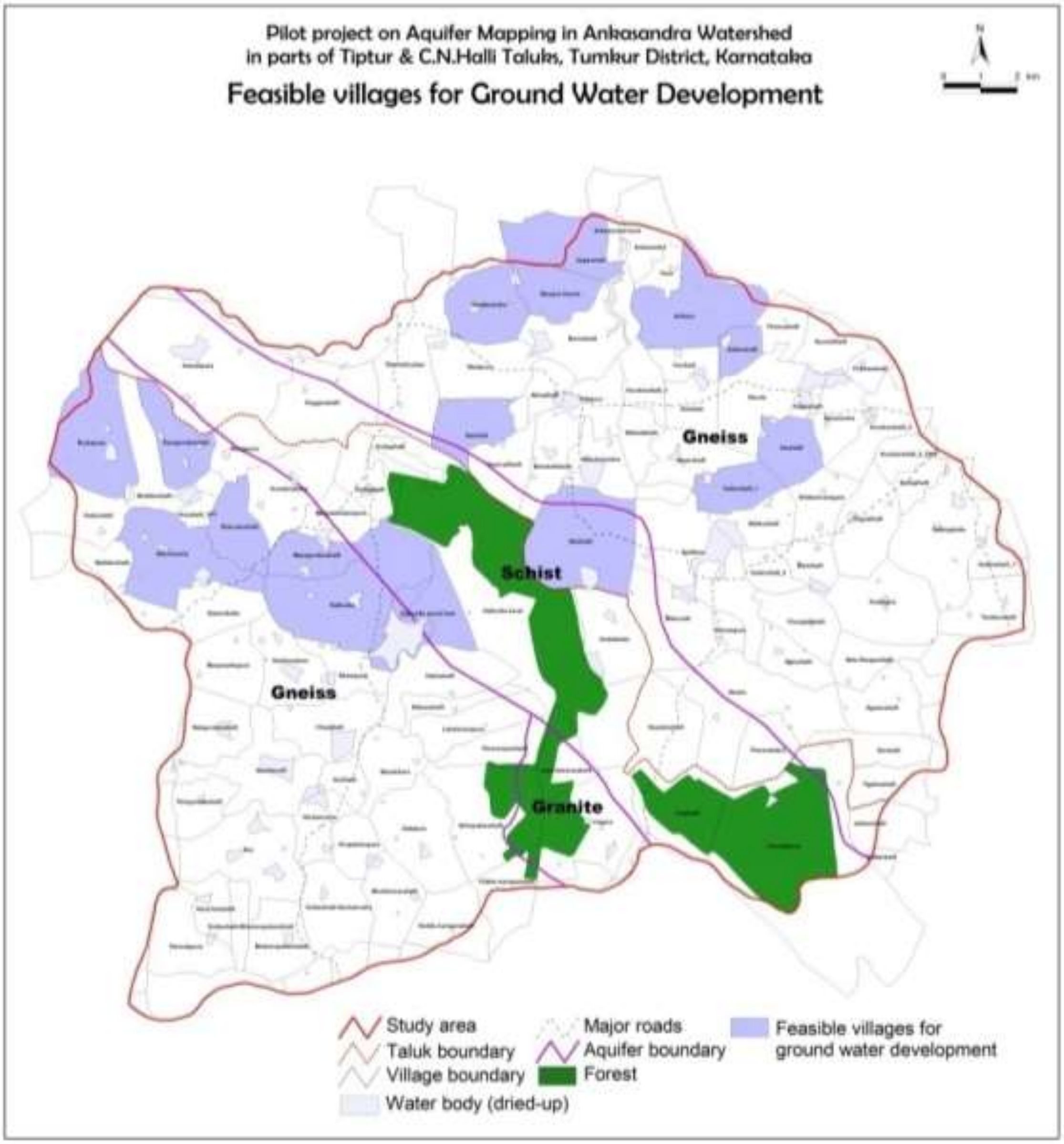


Fig. 6.25: Feasible villages for ground water development

6.2.13 Feasible areas for rainwater harvesting and artificial recharge of ground water (vis-a-vis sub-surface storage space available for recharge and surplus non committed surface water available for recharge)

The entire area is feasible for rainwater harvesting and artificial recharge in view of deep ground water levels. The list of villages feasible for artificial recharge is given in Table 6.11 and represented Fig. 6.26. There is considerable desaturation of aquifer in these villages.

Table 6.11: Taluk wise list of villages feasible for rainwater harvesting and artificial recharge to ground water

Tiptur Taluk		
Sl.No.	Village Name	Village Code
1	Adinayakanahalli	T_1
2	Alur	T_2
3	Baluvanerlu	T_4
4	Bhairanayakanahalli	T_5
5	Bhairapura	T_3
6	Bidarekatti	T_6
7	Bommanahalli	T_7
8	Chaudlapura	T_10
9	Chaulihalli	T_8
10	Chikka marapanahalli	T_9
11	Dasanakatte	T_11
12	Dodda marapanahalli	T_13
13	Doddakatte	T_12
14	Gatakanakere	T_14
15	Gedlahalli	T_16
16	Gowdanakatte	T_15
17	Halenahalli	T_17
18	Halkurike	T_18
19	Halkurike amani kere	T_19
20	Halkurike kaval	T_20
21	Harachanahalli	T_21
22	Harisamudra	T_22
23	Hosahalli_TPT	T_23
24	Hurlihalli	T_24
25	Irlagere	T_25
26	Jakkanahalli	T_26
27	Kallakere	T_27
28	Kambadahalli	T_28
29	Kenchamaranahalli	T_29
30	Kodagihalli	T_30
31	Kugihalla	T_31
32	Lakshmanapura	T_32
33	Mallidevihalli	T_33
34	Manakikere	T_34
35	Mayagondanahalli	T_35
36	Misetimmanahalli	T_36
37	Muddenahalli	T_37
38	Nelagondanahalli	T_38
39	Paragondanahalli	T_39

C.N.Halli Taluk		
Sl.No.	Village Name	Village Code
1	Agasarahalli	C_1
2	Ajjenahalli	C_2
3	Anekatte	C_3
4	Ankasandra	C_4
5	Ankasandra kaval	C_5
6	Arlikere	C_6
7	Bachihalli	C_7
8	Ballenahalli	C_8
9	Benakanakatte	C_9
10	Bete Ranganahalli	C_10
11	Bevinahalli	C_11
12	Chattasandra	C_12
13	Chikkenahalli	C_13
14	Chunganahalli	C_14
15	Dabbeghatta	C_15
16	Dasihalli	C_16
17	Dibbadahalli	C_17
18	Diggenahalli	C_18
19	Dugudihalli	C_19
20	Gerehalli	C_21
21	Gopalanahalli	C_22
22	Gowdanahalli	C_20
23	Hesarahalli	C_23
24	Kadenahalli	C_24
25	Kallenahalli	C_25
26	Kamalapura	C_26
27	Karehalli	C_27
28	Katenahalli	C_28
29	Kedagihalli	C_29
30	Kodalgara	C_30
31	Kuppuru	C_31
32	Kurubarahalli_1_CNH	C_32
33	Kurubarahalli_2_CNH	C_33
34	Madapura	C_34
35	Madihalli_CNH	C_35
36	Makuvalli	C_36
37	Mallenahalli	C_37
38	Manchasandra	C_38
39	Marasandra	C_39

Tiptur Taluk		
Sl.No.	Village Name	Village Code
40	Ramanahalli	T_40
41	Rangapura	T_41
42	Rudrapura	T_42
43	Sarathavalli	T_43
44	Siddankatti	T_44
45	Singenahalli	T_45
46	Suragondanahalli	T_46
47	Timmalapura	T_47
48	Timmarayanahalli	T_48
49	Vaderahalli_TPT	T_49
50	Vasudevarahalli	T_50
51	Virupakshapura	T_51

C.N.Halli Taluk		
Sl.No.	Village Name	Village Code
40	Mathighatta	C_40
41	Melanahalli	C_41
42	Navule	C_42
43	Pemmaladevi	C_43
44	Pinnenahalli	C_44
45	Pura	C_45
46	Sasalu	C_46
47	Savsettihalli	C_47
48	Settikere	C_48
49	Siddaramanagara	C_49
50	Somalapura	C_50
51	Tagachighatta	C_51
52	Tammadihalli	C_52
53	Tarabenahalli	C_53
54	Tigalanahalli	C_54
55	Upparahalli	C_55
56	Vaderahalli_CNH	C_56
57	Yerehalli	C_57

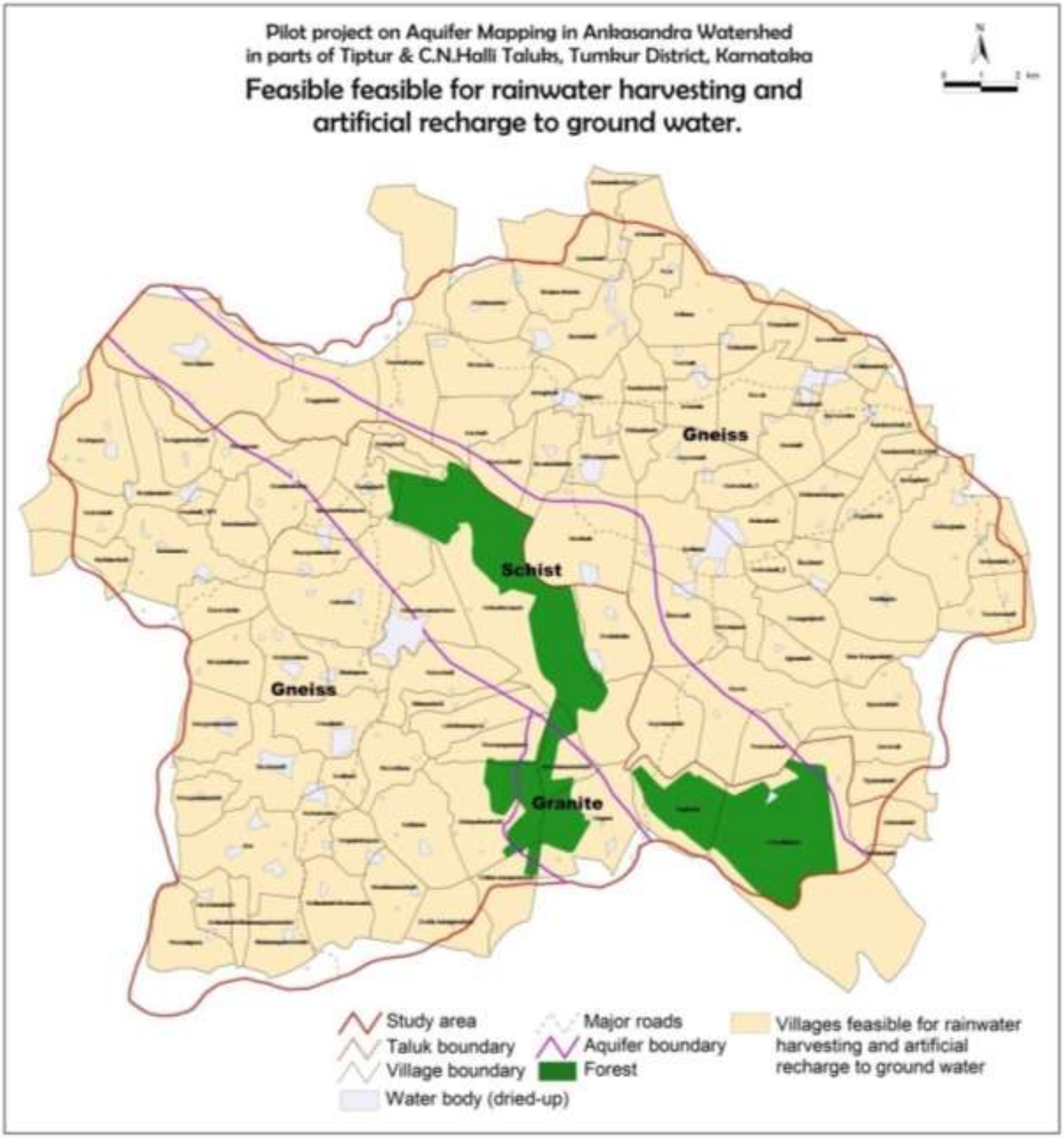


Fig. 6.26: Feasible villages for rainwater harvesting and artificial recharge

The sub-surface storage space availability for recharging the aquifers is calculated up to 10 m bgl. For calculating the sub-surface storage space, post-monsoon depth ground water level (Sept. 2013) was taken for consideration. The areas covered under various depth to ground water levels ranges like 0-10, 10-20, 20-30, 30-50, 50-70 and >70 m bgl were calculated under GIS environment and shown in Table 6.12. The sub-surface storage space availability is calculated based on the thickness of unsaturated zone for each depth to ground water level range. The total sub-surface storage space availability is 6,39,345ha.m. The specific yield is about 10% for the depth range 0-10 m whereas it is taken as 8% from 10-20 m and 4% from 20-30 m because of compaction of the formation. The specific yield/ storativity is taken as 1% in fractured system. Accordingly, water required to raise the ground water level from the present status to 10 m bgl is calculated and given in Table 6.12. The total amount of water required is 14,015 ha.m to raise the ground water level up to 10 m bgl in the entire area.

Table 6.12: Availability of sub-surface space storage (upto 10 m)

Sl. No.	DTWL Range (m bgl)	Area covered (Ha)*	Ground water level height required to be raised (m)	Sub-surface storage space availability (ha.m)	Specific Yield (%)	Thickness of water required (m)	Water required to raise the ground water level upto 10 m (ha.m)
1	0 - 10	3935	0	0	10	0	-
2	10 - 20	8725	5	43625	8	0.4	3490
3	20 – 30	10150	15	152250	4	0.6	6090
4	30 – 50	8394	30	251820	1	0.3	2518
5	50 – 70	2243	50	112150	1	0.5	1122
6	> 70	1060	75	79500	1	0.75	795
Total		**34507**		**639345**			**14015**

* Excluding forest area

The sub-surface storage space availability to bring up the water up to 5 m bgl in these aquifers is calculated. For calculating the sub-surface storage space, post-monsoon depth ground water level (Sept. 2013) was taken for consideration. The areas covered under various depth to ground water levels ranges like 0-10, 10-20, 20-30, 30-50, 50-70 and >70 m bgl were calculated under GIS environment and shown in Table 6.13. The sub-surface storage space availability is calculated based on the thickness of unsaturated zone for each depth to ground water level range. The total sub-surface storage space availability is 7,92,205ha.m. The specific yield is about 10% for the depth range 0-10 m whereas it is taken as 8% from 10-20 m and 4% from 20-30 m because of compaction of the formation. The specific yield/Storativity is taken as 1% in fractured system. Accordingly, water required to raise the ground water level from the present status to 5 m bgl is calculated for each depth range and given in Table 6.13. The total amount of water required is 20,120 ha.m to raise the ground water level up to5 m bgl in the entire area.

However, there is no surplus non-committed surface water available in the study area in most of the years. All the surface water is under utilisation. To arrest the falling ground water levels, it is recommended to transfer the water from Hemavathi (Cauvery basin) to the tune of 1,200 ha.m /year (12 MCM) and fill up all the existing tanks after desiltation continuously for 10 years so that deep aquifers are recharged and ground water level is expected to rise to 10 / 5 m bgl. This will improve the ground water condition in the area and the sustainability of the aquifers.

Table 6.13: Availability of sub-surface space storage (upto 5 m)

Sl. No.	DTWL Range (m bgl)	Area covered (Ha)*	Ground water level Height required to be raised (m)	Sub-surface storage space availability (ha.m)	Specific Yield (%)	Thickness of water required (m)	Water required to raise the ground water level upto 10 m (ha.m)
1	0 - 10	3935	0	0	10	0	-
2	10 - 20	8725	10	87250	8	0.8	6980
3	20 – 30	10150	20	203000	4	0.8	8120
4	30 – 50	8394	35	293790	1	0.35	2938
5	50 – 70	2243	55	123365	1	0.55	1234
6	> 70	1060	80	84800	1	0.8	848
Total		**34507**		**792205**			**20120**

6.2.14 Aquifer wise vulnerability (Quantity)

The collected data with respect of depth to ground water level, aquifer yield, density of wells, etc., the list of vulnerability villages in respect of ground water quantity is assessed and shown in Table 6.14 and represented in Fig. 6.27. It reveals that 92 villages (out of total of 108 villages considered) are water stressed in the study area. Out of which, 44 villages falling in Tiptur taluk and 48villages are falling in C.N.Halli taluk.

Table 6.14: Taluk wise list of vulnerability villages with respect to ground water quantity

Tiptur Taluk			C.N.Halli Taluk		
Sl.No.	**Village Name**	**Village Code**	**Sl.No.**	**Village Name**	**Village Code**
1	Adinayakanahalli	T_1	1	Agasarahalli	C_1
2	Alur	T_2	2	Ajjenahalli	C_2
3	Bhairanayakanahalli	T_5	3	Anekatte	C_3
4	Bhairapura	T_3	4	Ankasandra	C_4
5	Bidarekatti	T_6	5	Ankasandra kaval	C_5
6	Chaudlapura	T_10	6	Bachihalli	C_7
7	Chaulihalli	T_8	7	Ballenahalli	C_8
8	Chikka marapanahalli	T_9	8	Benakanakatte	C_9
9	Dasanakatte	T_11	9	Bete Ranganahalli	C_10

Tiptur Taluk			C.N.Halli Taluk		
Sl.No.	Village Name	Village Code	Sl.No.	Village Name	Village Code
10	Dodda marapanahalli	T_13	10	Bevinahalli	C_11
11	Doddakatte	T_12	11	Chikkenahalli	C_13
12	Gatakanakere	T_14	12	Chunganahalli	C_14
13	Gedlahalli	T_16	13	Dabbeghatta	C_15
14	Gowdanakatte	T_15	14	Dibbadahalli	C_17
15	Halenahalli	T_17	15	Diggenahalli	C_18
16	Halkurike kaval	T_20	16	Dugudihalli	C_19
17	Harachanahalli	T_21	17	Gerehalli	C_21
18	Harisamudra	T_22	18	Gopalanahalli	C_22
19	Hosahalli_TPT	T_23	19	Hesarahalli	C_23
20	Hurlihalli	T_24	20	Kadenahalli	C_24
21	Irlagere	T_25	21	Kamalapura	C_26
22	Jakkanahalli	T_26	22	Katenahalli	C_28
23	Kallakere	T_27	23	Kedagihalli	C_29
24	Kambadahalli	T_28	24	Kodalgara	C_30
25	Kenchamaranahalli	T_29	25	Kuppuru	C_31
26	Kodagihalli	T_30	26	Kurubarahalli_1_CNH	C_32
27	Kugihalla	T_31	27	Kurubarahalli_2_CNH	C_33
28	Lakshmanapura	T_32	28	Madapura	C_34
29	Mallidevihalli	T_33	29	Makuvalli	C_36
30	Manakikere	T_34	30	Manchasandra	C_38
31	Misetimmanahalli	T_36	31	Marasandra	C_39
32	Muddenahalli	T_37	32	Mathighatta	C_40
33	Nelagondanahalli	T_38	33	Melanahalli	C_41
34	Paragondanahalli	T_39	34	Navule	C_42
35	Ramanahalli	T_40	35	Pemmaladevi	C_43
36	Rangapura	T_41	36	Pinnenahalli	C_44
37	Sarathavalli	T_43	37	Pura	C_45
38	Siddankatti	T_44	38	Sasalu	C_46
39	Singenahalli	T_45	39	Savsettihalli	C_47
40	Timmalapura	T_47	40	Settikere	C_48
41	Timmarayanahalli	T_48	41	Siddaramanagara	C_49
42	Vaderahalli_TPT	T_49	42	Somalapura	C_50
43	Vasudevarahalli	T_50	43	Tagachighatta	C_51
44	Virupakshapura	T_51	44	Tammadihalli	C_52
			45	Tarabenahalli	C_53
			46	Tigalanahalli	C_54
			47	Vaderahalli_CNH	C_56
			48	Yerehalli	C_57

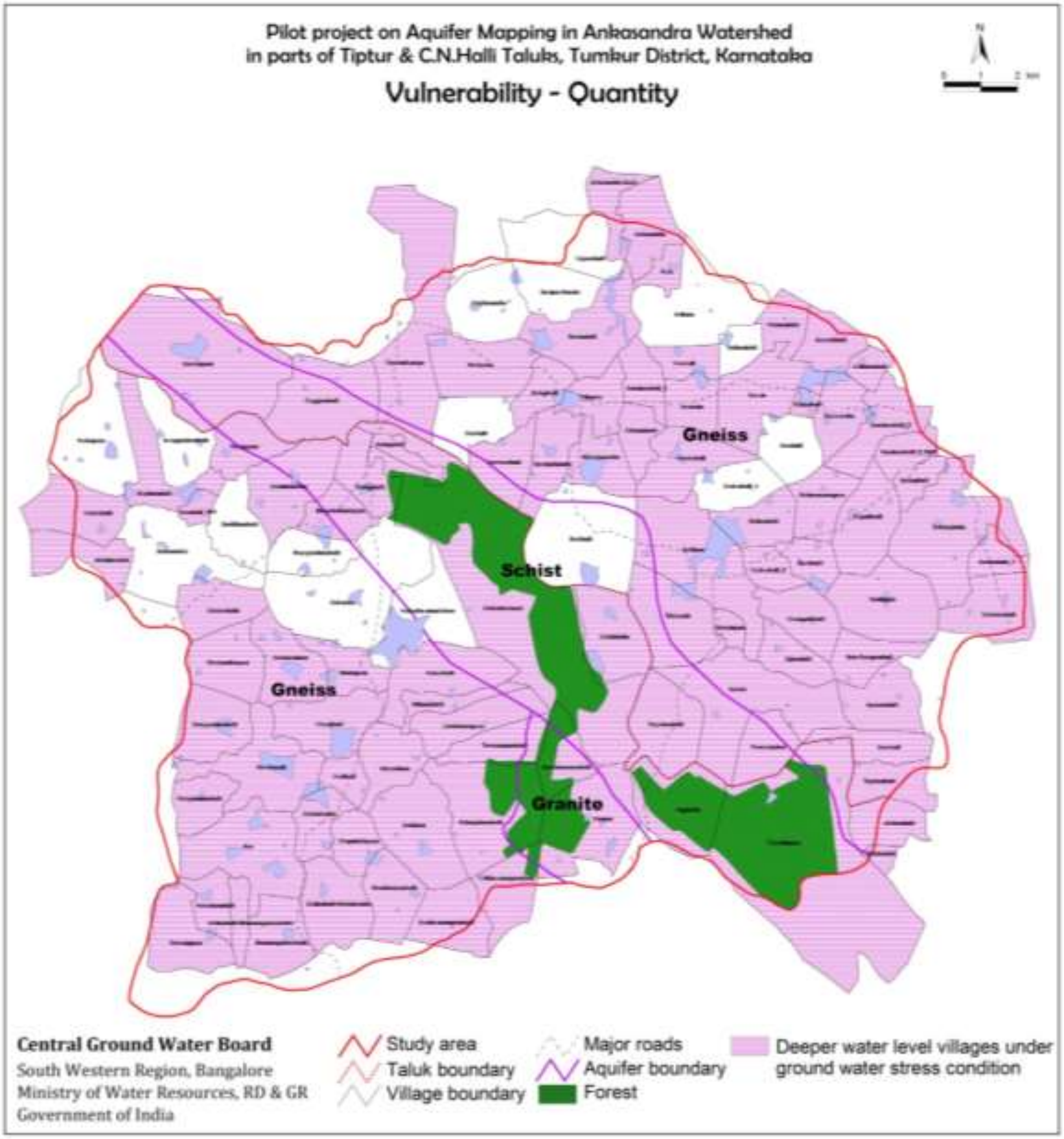


Fig. 6.27: Vulnerability with respect to ground water quantity

6.2.14 Aquifer wise vulnerability (Quality)

From the previous chapter 3.8.3, it is learnt that the parameters viz., pH, EC, Fluoride are within permissible limits. Only the concentrations of iron and nitrate are exceeding the acceptable limit in some of the villages. In majority of the area, the concentration of iron exceeds the acceptable limit of 0.3 ppm. The area with more than 0.3 ppm of iron is shown in Fig. 6.28. In addition, the map pertaining to Aquifer Management Plans is given in Fig. 6.29.

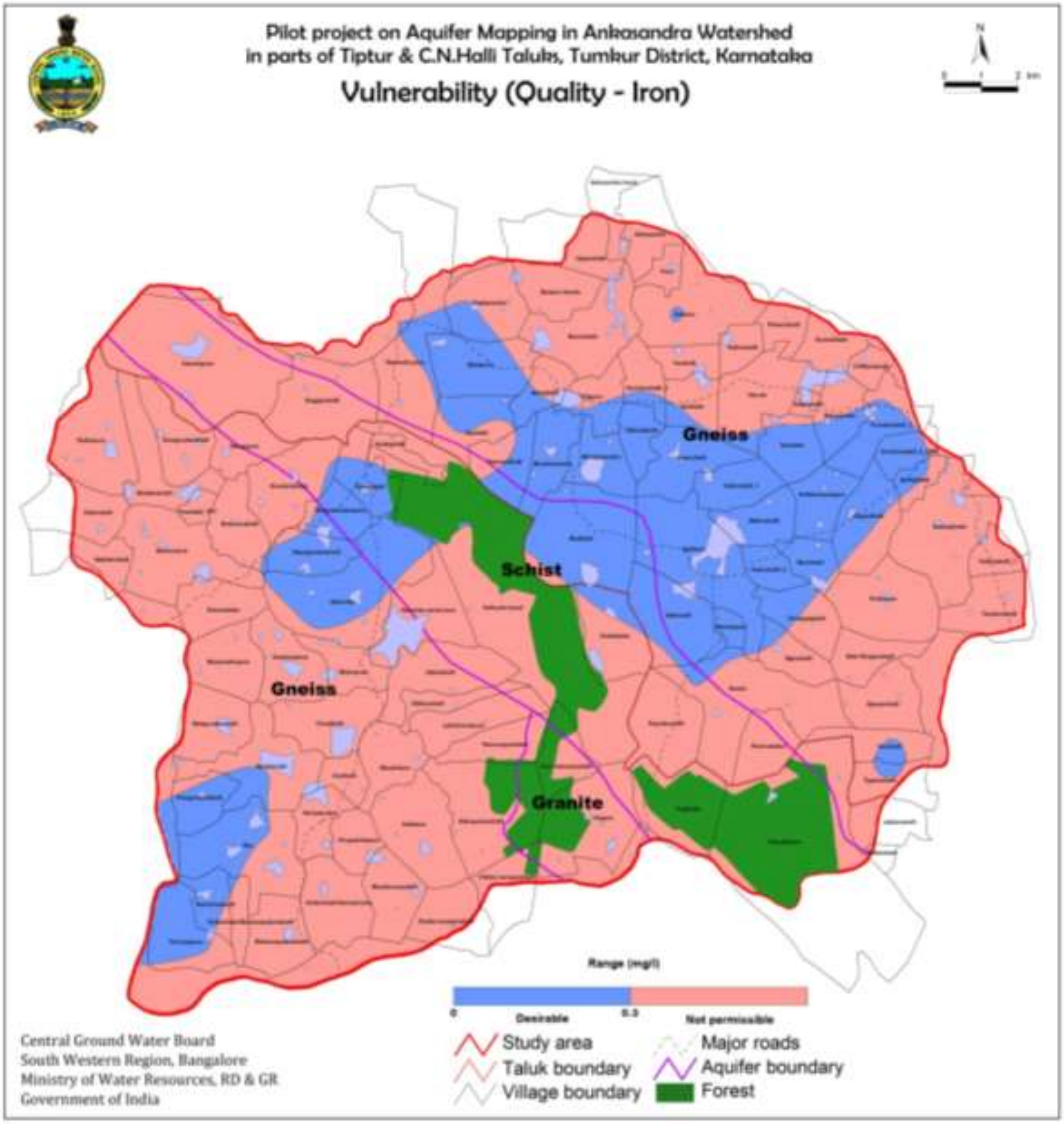
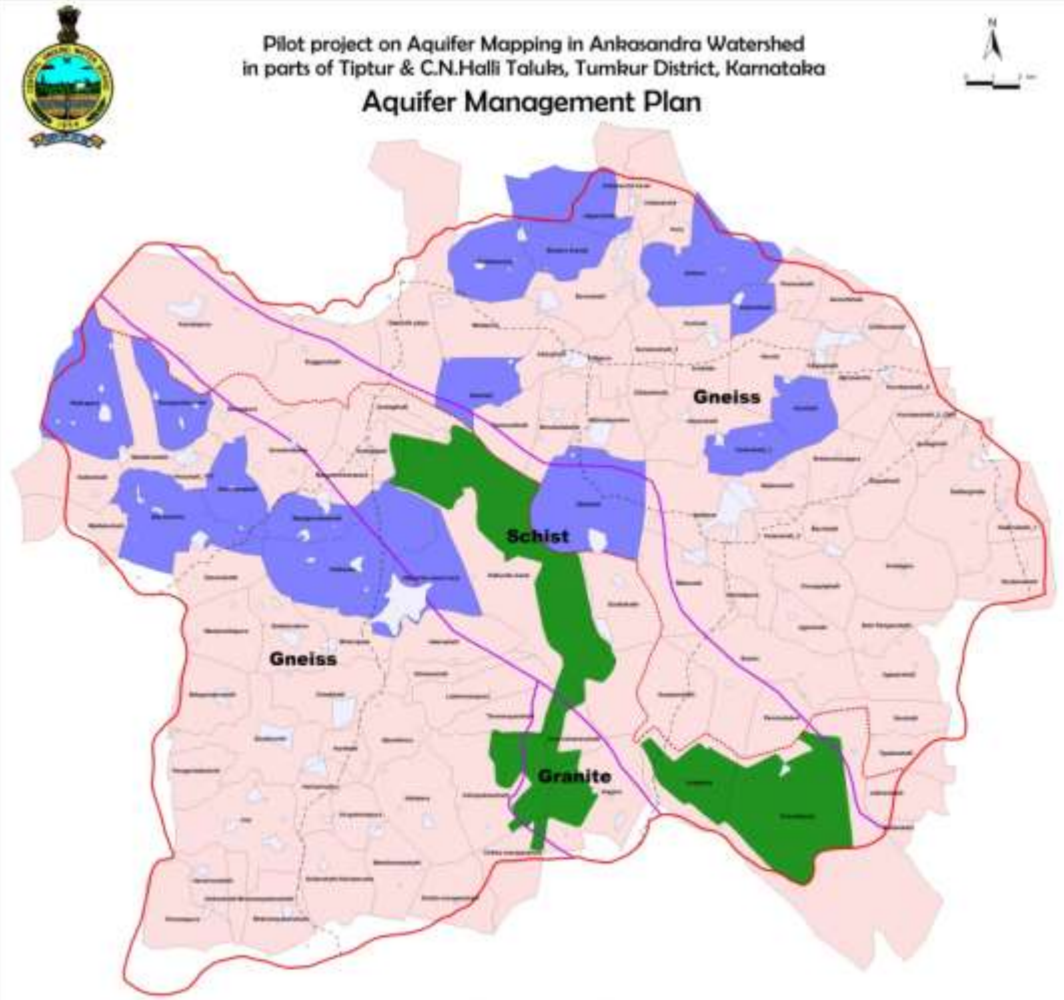


Fig. 6.28: Vulnerability with respect to ground water quantity (Iron)



Aquifer Management Plan

Aquifer	Depth of occurrence of fractures (m bgl)	Thickness (m)	Current Use	Recommendations for Aquifer Development					Aquifer Management Plan
				Type	Zones/Depth to be tapped	HP of pump to be lowered	Pumping Hours	Yield (Cu.m /Day)	
Aquifer I	44-190	Upto 190	Drinking, Domestic and Irrigation	Bore well	60 to 100 120 to 140 160 to 190	5	4	2 to 36	• Further ground water development is restricted only in 16 villages. • No further ground water development is recommended in 92 villages. • Well spacing norm of 200m is recommended to be followed between two productive bore wells. • Participatory ground water management is recommended at village level. • Permanent crops like coconut and areacanut and water intensive crops like paddy and banana should not be permitted. Low water intensive crops like ragi, jowar, groundnut, sunflower, cotton, red gram, etc. are encouraged. • Mulching of land surface is highly recommended to reduce the evaporation from soils. The ground water in hardrocks exists within the fractures and 2 or 3 set of fractures are likely to be encountered upto 190 m bgl.

Central Ground Water Board
South Western Region, Bangalore
Ministry of Water Resources, RD & GR
Government of India

Forest
Water body (Dried-up)
Aquifer boundary
Study area
Taluk boundary
Major roads
50 % of villages are falling outside study area

Aquifer management plans:
Feasible villages suitable for ground water development
Villages not feasible for ground water development and needs artificial recharge

Fig. 6.29: Aquifer Management Plan

7.0 IMPLEMENTATION PLAN & RECOMMENDATION

7.1 IMPLEMENTATION PLAN

More than 95% of the people in the study area depend on groundwater for their daily water supply. It is an agricultural economy and basically dependent on groundwater. Increase in ground water development since1970 is mainly due to the availability of low cost drilling technology fuelled by the pump set (submersible) revolution and institutional finance. Groundwater development has brought major benefits like food security, safe drinking water supply for households and industries, high value agriculture and horticulture. Excessive ground water extraction for agricultural activity has resulted in falling groundwater tables, groundwater contamination and associated problems.

7.1.1 Implementation plan with ground water development with management options

The present stage of ground water development is 187%. However, during the course of study, it is observed that the development is not uniform throughout the watershed. Still there is scope for development along with management measures in some villages. This has been identified and confirmed based on hydrogeological conditions. However, ground water development is restricted along with management practices in the following villages given in Table 7.1 and shown in Fig. 6.22.

Table 7.1: Taluk wise list of villages' ground water development

Sl.No.	C.N.Halli Taluk		Tiptur Taluk	
	Village Name	Village Code	Village Name	Village Code
1	Arlikere	C_6	Baluvanerlu	T_4
2	Chattasandra	C_12	Bommanahalli	T_7
3	Dasihalli	C_16	Halkurike	T_18
4	Gowdanahalli	C_20	Halkurike amani kere	T_19
5	Kallenahalli	C_25	Mayagondanahalli	T_35
6	Karehalli	C_27	Rudrapura	T_42
7	Madihalli_CNH	C_35	Suragondanahalli	T_46
8	Mallenahalli	C_37		
9	Upparahalli	C_55		

It has been estimated that about 330 borewells are feasible with an estimated discharge of 214 ha.m. The taluk-wise and village-wise geographical area, number of borewells feasible and unit draft for each borewellare given in Table 7.2.

Table 7.2: Taluk-wise and village-wise number of additional borewells feasible along with the ground water draft

Sl. No.	Taluk Name	Village Code	Village Name	Area (Ha)	Area (Sq.km)	Additional Wells feasible *	Unit draft for proposed borewell (ha.m/year)	Village wise total ground water draft (ha.m/year)
1	Tiptur	T_4	Baluvanerlu	577.68	5.78	28.9	0.648	18.7272
2	-do-	T_7	Bommanahalli	280.12	2.80	14	0.648	9.072
3	-do-	T_18	Halkurike	866.56	8.67	43.35	0.648	28.0908
4	-do-	T_19	Halkurike amani kere	438.55	4.39	21.95	0.648	14.2236
5	-do-	T_35	Mayagondanahalli	240.87	2.41	12.05	0.648	7.8084
6	-do-	T_42	Rudrapura	599.16	5.99	29.95	0.648	19.4076
7	-do-	T_46	Suragondanahalli	305.08	3.05	15.25	0.648	9.882
			Total	**3308.02**	**33.09**	**165**		**107**
8	C.N.Halli	C_6	Arlikere	590.01	5.90	29.5	0.648	19.116
9	-do-	C_12	Chattasandra	374.96	3.75	18.75	0.648	12.15
10	-do-	C_16	Dasihalli	289.42	2.89	14.45	0.648	9.3636
11	-do-	C_20	Gowdanahalli	242.78	2.43	12.15	0.648	7.8732
12	-do-	C_25	Kallenahalli	129.67	1.30	6.5	0.648	4.212
13	-do-	C_27	Karehalli	251.72	2.52	12.6	0.648	8.1648
14	-do-	C_35	Madihalli_CNH	725.56	7.26	36.3	0.648	23.5224
15	-do-	C_37	Mallenahalli	271.91	2.72	13.6	0.648	8.8128
16	-do-	C_55	Upparahalli	414.23	4.14	20.7	0.648	13.4136
			Total	**3290.26**	**32.91**	**165**		**107**

*It is proposed 5 borewells per sq.km

** Unit draft for the proposed borewells is calculated as Discharge (1.5 lps) X Hours pumped in a day (4 hrs) X 300 days in a year.

Watershed management practices such as contour bunding, check dams, gully plugs, percolation ponds, etc. are also recommended for sustainable ground water management in these villages. At the same time, 200 m spacing between two pumping borewells needs to be maintained to avoid mutual interference. Drip and micro-irrigation techniques are also to be adopted on large scale to increase the irrigation efficiency.

7.1.2 Implementation plan with no further ground water development and with management practices

It is observed that the depth to ground water levels at certain places is more than 100 m bgl. It reflects the severe ground water stress conditions in those villages. The borewell yields also havereduced over the years. These areas/villages need careful ground water use for sustainability. The following mitigation measures are recommended.

7.1.2.1 Supply side measures

- These are water harvesting measures, water retention measures and protection of natural recharge.
- Structures include recharge wells, percolation ponds, contour bunding, check dams, gully plugs and sub-surface dams to get positive results. Maintenance of structures is very much essential
- Use of organic material improves the soil health and capacity of the soil to retain moisture. The organic materials include cow-dung, compost, vermi-compost and green leaves, etc. Water harvesting and water retention also reduces flooding risks.
- Safeguarding natural recharge

  It is observed that most of the minor irrigation tanks are silted up over the years. The infiltration tests conducted in these tanks revealed a very poor infiltration rates. To safeguard the natural recharge from these tanks, de-siltation of these tanks should be taken up on priority.
- Unscientific sand removal from stream courses and river beds are to be banned or regulated. Sand removal lowers drainage lines in the area and induces more outflows from the aquifers. It reduces the capacity to store water in the sand of the river bed and recharge local groundwater resources.

7.1.2.2 Demand side measures

Demand side measures reduce the demand for ground water and facilitate efficient water use measures through land levelling, field bunding, drip irrigation, sprinkler irrigation, soil moisture conservation, use of compost, mulching, ploughing, etc.

The drip irrigation is mostly used for horticulture crops in the area (Coconut and Areacanut). It can be used for fertigation also (application of fertilizers in irrigation water). The drip irrigation increases the irrigation efficiency up to 90%. There is a need to promote micro-irrigation in the area. Presently, Government of Karnataka through Horticulture Department is giving subsidy up to 90% for drip irrigation.

Change in cropping system reduces water demand. Farmers may change to profitable low water use crops, instead of high water use crops such as Banana, Sugarcane and Paddy.

In the study area, under ground water irrigation, perennial crops like coconut and areacanut are grown. There is little or no scope for change of cropping pattern. However, it is recommended that in future low water intensive crops can be grown in the new areas and also the existing coconut crop areas can be replaced after certain years with low water intensive crops. The taluk wise list of villages where there is no scope for further ground water development is given in Table 7.3and shown in Fig. 6.24.

Table 7.3: Taluk wise list of villages for no further ground water development

Sl.No.	C.N.Halli Taluk		Tiptur Taluk	
	Village Name	Village Code	Village Name	Village Code
1	Agasarahalli	C_1	Adinayakanahalli	T_1
2	Ajjenahalli	C_2	Alur	T_2
3	Anekatte	C_3	Bhairanayakanahalli	T_5
4	Ankasandra	C_4	Bhairapura	T_3
5	Ankasandra kaval	C_5	Bidarekatti	T_6
6	Bachihalli	C_7	Chaudlapura	T_10
7	Ballenahalli	C_8	Chaulihalli	T_8
8	Benakanakatte	C_9	Chikka marapanahalli	T_9
9	Bete Ranganahalli	C_10	Dasanakatte	T_11
10	Bevinahalli	C_11	Dodda marapanahalli	T_13
11	Chikkenahalli	C_13	Doddakatte	T_12
12	Chunganahalli	C_14	Gatakanakere	T_14
13	Dabbeghatta	C_15	Gedlahalli	T_16
14	Dibbadahalli	C_17	Gowdanakatte	T_15
15	Diggenahalli	C_18	Halenahalli	T_17
16	Dugudihalli	C_19	Halkurike kaval	T_20
17	Gerehalli	C_21	Harachanahalli	T_21
18	Gopalanahalli	C_22	Harisamudra	T_22
19	Hesarahalli	C_23	Hosahalli_TPT	T_23
20	Kadenahalli	C_24	Hurlihalli	T_24
21	Kamalapura	C_26	Irlagere	T_25
22	Katenahalli	C_28	Jakkanahalli	T_26

Sl.No.	C.N.Halli Taluk		Tiptur Taluk	
	Village Name	Village Code	Village Name	Village Code
23	Kedagihalli	C_29	Kallakere	T_27
24	Kodalgara	C_30	Kambadahalli	T_28
25	Kuppuru	C_31	Kenchamaranahalli	T_29
26	Kurubarahalli_1_CNH	C_32	Kodagihalli	T_30
27	Kurubarahalli_2_CNH	C_33	Kugihalla	T_31
28	Madapura	C_34	Lakshmanapura	T_32
29	Makuvalli	C_36	Mallidevihalli	T_33
30	Manchasandra	C_38	Manakikere	T_34
31	Marasandra	C_39	Misetimmanahalli	T_36
32	Mathighatta	C_40	Muddenahalli	T_37
33	Melanahalli	C_41	Nelagondanahalli	T_38
34	Navule	C_42	Paragondanahalli	T_39
35	Pemmaladevi	C_43	Ramanahalli	T_40
36	Pinnenahalli	C_44	Rangapura	T_41
37	Pura	C_45	Sarathavalli	T_43
38	Sasalu	C_46	Siddankatti	T_44
39	Savsettihalli	C_47	Singenahalli	T_45
40	Settikere	C_48	Timmalapura	T_47
41	Siddaramanagara	C_49	Timmarayanahalli	T_48
42	Somalapura	C_50	Vaderahalli_TPT	T_49
43	Tagachighatta	C_51	Vasudevarahalli	T_50
44	Tammadihalli	C_52	Virupakshapura	T_51
45	Tarabenahalli	C_53		
46	Tigalanahalli	C_54		
47	Vaderahalli_CNH	C_56		
48	Yerehalli	C_57		

7.1.2.3 Participatory ground water management (PGWM)

It is expected that ground water resources can be managed in a better way through participatory approach. The concepts like "Know your aquifer" and "Manage your aquifer" are ideal to have optimum result in management. The concepts involve an understanding of the resource availability and to prepare the road map for utility including the monitoring mechanism.

These are described below.

a) Introduction to the local ground water situation

In the study area due to increase in number of borewells, ground water is being over-exploited from deeper aquifers upto 200 to 250m bgl. At certain places, the ground water level is more than 100 m bgl. The ground water is under stress in the area.

b) Local Regulation in Groundwater Management

Groundwater users often have no idea how much groundwater is available. The common 'belief' is that the groundwater isinexhaustible. Most wells are owned by individual families or small groups. The ground water resources are typically shared by many independent users. Local regulation is necessary because, (i) there are large numbers of small ground water users and makes it difficult to manage, (ii) required infra-structure for enforcing regulation does not exist in these areas. Whatever enforcement is there, it needs to be routed in local acceptance and (iii) there is no evidence that top down regulation (laws, well registration, user rights and ground water pricing) have worked anywhere on their own.

The examples that exist are still few. They now mainly concern on (i) shallow aquifers (ii) Management of water quantity – not water quality and (iii) management of small aquifer systems – not of large unconfined aquifers. Most examples are 'home-grown'. They have developed 'against the odds' without any outside support. Hence, promoting participatory groundwater management (PGWM) is essential to promote sustainable management.

c) Wise Groundwater Use

Wise ground water use consists of mitigating measures. The mitigating measures are (i) Supply measures and (ii) Demand measures.

Supply measures

- These measures will augment ground water supply. These are water harvesting measures, water retention measures and protection of the natural recharge.
- The water harvesting measures includes recharge wells, percolation ponds, contour bunding, check dams and gully plugs and sub-surface dams. These measures are to be implemented at sufficient density so that the positive results are noticeable. Maintenance of structures is very important which includes removal of silt from recharge beds.

- Use of organic manure will improve the soil structure and capacity of the soil to retain moisture. The organic materials include cow-dung, compost, vermin-compost and leaves, etc. Water harvesting and water retention will reduce flooding risks but, may also affect downstream availability of water. This impact needs to be considered.
- Safeguarding natural recharge - It is observed that most of the minor irrigation tanks are silted up over the years. The infiltration tests conducted in these tanks revealed that the infiltration rates are generally poor due to siltation. To safeguard the natural recharge from these tanks, desiltation of these tanks should be taken up on priority.
- Also **o**ne need to make sure that the natural recharge is safeguarded by avoiding sand mining in the area in streams and river beds. Indiscriminate sand and gravel mining affects groundwater availability. It lowers drainage lines in the area and induces more outflows from the aquifers. It reduces the capacity to store water in the sandy river bed .Retention of sand bed also helps to prevent flooding in rivers. Sand and gravel mining therefore need to be regulated

Demand measures

- Demand side measures reduce the demand for ground water and facilitate efficient water use measures through land levelling, field bunding, drip irrigation, sprinkler irrigation, soil moisture conservation, use of compost, mulching, ploughing, etc.
- The drip irrigation is mostly used for horticulture crops in the area (Coconut and Areacanut). It can be used for fertigation also (application of fertilizers in irrigation water). The drip irrigation increases the irrigation efficiency up to 90%. There is a need to promote micro-irrigation in the area. Presently, Govt. of Karnataka through Horticulture Department is giving subsidy up to 90% for drip irrigation.
- Change in cropping system reduces water demand. Farmers may change to profitable low water use crops, instead of high water use crops such as Banana, Sugarcane and Paddy.
- In the study area, under ground water irrigation, perennial crops like coconut and areacanut are grown. There is little or no scope for change of cropping pattern. However, it is recommended that in future low water intensive crops can be grown in the new areas and also the existing coconut crop areas can be replaced after certain years with low water intensive crops.

d) Promoting Micro Planning

Micro planning is required to identify measure – both in local regulation and local investment and to create peer efforts. Promoting micro planning needs raising awareness among stake holders, preparing action plan and to create peer network. Raising awareness needs training, problem analysis, discussion on legal and institution arrangements, etc. The micro planning requires to identifying water related problems, how these problems are linked to one another, their causes and effects. It also requires to identifying the solutions to the problems like types of crops grown, type and number of borewells to be constructed, conditions of tanks, depth to water table, quality of ground water, etc., in the village/area. The micro planning requires the preparation of simple water balance of the area based on the rainfall, types of crops grown, domestic water demand, etc. Micro planning should also include maintenance of water structures which are to be endorsed by local Panchayats.

e) Participatory Groundwater Monitoring

The Participatory Hydrological Monitoring (PHM) refers to set of activities carried out to keep track of the changes in a hydrological cycle by the users themselves with little input from outsiders. The objectives of PHM are about rainfall, ground water draft, and depth to ground water level relationships. Water use plans are evolved by the community, based on the utilizable ground water resources and people managed ground water systems.

The stakeholders in ground water management are farmers (men and women), drinking water users, other ground water users, government departments and local Panchayats. The PHM process requires awareness raising, delineation of watershed/aquifer system, water resource inventory. The water resources inventory includes inventory of surface water resources, number of borewells drilled in the village /area, types of crops grown, number of acres irrigated, status of ground water development, etc.

The PHM process includes setting up of the monitoring of rainfall (if rain gauge station available), display of daily rainfall on board, identification of defunct dug well/borewell for ground water level monitoring, display of ground water level on the board, etc. The PHC process also requires the training of local people in monitoring of rainfall and ground water level and display the same which requires farmer capacity building.

The PHM process also has to take up crop water budgeting which is the centre piece of PHM and concerns the preparation of common crop plan in line with expected ground water availability.

The objective and expected outputs of Crop Water Budgeting (CWB) are (i) updated base line resource inventory information, (ii) groundwater use in kharif quantified, (iii) groundwater need for rabi crops quantified and (iv) groundwater balance for rabi projected based on PHM data, resource inventory and crop plan.

The activities involved in Crop Water Budgeting (CWB) are (i) crop water budgeting workshop – finalizing crop plans, (ii) support in agricultural extension (suggestion alternative less water demanding crops) and (iii) adoption Survey and Groundwater Balance Estimation, using results of crop adoption survey

Results for Andhra Pradesh, India

This methodology is being used in Andhra Pradesh, India and has reduced rice cultivation to less than 7% and facilitated the introduction of new high productivity crops.

f) Making Use of Water Laws

The essentials of good ground water law are it should be implemented, which relates to other processes such as surface water management, physical planning, pollution control and the processes of monitoring linked to them. There are two main categories of ground water laws, viz., enabling laws and regulatory laws. The enabling laws allow users to make rules and form own organisations. These will comply with minimum requirement. The new wells should be approved through procedures of committees. The regulatory laws determines well permits, drillers licenses, rules on well spacing, zoning rules and pumping concessions, etc. If the law is to be effective, it should be a fair and reasonable way to resolve the main water issue in the area. The law should be widely known and acceptable to all.

g) Awareness Building in Water Management

The awareness raising is important in supporting participatory processes. It develops self-regulating water institutions. Awareness building is to be given communities to establish and improve local institutions for the management of water resources. Planning awareness campaigns requires a good strategy which depends on sound knowledge of physical, social and cultural circumstances of the target groups. Try using existing channels of communications to enhance appeal and become the talk of the town. Awareness rising should be seen as an interactive movement in which as many stockholders as possible are involved.

In addition, the following management practices/methods are recommended for sustainability of ground water resources in the study area.

- **New Coconut/Aracanut crops should be discouraged:** In future, perennial crops like coconut and areacanut and water intensive crops like paddy and banana should not be permitted to grow by the farmers. Alternate low water intensive crops like groundnut, sunflower, cotton, red gram,etc. may be encouraged.
- Mulching of land surface to reduce the evaporation from soils.

7.2 RECOMMENDATIONS

The following recommendations may be followed for better aquifer management.

➢ It has been observed heterogeneity in the aquifer systems in the area. Variation in ground water yield has been observed over very small distances.

➢ For better understanding of the aquifer system, network density may be increased in similar areas.

➢ The stage of ground water development is 187% i.e., the area is over-exploited. However, during the course of study, it is observed that the development is not uniform throughout the watershed. There are stillsome pockets with scope for development, where depth to ground water levels is less than 10 m bgl. In the following villages viz., Aralikere, Chattasndra, Dasihalli, Gaudanahalli, Kallenahalli, Karehalli, Madihalli, Mallenahalli and Upparahalli in C.N.Halli taluk and Balavanerala, Bommanahalli, Halkurike, Halkurikeamanikere, Mayagondanahalli, Rudrapura and Suragondanahalli in Tiptur taluk are having some scope for further development. In the above villages, it is estimated that the additional 330 borewells can be constructed with an average unit draft of 0.65 ha.m. However, while constructing borewells minimum spacing norm of 200m between two productive borewells may be followed. Simultaneously, the management practices should also be taken up for sustainable development of ground water resources.

➢ It is recommended to de-silt all the existing minor irrigation tanks so that their holding capacity increase and increases the infiltration rates. Whenever water reaches these tanks it will augment ground water.

- There is no surplus surface water in the watershed. All the water is under utilisation. It is observed that the area is having deep to very deep ground water levels. At some places, the depth to ground water levels is more than 100 m bgl. The entire area is feasible for rainwater harvesting and artificial recharge to ground water. The sub-surface storage space availability for recharging the aquifers is 6,39,345 ha.m for raising the ground water level upto 10 m bgl. Whereas, it is 7,92,205 ha.m for raising the water up to 5 m bgl. The total amount of water required is 14,015 ha.m or 20,120 ha.m to raise the ground water levels upto 10 m bgl and 5 m bgl respectively.
- The live capacity of the all the minor irrigation tanks in the study area is 1205 ha.m. Since there is acute shortage of surface water in the study area, most of these tanks are dry throughout the year. It is recommended to bring water from Hemavathi Reservoir (adjacent basin) to the tune of 1200 ha.m/year to fill up these desilted tanks and it may be continued for several years till depth to ground water levels in the study area raises upto satisfactory level. It will improve the ground water recharge to the aquifer and facilitates the rise in ground water levels and ultimately sustainability of the ground water system.
- The deep to very deep ground water levels reflects the severe ground water stress conditions in the area. These conditions demand wise ground water use for sustainable ground water levels. The following mitigating measures – supply measures and demand measures are recommended for sustainable development of ground water resources.
- Participatory ground water management is recommended in the area for better understanding of the aquifer system and managing the aquifer by user themselves.
- In future, perennial crops like coconut, areacanut and water intensive crops like paddy and banana should not be permitted to grow by the farmers. Alternate low water intensive crops like groundnut, sunflower, cotton, red gram, etc. may be encouraged.

- The majority of farmers are practicing drip irrigation in the area. It is recommended to extend to all the farmers and to further increase the irrigation efficiency, sub-surface drip irrigation is recommended.

- Awareness may be created among farmers about the importance of mulching to reduce the evaporation loss from the soils.
- During MI Census, additional information of borewells on co-ordinates, total depth, casing length lowered, fractures encountered at various depths, and correspondingyield, area irrigated, crops grown, soil type, quality, geology, etc. are to be collected to create comprehensive database and also for better management of the aquifers.
- The current trend of chasing the declining water table in search of deeper water bearing zones has entailed high risk of drilling dry or very low yielding wells in hardrocks. Some of the farmers by drilling several borewells in their agricultural land in search of water with loans from bank/finance institutions at high interest rates pushed to permanent bankruptcy. To avoid farmers' distress, Borewell Insurance Corporation may be initiated to help the farmers.
- Some of the borewells which are successful at the time of drilling, becoming seasonal especially during summer season in drought years. To mitigate this situation, crop insurance may be implemented.

ANNEXURES

Annexure 1.1: Village wise population as per Census 2011, Titpur taluk

Sl.No.	Village Name	Village Code	Population_2011
1	Adinayakanahalli	T_1	628
2	Alur	T_2	716
3	Annapura	TP_1	Urban
4	Annemaranahalli	TP_2	664
5	Bagavala	TP_3	477
6	Baluvanerlu	T_4	1597
7	Bennayakanahalli	TP_4	1629
8	Bhairanayakanahalli	T_5	684
9	Bhairapura	T_3	604
10	Bidarekatti	T_6	-
11	Bommalapura	TP_5	865
12	Bommanahalli	T_7	419
13	Chaudlapura	T_10	211
14	Chaulihalli	T_8	785
15	Chikkamarapanahalli	T_9	440
16	Dasanakatte	T_11	642
17	Doddamarapanahalli	T_13	420
18	Doddakatte	T_12	181
19	Gatakanakere	T_14	802
20	Gedlahalli	T_16	847
21	Gowdanakatte	T_15	765
22	Gudigondanahalli	TP_6	819
23	Halenahalli	T_17	1150
24	Halkurike	T_18	2984
25	Halkurike amani kere	T_19	188
26	Halkurikekaval	T_20	53
27	Harachanahalli	T_21	490
28	Harisamudra	T_22	454
29	Hosahalli_TPT	T_23	197
30	Hulihalli	TP_7	1237
31	Hurlihalli	T_24	308
32	Idenhalli	TP_8	1980
33	Irlagere	T_25	615
34	Jakkanahalli	T_26	1068
35	Kallakere	T_27	992
36	Kambadahalli	T_28	-
37	Kanchaghatta	TP_9	1074

Sl.No.	Village Name	Village Code	Population_2011
38	Kenchamaranahalli	T_29	17
39	Kodagihalli	T_30	683
40	Kugihalla	T_31	-
41	Lakshmanapura	T_32	682
42	Madenur	TP_10	2340
43	Madihalli_TPT	TP_11	1488
44	Mallidevihalli	T_33	259
45	Manakikere	T_34	979
46	Mayagondanahalli	T_35	356
47	Misetimmanahalli	T_36	362
48	Muddenahalli	T_37	600
49	Nayakanahalli	TP_12	420
50	Nelagondanahalli	T_38	333
51	Paragondanahalli	T_39	466
52	Ramanahalli	T_40	595
53	Ramashettihalli	TP_13	1190
54	Ramenahalli	TP_14	709
55	Rangapura	T_41	413
56	Rattenahalli	TP_15	310
57	Rudrapura	T_42	731
58	Sarathavalli	T_43	1891
59	Siddankatti	T_44	-
60	Sidlahalli	TP_16	534
61	Singenahalli	T_45	354
62	Suragondanahalli	T_46	652
63	Timmalapura	T_47	680
64	Timmarayanahalli	T_48	435
65	Vaderahalli_TPT	T_49	50
66	Vasudevarahalli	T_50	338
67	Virupakshapura	T_51	259
68	Vittlapura	TP_17	188

Annexure 1.2: Village wise population as per Census 2011, C.N.Halli taluk

Sl.No.	Village Name	Village Code	Population_2011
1	Agasarahalli	C_1	578
2	Ajjenahalli	C_2	350
3	Anekatte	C_3	619
4	Ankasandra	C_4	837
5	Ankasandrakaval	C_5	64
6	Arlikere	C_6	1027
7	Bachihalli	C_7	464
8	Ballenahalli	C_8	325
9	Bangarakere	CP_1	648
10	Belagihalli	CP_2	803
11	Benakanakatte	C_9	422
12	BeteRanganahalli	C_10	8
13	Bevinahalli	C_11	614
14	Byadarahalli	CP_3	393
15	C.N.Halli	CP_4	Urban
16	Chattasandra	C_12	290
17	Chikkenahalli	C_13	175
18	Chunganahalli	C_14	646
19	Dabbeghatta	C_15	-
20	Dasihalli	C_16	685
21	Dibbadahalli	C_17	289
22	Diggenahalli	C_18	241
23	Dugudihalli	C_19	518
24	Gerehalli	C_21	267
25	Gopalanahalli	C_22	426
26	Gowdanahalli	C_20	403
27	Hesarahalli	C_23	906
28	Hosahalli_CNH	CP_5	410
29	Jayachamarajapura	CP_6	1027
30	Jogihalli	CP_7	23
31	Kadenahalli	C_24	369
32	Kallenahalli	C_25	549
33	Kamalapura	C_26	2202
34	Kantalagere	CP_8	397
35	Karehalli	C_27	347
36	Katenahalli	C_28	-
37	Kedagihalli	C_29	-
38	Kengalapura	CP_9	1155

Sl.No.	Village Name	Village Code	Population_2011
39	Kodalgara	C_30	274
40	Kuppuru	C_31	971
41	Kurubarahalli_1_CNH	C_32	83
42	Kurubarahalli_2_CNH	C_33	-
43	Madapura	C_34	987
44	Madihalli_CNH	C_35	621
45	Makuvalli	C_36	732
46	Malagondanahalli	CP_10	563
47	Mallenahalli	C_37	355
48	Malligehalli	CP_11	-
49	Malligere	CP_12	1825
50	Manchasandra	C_38	414
51	Marasandra	C_39	398
52	Mathighatta	C_40	1843
53	Melanahalli	C_41	628
54	Navule	C_42	670
55	Pemmaladevi	C_43	10
56	Pinnenahalli	C_44	64
57	Pura	C_45	141
58	Sasalu	C_46	1658
59	Savsettihalli	C_47	484
60	Settikere	C_48	3158
61	Shavigehalli	CP_13	179
62	Siddaramanagara	C_49	172
63	Somalapura	C_50	398
64	Tagachighatta	C_51	613
65	Tammadihalli	C_52	543
66	Tarabenahalli	C_53	810
67	Tigalanahalli	C_54	405
68	Upparahalli	C_55	757
69	Vaderahalli_CNH	C_56	295
70	Yerehalli	C_57	544

Taluk wise details of villages			
Taluk	**Fully covered**	**Partially covered**	**Total**
Tiptur	51	17	68
C.N.Halli	57	13	70
Total	**108**	**30**	**138**

NOTE

C	C.N.Halli
T	Tiptur
CP	C.N.Halli - partially covered villages
TP	Tiptur - partially covered villages

Annexure 3.1: Geo-electrical parameters of VES soundings

Sl. No.	VES No.	Village	Latitude	Longitude	Ele-vation	Apparent resistivity AB/2 in ohm m					Resistivity in ohm m				Thickness in m			
						25	50	100	150	200	ρ1	ρ2	ρ3	ρ4	h1	h2	h3	H
1	A-1	Bhairanayakanahalli	13.30225	76.45933	821	182	386	857	1308	1545	95	143	480		0.5	15	18	33.5
2	A-2	Alur	13.30156	76.45233	823	82	147	272	327	390	27	64	250		1.75	16	20	37.75
3	A-3	Manakinakere	13.33967	76.47503	803	91	157	278	402	480	106	53	238		1	15	19	35
4	A-4	Bhairapura	13.35714	76.47367	781	179	404	654	910	1200	60	150	450		3.75	6	35	44.75
5	A-5	Ghatakanakere	13.35661	76.45547	794	40	84	171	276	350	50	6	238		1	4	8	13
6	A-6	Muddenahalli thanda	13.37522	76.45764	812	69	99	190	297	398	85	16	100		1.5	4	41	46.5
7	A-7	H. Muddenahalli	13.37153	76.47547	786	323	519	548	750	900	176	236	767		1.5	17	137	155.5
8	A-8	Basavarajapura	13.39211	76.47719	790	45	99	161	270	350	101	21	41		1.3	6	19	26.3
9	A-9	Kodigehalli	13.41067	76.47711	756	40	82	124	196	252	25	4.5	16		0.75	1.5	9	11.25
10	A-10	Marisiddaiahnapalya	13.40942	76.45597	773	39	70	145	220	300	10	8	14		1	2	9	12
11	A-11	Gandanakatte cross	13.39125	76.45789	803	163	242	387	220	650	112	150	263		1.5	8	60	69.5
12	A-12	Gandhinagara	13.43028	76.48311	777	750	949	1173	513	1990	1200	946	1359		0.5	15		15.5
13	A-13	Kairara Junction	13.44436	76.48319	783	653	915	1190	1502	2002	400	750	9999		1.75	56		57.75
14	A-14	kamalapura	13.43142	76.44194	789	37	63	119	1602	186	17	5	113		1.5	3.75	35	40.25
15	A-15	Rangapura	13.40972	76.43889	804	273	489	758	902	1205	145	102	245	VH	2	5	45	52
16	A-16	Kupparadoddahalli	13.28800	76.43753	836	190	230	260	330	420	150	95	226		0.75	3	100	103.75
17	A-17	Harachanahalli	13.30122	76.43514	823	86	187	411	750	1002	21	23	9999		0.75	5.5		6.25
18	A-18	Paruvagondanahalli	13.32244	76.44108	818	85	171	281	403	520	129	30	333		1.25	7.25	58	66.5
19	A-19	Manjunathanagar	13.28733	76.46722	869	67	158	248	370	503	89	25	265		0.5	7	40	47.5
20	A-20	Nelagondanahalli	13.34167	76.43889		150	96	121	152	192	52	45	146		1.75	2	76	79.75
21	A-21	D.Manjunathanagar	13.35694	76.43889		82	147	215	313	407	38	410	133		0.5	2	52	54.5
22	A-22	Mavinahalli	13.33889	76.45833		138	270	535	805	1102	57	73	172		0.75	1.5	35	37.25
23	A-23	Virupakshapura	13.32144	76.47447	823	110	223	408	510	702.15	64	69	102		0.75	1.5	24	26.25
24	A-24	Baluvaneralu	13.38072	76.41958	806	192	309	341	517	603	225	120	377		0.5	2	138	140.5
25	A-25	B. Muddenahalli	13.40436	76.41981	810	113	83	173	299	402.15	87	40	9999		1.5	20		21.5
26	A-26	Muddanayakanapalya	13.41467	76.42397	794	36	64	124	155	191	19	4	62		1.5	3	23	27.5
27	A-27	Bommanahalli	13.38900	76.44100	808	71	139	268	430	605	187	14	55		1	2	18	21
28	A-28	Dasanakatte	13.37550	76.43839	815	62	117	270	380	500	170	18	38		1	1.5	15	17.5
29	A-29	L.Gollarahatti	13.33889	76.50006	816	372	675	1100	1607	2011	306	20	401		1.5	2.5	4	8
30	A-30	H.Gollarahatti	13.35036	76.49672	794	127	252	516	848	1107	35	12	87		1	2	13	16
31	A-31	Timmarayanahalli	13.34189	76.50942	829	409	962	1489	2202	2850	162	53	208		1	1.5	10	12.5
32	A-32	Kalkere	13.31633	76.48981	810	141	264	516	795	1003	263	67	88		1	4	16	21
33	A-33	Doddamarappanahalli	13.30464	76.49114	843	244	420	979	1206	1505	101	84	271		0.75	2.75	23	26.5
34	A-34	KamalapuraTankbed	13.43267	76.43189	792	47	76	131	179	221	23	13	128		1.25	5.75	57.5	64.5

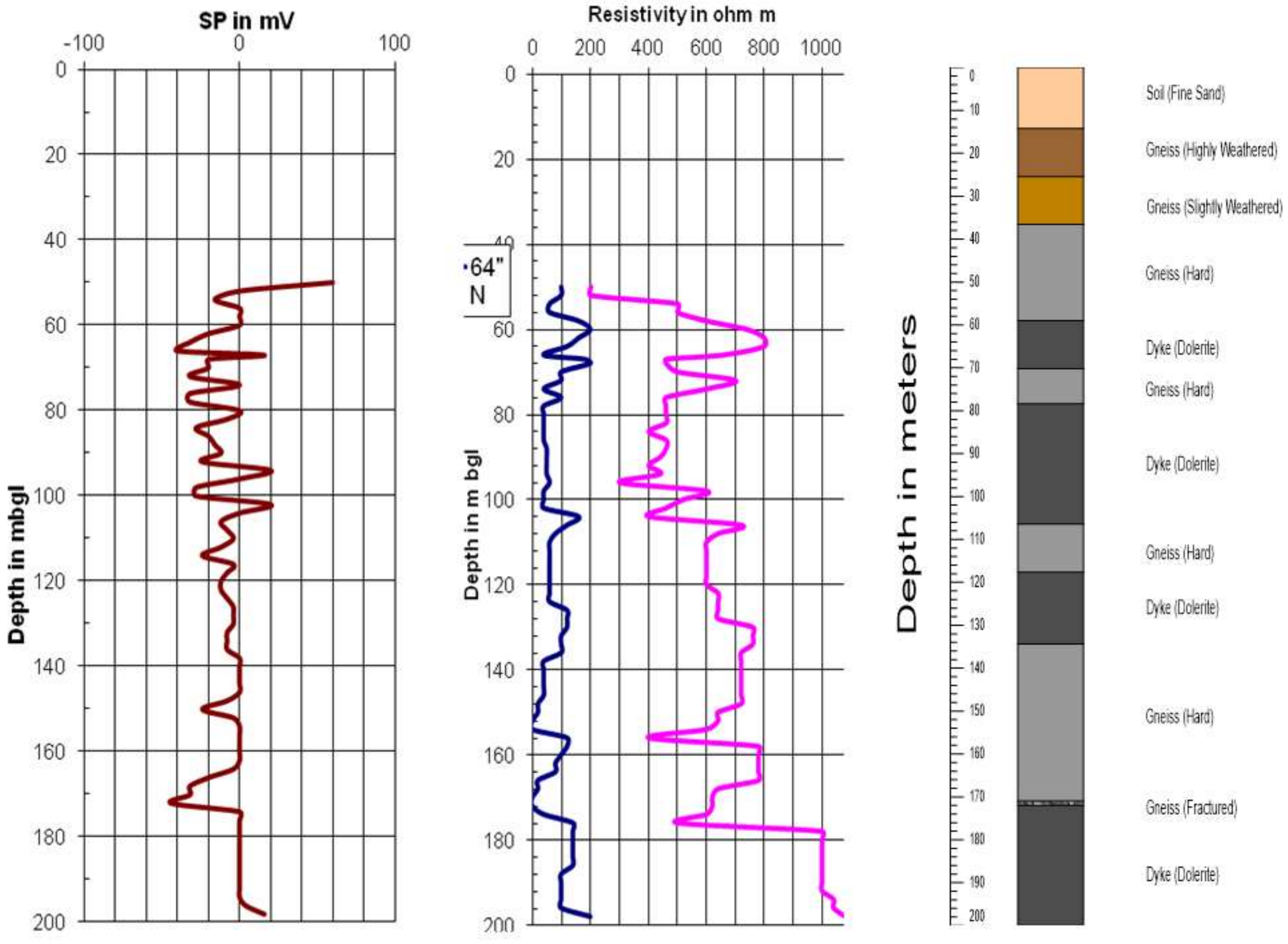
Sl. No.	VES No.	Village	Latitude	Longitude	Ele-vation	Apparent resistivity AB/2 in ohm m					Resistivity in ohm m				Thickness in m			
						25	50	100	150	200	ρ1	ρ2	ρ3	ρ4	h1	h2	h3	H
35	A-35	Daggenahalli	13.42178	76.45692	785	31	65	131	214	280	85	3	9999		1.75	4		5.75
36	A-36	Tammadihalli	13.41050	76.49589	758	24	57	116	175	240	9	3	145		1.75	4	6	11.75
37	A-37	Misethimmanahalli	13.29919	76.47814	842	230	498	741	1105	1510	92	45	450		1.5	4	24	29.5
38	B-1	Bandegetu (18.6 km stone)	13.30092	76.52956	872	236	335	1108	1666	2050	114	72.4	9999		1	6.33		7.33
39	B-2	Halkurki 1	13.31739	76.54633	866	41	82	205	314	423	69.2	30	9999		1.63	18.4		20.03
40	B-3	Gopalanahalli (bet 13 & 14 km stone)	13.33883	76.55064	812	43	95	182	229	271	29.3	11	461		2.45	4.62		7.07
41	B-4	Gopalanahalli (11 km stone)	13.35550	76.55686	798	58	121	221	283	409	44.5	38.5	1620		1.67	14.5		16.17
42	B-5	Malavalli (temple)	13.37025	76.55078	779	189	286.51	115	119	280	134	372	105		0.82	1.23	10.6	12.65
43	B-6	Dugadihalli	13.38972	76.59136	796	94	176	291	458	639	87.8	53.3	383		2.12	11.1	32.9	46.12
44	B-7	Kodigehallipalya (1 km stone)	13.40703	76.61486	803	160	258	561	647	803	90.5	54	284		1.78	3.51	13.2	18.49
45	B-8	Sasalu	13.35611	76.57311	775	77	113	192	278	367	37.4	23.6	103		0.99	4.02	24.3	29.31
46	B-9	Agasarahalli	13.35242	76.58697	798	181	365	810	1302	1331	37.2	248	9999		2.8	11		13.8
47	B-10	Agasarahalli	13.35114	76.60922	826	430	614	792	1208	1251	222	224	816	VH	1	7.5	79	87.5
48	B-11	Gerahalli	13.33736	76.60783	840	58	104	171	260	350	331	23	86		1.2	5.7	19	25.9
49	B-12	Jakkanahalli	13.30833	76.60800	849	92	158	280	409	480	69.7	51.3	219		1.3	8.66	43.4	53.36
50	B-13	Melanahalli (1 km stone)	13.44167	76.61111	768	81	109	198	311	354	25	103	53		0.6	1.36	21.7	23.66
51	B-14	Marasandra	13.42572	76.59328	763	124	192	299	516	590	23	93	1549		0.94	14.3		15.24
52	B-15	Navule	13.42686	76.57394	767	77	12	249	424	485	30.2	66.6	9999		0.73	26.8		27.53
53	B-16	Kuppulu (8 km stone)	13.42167	76.55150	754	25	57	111	159	221	3	26	9999		1.9	3.07		4.97
54	B-17	Hesarahalli	13.40972	76.55000	766	54	113	215	307	370	31.8	44	5595		1.96	16.5		18.46
55	B-18	Settikere	13.38333	76.55000	742	271	467	581	564	778	92	145	562		1.25	8	70	79.25
56	B-19	Madihalli	13.39042	76.53578	750	27	54	98	146	191	18	90	259		1.5	19	30	50.5
57	B-20	Marchahalli	13.41097	76.52908	741	81	151	249	260	319	96	112	175		1.5	25	75	101.5
58	B-21	Abhujahalli	13.42669	76.52292	737	72	102	198	318	449	25	58	131		0.5	20	40	60.5
59	B-22	Kalubhavipalya	13.37144	76.56883	759	28	54	115	171	246	15	48	250		0.5	35	65	100.5
60	B-23	Tittigoranapalya	13.36592	76.57994	796	156	328	708	1076	1182	176	101	275		1.5	10	32	43.5
61	B-24	Kodalagara	13.37422	76.59069	789	275	268	1116	1909	1683	41	47	618		1.25	3	34	38.25
62	B-25	Vaddarahatti	13.36306	76.62772	844	49	63	151	232	321	48	25	46		1.5	5	31	37.5
63	B-26	Kadenahalli	13.39167	76.65833	810	53	46	33	20	20	241	44	46		1	35	55	91
64	B-27	Tammedihalli	13.41389	76.51528	740	143	214	323	234	543	36	400	47		0.25	12.5	25	37.75

Sl. No.	VES No.	Village	Latitude	Longitude	Ele-vation	Apparent resistivity AB/2 in ohm m					Resistivity in ohm m				Thickness in m			
						25	50	100	150	200	ρ1	ρ2	ρ3	ρ4	h1	h2	h3	H
65	B-28	Chattasandra	13.45081	76.50167	751	187	271	467	660	788	143	88	246		0.5	5	46	51.5
66	B-29	Madapur	13.42761	76.49822	770	104	135	250	361	523	106	71	118		3	8.5	42	53.5
67	B-30	Banjra thanda	13.44192	76.52072	760	113	156	297	351	424	111	83	153		1.5	8	54	63.5
68	B-31	Berinahalli	13.43944	76.53019	742	81	136	234	312	396	11	250	30		0.85	6.5	16	23.35
69	B-32	Ballenahalli	13.43947	76.53019	852	234	377	769	1128	1462	40	250	347		1.25	5	34	40.25
70	B-33	Aralikere	13.44703	76.54781	821	236	452	696	694	911	70	256	461		2	11	50	63
71	B-34	Ankasandra	13.46289	76.54383	821	121	238	452	694	78	123	56	212		0.5	10	21	31.5
72	B-35	Maligehalli	13.43517	76.60431	799	385	807	1033	1177	1089	29	218	786		0.5	6	60	66.5
73	A-38	V. Gollarahatti	13.29944	76.45139		171	221	506	633	802	150	66	185	VH	0.75	4	36	40.75
74	A-39	Virupakshapura	13.31111	76.47222		91	139	288	406	520	50	28	82	VH	0.5	2	26	28.5
75	A-40	Saratvalli	13.33389	76.45222		107	141	235	328	405	97	40	106	VH	0.5	2	44	46.5
76	A-41	Manakinakere	13.33889	76.48472		169	324	472	605	710	22	56	250	VH	0.5	4	32	36.5
77	A-42	Halenahalli	13.35392	76.48656	801	230	276	430	730	1001	192	73	246	VH	1	2.5	50	53.5
78	A-43	Mayagondanahalli	13.37922	76.46981	813	247	359	550	650	801	65	167	370	VH	0.5	8.5	55	64
79	A-44	Duggenahalli	13.41875	76.46103	798	33	58	109	130	172	99	32	85	VH	1.5	28	34	63.5
80	A-45	Adinayakanahalli	13.31550	76.50103	847	275	656	964	1312	1502	125	225	455	VH	1	18	25	44
81	A-46	Doddamarappanahalli	13.29239	76.50692	871	187	358	641	995	1302	250	127	263	VH	0.5	13	25	38.5
82	A-47	Eralagere	13.33167	76.53242	839	441	868	1563	2011	2502	250	190	850	VH	0.5	7	25	32.5
83	A-48	Baluvanerulujn	13.36856	76.42617	830	62	114	238	384	502	98	20	44	VH	0.75	2	17	19.75
84	A-49	Doodanapalya	13.38814	76.41247	811	78	136	390	520	610	120	11	85	VH	0.75	2	17	19.75
85	A-50	Rudrapura	13.40236	76.41111	811	294	462	803	1105	1405	156	104	253	VH	2.5	3	28	33.5
86	A-51	Sasivalard	13.42939	76.40956	835	60	76	131	202	280	109	19	70	VH	1	5	43	49
87	A-52	Balenahalli	13.39003	76.57614	775	256	327	553	780	903	22	81	450	VH	0.5	4	60	64.5
88	A-53	Goudanahalli	13.39950	76.56003	769	110	198	351	415	510	22	81	450	VH	0.5	4	60	64.5
89	A-54	D.Kallenahalli	13.39992	76.61214	821	71	129	84	208	403	95	15	105	VH	1	3	79	83
90	A-55	Savsettihalli	13.43767	76.59772	801	618	730	894	1007	1305	265	227	721	VH	0.5	3.5	77	81
91	A-56	Bommanahalli thanda	13.38314	76.44911	817	245	346	532	690	802	405	527	245	VH	0.5	2	46	48.5
92	A-57	Marisiddanapalya	13.39747	76.45422	797	562	668	1053	1600	2103	290	441	780	VH	1	4	68	73
93	A-58	Malligererd	13.42389	76.47256	782	41	62	119	183	250	370	33	37	VH	1	14	29	44
94	A-59	Chattasandrajn	13.48972	76.49756	782	274	421	902	1302	1705	313	450	61	VH	0.5	9	14	23.5
95	A-60	Singenahalli	13.39097	76.46378	777	64	122	262	360	471	60	8	45	VH	1	2	15	18
96	A-61	Kamalapuraextn	13.43236	76.42422	813	44	81	156	210	290	65	9	47	VH	1.5	2.5	27	31
97	A-62	Hosur	13.42228	76.44189	802	40	81	162	220	285	33	12	30	VH	1.5	2.5	17.5	21.5
98	EWS-1	Sarathvalli	13.32778	76.45569	830	48	103	233	325	397	132	20	195	VH	0.75	6.5	46.5	53.75
99	EWS-2	Manjunathapura	13.35753	76.43481	822	209	269	453	650	936	210	75	350	VH	1.5	8	42	51.5
100	EWS-3	Bommenahalli	13.39789	76.44089	784	120	153	220	305	396	114	56	250	VH	4	6.5	58	70.5
101	EWS-4	Rudrapura	13.40725	76.41103	802	325	572	691	853	1161	117	25	380	VH	0.75	4	34	38.75

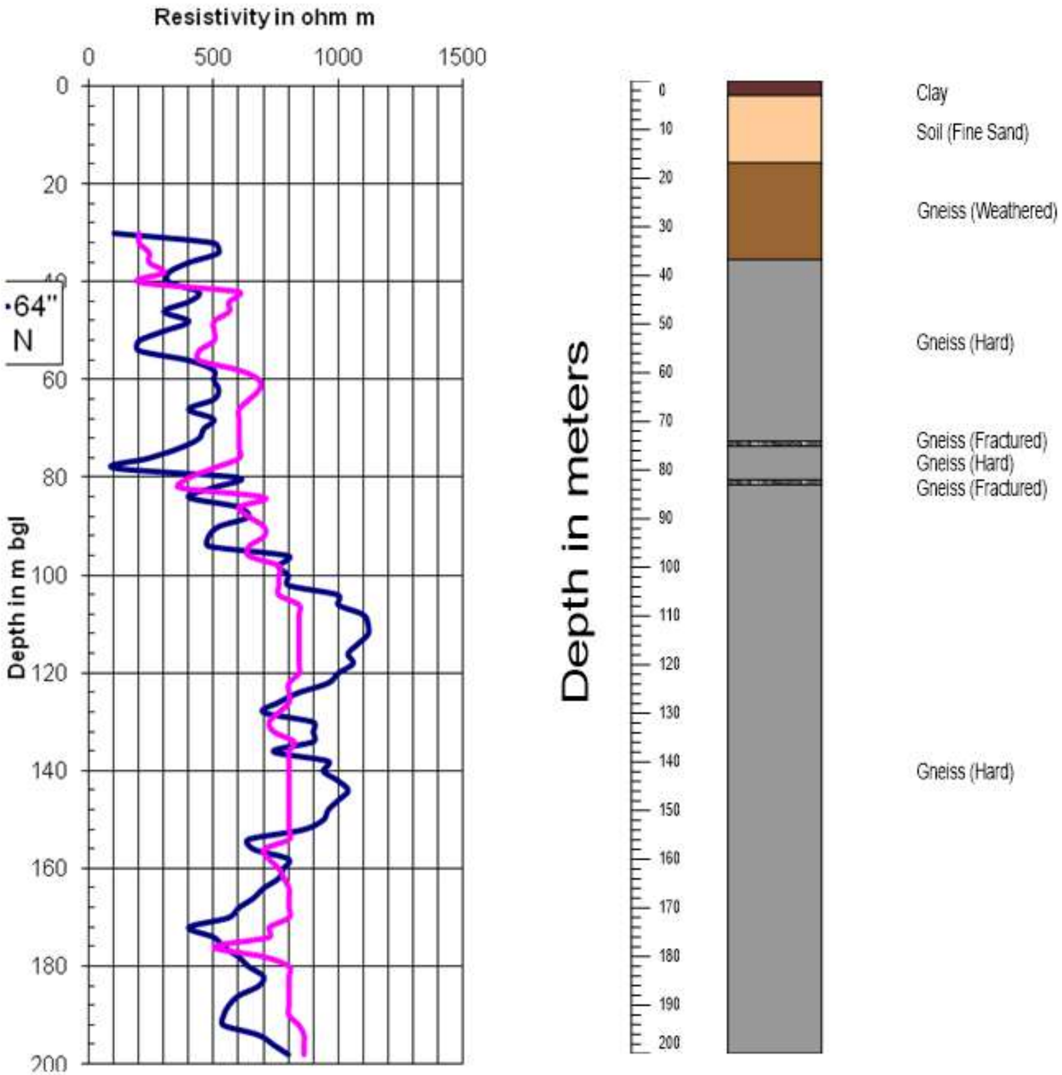
Sl. No.	VES No.	Village	Latitude	Longitude	Ele-vation	Apparent resistivity AB/2 in ohm m					Resistivity in ohm m				Thickness in m			
						25	50	100	150	200	ρ1	ρ2	ρ3	ρ4	h1	h2	h3	H
102	EWS-5	Basavarajapura	13.39767	76.47689	783	30	64	130	175	224	101	21	41	VH	1.3	6	19	26.3
103	EWS-6	Halkurke	13.37256	76.47811	792	30	47	77	157	247	40	78	155	VH	2	8	25	35
104	EWS-7	Kamalapura	13.42625	76.43981	783	263	415	705	616	664	240	156	415	VH	1	9	30	40
105	EWS-8	Madapura(thanda)	13.43756	76.49997	770	68	190	425	724	1014	65	176	308	VH	2	9	24	35
106	EWS-9	Kuppur	13.42122	76.53122	745	28	53	105	140	183	40	55	120	VH	1.5	11.5	26	39
107	EWS-10	Timmalapura	13.29448	76.43042	851	263	415	705	616	664	48	142	215	VH	0.75	11.25	37	49
108	EWS-11	Huchchanahatti	13.28578	76.48456	866	120	214	411	541	676	125	225	455	VH	1	18	25	44
109	EWS-12	Adinayakanahalli	13.32447	76.53547	816	117	171	325	465	616	124	230	350	VH	1.5	20	26	47.5
110	EWS-13	Ankasandra	13.46306	76.54222	738	29	59	135	228	280	35	60	150	VH	2.5	11.5	26	40
111	EWS-14	Navule	13.42689	76.57081	778	153	278	576	820	894	30.2	66.6	VH	VH	0.73	26.8		27.53
112	EWS-15	Melanahalli	13.42131	76.60403	790	120	215	312	440	702	125	205	304	VH	1.5	5.5	32	39
113	EWS-16	Tarabenahalli	13.37247	76.63458	843	123	220	305	389	654	126	210	320	VH	2	6	30	38
114	EWS-17	Tarabenahalli bovicoclony	13.36794	76.62894	846	117	217	443	644	820	130	85	350	VH	0.8	7.2	34	42
115	EWS-18	Siddaramanagara	13.38908	76.58825	797	99	183	269	383	450	109	76	270	VH	1	9	40	50
116	EWS-19	Siddaramanagara Temple	13.40326	76.59234	805	171	383	723	760	863	180	120	650	VH	0.5	5.5	25	31
117	EWS-20	Madihalli (Anganavadikendra)	13.38839	76.52928	770	28	52	106	159	215	40	54	110	VH	1.5	12	38.5	52
118	EWS-21	Gollarahatti	13.37736	76.54628	788	102	140	265	380	450	110	250	380	VH	1	12	37	50
119	EWS-22	Sasalu	13.35647	76.56906	776	26	59	143	237	290	37.4	23.6	103	VH	1	4	24.3	29.3
120	EWS-23	Irlagere	13.32306	76.54406	836	83	195	411	651	931	250	190	850	VH	0.5	7	25	32.5
121	EWS-24	Gopalanahalli	13.34561	76.55333	791	55	196	325	380	458	58	35	255	VH	0.5	4	55	59.5
122	EWS-25	Bandegate	13.30017	76.52583	884	220	440	650	800	1022	200	400	650	VH	0.75	5.25	25	
123	EWS-26	Duggenahalli	13.41347	76.42111	794	100	140	255	385	445	99	32	85	VH	1.5	28	34	63.5
124	EWS-27	Bharanapura	13.41844	76.44514	775	29	61	122	188	253	35	65	135	VH	1	8	23	34
125	EWS-28	Hosur(Doddikatte)	13.37425	76.53547	788	209	269	453	645	936	42	79	145	VH	1.5	7.5	31	40

Annexure 3.2: Geophysical logging of exploratory borewells along with lithologs

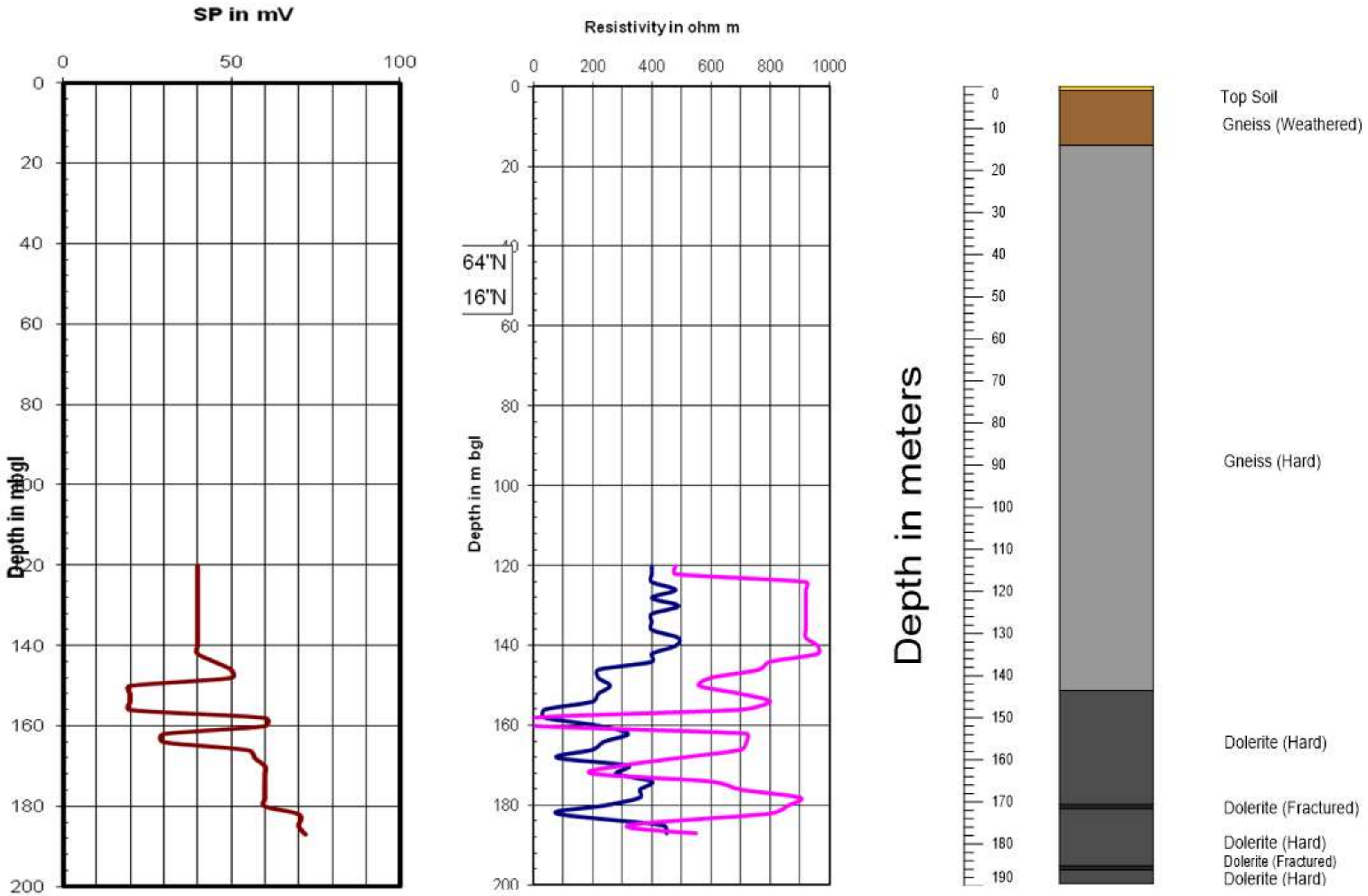
Madapurahattithanda EW site



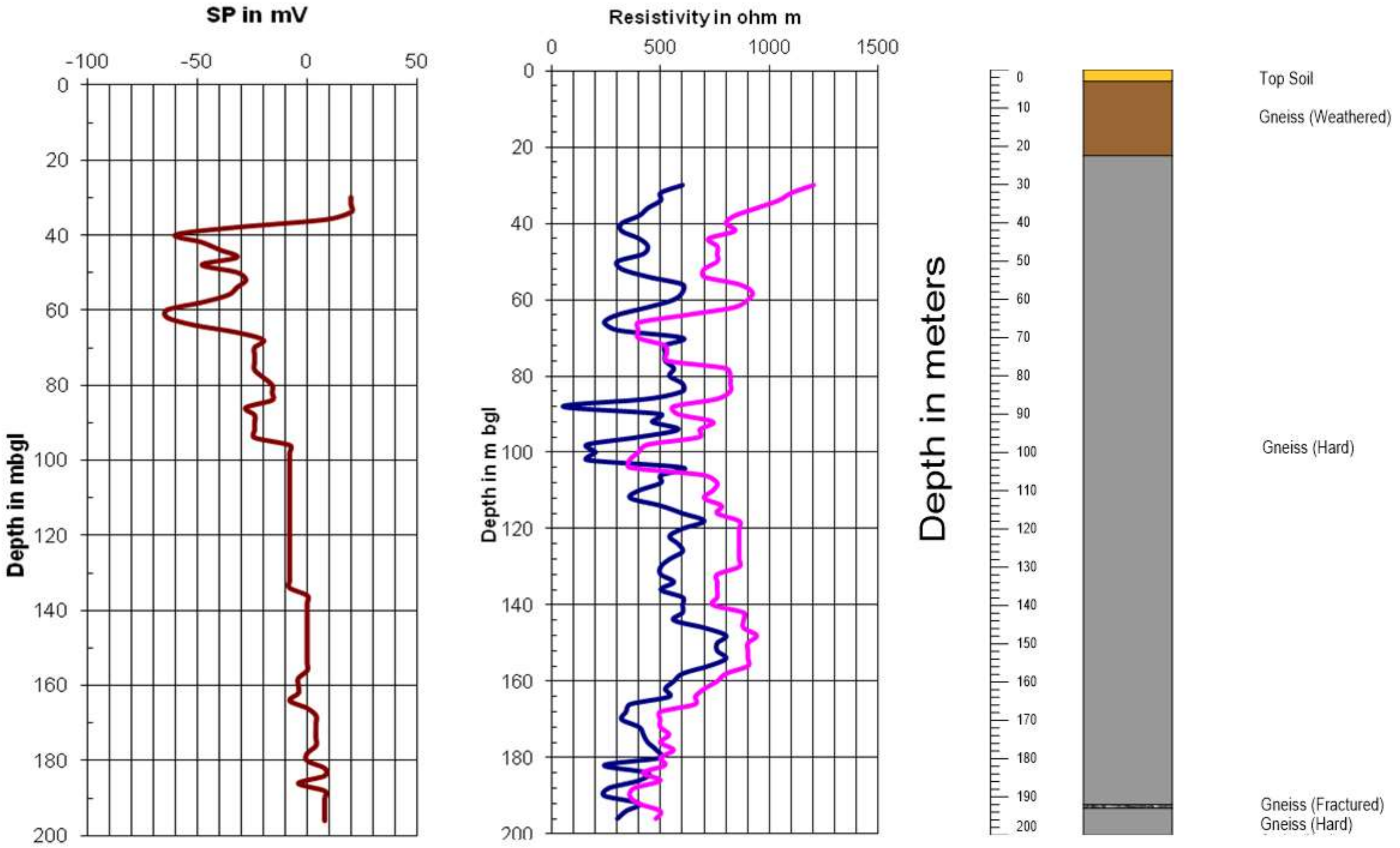
Shettikere EW site



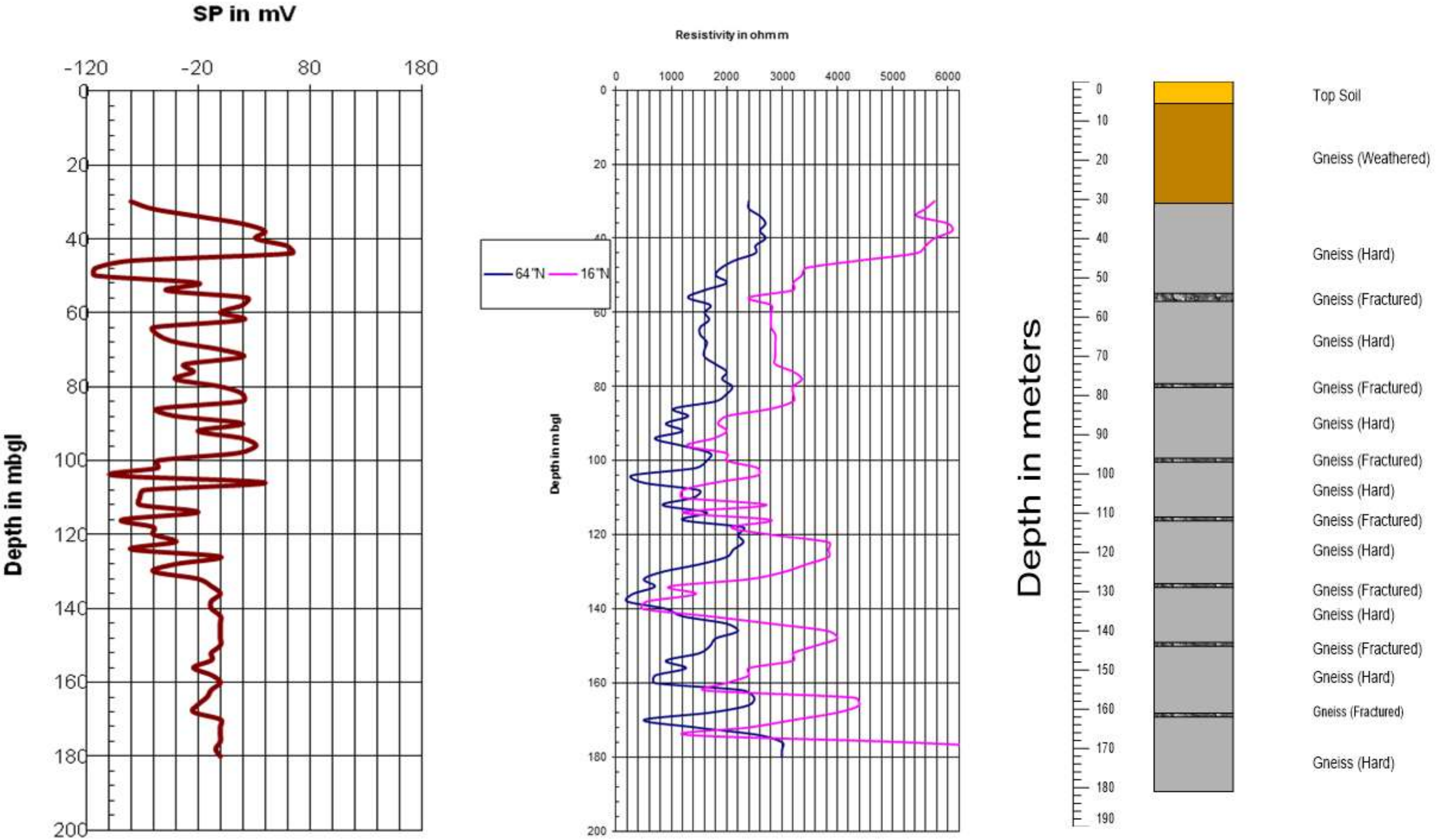
Huchanahatti EW site



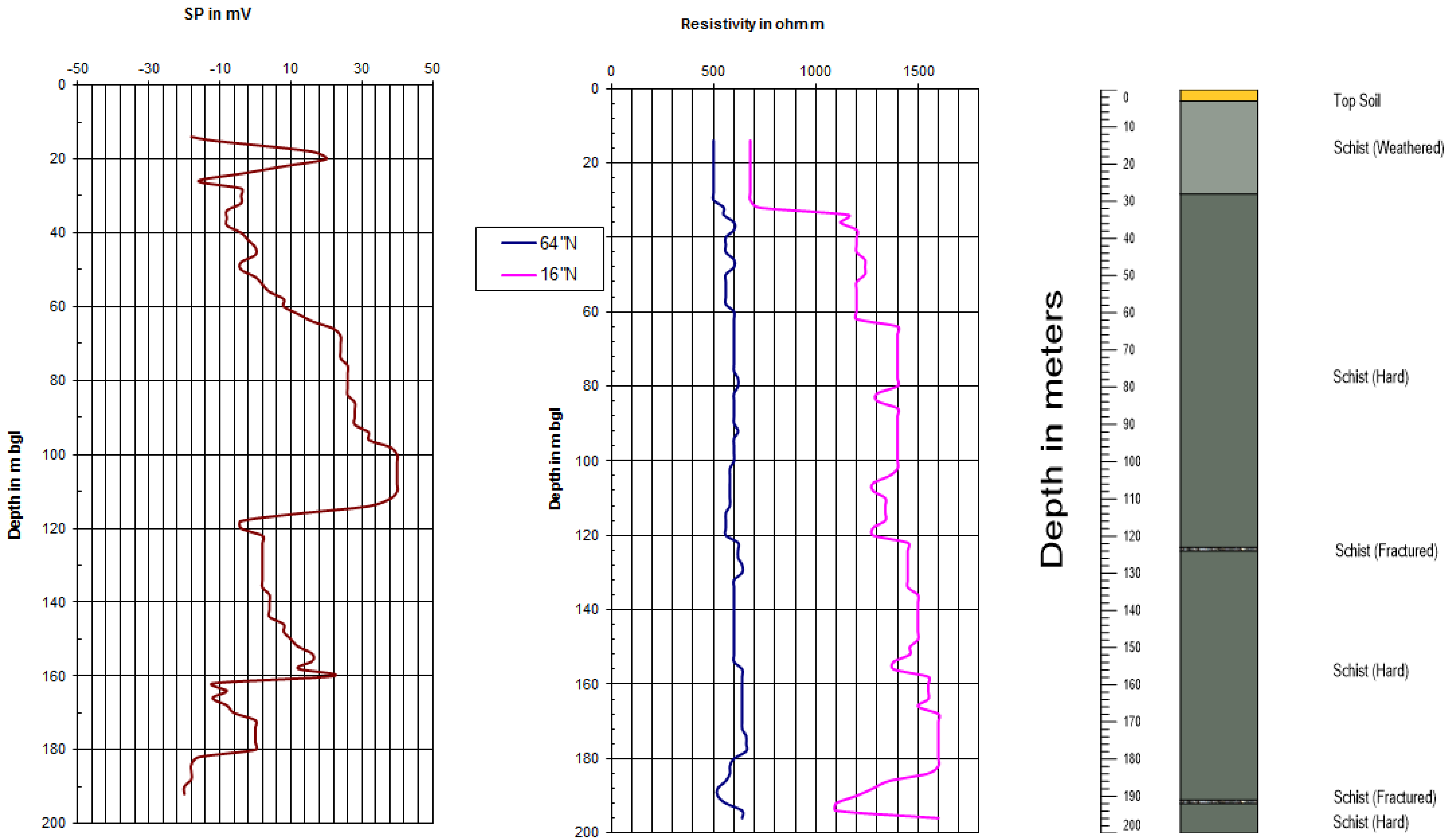
Bommanhalli thanda EW site



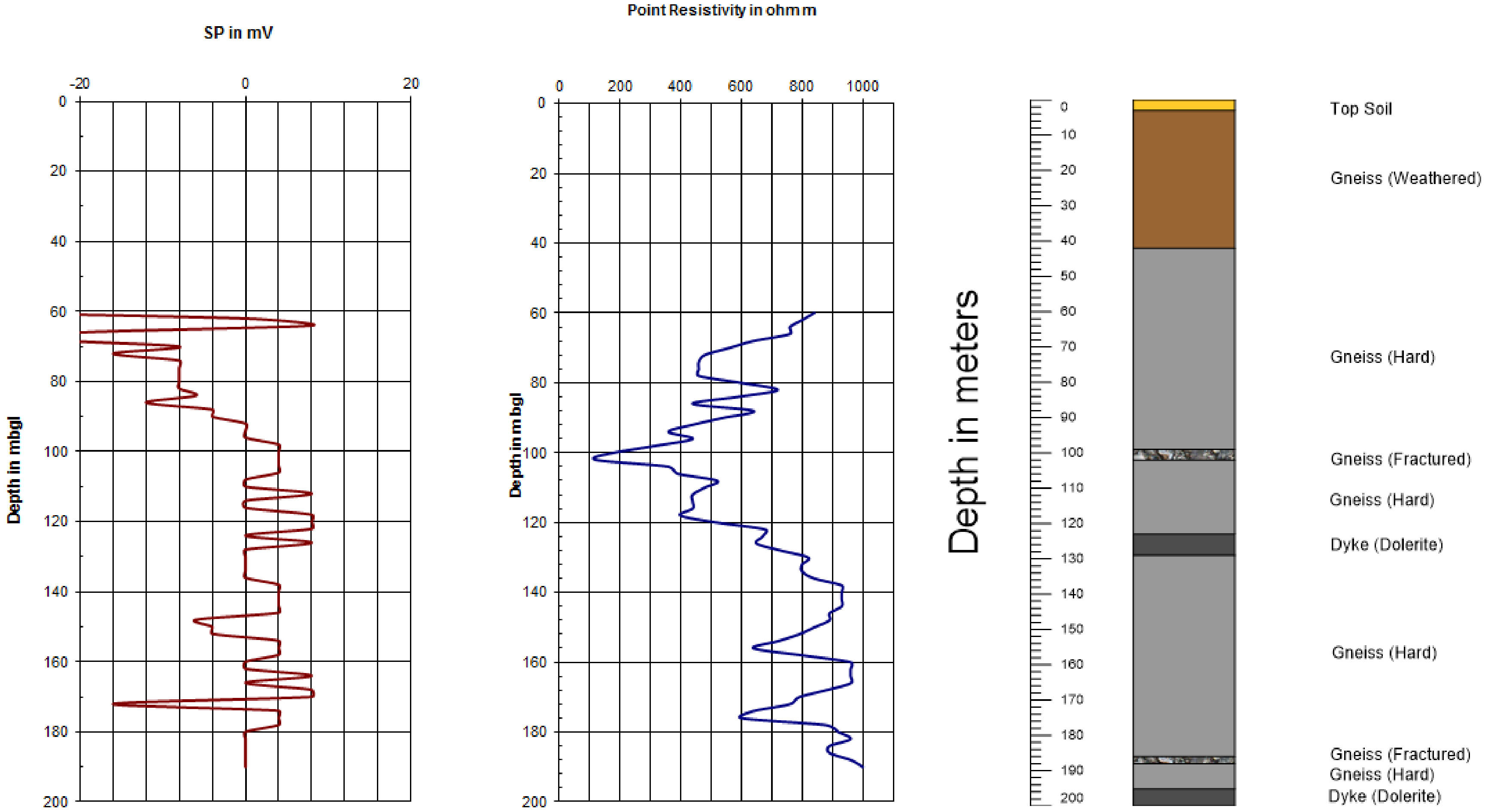
Sasalu EW site



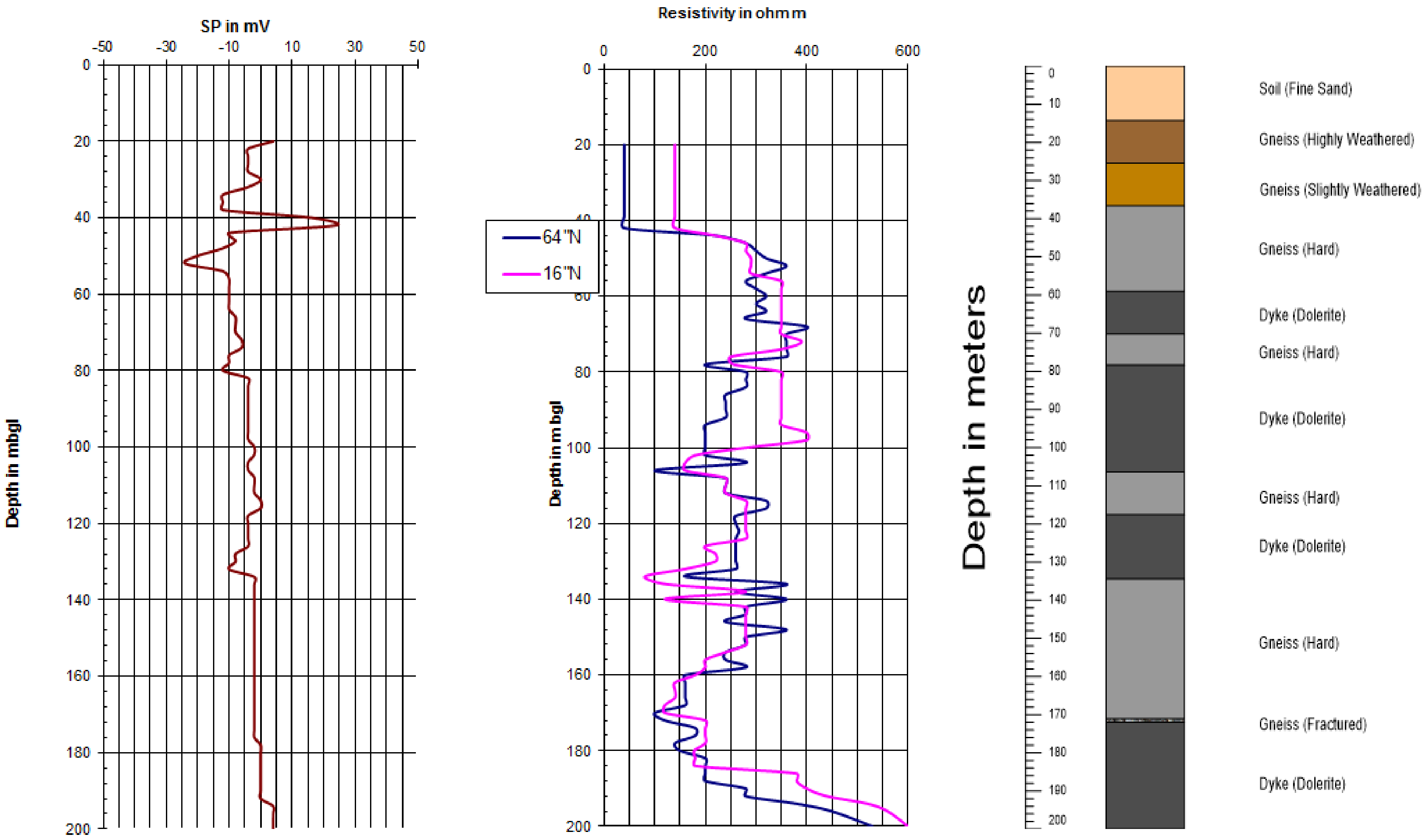
HosurEW site

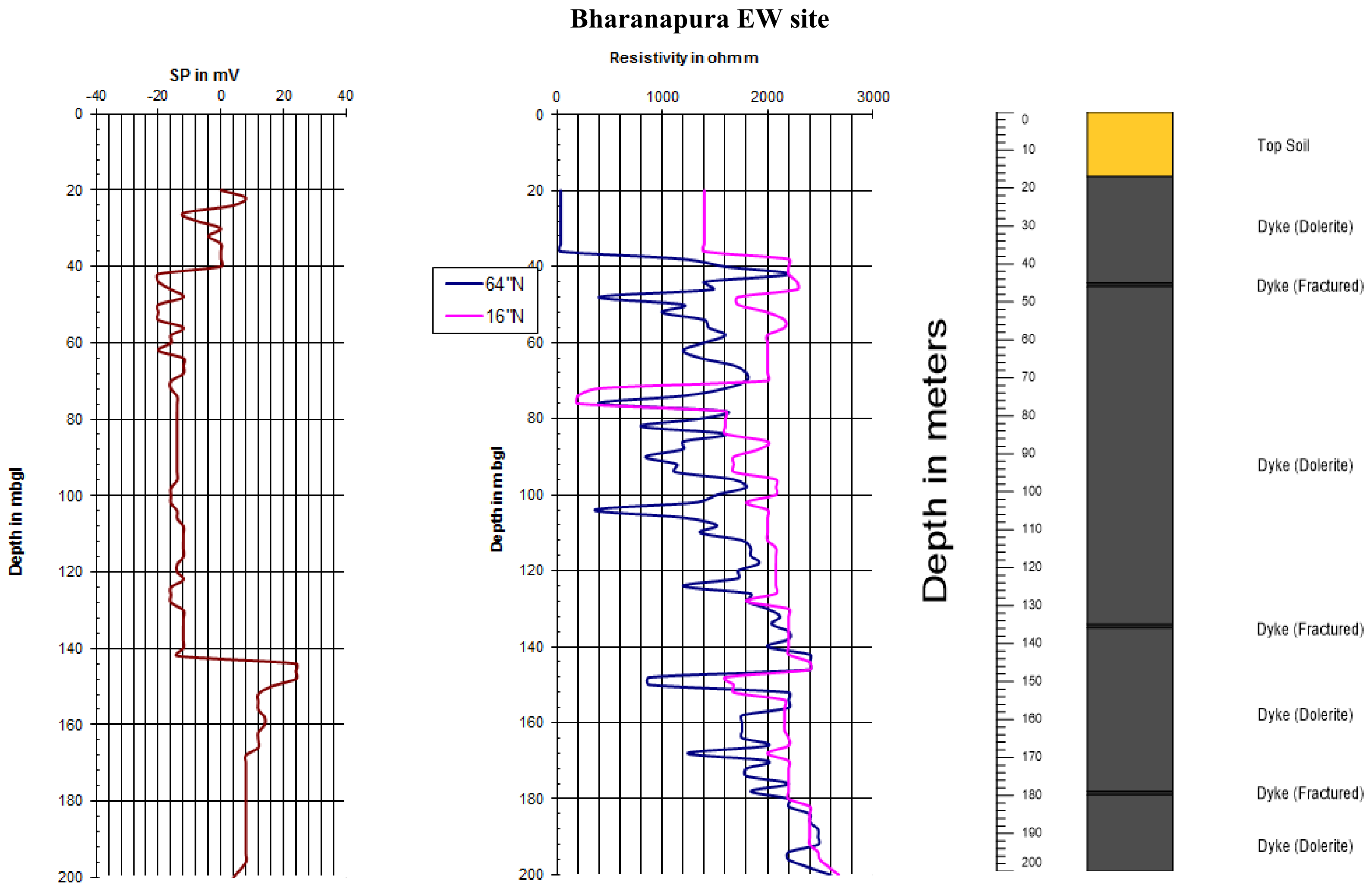


Sarathavalli EW site

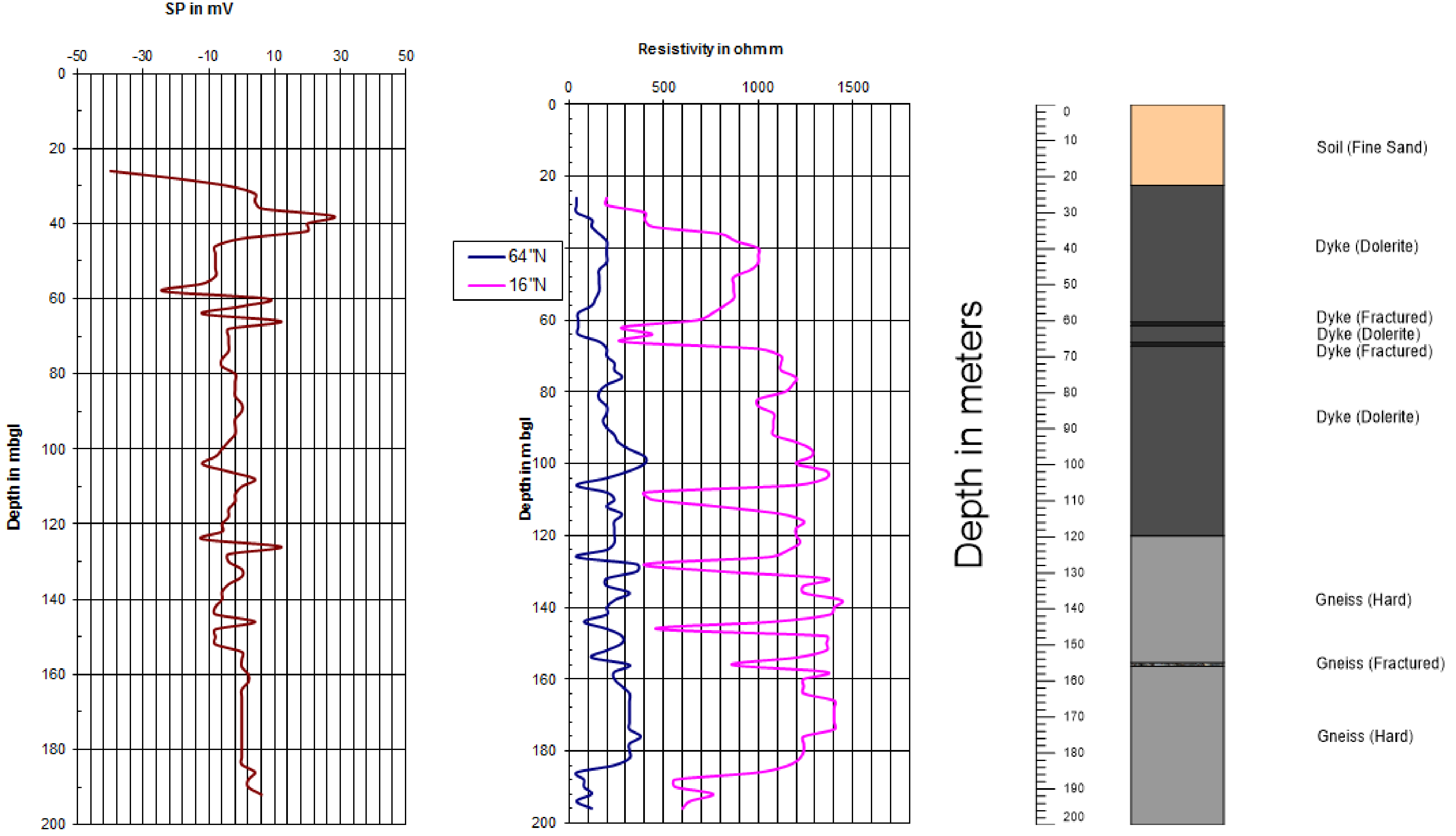


MadihalliEW site

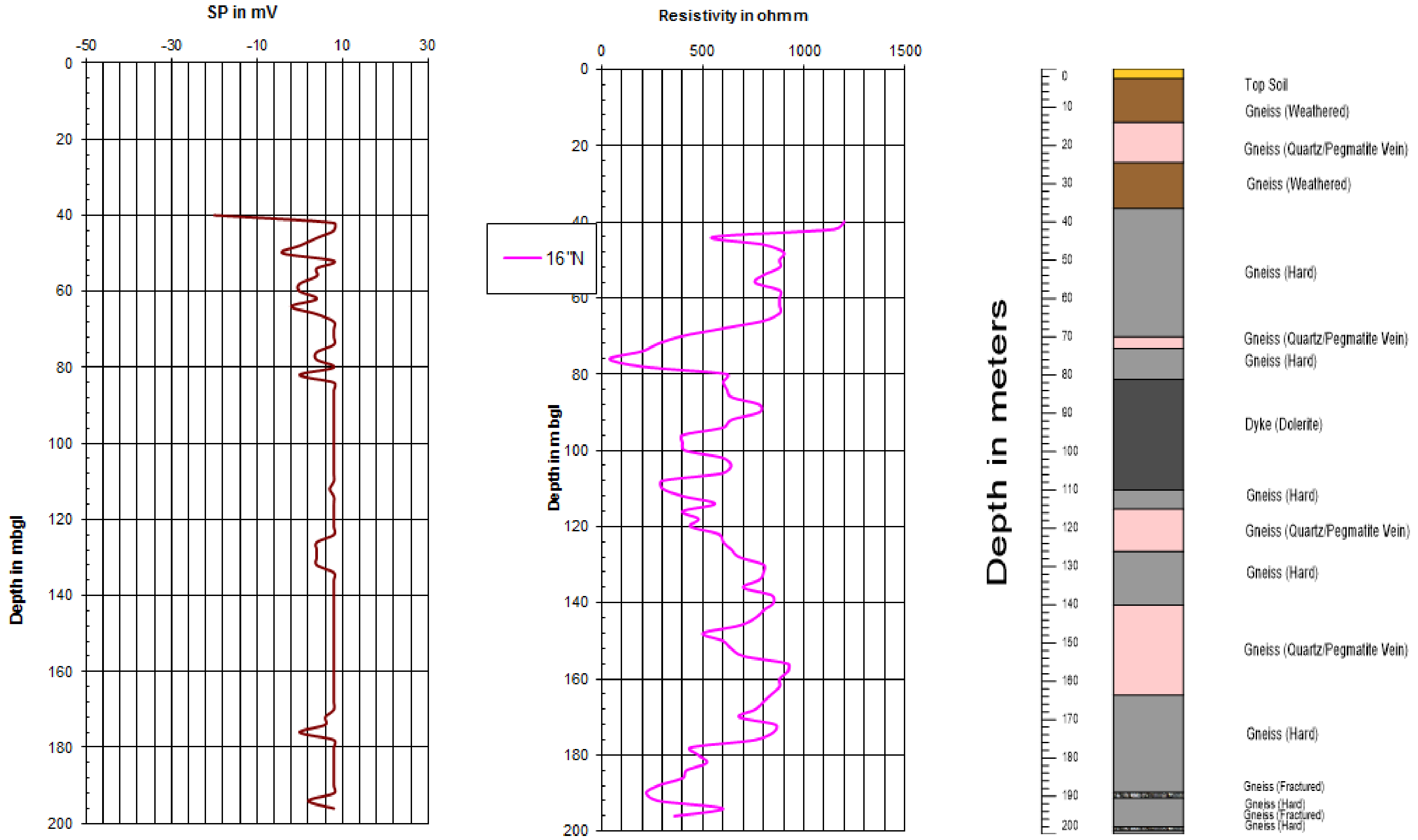



Bharanapura EW site
SP in mV
Depth in mbgl
Resistivity in ohm m
Depth in m bgl
64"N
16"N
Depth in meters
Top Soil
Dyke (Dolerite)
Dyke (Fractured)
Dyke (Dolerite)
Dyke (Fractured)
Dyke (Dolerite)
Dyke (Fractured)
Dyke (Dolerite)

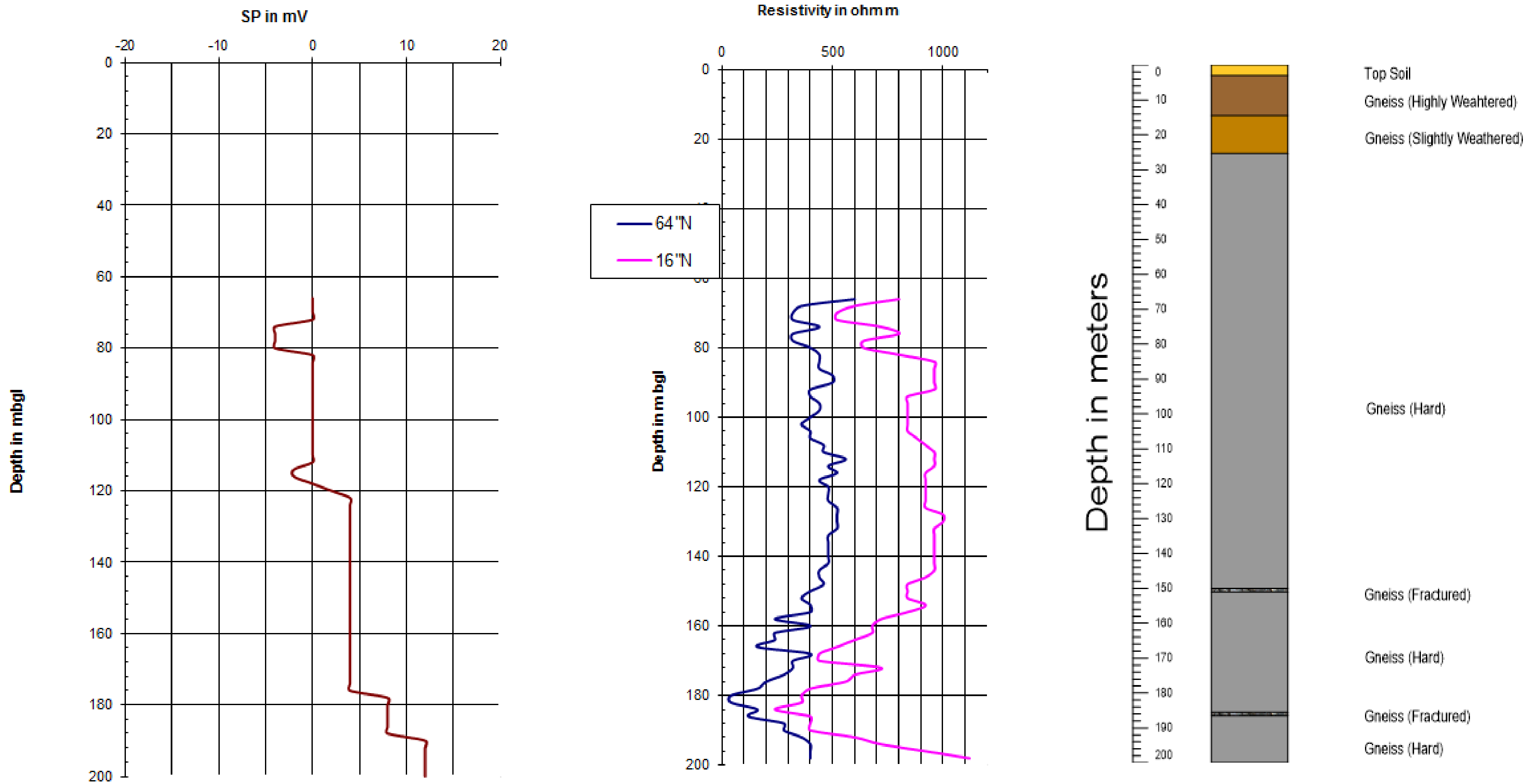
Baluvanerlu EW site



Adinayakanahalli EW site



Navule EW site



Annexure 3.3: Month-wise ground water level data of observation wells

Sl. No.	Village Name	Taluk	Well type	Lati-tude	Long-itude	RL of GL	RL of MP	MP (m agl)	Sept 2011	Nov. 2011	Jan. 2012	Feb. 2012	Apr. 2012	May 2012	June 2012	July 2012	Aug. 2012	Oct. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Feb. 2013	Mar. 2013	May 2013	June 2013	July 2013	Sept. 2013	Jan. 2014	Mar. 2014	Apr. 2014
1	Agasarahalli	C.N.Halli	HP	13.35250	76.61136	836.59	837.05	0.46	24.49	30.04	-	15.84	17.80	17.87	19.20	19.69	30.59	20.59	20.84	21.63	24.69	22.24	22.64	23.44	20.74	24.02	21.18	19.27	20.31	21.54
2	Alur	Tiptur	HP	13.31678	76.45192	805.365	805.81	0.44	35.86	30.06	30.06	32.57	36.98	36.99	42.17	38.25	39.66	55.56	63.56	51.44	56.16	63.56	63.56	63.56	52.71	54.84	88.39	87.56	74.87	83.00
3	Anekatte	C.N.Halli	HP	13.42233	76.55700	752.865	753.275	0.41	13.49	-	21.74	27.44	24.72	26.08	27.61	28.17	31.54	24.49	29.89	29.77	28.45	40.19	54.29	59.29	31.54	56.71	38.29	41.69	70.71	75.89
4	Ankasandra	C.N.Halli	HP	13.46400	76.54100	726.545	726.91	0.37	8.33	8.37	-	12.34	15.74	23.37	27.74	35.54	33.22	27.81	30.14	37.29	41.59	46.94	48.09	54.19	28.64	38.14	24.44	29.35	76.74	92.69
5	Aralikere	C.N.Halli	DW	13.44733	76.55286	742.08	743	0.92	6.33	4.24	5.90	13.86	8.15	6.64	8.03	8.48	8.98	5.78	4.78	5.78	7.00	7.88	9.08	10.68	9.33	10.53	7.14	8.47	10.83	9.98
6	Aralikere	C.N.Halli	HP	13.44469	76.55381	742.8	743.255	0.46	-	-	-	7.39	18.68	14.35	13.55	13.40	18.87	21.65	18.25	21.13	22.95	27.25	33.85	29.70	21.70	24.65	18.69	20.77	34.01	22.13
7	B.Hosahalli	Tiptur	DW	13.39550	76.43350	788.565	789.515	0.95	-	-	-	9.93	11.30	10.46	12.95	12.30	13.15	13.15	13.35	13.75	-	-	-	-	-	-	-	-	-	7.35
8	B.Hosahalli	Tiptur	HP	13.39544	76.43283	787.81	788.355	0.55	-	-	-	12.73	-	-	12.25	11.47	12.50	12.35	12.65	13.55	14.02	13.95	14.05	16.70	12.45	17.90	13.29	14.73	38.19	20.53
9	Bairapura	Tiptur	HP	13.35097	76.47497	775.66	776.35	0.69	-	-	-	18.51	6.79	16.49	17.23	7.26	19.01	13.41	13.71	16.74	13.93	23.21	21.61	31.16	31.51	33.69	6.38	35.59	41.84	44.89
10	Balavaneralu	Tiptur	DW	13.38814	76.42300	792.31	793.505	1.20	16.70	4.67	3.44	3.70	4.58	5.56	6.08	6.20	6.70	6.90	6.90	7.15	7.75	7.90	7.90	-	-	-	-	-	-	7.90
11	Balavaneralu	Tiptur	HP	13.38897	76.42275	790.635	791.26	0.63	-	-	-	8.60	4.70	7.65	6.14	6.62	6.10	6.83	6.58	7.07	7.03	7.63	9.78	8.83	8.68	8.92	7.80	9.62	11.64	11.18
12	Bandegate	Tiptur	HP	13.30400	76.53500	877.125	877.465	0.34	18.36	18.70	19.15	6.63	24.25	11.88	32.00	30.21	20.40	18.81	20.96	20.36	19.62	19.86	22.66	27.01	21.96	35.76	8.88	19.26	20.36	28.16
13	Banjara thanda	C.N.Halli	DW	13.44586	76.51917	749.93	750.84	0.91	18.09	12.17	12.90	2.04	2.40	3.09	4.19	4.54	6.19	2.99	2.84	3.38	4.14	4.29	5.19	6.54	6.19	6.60	2.46	6.19	6.94	7.29
14	Basavarajapura	Tiptur	DW	13.38389	76.45333	-	-	-	18.80	16.59	30.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.20
15	Bevanahalli thanda	C.N.Halli	HP	13.44292	76.52075	755.76	756.29	0.53	-	-	-	26.10	26.41	31.95	34.04	34.47	35.67	26.62	23.42	31.19	33.90	21.07	34.87	36.57	34.67	44.97	33.85	35.52	59.69	53.23
16	Bhairanayakanahalli	Tiptur	DW	13.29806	76.45528	-	-	-	28.50	30.50	30.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.50
17	Bharanapura	C.N.Halli	DW	13.41889	76.48194	-	-	-	30.50	8.10	8.82	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Bommanahalli	Tiptur	DW	13.39825	76.44039	778.46	779.875	1.41	15.59	2.89	3.55	3.13	4.20	3.17	5.44	5.69	6.21	6.39	6.09	6.47	7.17	7.39	7.89	8.99	9.29	9.79	8.49	9.83	10.90	8.89
19	Bommanahalli	Tiptur	HP	13.39808	76.44075	777.41	777.94	0.53	-	-	-	2.94	4.98	-	4.37	4.82	5.53	6.17	6.02	6.02	4.87	6.82	7.32	7.57	8.97	9.47	6.91	8.68	12.32	13.44
20	Bommanahalli thanda	Tiptur	HP	13.38328	76.44956	809.195	809.76	0.56	-	-	-	20.48	21.05	24.72	26.24	24.36	25.16	26.59	26.54	30.42	28.24	27.54	30.04	28.79	29.19	29.48	32.66	31.24	32.90	31.74
21	Byadarhalli	Tiptur	DW	13.34361	76.48472	-	-	-	14.90	12.52	17.37	-	-	40.42	38.00	-	-	38.00	38.30	-	-	-	-	-	58.10	39.20	23.52	-	-	-
22	Chattasandra	C.N.Halli	DW	13.44794	76.50144	755.165	756.12	0.96	17.85	5.34	8.39	5.44	6.84	6.87	8.09	10.45	9.04	7.94	7.04	7.41	7.58	8.04	9.04	9.64	9.84	10.08	7.34	8.20	9.84	10.62
23	Chattasandra	C.N.Halli	HP	13.44656	76.50119	755.8	756.22	0.42	-	-	-	10.96	11.65	-	7.18	7.58	8.83	7.98	5.43	6.11	8.86	9.28	8.28	8.88	8.78	9.15	4.55	7.70	9.69	32.61
24	Choulahalli	Tiptur	HP	13.34131	76.45953	797.195	797.615	0.42	-	-	-	21.03	29.11	22.40	29.98	-	40.68	45.38	74.58	42.08	56.48	60.68	60.68	63.13	57.28	-	45.77	83.08	89.71	74.38
25	Chunganahalli	C.N.Halli	HP	13.37597	76.58514	778.03	778.51	0.48	-	-	-	17.96	21.94	19.72	54.42	59.27	70.87	54.82	55.37	58.22	63.67	77.97	84.67	84.67	71.72	79.64	23.13	36.33	49.42	35.42
26	Dasanakatte	Tiptur	HP	13.37608	76.43367	806.895	807.38	0.49	14.92	14.42	13.30	-	26.87	21.64	27.16	24.57	28.42	29.32	26.72	20.16	31.12	35.72	39.62	41.07	41.97	45.45	24.07	27.52	27.31	49.82
27	DasihalliPalya	C.N.Halli	DW	13.42181	76.49689	754.34	755.14	0.80	15.20	14.70	16.05	3.10	3.66	4.84	6.92	8.20	9.30	5.80	3.90	4.54	5.55	6.80	8.70	10.90	10.00	10.30	8.80	9.85	10.80	10.35
28	DasihalliPalya	C.N.Halli	HP	13.42164	76.49703	754.055	754.61	0.56	-	-	-	0.61	7.30	8.39	12.19	10.89	11.74	6.74	5.99	6.74	8.13	10.99	14.64	18.59	16.99	21.34	6.28	18.06	21.77	21.87
29	Dasikere	C.N.Halli	DW	13.39194	76.54694	753.31	754.225	0.92	7.38	7.56	7.99	8.73	10.18	9.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.98
30	Dasikere	C.N.Halli	HP	13.39372	76.54781	749.365	749.825	0.46	-	-	-	-	7.58	8.85	9.82	11.04	12.64	12.09	7.94	12.82	15.42	17.64	17.74	20.94	15.74	16.69	8.64	10.54	26.12	27.64
31	Dugganahalli	C.N.Halli	HP	13.41847	76.46181	776.11	776.595	0.49	-	13.32	13.78	26.33	28.50	27.79	30.62	31.07	32.22	46.52	32.47	32.85	36.41	36.87	39.72	51.67	49.64	41.87	34.94	45.33	47.81	46.96
32	Dugudihalli	C.N.Halli	DW	13.39361	76.59778	-	-	-	13.35	14.54	20.41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	Gandhinagara	C.N.Halli	DW/NHS	-	-	778.87	779.785	0.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.29
34	Gatakanakere	Tiptur	HP	13.35386	76.45686	795.96	796.58	0.62	11.98	-	23.36	-	18.86	15.87	14.98	19.33	20.68	12.88	15.58	21.56	23.63	39.38	39.38	43.48	35.78	30.12	33.56	38.50	55.52	33.63
35	Gaudanahalli	C.N.Halli	HP	13.40100	76.56161	760.65	761.08	0.43	30.07	30.07	30.07	-	9.11	7.43	9.12	8.67	5.43	8.47	8.07	8.65	9.51	9.97	10.47	12.42	10.37	10.63	6.40	6.82	10.84	10.30
36	Gerahalli	C.N.Halli	HP	13.33861	76.60803	836.605	837.15	0.54	25.01	24.34	-	27.79	30.94	32.98	39.88	36.16	41.06	38.32	40.26	42.22	38.11	57.36	54.26	55.56	51.16	46.76	46.22	50.58	53.36	46.56
37	Gopalanahalli	C.N.Halli	PZ/DMG	13.34597	76.55317	796.825	796.825	0.00	5.35	4.86	6.53	7.91	9.04	13.36	43.40	15.23	24.22	10.85	22.10	22.32	24.86	26.60	29.15	33.35	31.55	33.40	-	-	-	-
38	Hale Bevanahalli	C.N.Halli	HP	13.43683	76.52769	737.22	737.76	0.54	-	-	-	14.23	16.60	17.14	19.76	19.81	22.01	15.11	-	-	-	-	-	-	-	-	-	-	-	-
39	Halenahalli	Tiptur	HP	13.35739	76.48575	796.38	796.99	0.61	-	-	-	11.99	9.54	11.32	12.97	11.24	14.69	11.96	13.09	14.59	14.41	18.79	19.49	19.19	15.34	20.16	14.05	20.54	27.51	24.58
40	Halkurike	Tiptur	DW	13.37414	76.47561	773.01	773.775	0.76	0.79	0.78	-	1.94	3.18	3.10	4.17	1.86	3.54	2.66	2.74	3.33	4.11	4.59	5.34	4.34	2.59	3.34	0.94	2.94	5.64	6.14
41	Harisamudra Gate	Tiptur	HP	13.31989	76.46492	799.91	800.435	0.52	-	-	-	27.46	32.74	28.95	61.29	8.83	45.74	41.73	65.83	48.28	64.48	86.13	87.98	84.48	84.48	71.30	87.48	87.48	87.48	52.98
42	Hesarahalli	C.N.Halli	HP	13.40778	76.55178	750.075	750.595	0.52	-	-	-	13.90	16.90	-	17.76	18.82	20.68	22.96	20.28	21.19	23.03	27.08	29.73	32.03	27.58	41.24	26.30	28.80	72.48	70.38
43	Huchanahatti	Tiptur	HP	13.29431	76.48919	843.65	844.03	0.38	-	-	-	24.97	-	30.07	30.44	30.90	35.74	48.32	34.02	33.98	33.92	36.32	34.82	36.02	37.57	23.37	36.48	37.88	38.36	43.42
44	Hosur (Makuvalligollarahatti)	Tiptur	HP	13.37639	76.53694	777.26	777.57	0.31	30.19	30.19	30.19	22.29	20.47	18.99	26.86	26.89	29.59	28.39	26.32	28.14	31.57	33.39	33.89	52.84	42.29	45.69	19.30	21.34	38.45	48.64
45	Hurulahalli	Tiptur	HP	13.33097	76.47461	794.765	794.935	0.17	-	-	-	34.00	44.03	47.76	90.83	59.75	55.93	45.61	47.63	45.28	-	53.73	53.73	62.28	65.03	67.83	77.99	79.98	87.83	-
46	Irlagere	Tiptur	HP	13.32761	76.53447	818.74	819.205	0.47	-	-	-	4.12	5.04	7.64	10.34	7.18	10.42	10.89	12.59	14.04	13.16	14.79	19.69	21.64	18.09	18.82	14.92	16.44	14.84	22.24
47	Kadenahalli	C.N.Halli	HP	13.38431	76.62844	810.64	811.19	0.55	15.35	19.61	20.07	25.69	27.33	-	38.90	36.35	28.65	34.15	41.85	29.83	28.09	29.15	35.35	41.55	43.40	44.25	41.23	30.55	47.59	28.95
48	Kedigehallipalya	C.N.Halli	HP	13.40547	76.61331	786.31	786.745	0.44	20.31	13.52	14.24	17.73	20.54	20.23	26.18	23.86	26.26	23.41	26.81	24.78	26.66	27.76	30.06	41.56	37.56	53.76	32.03	29.04	35.32	87.90
49	Kallakere	Tiptur	HP	13.31742	76.49006	808.735	809.355	0.62	28.78	11.37	13.91	-	20.32	20.25	19.59	17.48	15.78	17.30	16.60	16.80	16.96	17.98	18.88	21.08	20.48	20.20	12.64	14.48	17.40	3.58
50	Kallenahalli	C.N.Halli	DW	13.43247	76.56633	754.24	755.02	0.78	3.57	3.03	3.98	4.27	3.81	3.45	5.12	5.52	5.87	3.92	3.87	4.63	5.47	6.02	5.92	6.12	5.32	6.17	2.10	6.06	6.17	5.32
51	Kallenahalli	C.N.Halli	HP	13.43506	76.56617	750.375	750.84	0.47	-	-	-	20.47	23.74	27.09	20.42	23.24	30.07	15.74	16.14	20.60	24.77	29.24	28.74	30.54	24.84	35.48	15.62	17.75	40.14	30.04
52	Kamalapura	C.N.Halli	HP	13.42700	76.43853	785.385	785.815	0.43	25.62	23.54	18.75	12.71	13.84	12.54	20.57	22.37	20.85	20.52	21.47	21.63	23.44	19.32	24.77	25.37	23.27	25.17	19.76	25.28	26.73	-
53	Karehalli	C.N.Halli	DW	13.41731	76.57656	770.19	771.06	0.87	1.78	1.86	2.18	5.52	6.77	2.13	3.13	3.43	3.48	1.73	2.08	2.60	3.38	5.08	6.23	6.48	5.33	5.03	1.91	2.30	9.03	8.58
54	Karehalli	C.N.Halli	HP	13.41403	76.57831	771.48	771.965	0.49	-	-	-	5.44	4.62	4.11	5.35	6.06	5.69	4.11	3.91	4.69	6.51	7.81	9.81	9.66	9.96	10.45	4.59	5.71	12.42	12.02
55	Kaval	Tiptur	HP	13.30631	76.52231	881.225	881.72	0.50	-	-	-	21.45	26.31	28.76	25.06	23.56	26.23	26.81	65.33	28.28	39.66	40.76	26.01	28.61	25.71	31.21	23.23	27.90	32.72	27.65
56	Khaimara Junction	C.N.Halli	HP	13.44058	76.48408	787.03	787.47	0.44	21.11	-	21.72	12.68	15.74	18.84	16.89	17.51	20.21	18.99	17.41	18.86	18.78	18.76	21.11	21.66	22.36	24.74	21.37	25.39	27.78	35.12
57	Kodagihalli	Tiptur	HP	13.40286	76.47631	763.2	763.635	0.43	13.42	10.81	12.51	-	17.11	23.16	23.27	21.57	26.04	27.27	28.52	25.37	30.67	31.67	28.57	34.87	33.67	34.19	24.15	33.56	50.47	43.52
58	Kodalagara	C.N.Halli	HP	13.36981	76.60236	816.05	816.55	0.50	-	-	-	16.30	15.67	17.99	19.53	19.00	23.40	22.95	22.95	26.88	29.09	31.00	31.70	36.00	36.40	55.60	10.76	18.12	22.40	22.20
59	Kuppuradoddahalli	Tiptur	HP	13.28583	76.43892	843.19	843.715	0.52	20.28	17.38	23.93	26.95	41.80	32.11	50.24	32.80	41.78	33.53	36.08	37.95	43.14	47.58	52.18	51.08	52.58	52.03	48.65	59.95	75.60	49.28
60	Kuppuru	C.N.Halli	PZ/DMG	13.42167	76.53083	738.27	738.86	0.59	29.91	29.91	13.37	-	-	-	26.13	25.66	42.41	20.66	20.26	21.65	30.85	42.41	42.41	42.41	42.41	42.41	42.41	42.41	42.41	29.41
61	Lakshmanapura	Tiptur	HP	13.34328	76.48853	782.745	783.115	0.37	-	-	-	-	21.48	17.04	33.53	29.05	24.28	26.93	29.93	31.73	32.70	47.33	44.53	45.33	42.33	28.83	24.81	28.73	34.73	62.01
62	Madapurahatti	C.N.Halli	HP	13.43653	76.50075	773.41	773.855	0.45	-	-	-	21.50	23.25	23.63	26.29	27.00	31.55	27.50	22.70	23.79	30.61	39.35	37.95	30.41	28.75	31.91	31.18	32.66	47.71	34.45
63	Madihalli	C.N.Halli	DW	13.39389	76.53028	758.59	759.61	1.02	4.68	2.93	4.48	4.61	5.76	6.72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.68
64	Madihalli	C.N.Halli	HP	13.38828	76.52942	764.8	765.32	0.52	-	-	-	-	13.93	11.47	16.12	16.28	18.83	19.28	13.58	17.26	22.87	19.53	21.18	25.58	17.48	24.78	14.36	-	-	38.48
65	Makuvalli	C.N.Halli	HP	13.37197	76.55661	764.275	764.715	0.44	-	-	-	10.77	8.99	11.34	16.11	8.31	19.38	17.56	18.66	20.74	23.11	33.76	35.71	32.26	21.71	47.91	25.80	28.72	31.92	46.88
66	Manakikere	Tiptur	HP	13.33694	76.48222	794.645	795.29	0.64	-	-	-	-	37.26	41.48	50.01	44.91	87.36	87.36	53.06	50.86	48.70	53.48	56.01	50.98	-	-	-	-	-	-
67	Manchasandra	C.N.Halli	HP	13.40992	76.53019	751.185	751.72	0.54	9.31	8.08	11.29	-	15.30	14.44	17.76	18.51	23.16	18.81	18.31	19.69	24.56	23.76	25.76	37.16	32.61	29.72	23.20	32.06	40.36	31.56
68	Manjunathapura	Tiptur	HP	13.35806	76.43364	819.975	820.475	0.50	5.30	5.86	-	12.02	13.16	15.96	16.56	15.90	16.63	17.78	18.60	19.06	19.96	34.20	35.70	39.60	34.20	24.45	25.33	34.60	33.26	27.20
69	Mayagondanahalli	Tiptur	DW	13.38311	76.46667	786.62	787.475	0.86	15.65	13.57	14.97	-	6.19	4.19	5.52	5.24	5.04	2.84	2.39	3.18	4.44	4.94	5.84	7.14	4.84	5.00	1.47	4.64	6.54	7.39
70	Mayagondanahalli	Tiptur	HP	13.38450	76.46744	779.465	779.95	0.49	-	-	-	-	3.38	4.42	5.41	7.46	5.71	2.21	0.66	1.41	2.75	3.21	4.51	6.61	5.61	5.75	-0.49	3.72	4.70	8.43
71	Melanahalli	C.N.Halli	HP	13.42128	76.60425	775.095	775.585	0.49	7.46	7.93	-	15.16	18.39	15.86	22.63	22.76	25.26	21.93	23.91	25.27	41.44	41.71	35.41	37.26	28.86	84.51	39.37	42.47	80.51	64.11
72	Misetimmanahalli	Tiptur	DW	13.30750	76.48056	-	-	-	19.65	19.17	21.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
73	Muddanayakanapalya	Tiptur	DW	13.41517	76.42692	797.37	798.23	0.86	-	-	-	5.24	6.57	6.59	7.29	7.54	7.94	8.14	7.44	7.49	8.05	7.94	8.14	9.39	7.24	7.94	3.14	5.21	5.94	6.79
74	Muddanayakanapalya	Tiptur	HP	13.41817	76.42606	791.445	791.88	0.43	-	-	-	2.57	1.80	1.81	2.47	2.62	2.79	2.52	2.07	2.35	2.95	3.02	3.27	3.67	2.57	2.85	0.30	2.10	1.93	-
75	Muddenahalli	Tiptur	HP	13.37211	76.46850	793.18	793.63	0.45	-	-	-	12.12	16.85	17.33	21.75	18.25	18.65	18.15	10.25	17.57	18.09	20.60	19.35	20.35	20.65	20.75	18.41	22.13	24.40	20.97
76	Nelagondanahalli	Tiptur	HP	13.33850	76.44400	812.805	813.375	0.57	-	-	-	25.69	28.01	27.94	34.43	27.93	29.75	31.79	33.23	42.30	35.43	36.98	51.83	58.63	45.63	61.43	86.43	86.43	86.43	39.13
77	Rudrapura	Tiptur	DW	13.40578	76.41167	796.665	797.58	0.92	2.78	2.50	3.05	2.51	7.35	5.91	4.93	5.48	6.08	6.48	6.58	6.78	7.30	7.48	7.98	-	-	-	8.41	-	-	-
78	Rudrapura	Tiptur	HP	13.40642	76.41353	796.175	796.67	0.50	-	-	-	3.51	3.23	4.50	5.36	5.16	5.56	6.06	5.46	5.61	6.34	6.41	6.81	7.01	5.61	6.61	7.38	8.20	9.25	10.07
79	Saratvalli	Tiptur	HP	13.33006	76.45578	797.225	797.715	0.49	20.61	18.83	30.01	-	22.88	21.99	23.61	24.76	27.17	-	-	26.01	28.71	31.91	38.21	-	-	-	-	-	-	-

Sl. No.	Village Name	Taluk	Well type	Lati-tude	Long-itude	RL of GL	RL of MP	MP (m agl)	Sept 2011	Nov. 2011	Jan. 2012	Feb. 2012	Apr. 2012	May 2012	June 2012	July 2012	Aug. 2012	Oct. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Feb. 2013	Mar. 2013	May 2013	June 2013	July 2013	Sept. 2013	Jan. 2014	Mar. 2014	Apr. 2014
80	SaratvalliGollarhatti	Tiptur	HP	13.33335	76.43142	822.365	822.99	0.63	-	-	-	11.58	13.64	15.16	14.06	15.58	16.68	17.33	18.48	18.70	20.53	21.58	27.48	26.18	22.58	24.28	15.06	23.48	31.04	35.35
81	Sasalu	C.N.Halli	HP	13.35525	76.56917	780.19	780.59	0.40	9.80	6.42	7.28	7.18	15.27	20.80	22.68	21.55	25.38	25.00	25.05	27.70	31.63	34.95	-	-	-	-	-	-	-	-
82	Savsettihalli colony	C.N.Halli	HP	13.43197	76.59294	769.76	770.175	0.41	12.32	8.77	10.18	9.96	13.45	12.97	15.09	16.09	17.99	10.09	16.94	16.96	21.27	20.44	23.84	25.64	20.69	28.07	23.71	25.96	33.45	37.22
83	Settikere	C.N.Halli	DW	13.38306	76.55278	-	-	-	4.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	Siddaramnagara	C.N.Halli	HP	13.38400	76.58400	785.675	786.235	0.56	-	-	-	-	-	-	72.64	71.69	78.09	68.24	69.54	72.64	75.34	79.54	87.14	88.44	88.44	88.44	88.44	99.44	93.79	99.44
85	Somalapura	C.N.Halli	HP	13.36472	76.57167	781.565	782.03	0.46	-	30.04	30.04	18.25	19.32	25.04	29.16	27.99	34.09	30.59	29.59	30.26	35.49	50.34	53.64	56.79	50.79	54.74	25.56	31.35	35.40	59.94
86	Suragondanahalli	Tiptur	DW	13.40578	76.43214	780.81	781.69	0.88	-	-	-	4.44	4.06	3.55	5.04	4.27	5.32	4.62	4.22	5.22	6.48	6.82	7.67	7.02	6.27	6.52	2.72	3.32	3.63	4.07
87	Suragondanahalli	Tiptur	HP	13.40594	76.43172	781.53	782.085	0.56	-	-	-	15.73	10.83	18.93	15.94	15.39	25.44	31.99	22.34	30.84	33.11	30.04	31.69	26.39	28.59	29.04	19.21	39.04	24.97	15.53
88	Tagachighatta colony	C.N.Halli	HP	13.43053	76.51664	749.345	749.785	0.44	-	-	-	17.81	22.66	16.66	24.51	25.21	27.16	19.88	17.51	18.23	23.92	22.06	26.96	35.56	31.31	34.26	25.70	28.66	-	44.56
89	Tammadihalli	C.N.Halli	HP	13.41372	76.50739	751.52	752.09	0.57	2.38	5.58	5.82	-	21.14	23.39	21.83	19.25	19.98	19.03	15.78	18.13	21.31	23.48	19.53	22.13	21.93	27.41	14.19	23.93	32.12	35.33
90	Tarabenahalli	C.N.Halli	PZ/DMG	13.37364	76.63428	827.375	827.53	0.15	19.35	18.90	21.87	25.75	35.08	30.06	47.68	29.65	33.45	30.40	-	-	-	-	-	-	-	-	-	-	-	32.55
91	Tigalanahalli	C.N.Halli	HP	13.32764	76.60908	832.005	832.29	0.28	-	-	-	36.44	45.31	45.90	50.81	59.62	71.72	46.37	48.62	47.02	49.22	61.02	82.72	82.72	66.42	51.27	47.93	54.91	80.72	54.02
92	Timmalapura	Tiptur	HP	13.30000	76.42700	848.435	848.9	0.47	28.04	24.40	-	13.27	28.95	28.05	41.44	29.64	36.64	33.97	33.99	34.24	39.49	39.14	43.44	54.89	44.79	46.24	-	-	-	-
93	Timmarayanahalli	Tiptur	HP	13.33417	76.50444	-	-	-	21.30	15.07	20.94	-	-	-	47.40	46.60	88.00	88.00	64.20	72.00	72.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00	58.20
94	Vaderahalli	C.N.Halli	HP	13.38583	76.57628	770.67	771.125	0.46	-	-	-	-	13.38	12.34	16.08	14.50	16.75	15.60	15.30	16.35	17.23	18.30	18.10	19.85	18.65	18.45	8.06	15.77	20.14	17.55
95	T.B.Colony	C.N.Halli	HP	13.36764	76.62950	837.02	837.565	0.55	-	-	-	28.98	31.33	32.23	32.75	32.95	33.25	33.08	34.45	34.23	35.41	35.95	36.65	39.60	38.00	38.25	40.11	41.61	37.61	38.65
96	Vasudevarahalli	Tiptur	HP	13.29886	76.44186	827.045	827.575	0.53	29.97	29.97	29.97	34.13	45.41	34.87	38.77	35.02	48.05	38.00	41.37	37.37	36.52	52.67	40.97	50.22	47.02	37.07	49.92	57.59	66.29	33.84
97	Virupakshapura	Tiptur	HP	13.31461	76.46994	803.94	804.335	0.39	-	-	-	25.65	35.06	32.03	38.91	47.39	56.71	52.51	36.81	54.14	67.01	65.31	68.71	77.86	59.81	69.61	68.39	70.81	80.61	114.67
98	Gudigondanahalli	Tiptur-outside	HP	13.30475	76.41744	839.760	840.274	0.51	-	-	-	-	-	-	26.93	25.48	33.91	31.26	49.31	33.17	37.79	37.96	39.21	45.31	37.41	53.09	26.11	35.66	55.07	47.29
99	Hulihalli	Tiptur-outside	HP	13.36236	76.41667	813.865	814.425	0.56	-	-	-	-	-	-	15.71	16.23	18.93	18.86	19.68	19.29	21.18	24.68	26.38	32.33	22.03	19.11	19.48	24.07	17.22	28.63
100	Sasival	Arasikere-outside	DW	13.44686	76.39367	784.970	785.875	0.90	-	-	-	-	-	-	10.18	10.58	11.43	11.68	11.88	11.88	12.88	14.98	17.13	18.18	11.48	12.26	11.51	14.20	15.22	14.50
101	Sasival	Arasikere-outside	HP	13.44072	76.40114	797.065	798.070	1.01	-	-	-	-	-	-	3.57	3.96	4.22	4.47	4.74	4.92	5.22	7.19	8.54	9.59	6.04	6.77	5.66	7.05	9.18	5.76
102	GollarahattiAnkasandra	C.N.Halli-outside	HP	13.47275	76.54136	729.395	729.935	0.54	-	-	-	-	-	-	24.34	21.54	30.04	29.54	30.49	26.84	35.64	39.54	44.69	51.39	44.54	38.89	28.54	36.58	71.01	80.89
103	Chikkamarapanahalli	Tiptur-outside	HP	13.29861	76.51850	870.225	870.735	0.51	-	-	-	-	-	-	22.30	19.25	22.55	22.75	22.15	22.34	23.41	24.55	24.75	29.10	24.75	25.20	19.93	22.65	21.58	22.59
104	Byadarahalli	C.N.Halli-outside	HP	13.35106	76.62836	830.775	840.465	9.69	-	-	-	-	-	-	37.56	39.61	37.26	-	-	39.72	43.56	39.56	64.76	63.31	57.66	38.76	23.08	16.46	53.19	39.11
105	Kodipalya	C.N.Halli-outside	PZ/DMG	13.46117	76.48333	747.250	747.550	0.30	-	-	-	-	-	-	-	14.21	16.70	15.75	16.80	16.02	20.35	22.10	26.30	27.95	26.15	27.72	23.77	30.90	35.12	55.00
106	Sarathavalli EW	Tiptur	Pz	13.32758	76.45583	803.420	803.930	0.510	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82.01	89.09	94.11
107	Balavanerlu EW	Tiptur	Pz	13.38367	76.42222	808.545	808.970	0.425	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31.28	38.12	45.04
108	Bommanahallithanda EW	Tiptur	Pz	13.38142	76.44703	816.815	817.135	0.320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33.84	33.30	33.82
109	Bharanapura EW	C.N.Halli	Pz	13.41797	76.47914	766.055	766.535	0.480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.97	26.58	26.63
110	Hosur EW	C.N.Halli	Pz	13.41983	76.44367	776.445	776.865	0.420	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29.56	41.45	45.52
111	Madapurahattithanda EW	C.N.Halli	Pz	13.43742	76.49990	769.115	769.395	0.280	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31.89	39.76	36.45
112	Navule EW	C.N.Halli	Pz	13.42721	76.57100	763.125	763.395	0.270	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29.85	61.38	68.77
113	Ankasandra EW	C.N.Halli	Pz	13.46306	76.54227	731.135	731.555	0.420	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52.74	-	100.08
114	Huchanahatti EW	Tiptur	Pz	13.28583	76.48442	863.565	863.915	0.350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100.65	110.05	132.87
115	Adinayakanahalli EW	Tiptur	Pz	13.32445	76.49943	800.600	800.635	0.035	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45.09	65.87	82.59
116	Settikere EW	C.N.Halli	Pz	13.37811	76.56196	766.615	766.785	0.170	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27.39	37.62	52.13
117	Sasalu EW	C.N.Halli	Pz	13.35631	76.56867	780.455	780.850	0.395	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34.72	47.91	58.79
118	Madihalli EW	C.N.Halli	Pz	13.38828	76.52911	765.130	765.460	0.330	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21.64	27.79	32.57
119	T.B.Colony EW	C.N.Halli	Pz	13.36789	76.62906	836.410	836.890	0.480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34.45	-	38.82

Annexure 3.4: Elevation of ground water levels of Observation wells from mean sea level (Water table)

Sl.No.	Village_Name	Taluk	Well_type	Latitude	Longitude	RL of GL	RL-of-MP	MP	Sept.11	Nov.11	Jan.12	Feb.12	Apr.12	May.12	June.12	July.12	Aug.12	Oct.12	Nov.12	Dec.12	Jan.13	Feb.13	Mar.13	May.13	June.13	July.13	Sept.13	Jan.14	Mar.14	Apr.14
1	Agasarahalli	C.N.Halli	HP	13.35250	76.61136	836.59	837.05	0.46	-	806.55	-	820.75	818.79	818.72	817.39	816.90	806.00	816.00	815.75	814.96	811.90	814.35	813.95	813.15	815.85	812.57	815.41	817.32	816.28	815.05
2	Alur	Tiptur	HP	13.31678	76.45192	805.365	805.81	0.44	769.51	775.31	775.31	772.80	768.39	768.38	763.20	767.12	765.71	749.81	741.81	753.93	749.21	741.81	741.81	741.81	752.66	750.53	716.98	717.81	730.50	722.37
3	Anekatte	C.N.Halli	HP	13.42233	76.55700	752.865	753.275	0.41	739.38	-	731.13	725.43	728.15	726.79	725.26	724.70	721.33	728.38	722.98	723.10	724.42	712.68	698.58	693.58	721.33	696.16	714.58	711.18	682.16	676.98
4	Ankasandra	C.N.Halli	HP	13.46400	76.54100	726.545	726.91	0.37	718.21	718.17	-	714.21	710.81	703.18	698.81	691.01	693.33	698.74	696.41	689.26	684.96	679.61	678.46	672.36	697.91	688.41	702.11	697.20	649.81	633.86
5	Aralikere	C.N.Halli	DW	13.44733	76.55286	742.08	743	0.92	735.75	737.84	736.18	728.22	733.93	735.44	734.05	733.60	733.10	736.30	737.30	736.30	735.08	734.20	733.00	731.40	732.75	731.55	734.94	733.61	731.25	732.10
6	Aralikere	C.N.Halli	HP	13.44469	76.55381	742.8	743.255	0.46	-	-	-	735.41	724.13	728.46	729.26	729.41	723.94	721.16	724.56	721.68	719.86	715.56	708.96	713.11	721.11	718.16	724.12	722.04	708.80	720.68
7	B.Hosahalli	Tiptur	DW	13.39550	76.43350	788.565	789.515	0.95	-	-	-	778.64	777.27	778.11	775.62	776.27	775.42	775.42	775.22	774.82	-	-	-	-	-	-	-	-	-	781.22
8	B.Hosahalli	Tiptur	HP	13.39544	76.43283	787.81	788.355	0.55	-	-	-	775.08	-	-	775.56	776.34	775.31	775.46	775.16	774.26	773.79	773.86	773.76	771.11	775.36	769.91	774.52	773.08	749.62	767.28
9	Bairapura	Tiptur	HP	13.35097	76.47497	775.66	776.35	0.69	-	-	-	757.15	768.87	759.17	758.43	768.40	756.65	762.25	761.95	758.92	761.73	752.45	754.05	744.50	744.15	741.97	769.28	740.07	733.82	730.77
10	Balavaneralu	Tiptur	DW	13.38814	76.42300	792.31	793.505	1.20	775.61	787.64	788.87	788.61	787.73	786.75	786.23	786.11	785.61	785.41	785.41	785.16	784.56	784.41	784.41	-	-	-	-	-	-	784.41
11	Balavaneralu	Tiptur	HP	13.38897	76.42275	790.635	791.26	0.63	-	-	-	782.04	785.94	782.99	784.50	784.02	784.54	783.81	784.06	783.57	783.61	783.01	780.86	781.81	781.96	781.72	782.84	781.02	779.00	779.46
12	Bandegate	Tiptur	HP	13.30400	76.53500	877.125	877.465	0.34	858.77	858.43	857.98	870.50	852.88	865.25	845.13	846.92	856.73	858.32	856.17	856.77	857.51	857.27	854.47	850.12	855.17	841.37	868.25	857.87	856.77	848.97
13	Banjara thanda	C.N.Halli	DW	13.44586	76.51917	749.93	750.84	0.91	731.84	737.76	737.03	747.89	747.53	746.84	745.74	745.39	743.74	746.94	747.09	746.55	745.79	745.64	744.74	743.39	743.74	743.33	747.47	743.74	742.99	742.64
14	Basavarajapura	Tiptur	DW	13.38389	76.45333	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Bevanahalli thanda	C.N.Halli	HP	13.44292	76.52075	755.76	756.29	0.53	-	756.29	-	729.66	729.35	723.81	721.72	721.29	720.09	729.14	732.34	724.57	721.86	734.69	720.89	719.19	721.09	710.79	721.91	720.24	696.07	702.53
16	Bhairanayakanahalli	Tiptur	DW	13.29806	76.45528	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Bharanapura	C.N.Halli	DW	13.41889	76.48194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Bommanahalli	Tiptur	DW	13.39825	76.44039	778.46	779.875	1.41	762.88	775.58	774.92	775.34	774.27	775.30	773.03	772.78	772.26	772.08	772.38	772.00	771.30	771.08	770.58	769.48	769.18	768.68	769.98	768.64	767.57	769.58
19	Bommanahalli	Tiptur	HP	13.39808	76.44075	777.41	777.94	0.53	-	-	-	774.47	772.43	-	773.04	772.59	771.88	771.24	771.39	771.39	772.54	770.59	770.09	769.84	768.44	767.94	770.50	768.73	765.09	763.97
20	Bommanahalli thanda	Tiptur	HP	13.38328	76.44956	809.195	809.76	0.56	-	-	-	788.72	788.15	784.48	782.96	784.84	784.04	782.61	782.66	778.78	780.96	781.66	779.16	780.41	780.01	779.72	776.54	777.96	776.30	777.46
21	Byadarhalli	Tiptur	DW	13.34361	76.48472	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	Chattasandra	C.N.Halli	DW	13.44794	76.50144	755.165	756.12	0.96	737.32	749.82	746.77	749.72	748.32	748.29	747.07	744.72	746.12	747.22	748.12	747.75	747.58	747.12	746.12	745.52	745.32	745.09	747.82	746.96	745.32	744.55
23	Chattasandra	C.N.Halli	HP	13.44656	76.50119	755.8	756.22	0.42	-	-	-	744.84	744.15	-	748.62	748.22	746.97	747.82	750.37	749.69	746.94	746.52	747.52	746.92	747.02	746.65	751.25	748.10	746.11	723.19
24	Choulahalli	Tiptur	HP	13.34131	76.45953	797.195	797.615	0.42	-	-	-	776.17	768.09	774.80	767.22	-	756.52	751.82	722.62	755.12	740.72	736.52	736.52	734.07	739.92	-	751.43	714.12	707.49	722.82
25	Chunganahalli	C.N.Halli	HP	13.37597	76.58514	778.03	778.51	0.48	-	-	-	760.07	756.09	758.31	723.61	718.76	707.16	723.21	722.66	719.81	714.36	700.06	693.36	693.36	706.31	698.39	754.90	741.70	728.61	742.61
26	Dasanakatte	Tiptur	HP	13.37608	76.43367	806.895	807.38	0.49	791.98	792.48	793.60	-	780.03	785.26	779.74	782.33	778.48	777.58	780.18	786.74	775.78	771.18	767.28	765.83	764.93	761.45	782.83	779.38	779.59	757.08
27	DasihalliPalya	C.N.Halli	DW	13.42181	76.49689	754.34	755.14	0.80	739.14	739.64	738.29	751.24	750.68	749.50	747.42	746.14	745.04	748.54	750.44	749.80	748.79	747.54	745.64	743.44	744.34	744.04	745.54	744.49	743.54	743.99
28	DasihalliPalya	C.N.Halli	HP	13.42164	76.49703	754.055	754.61	0.56	-	-	-	753.44	746.75	745.66	741.86	743.16	742.31	747.31	748.06	747.31	745.92	743.06	739.41	735.46	737.06	732.71	747.77	735.99	732.28	732.18
29	Dasikere	C.N.Halli	DW	13.39194	76.54694	753.31	754.225	0.92	745.93	745.75	745.32	744.58	743.13	743.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	743.33
30	Dasikere	C.N.Halli	HP	13.39372	76.54781	749.365	749.825	0.46	-	-	-	-	741.79	740.52	739.55	738.33	736.73	737.28	741.43	736.55	733.95	731.73	731.63	728.43	733.63	732.68	740.73	738.83	723.25	721.73
31	Dugganahalli	C.N.Halli	HP	13.41847	76.46181	776.11	776.595	0.49	-	762.80	762.34	749.79	747.62	748.33	745.50	745.05	743.90	729.60	743.65	743.27	739.71	739.25	736.40	724.45	726.48	734.25	741.18	730.79	728.31	729.16
32	Dugudihalli	C.N.Halli	DW	13.39361	76.59778	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	Gandhinagara	C.N.Halli	DW/NHS	13.43100	76.48344	778.87	779.785	0.91	-	-	-	-	-	-	-	-	779.79	-	-	-	-	-	-	779.79	-	-	-	-	-	768.59
34	Gatakanakere	Tiptur	HP	13.35386	76.45686	795.96	796.58	0.62	783.98	-	772.60	-	777.10	780.09	780.98	776.63	775.28	783.08	780.38	774.40	772.33	756.58	756.58	752.48	760.18	765.84	762.40	757.46	740.44	762.33
35	Gaudanahalli	C.N.Halli	HP	13.40100	76.56161	760.65	761.08	0.43	730.58	730.58	730.58	-	751.54	753.22	751.53	751.98	755.22	752.18	752.58	752.00	751.14	750.68	750.18	748.23	750.28	750.02	754.25	753.83	749.81	750.35
36	Gerahalli	C.N.Halli	HP	13.33861	76.60803	836.605	837.15	0.54	811.60	812.27	-	808.82	805.67	803.63	796.73	800.45	795.55	798.29	796.35	794.39	798.50	779.25	782.35	781.05	785.45	789.85	790.39	786.03	783.25	790.05
37	Gopalanahalli	C.N.Halli	PZ/DMG	13.34597	76.55317	796.825	796.825	0.00	791.48	791.97	790.30	788.92	787.79	783.47	753.43	781.60	772.61	785.98	774.73	774.51	771.97	770.23	767.68	763.48	765.28	763.43	-	-	-	-
38	Hale Bevanahalli	C.N.Halli	HP	13.43683	76.52769	737.22	737.76	0.54	-	-	-	722.99	720.62	720.08	717.46	717.41	715.21	722.11	-	-	-	-	-	737.76	-	-	-	-	-	-
39	Halenahalli	Tiptur	HP	13.35739	76.48575	796.38	796.99	0.61	-	-	-	784.39	786.84	785.06	783.41	785.14	781.69	784.42	783.29	781.79	781.97	777.59	776.89	777.19	781.04	776.22	782.33	775.84	768.87	771.80
40	Halkurike	Tiptur	DW	13.37414	76.47561	773.01	773.775	0.76	772.23	772.24	772.22	771.08	769.84	769.92	768.85	771.16	769.48	770.36	770.28	769.69	768.91	768.43	767.68	768.68	770.43	769.68	772.08	770.08	767.38	766.88
41	Harisamudra Gate	Tiptur	HP	13.31989	76.46492	799.91	800.435	0.52	-	-	-	772.46	767.18	770.97	738.63	791.09	754.18	758.19	734.09	751.64	735.43	713.79	711.94	715.44	715.44	728.62	712.44	712.44	712.44	746.94
42	Hesarahalli	C.N.Halli	HP	13.40778	76.55178	750.075	750.595	0.52	-	-	-	736.18	733.18	-	732.32	731.26	729.40	727.12	729.80	728.89	727.05	723.00	720.35	718.05	722.50	708.84	723.78	721.28	677.60	679.70
43	Huchanahatti	Tiptur	HP	13.29431	76.48919	843.65	844.03	0.38	-	-	-	818.68	-	813.58	813.21	812.75	807.91	795.33	809.63	809.67	809.73	807.33	808.83	807.63	806.08	820.28	807.17	805.77	805.29	800.23
44	Hosur (Makuvalligollarahatti)	Tiptur	HP	13.37639	76.53694	777.26	777.57	0.31	747.07	747.07	747.07	754.97	756.79	758.27	750.40	750.37	747.67	748.87	750.94	749.12	745.69	743.87	743.37	724.42	734.97	731.57	757.96	755.92	738.81	728.62
45	Hurulahalli	Tiptur	HP	13.33097	76.47461	794.765	794.935	0.17	-	-	-	760.77	750.74	747.01	703.94	735.02	738.84	749.16	747.14	749.49	-	741.04	741.04	732.49	729.74	726.94	716.78	714.79	706.94	-
46	Irlagere	Tiptur	HP	13.32761	76.53447	818.74	819.205	0.47	-	-	-	814.62	813.70	811.10	808.41	811.56	808.33	807.86	806.16	804.71	805.59	803.96	799.06	797.11	800.66	799.93	803.83	802.31	803.91	796.51
47	Kadenahalli	C.N.Halli	HP	13.38431	76.62844	810.64	811.19	0.55	795.29	791.03	790.57	784.95	783.31	-	771.74	774.29	781.99	776.49	768.79	780.81	782.55	781.49	775.29	769.09	767.24	766.39	769.41	780.09	763.05	781.69
48	Kedigehallipalya	C.N.Halli	HP	13.40547	76.61331	786.31	786.745	0.44	766.00	772.79	772.07	768.58	765.77	766.08	760.13	762.45	760.05	762.90	759.50	761.53	759.65	758.55	756.25	744.75	748.75	732.55	754.28	757.27	750.99	698.41
49	Kallakere	Tiptur	HP	13.31742	76.49006	808.735	809.355	0.62	779.96	797.37	794.83	-	788.42	788.49	789.15	791.26	792.96	791.44	792.14	791.94	791.78	790.76	789.86	787.66	788.26	788.54	796.10	794.26	791.34	805.16
50	Kallenahalli	C.N.Halli	DW	13.43247	76.56633	754.24	755.02	0.78	750.67	751.21	750.26	749.97	750.43	750.79	749.12	748.72	748.37	750.32	750.37	749.61	748.77	748.22	748.32	748.12	748.92	748.07	752.14	748.18	748.07	748.92
51	Kallenahalli	C.N.Halli	HP	13.43506	76.56617	750.375	750.84	0.47	-	-	-	729.91	726.64	723.29	729.96	727.14	720.31	734.64	734.24	729.78	725.61	721.14	721.64	719.84	725.54	714.90	734.76	732.63	710.24	720.34
52	Kamalapura	C.N.Halli	HP	13.42700	76.43853	785.385	785.815	0.43	759.77	761.85	766.64	772.68	771.55	772.85	764.82	763.02	764.54	764.87	763.92	763.76	761.95	766.07	760.62	760.02	762.12	760.22	765.63	760.11	758.66	-
53	Karehalli	C.N.Halli	DW	13.41731	76.57656	770.19	771.06	0.87	768.41	768.33	768.01	764.67	763.42	768.06	767.06	766.76	766.71	768.46	768.11	767.59	766.81	765.11	763.96	763.71	764.86	765.16	768.28	767.89	761.16	761.61
54	Karehalli	C.N.Halli	HP	13.41403	76.57831	771.48	771.965	0.49	-	-	-	766.04	766.86	767.37	766.13	765.42	765.79	767.37	767.57	766.79	764.97	763.67	761.67	761.82	761.52	761.04	766.89	765.77	759.07	759.47
55	Kaval	Tiptur	HP	13.30631	76.52231	881.225	881.72	0.50	-	-	-	859.78	854.92	852.47	856.17	857.67	855.00	854.42	815.90	852.95	841.57	840.47	855.22	852.62	855.52	850.02	858.00	853.33	848.51	853.58
56	Khaimara Junction	C.N.Halli	HP	13.44058	76.48408	787.03	787.47	0.44	765.92	-	765.31	774.35	771.29	768.19	770.14	769.52	766.82	768.04	769.62	768.17	768.25	768.27	765.92	765.37	764.67	762.29	765.66	761.64	759.25	751.91
57	Kodagihalli	Tiptur	HP	13.40286	76.47631	763.2	763.635	0.43	749.79	752.40	750.70	-	746.10	740.05	739.94	741.64	737.17	735.94	734.69	737.84	732.54	731.54	734.64	728.34	729.54	729.02	739.06	729.65	712.74	719.69
58	Kodalagara	C.N.Halli	HP	13.36981	76.60236	816.05	816.55	0.50	-	-	-	799.75	800.38	798.06	796.52	797.05	792.65	793.10	793.10	789.17	786.96	785.05	784.35	780.05	779.65	760.45	805.29	797.93	793.65	793.85
59	Kuppuradoddahalli	Tiptur	HP	13.28583	76.43892	843.19	843.715	0.52	822.92	825.82	819.27	816.25	801.40	811.09	792.96	810.40	801.42	809.67	807.12	805.25	800.06	795.62	791.02	792.12	790.62	791.17	794.55	783.25	767.60	793.92
60	Kuppuru	C.N.Halli	PZ/DMG	13.42167	76.53083	738.27	738.86	0.59	708.36	708.36	724.90	-	-	-	712.14	712.61	695.86	717.61	718.01	716.62	707.42	695.86	695.86	695.86	695.86	695.86	695.86	695.86	695.86	708.86
61	Lakshmanapura	Tiptur	HP	13.34328	76.48853	782.745	783.115	0.37	-	-	-	-	761.27	765.71	749.22	753.70	758.47	755.82	752.82	751.02	750.05	735.42	738.22	737.42	740.42	753.92	757.94	754.02	748.02	720.74
62	Madapurahatti	C.N.Halli	HP	13.43653	76.50075	773.41	773.855	0.45	-	-	-	751.92	750.17	749.79	747.13	746.41	741.86	745.91	750.71	749.63	742.81	734.06	735.46	743.01	744.66	741.50	742.24	740.76	725.70	738.96
63	Madihalli	C.N.Halli	DW	13.39389	76.53028	758.59	759.61	1.02	753.91	755.66	754.11	753.98	752.83	751.87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	749.91
64	Madihalli	C.N.Halli	HP	13.38828	76.52942	764.8	765.32	0.52	-	-	-	-	750.87	753.33	748.68	748.52	745.97	745.52	751.22	747.54	741.93	745.27	743.62	739.22	747.32	740.02	750.44	-	-	726.32
65	Makuvalli	C.N.Halli	HP	13.37197	76.55661	764.275	764.715	0.44	-	-	-	753.51	755.29	752.94	748.17	755.97	744.90	746.72	745.62	743.54	741.17	730.52	728.57	732.02	742.57	716.37	738.48	735.56	732.36	717.40
66	Manakikere	Tiptur	HP	13.33694	76.48222	794.645	795.29	0.64	-	-	-	-	757.39	753.17	744.64	749.74	707.29	707.29	741.59	743.79	745.95	741.17	738.64	743.67	-	-	-	-	-	-
67	Manchasandra	C.N.Halli	HP	13.40992	76.53019	751.185	751.72	0.54	741.87	743.10	739.89	-	735.88	736.74	733.42	732.67	728.02	732.37	732.87	731.49	726.62	727.42	725.42	714.02	718.57	721.46	727.98	719.12	710.82	719.62
68	Manjunathapura	Tiptur	HP	13.35806	76.43364	819.975	820.475	0.50	814.68	814.12	-	807.96	806.82	804.02	803.42	804.08	803.35	802.20	801.38	800.92	800.02	785.78	784.28	780.38	785.78	795.53	794.65	785.38	786.72	792.78
69	Mayagondanahalli	Tiptur	DW	13.38311	76.46667	786.62	787.475	0.86	770.98	773.06	771.66	-	780.43	782.43	781.10	781.38	781.58	783.78	784.23	783.44	782.18	781.68	780.78	779.48	781.78	781.62	785.15	781.98	780.08	779.23
70	Mayagondanahalli	Tiptur	HP	13.38450	76.46744	779.465	779.95	0.49	-	-	-	-	776.08	775.04	774.05	772.00	773.75	777.25	778.80	778.05	776.71	776.25	774.95	772.85	773.85	773.71	779.95	775.74	774.76	771.03
71	Melanahalli	C.N.Halli	HP	13.42128	76.60425	775.095	775.585	0.49	767.64	767.17	-	759.94	756.71	759.24	752.47	752.34	749.84	753.17	751.19	749.83	733.66	733.39	739.69	737.84	746.24	690.59	735.73	732.63	694.59	710.99
72	Misetimmanahalli	Tiptur	DW	13.30750	76.48056	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
73	Muddanayakanapalya	Tiptur	DW	13.41517	76.42692	797.37	798.23	0.86	-	-	-	792.13	790.80	790.78	790.08	789.83	789.43	789.23	789.93	789.88	789.32	789.43	789.23	787.98	790.13	789.43	794.23	792.16	791.43	790.58
74	Muddanayakanapalya	Tiptur	HP	13.41817	76.42606	791.445	791.88	0.43	-	-	-	788.88	789.65	789.64	788.98	788.83	788.66	788.93	789.38	789.10	788.50	788.43	788.18	787.78	788.88	788.60	791.15	789.35	789.52	-
75	Muddenahalli	Tiptur	HP	13.37211	76.46850	793.18	793.63	0.45	-	-	-	781.06	776.33	775.85	771.43	774.93	774.53	775.03	782.93	775.61	775.09	772.58	773.83	772.83	772.53	772.43	774.77	771.05	768.78	772.21
76	Nelagondanahalli	Tiptur	HP	13.33850	76.44400	812.805	813.375	0.57	-	-	-	787.12	784.80	784.87	778.38	784.88	783.06	781.02	779.58	770.51	777.38	775.83	760.98	754.18	767.18	751.38	726.38	726.38	726.38	773.68
77	Rudrapura	Tiptur	DW	13.40578	76.41167	796.665	797.58	0.92	793.88	794.16	793.61	794.15	789.31	790.75	791.73	791.18	790.58	790.18	790.08	789.88	789.36	789.18	788.68	-	-	-	788.25	-	-	-
78	Rudrapura	Tiptur	HP	13.40642	76.41353	796.175	796.67	0.50	-	-	-	792.67	792.95	791.68	790.82	791.02	790.62	790.12	790.72	790.57	789.84	789.77	789.37	789.17	790.57	789.57	788.80	787.97	786.93	786.11
79	Saratvalli	Tiptur	HP	13.33006	76.45578	797.225	797.715	0.49	776.62	778.40	767.22	-	774.35	775.24	773.62	772.47	770.06	-	-	771.22	768.52	765.32	759.02	797.72	-	-	797.72	-	-	-
80	SaratvalliGollarhatti	Tiptur	HP	13.33335	76.43142	822.365	822.99	0.63	-	-	-	810.79	808.73	807.21	808.31	806.79	805.69	805.04	803.89	803.67	801.84	800.79	794.89	796.19	799.79	798.09	807.31	798.89	791.33	787.02

Sl.No.	Village_Name	Taluk	Well_type	Latitude	Longitude	RL of GL	RL-of-MP	MP	Sept.11	Nov.11	Jan.12	Feb.12	Apr.12	May.12	June.12	July.12	Aug.12	Oct.12	Nov.12	Dec.12	Jan.13	Feb.13	Mar.13	May.13	June.13	July.13	Sept.13	Jan.14	Mar.14	Apr.14
81	Sasalu	C.N.Halli	HP	13.35525	76.56917	780.19	780.59	0.40	770.39	773.77	772.91	773.01	764.92	759.39	757.51	758.64	754.81	755.19	755.14	752.49	748.56	745.24	-	-	-	-	-	-	-	-
82	Savsettihalli colony	C.N.Halli	HP	13.43197	76.59294	769.76	770.175	0.41	757.45	761.00	759.59	759.81	756.32	756.80	754.68	753.68	751.78	759.68	752.83	752.81	748.50	749.33	745.93	744.13	749.08	741.70	746.06	743.81	736.32	732.55
83	Settikere	C.N.Halli	DW	13.38306	76.55278	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	Siddaramnagara	C.N.Halli	HP	13.38400	76.58400	785.675	786.235	0.56	-	-	-	-	-	-	713.04	713.99	707.59	717.44	716.14	713.04	710.34	706.14	698.54	697.24	697.24	697.24	697.24	686.24	691.89	686.24
85	Somalapura	C.N.Halli	HP	13.36472	76.57167	781.565	782.03	0.46	-	751.53	751.53	763.32	762.25	756.53	752.41	753.58	747.48	750.98	751.98	751.31	746.08	731.23	727.93	724.78	730.78	726.83	756.01	750.22	746.17	721.63
86	Suragondanahalli	Tiptur	DW	13.40578	76.43214	780.81	781.69	0.88	-	-	-	776.37	776.75	777.26	775.77	776.54	775.49	776.19	776.59	775.59	774.33	773.99	773.14	773.79	774.54	774.29	778.09	777.49	777.18	776.74
87	Suragondanahalli	Tiptur	HP	13.40594	76.43172	781.53	782.085	0.56	-	-	-	765.80	770.70	762.60	765.59	766.14	756.09	749.54	759.19	750.69	748.42	751.49	749.84	755.14	752.94	752.49	762.32	742.49	756.56	766.00
88	Tagachighatta colony	C.N.Halli	HP	13.43053	76.51664	749.345	749.785	0.44	-	-	-	731.54	726.69	732.69	724.84	724.14	722.19	729.47	731.84	731.12	725.43	727.29	722.39	713.79	718.04	715.09	723.65	720.69	-	704.79
89	Tammadihalli	C.N.Halli	HP	13.41372	76.50739	751.52	752.09	0.57	749.14	745.94	745.70	-	730.38	728.13	729.69	732.27	731.54	732.49	735.74	733.39	730.21	728.04	731.99	729.39	729.59	724.11	737.33	727.59	719.40	716.19
90	Tarabenahalli	C.N.Halli	PZ/DMG	13.37364	76.63428	827.375	827.53	0.15	808.03	808.48	805.51	801.63	792.30	797.32	779.70	797.73	793.93	796.98	-	-	-	-	-	-	-	-	-	-	-	794.83
91	Tigalanahalli	C.N.Halli	HP	13.32764	76.60908	832.005	832.29	0.28	-	-	-	795.57	786.70	786.11	781.20	772.39	760.29	785.64	783.39	784.99	782.79	770.99	749.29	749.29	765.59	780.74	784.08	777.10	751.29	777.99
92	Timmalapura	Tiptur	HP	13.30000	76.42700	848.435	848.9	0.47	820.40	824.04	-	835.17	819.49	820.39	807.00	818.80	811.80	814.47	814.45	814.20	808.95	809.30	805.00	793.55	803.65	802.20	-	-	-	-
93	Timmarayanahalli	Tiptur	HP	13.33417	76.50444	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
94	Vaderahalli	C.N.Halli	HP	13.38583	76.57628	770.67	771.125	0.46	-	-	-	-	757.30	758.34	754.60	756.18	753.93	755.08	755.38	754.33	753.45	752.38	752.58	750.83	752.03	752.23	762.61	754.91	750.54	753.13
95	T.B.Colony	C.N.Halli	HP	13.36764	76.62950	837.02	837.565	0.55	-	-	-	808.04	805.69	804.79	804.27	804.07	803.77	803.94	802.57	802.79	801.61	801.07	800.37	797.42	799.02	798.77	796.91	795.41	799.41	798.37
96	Vasudevarahalli	Tiptur	HP	13.29886	76.44186	827.045	827.575	0.53	797.08	797.08	797.08	792.92	781.64	792.18	788.28	792.03	779.00	789.05	785.68	789.68	790.53	774.38	786.08	776.83	780.03	789.98	777.13	769.46	760.76	793.21
97	Virupakshapura	Tiptur	HP	13.31461	76.46994	803.94	804.335	0.39	-	-	-	778.30	768.89	771.92	765.04	756.56	747.24	751.44	767.14	749.81	736.94	738.64	735.24	726.09	744.14	734.34	735.56	733.14	723.34	689.28
98	Gudigondanahalli	Tiptur-outside	HP	13.30475	76.41744	839.760	840.274	0.51	-	-	-	-	-	-	812.83	814.28	805.85	808.50	790.45	806.59	801.97	801.80	800.55	794.45	802.35	786.67	813.65	804.10	784.69	792.47
99	Hulihalli	Tiptur-outside	HP	13.36236	76.41667	813.865	814.425	0.56	-	-	-	-	-	-	798.16	797.64	794.94	795.01	794.19	794.58	792.69	789.19	787.49	781.54	791.84	794.76	794.39	789.80	796.65	785.24
100	Sasival	Arasikere-outside	DW	13.44686	76.39367	784.970	785.875	0.90	-	-	-	-	-	-	774.79	774.39	773.54	773.29	773.09	773.09	772.09	769.99	767.84	766.79	773.49	772.71	773.46	770.78	769.76	770.48
101	Sasival	Arasikere-outside	HP	13.44072	76.40114	797.065	798.070	1.01	-	-	-	-	-	-	793.50	793.11	792.85	792.60	792.33	792.15	791.85	789.88	788.53	787.48	791.03	790.30	791.41	790.02	787.89	791.31
102	GollarahattiAnkasandra	C.N.Halli-outside	HP	13.47275	76.54136	729.395	729.935	0.54	-	-	-	-	-	-	705.06	707.86	699.36	699.86	698.91	702.56	693.76	689.86	684.71	678.01	684.86	690.51	700.86	692.82	658.39	648.51
103	Chikkamarapanahalli	Tiptur-outside	HP	13.29861	76.51850	870.225	870.735	0.51	-	-	-	-	-	-	847.93	850.98	847.68	847.48	848.08	847.89	846.82	845.68	845.48	841.13	845.48	845.03	850.30	847.58	848.65	847.64
104	Byadarahalli	C.N.Halli-outside	HP	13.35106	76.62836	830.775	840.465	9.69	-	-	-	-	-	-	793.22	791.17	793.52	-	-	791.06	787.22	791.22	766.02	767.47	773.12	792.02	807.70	814.32	777.59	791.67
105	Kodipalya	C.N.Halli-outside	PZ/DMG	13.46117	76.48333	747.250	747.550	0.30	-	-	-	-	-	-	-	733.04	730.55	731.50	730.45	731.23	726.90	725.15	720.95	719.30	721.10	719.53	723.48	716.35	712.13	692.25

Annexure 3.5: Ground water level fluctuation data of Observation wells

Sl. No.	Village name	Nov.11 to May.12	May.12 to Nov. 12	Nov.12 to May.13	May.13 to Sept.13	Sept.13 to Apr.14	Nov.11 to Nov. 12	May.12 to May.13	Nov.12 to Sept.13	May.13 to Apr.14	Nov.11 to Apr.14
1	Agasarahalli	12.17	-2.97	-2.60	2.26	-0.36	9.20	-5.57	-0.34	1.90	8.50
2	Alur	-6.93	-26.57	0.00	-24.83	5.39	-33.50	-26.57	-24.83	-19.44	-52.94
3	Anekatte	-	-3.81	-29.40	21.00	-37.60	-	-33.21	-8.40	-16.60	-
4	Ankasandra	-14.99	-6.77	-24.05	29.75	-68.25	-21.76	-30.82	5.70	-38.50	-84.31
5	Aralikere	-2.40	1.86	-5.90	3.54	-2.84	-0.54	-4.04	-2.36	0.70	-5.74
6	Aralikere	-	-3.90	-11.45	11.01	-3.44	-	-15.35	-0.44	7.57	-
7	B.Hosahalli	-	-2.89	-	-	-	-	-	-	-	-
8	B.Hosahalli	-	-	-4.05	3.41	-7.24	-	-	-0.64	-3.83	-
9	Bairapura	-	2.78	-17.45	24.78	-38.51	-	-14.67	7.33	-13.73	-
10	Balavaneralu	-0.89	-1.34	-	-	-	-2.23	-	-	-	-3.23
11	Balavaneralu	-	1.07	-2.25	1.03	-3.38	-	-1.18	-1.22	-2.35	-
12	Bandegate	6.82	-9.08	-6.05	18.13	-19.28	-2.26	-15.13	12.08	-1.15	-9.46
13	Banjara thanda	9.08	0.25	-3.70	4.08	-4.83	9.33	-3.45	0.38	-0.75	4.88
14	Basavarajapura	-	-	-	-	-	-	-	-	-	2.39
15	Bevanahalli thanda	-	8.53	-13.15	2.72	-19.38	-	-4.62	-10.43	-16.66	-
16	Bhairanayakanahalli	-	-	-	-	-	-	-	-	-	18.00
17	Bharanapura	-	-	-	-	-	-	-	-	-	-
18	Bommanahalli	-0.28	-2.92	-2.90	0.50	-0.40	-3.20	-5.82	-2.40	0.10	-6.00
19	Bommanahalli	-	-	-1.55	0.66	-6.53	-	-	-0.89	-5.87	-
20	Bommanahalli thanda	-	-1.82	-2.25	-3.87	0.92	-	-4.07	-6.12	-2.95	-
21	Byadarhalli	-27.90	2.12	-	-	-	-25.78	-	14.78	-	-
22	Chattasandra	-1.53	-0.17	-2.60	2.30	-3.27	-1.70	-2.77	-0.30	-0.97	-5.27
23	Chattasandra	-	-	-3.45	4.33	-28.06	-	-	0.88	-23.73	-
24	Choulahalli	-	-52.18	11.45	17.36	-28.61	-	-40.73	28.81	-11.25	-
25	Chunganahalli	-	-35.65	-29.30	61.54	-12.29	-	-64.95	32.24	49.25	-
26	Dasanakatte	-7.22	-5.08	-14.35	17.00	-25.75	-12.30	-19.43	2.65	-8.75	-35.40
27	DasihalliPalya	9.86	0.94	-7.00	2.10	-1.55	10.80	-6.06	-4.90	0.55	4.35
28	DasihalliPalya	-	2.40	-12.60	12.31	-15.59	-	-10.20	-0.29	-3.28	-
29	Dasikere	-2.20	-	-	-	-	-	-	-	-	-2.42
30	Dasikere	-	0.91	-13.00	12.30	-19.00	-	-12.09	-0.70	-6.70	-
31	Dugganahalli	-14.47	-4.68	-19.20	16.73	-12.02	-19.15	-23.88	-2.47	4.71	-33.64
32	Dugudihalli	-	-	-	-	-	-	-	-	-	-
33	Gandhinagara	-	-	-	-	-	-	-	-	-	-

Sl. No.	Village name	Nov.11 to May.12	May.12 to Nov. 12	Nov.12 to May.13	May.13 to Sept.13	Sept.13 to Apr.14	Nov.11 to Nov. 12	May.12 to May.13	Nov.12 to Sept.13	May.13 to Apr.14	Nov.11 to Apr.14
34	Gatakanakere	-	0.29	-27.90	9.92	-0.07	-	-27.61	-17.98	9.85	-
35	Gaudanahalli	22.64	-0.64	-4.35	6.02	-3.90	22.00	-4.99	1.67	2.12	19.77
36	Gerahalli	-8.64	-7.28	-15.30	9.34	-0.34	-15.92	-22.58	-5.96	9.00	-22.22
37	Gopalanahalli	-8.50	-8.74	-11.25	-	-	-17.24	-19.99	-	-	-
38	Hale Bevanahalli	-	-	-	-	-	-	-	-	-	-
39	Halenahalli	-	-1.77	-6.10	5.14	-10.53	-	-7.87	-0.96	-5.39	-
40	Halkurike	-2.32	0.36	-1.60	3.40	-5.20	-1.96	-1.24	1.80	-1.80	-5.36
41	Harisamudra Gate	-	-36.88	-18.65	-3.00	34.50	-	-55.53	-21.65	31.50	-
42	Hesarahalli	-	-	-11.75	5.73	-44.08	-	-	-6.02	-38.35	-
43	Huchanahatti	-	-3.95	-2.00	-0.46	-6.94	-	-5.95	-2.46	-7.40	-
44	Hosur (Makuvalligollarahatti)	11.20	-7.33	-26.52	33.54	-29.34	3.87	-33.85	7.02	4.20	-18.45
45	Hurulahalli	-	0.13	-14.65	-15.71	-	-	-14.52	-30.36	-	-
46	Irlagere	-	-4.94	-9.05	6.72	-7.32	-	-13.99	-2.33	-0.60	-
47	Kadenahalli	-	-	0.30	0.32	12.28	-22.24	-	0.62	12.60	-9.34
48	Kedigehallipalya	-6.71	-6.58	-14.75	9.53	-55.87	-13.29	-21.33	-5.22	-46.34	-74.38
49	Kallakere	-8.88	3.65	-4.48	8.44	9.06	-5.23	-0.83	3.96	17.50	7.79
50	Kallenahalli	-0.42	-0.42	-2.25	4.02	-3.22	-0.84	-2.67	1.77	0.80	-2.29
51	Kallenahalli	-	10.95	-14.40	14.92	-14.42	-	-3.45	0.52	0.50	-
52	Kamalapura	11.00	-8.93	-3.90	5.61	-	2.07	-12.83	1.71	-	-
53	Karehalli	-0.27	0.05	-4.40	4.57	-6.67	-0.22	-4.35	0.17	-2.10	-6.72
54	Karehalli	-	0.20	-5.75	5.07	-7.42	-	-5.55	-0.68	-2.35	-
55	Kaval	-	-36.57	36.72	5.38	-4.42	-	0.15	42.10	0.96	-
56	Khaimara Junction	-	1.43	-4.25	0.29	-13.75	-	-2.82	-3.96	-13.46	-
57	Kodagihalli	-12.35	-5.36	-6.35	10.72	-19.37	-17.71	-11.71	4.37	-8.65	-32.71
58	Kodalagara	-	-4.96	-13.05	25.24	-11.44	-	-18.01	12.19	13.80	-
59	Kuppuradoddahalli	-14.73	-3.97	-15.00	2.43	-0.63	-18.70	-18.97	-12.57	1.80	-31.90
60	Kuppuru	-	-	-22.15	0.00	13.00	9.65	-	-22.15	13.00	0.50
61	Lakshmanapura	-	-12.89	-15.40	20.52	-37.20	-	-28.29	5.12	-16.68	-
62	Madapurahatti	-	0.92	-7.70	-0.77	-3.28	-	-6.78	-8.47	-4.05	-
63	Madihalli	-3.79	-	-	-	-	-	-	-	-	-5.75
64	Madihalli	-	-2.11	-12.00	11.22	-24.12	-	-14.11	-0.78	-12.90	-
65	Makuvalli	-	-7.32	-13.60	6.46	-21.08	-	-20.92	-7.14	-14.62	-
66	Manakikere	-	-11.58	2.08	-	-	-	-9.50	-	-	-
67	Manchasandra	-6.36	-3.87	-18.85	13.96	-8.36	-10.23	-22.72	-4.89	5.60	-23.48

Sl. No.	Village name	Nov.11 to May.12	May.12 to Nov. 12	Nov.12 to May.13	May.13 to Sept.13	Sept.13 to Apr.14	Nov.11 to Nov. 12	May.12 to May.13	Nov.12 to Sept.13	May.13 to Apr.14	Nov.11 to Apr.14
68	Manjunathapura	-10.10	-2.64	-21.00	14.27	-1.87	-12.74	-23.64	-6.73	12.40	-21.34
69	Mayagondanahalli	9.37	1.80	-4.75	5.67	-5.92	11.17	-2.95	0.92	-0.25	6.17
70	Mayagondanahalli	-	3.76	-5.95	7.10	-8.92	-	-2.19	1.15	-1.82	-
71	Melanahalli	-7.93	-8.05	-13.35	-2.11	-24.74	-15.98	-21.40	-15.46	-26.85	-56.18
72	Misetimmanahalli	-	-	-	-	-	-	-	-	-	-
73	Muddanayakanapalya	-	-0.85	-1.95	6.25	-3.65	-	-2.80	4.30	2.60	-
74	Muddanayakanapalya	-	-0.26	-1.60	3.37	-	-	-1.86	1.77	-	-
75	Muddenahalli	-	7.08	-10.10	1.94	-2.56	-	-3.02	-8.16	-0.62	-
76	Nelagondanahalli	-	-5.29	-25.40	-27.80	47.30	-	-30.69	-53.20	19.50	-
77	Rudrapura	-3.41	-0.67	-	-	-	-4.08	-	-1.83	-	-
78	Rudrapura	-	-0.96	-1.55	-0.37	-2.69	-	-2.51	-1.92	-3.06	-
79	Saratvalli	-3.16	-	-	-	-	-	-	-	-	-
80	SaratvalliGollarhatti	-	-3.32	-7.70	11.12	-20.29	-	-11.02	3.42	-9.17	-
81	Sasalu	-14.38	-4.25	-	-	-	-18.63	-	-	-	-
82	Savsettihalli colony	-4.20	-3.97	-8.70	1.93	-13.51	-8.17	-12.67	-6.77	-11.58	-28.45
83	Settikere	-	-	-	-	-	-	-	-	-	-
84	Siddaramnagara	-	-	-18.90	0.00	-11.00	-	-	-18.90	-11.00	-
85	Somalapura	5.00	-4.55	-27.20	31.23	-34.38	0.45	-31.75	4.03	-3.15	-29.90
86	Suragondanahalli	-	-0.67	-2.80	4.30	-1.35	-	-3.47	1.50	2.95	-
87	Suragondanahalli	-	-3.41	-4.05	7.18	3.68	-	-7.46	3.13	10.86	-
88	Tagachighatta colony	-	-0.85	-18.05	9.86	-18.86	-	-18.90	-8.19	-9.00	-
89	Tammadihalli	-17.81	7.61	-6.35	7.94	-21.14	-10.20	1.26	1.59	-13.20	-29.75
90	Tarabenahalli	-11.16	-	-	-	-	-	-	-	-	-13.65
91	Tigalanahalli	-	-2.72	-34.10	34.79	-6.09	-	-36.82	0.69	28.70	-
92	Timmalapura	-3.65	-5.94	-20.90	-	-	-9.59	-26.84	-	-	-
93	Timmarayanahalli	-	-	-23.80	0.00	29.80	-49.13	-	-23.80	29.80	-43.13
94	Vaderahalli	-	-2.96	-4.55	11.78	-9.48	-	-7.51	7.23	2.30	-
95	T.B.Colony	-	-2.22	-5.15	-0.51	1.46	-	-7.37	-5.66	0.95	-
96	Vasudevarahalli	-4.90	-6.50	-8.85	0.30	16.08	-11.40	-15.35	-8.55	16.38	-3.87
97	Virupakshapura	-	-4.78	-41.05	9.47	-46.28	-	-45.83	-31.58	-36.81	-
98	Gudigondanahalli	-	-	4.00	19.20	-21.18	-	-	23.20	-1.98	-
99	Hulihalli	-	-	-12.65	12.85	-9.15	-	-	0.20	3.70	-
100	Sasival	-	-	-6.30	6.67	-2.99	-	-	0.37	3.68	-
101	Sasival	-	-	-4.85	3.93	-0.10	-	-	-0.92	3.84	-
102	GollarahattiAnkasandra	-	-	-20.90	22.85	-52.35	-	-	1.95	-29.50	-

Sl. No.	Village name	Nov.11 to May.12	May.12 to Nov. 12	Nov.12 to May.13	May.13 to Sept.13	Sept.13 to Apr.14	Nov.11 to Nov. 12	May.12 to May.13	Nov.12 to Sept.13	May.13 to Apr.14	Nov.11 to Apr.14
103	Chikkamarapanahalli	-	-	-6.95	9.17	-2.66	-	-	2.22	6.51	-
104	Byadarahalli	-	-	-	40.23	-16.03	-	-	-	24.20	-
105	Kodipalya	-	-	-11.15	4.18	-31.23	-	-	-6.97	-27.05	-

Annexure 3.6: Water quality data (Sept. 2011)

Id	Location	Taluk	Type of well	Latitude	Longitude	Date	pH	EC (µS/cm-25°C)	CO3--	HCO3-	CI-	NO3	SO4	F-	PO4	Ca++	Mg++	TH	Na+	K+	Zn	Cu	Ni	Fe
1	Agasarahalli	C.N.Halli	HP	13.353	76.611	24-09-2011	7.7	650	0	152	114	19	14	0.83	0	52	2	140	81	5.3	0.054	0.0001	0.031	0.68
2	Alur	Tiptur	HP	13.317	76.452	20-09-2011	7.4	1090	0	335	114	30	70	0.70	0	52	41	300	100	19.7	0.25	0.003	0.0001	0.28
3	Anekatte	C.N.Halli	HP	13.422	76.557	22-09-2011	7.5	1480	0	390	192	52	94	0.68	0	112	17	350	172	9.8	0.006	0.003	0.027	0.36
4	Ankasandra	C.N.Halli	HP	13.464	76.541	22-09-2011	7.7	1320	0	213	256	58	66	0.80	0	108	24	370	128	7.4	8.03	0.0001	0.038	4
5	Aralikere	C.N.Halli	HP	13.445	76.554	22-09-2011	7.2	1870	0	122	341	190	180	0.70	0	200	29	620	136	13.0	2.19	0.008	0.028	0.18
6	Balavaneralu	Tiptur	HP	13.389	76.423	21-09-2011	7.4	1430	0	445	170	36	68	1.20	0	116	31	420	127	12.6	0.0001	0.003	0.018	0.36
7	Bandegate	Tiptur	HP	13.304	76.535	24-09-2011	7.5	860	0	238	128	15	34	0.79	0	52	17	200	104	1.9	0.0001	0.0001	0.036	0.92
8	Banjara thanda	C.N.Halli	DW	13.446	76.519	22-09-2011	7.8	690	0	323	36	5	18	1.60	0	36	14	150	84	5.2	0.099	0.0001	0.016	0.82
9	Basavarajapura	Tiptur	DW	13.38	76.45	21-09-2011	7.3	1700	0	415	305	16	52	0.53	0	108	70	560	126	11.0	0.068	0.003	0.033	0.24
10	Bhairanayakanahalli	Tiptur	DW	13.298	76.455	20-09-2011	7.2	1970	0	342	334	76	150	0.80	0	168	60	670	137	11.0	2.56	0.009	0.046	0.8
11	Bharanapura	C.N.Halli	DW	13.419	76.482	21-09-2011	7.9	1480	0	525	185	34	18	1.20	0	40	94	490	109	2.3	0.033	0.0001	0.0001	0.88
12	Bommanahalli	Tiptur	HP	13.398	76.441	21-09-2011	7.4	870	0	323	71	32	38	1.04	0	56	17	210	85	25.0	0.0001	0.002	0.011	0.96
13	Byadarahalli	Tiptur	DW	13.344	76.485	25-09-2011	7.5	1600	0	482	213	34	80	0.90	0	68	24	270	230	20.4	0.033	0.0001	0.0001	0.92
14	Chattasandra	C.N.Halli	HP	13.447	76.501	22-09-2011	7.6	910	0	128	220	8	22	0.97	0	56	22	230	100	4.5	0.0001	0.0001	0.012	0.28
15	Dasanakatte	Tiptur	HP	13.376	76.434	25-09-2011	8.5	900	15	140	170	25	36	1.5	0	12	24	130	142	7.5	0.0002	0.0001	0.0002	0.36
16	Dasikere	C.N.Halli	HP	13.394	76.548	23-09-2011	7.7	1960	0	549	213	77	140	1.14	0	104	63	520	208	4.9	0.233	0.011	0.041	0.14
17	Desihallipalya	C.N.Halli	HP	13.422	76.497	23-09-2011	7.7	690	0	274	57	5	30	0.94	0	52	12	180	69	6.4	0.013	0.0001	0.009	0.18
18	Dugganahalli	C.N.Halli	HP	13.418	76.462	21-09-2011	7.5	1460	0	476	170	54	44	1.04	0	96	73	540	85	3.2	3.31	0.032	0.036	0.32
19	Dugudihalli	C.N.Halli	DW	13.394	76.598	24-09-2011	7.7	760	0	104	170	6	42	0.93	0	40	29	220	68	8.4	0.0001	0.0001	0.014	0.16
20	Garehalli	C.N.Halli	HP	13.339	76.608	24-09-2011	7.3	850	0	220	135	19	30	0.57	0	76	17	260	72	4.3	0.013	0.0001	0.011	0.28
21	Gaudanahalli	C.N.Halli	HP	13.401	76.562	23-09-2011	7.7	970	0	128	220	12	54	0.76	0	56	14	200	122	10.7	0.165	0.011	0.022	0.16
22	Gopalanahalli	C.N.Halli	BW	13.346	76.553	24-09-2011	7.3	2570	0	518	398	150	160	0.69	0	108	111	730	238	27.4	0.003	0.0002	0.023	0.32
23	Gotakanakere	Tiptur	HP	13.354	76.457	25-09-2011	7.6	970	0	183	199	15	30	1.10	0	28	17	140	156	3.8	0.0001	0.0001	0.0006	0.34
24	Halkurike	Tiptur	DW	13.374	76.476	21-09-2011	7.3	1860	0	390	312	12	140	0.98	0	120	10	340	264	11.3	0.079	0.006	0.047	0.24
25	Hosur	Tiptur	HP	13.376	76.537	23-09-2011	7.4	1070	0	506	57	17	22	0.75	0	60	48	350	80	1.6	0.075	0.0001	0.033	0.16
26	Kadenahalli	C.N.Halli	HP	13.384	76.628	24-09-2011	7.4	1080	0	232	192	22	48	0.90	0	48	24	220	144	3.1	0.009	0.0001	0.028	1.56
27	Kallakere	Tiptur	HP	13.317	76.490	25-09-2011	7.7	740	0	354	28	5	24	1.20	0	40	14	160	91	8.7	0.006	0.0001	0.0001	0.6
28	Kallenahalli	C.N.Halli	HP	13.435	76.566	22-09-2011	7.7	820	0	323	57	6	48	1.10	0	44	27	220	82	7.9	0.038	0.001	0.024	1.48
29	Kamalapura	C.N.Halli	HP	13.427	76.439	21-09-2011	7.6	1020	0	396	92	34	20	1.00	0	60	48	350	72	2.1	0.049	0.001	0.002	3.3
30	Karehalli	C.N.Halli	HP	13.414	76.578	22-09-2011	8.2	630	0	274	28	4	38	1.20	0	48	14	180	58	5.5	0.003	0.001	0.017	0.2
31	Kedigehalli	C.N.Halli	HP	13.405	76.613	24-09-2011	7.3	1160	0	458	85	4	72	1.00	0	56	31	270	133	6.7	0.327	0.0002	0.04	0.16
32	Khaimara Junction	C.N.Halli	HP	13.441	76.484	22-09-2011	7.8	830	0	354	64	10	16	0.89	0	72	17	250	72	5.9	0.0001	0.002	0.034	0.28
33	Kodagihalli	Tiptur	HP	13.403	76.476	23-09-2011	7.7	1940	0	360	440	10	30	0.40	0	48	116	600	166	5.8	0.985	0.0001	0.033	0.16
34	Kuppur	C.N.Halli	PZ/DMG	13.422	76.531	22-09-2011	7.6	2070	0	238	454	28	160	0.30	0	112	102	700	151	2.9	0.0001	0.011	0.024	0.32
35	Kuppuradoddahalli	Tiptur	HP	13.286	76.439	20-09-2011	7.2	1230	0	467	85	55	58	0.87	0	60	58	390	98	8.2	0.107	0.001	0.139	0.34
36	Madihalli	C.N.Halli	HP	13.388	76.529	23-09-2011	7.6	1860	0	470	312	16	74	0.65	0	72	138	750	81	1.9	0.047	0.0001	0.03	0.14
37	Manchasandra	C.N.Halli	HP	13.410	76.530	23-09-2011	7.8	1030	0	140	227	18	56	0.85	0	56	24	240	124	2.6	0.168	0.0001	0.029	0.2
38	Manjunathapura	Tiptur	HP	13.358	76.434	25-09-2011	7.9	840	0	220	135	29	24	0.3	0	48	17	190	100	4.3	0.0001	0.001	0.0001	1.2
39	Mayagondanahalli	Tiptur	HP	13.385	76.467	21-09-2011	7.5	850	0	281	85	20	48	1.15	0	52	19	210	94	7.6	0.007	0.003	0.017	0.28
40	Melanahalli	C.N.Halli	HP	13.421	76.604	24-09-2011	7.6	1070	0	189	213	9	58	0.67	0	36	29	210	147	2.0	0.0001	0.0001	0.037	0.25
41	Misetimmanahalli	Tiptur	DW	13.31	76.48	25-09-2011	7.6	1080	0	409	85	10	70	0.73	0	40	36	250	122	11.0	0.0001	0.0001	0.045	5.4
42	Rudrapura	Tiptur	HP	13.406	76.414	21-09-2011	7.6	1820	0	616	206	15	94	1.50	0	32	58	320	265	2.3	0.0001	0.007	0.0001	0.64
43	Saratvalli	Tiptur	HP	13.330	76.456	20-09-2011	7.7	800	0	232	92	15	56	0.77	0	36	22	180	97	5.9	0.082	0.0001	0.063	0.36
44	Sasalu	C.N.Halli	HP	13.355	76.569	24-09-2011	7.6	1670	0	311	248	88	140	0.73	0	148	10	410	176	30.5	0.156	0.002	0.015	0.34
45	Savsettihalli	C.N.Halli	HP	13.432	76.593	24-09-2011	7.4	1260	0	397	121	60	70	1.04	0	90	14	290	156	7.0	2.16	0.0001	0.038	0.88
46	Settikere	C.N.Halli	DW	13.383	76.553	23-09-2011	7.4	1030	0	178	192	32	64	0.81	0	64	22	250	117	7.4	0.142	0.014	0.044	0.16
47	Somalapura	C.N.Halli	HP	13.365	76.572	24-09-2011	7.2	1490	0	329	262	5	86	0.68	0	108	43	450	131	6.9	0.0001	0.008	0.042	0.26
48	Tammadihalli	C.N.Halli	HP	13.414	76.507	23-09-2011	7.6	1740	0	372	348	7	50	0.61	0	60	46	340	237	8.3	0.093	0.00011	0.052	0.36
49	Tarabenahalli	C.N.Halli	BW	13.374	76.634	24-09-2011	7.3	1290	0	226	248	36	66	0.65	0	84	12	260	173	5.7	0.008	0.0001	0.022	0.38
50	Timmalapura	Tiptur	HP	13.300	76.427	20-09-2011	7.3	1180	0	396	106	44	66	0.78	0	48	60	370	95	9.6	0.438	0.003	0.504	0.24
51	Timmarayanahalli	Tiptur	DW	13.334	76.504	25-09-2011	7.6	780	0	262	99	3	26	1.10	0	52	17	200	79	6.3	0.0001	0.0001	0.0001	2.5
52	Vasudevarahalli	Tiptur	HP	13.299	76.442	20-09-2011	7.4	1050	0	384	78	10	76	0.92	0	36	53	310	87	18.3	0.001	0.002	0.039	0.32

Annexure 3.7: Water quality data (May 2012)

Id	Location	Taluk	Type of well	Latitude	Longitude	Date	pH	EC (µS/cm-25°C)	CO3--	HCO3-	Cl-	NO3	SO4	F-	PO4	Ca++	Mg++	TH	Na+	K+	B
1	Agasarahalli	C.N.Halli	HP	13.353	76.611	25-05-2012	8.4	630	15	201	50	41	14	0.7	0.039	20	12	100	95	4.4	0.002
2	Anekatte	C.N.Halli	HP	13.422	76.557	25-05-2012	8.1	420	0	128	43	37	10	0.25	0.07	16	14	100	46	2.8	0.001
3	Ankasandra	C.N.Halli	HP	13.464	76.541	25-05-2012	8.4	870	15	171	156	12	34	0.67	0.039	44	27	220	89	15.4	0.001
4	Ankasandra Gollarahatti	C.N.Halli	HP	13.473	76.541	25-05-2012	8.2	1150	0	146	220	45	94	0.57	0.007	24	31	190	172	7.3	0.002
5	Aralikere	C.N.Halli	HP	13.445	76.554	25-05-2012	8.2	550	0	146	71	22	28	0.46	0.01	24	14	120	65	8.5	0.002
6	B. Hosahalli	Tiptur	DW	13.396	76.434	22-05-2012	7.9	1480	0	262	298	69	42	0.65	0.02	124	46	500	102	6.4	0.004
7	B. Hosahalli	Tiptur	HP	13.395	76.433	22-05-2012	8.1	4440	0	178	1228	100	244	0.23	0.40	156	267	1490	328	9.8	0.009
8	Balavaneralu	Tiptur	HP	13.389	76.423	23-05-2012	8.9	2040	39	226	426	55	104	0.54	0.19	80	53	420	213	101.0	0.003
9	Balavaneralu	Tiptur	HP	13.389	76.423	23-05-2012	8.2	2340	0	201	561	90	134	0.57	0.08	96	39	400	329	35.2	0.072
10	Bandegate	Tiptur	HP	13.304	76.535	26-05-2012	8.1	540	0	140	85	19	14	0.66	0.03	16	19	120	65	1.9	0.001
11	Banjar thanda	C.N.Halli	DW	13.446	76.519	23-05-2012	8.2	2320	0	159	582	50	152	0.59	0.16	52	41	300	391	5.0	0.001
12	Bommanahalli	Tiptur	HP	13.398	76.441	22-05-2012	7.9	870	0	274	85	25	60	0.9	0.11	28	34	210	84	31.5	0.053
13	Bevanahalli thanda	C.N.Halli	HP	13.443	76.521	23-05-2012	7.8	1440	0	201	284	60	96	0.41	0.07	68	56	400	138	13.2	0.003
14	Bhairapura	Tiptur	HP	13.351	76.475	24-05-2012	8.5	1410	18	244	220	25	128	0.69	0.10	44	29	230	211	10	0.001
15	Bommanahalli thanda	Tiptur	HP	13.383	76.450	22-05-2012	8	700	0	220	64	31	48	1.1	0.01	12	31	160	80	9	0.001
16	Chattasandra	C.N.Halli	HP	13.447	76.501	23-05-2012	7.7	2270	0	207	511	91	160	0.64	0.16	72	48	380	339	5.6	0.003
17	Chikkamarappanahalli	Tiptur	HP	13.299	76.519	26-05-2012	8.1	710	0	116	128	36	40	0.85	0.007	28	34	210	60	8.1	0.021
18	Choulahalli	Tiptur	HP	13.341	76.460	24-05-2012	8.4	790	15	220	78	40	42	0.44	0.04	12	39	190	87	7.2	0.001
19	Dasanakatte	Tiptur	HP	13.376	76.434	22-05-2012	7.9	860	0	299	78	60	16	1	0.06	40	31	230	87	6.1	0.001
20	Dasikere	C.N.Halli	HP	13.394	76.548	24-05-2012	8.6	1650	30	213	298	65	118	0.52	0.07	28	87	430	172	8.4	0.001
21	Dugianahalli	C.N.Halli	HP	13.418	76.462	23-05-2012	8.5	1780	30	311	277	43	150	0.52	0.10	80	68	480	174	17.0	0.001
22	Dugianahalli	C.N.Halli	HP	13.425	76.461	23-05-2012	8.6	1870	30	360	348	22	70	0.76	0.10	40	19	180	343	5.7	0.001
23	Dugianahalli	C.N.Halli	HP	13.420	76.461	23-05-2012	8.5	1240	30	268	163	16	96	1.1	0.11	12	22	120	217	15.0	0.001
24	Gerahalli	C.N.Halli	HP	13.339	76.608	25-05-2012	8.1	540	0	128	92	12	20	0.3	0.01	28	24	170	42	5.2	0.001
25	Gaudanahalli	C.N.Halli	HP	13.401	76.562	25-05-2012	8.3	810	12	146	114	35	64	0.67	0.04	40	19	180	99	6.2	0.011
26	Gopalanahalli	C.N.Halli	BW	13.346	76.553	26-05-2012	8.6	1290	27	250	206	29	70	0.55	0.04	60	51	360	119	18.1	0.095
27	Gatakanakere	Tiptur	HP	13.354	76.457	22-05-2012	8.2	790	0	305	71	30	14	0.99	0.12	20	17	120	121	4	0.002
28	Hosur	Tiptur	HP	13.376	76.537	24-05-2012	8.1	1330	0	146	270	81	87	0.4	0.01	72	53	400	115	9.8	0.001
29	Kallakere	Tiptur	HP	13.317	76.490	24-05-2012	8.5	610	12	226	43	12	24	0.8	0.07	20	14	110	82	6.2	0.001
30	Kallenahalli	C.N.Halli	HP	13.435	76.566	25-05-2012	8.4	1620	15	165	305	45	172	0.41	0.03	48	34	260	220	48.8	0.001
31	Kamlapura	C.N.Halli	HP	13.427	76.439	23-05-2012	8.2	1400	0	287	241	62	68	0.36	0.09	36	80	420	120	2	0.002
32	Kerehalli	C.N.Halli	HP	13.414	76.578	25-05-2012	8.2	570	0	122	99	33	10	1	0.01	16	22	130	67	5.6	0.001
33	Halenahalli	Tiptur	HP	13.357	76.486	24-05-2012	8.4	1990	18	122	490	19	145	0.43	0.16	84	48	410	252	26	0.002
34	Harisamudra Gate	Tiptur	HP	13.320	76.465	22-05-2012	7.8	1150	0	384	156	19	20	0.5	0.04	20	65	320	109	12.3	0.025
35	Hesarahalli	C.N.Halli	HP	13.408	76.552	25-05-2012	8.3	590	9	140	78	25	28	0.41	0.04	12	31	160	58	3.2	0.001
36	Hosahatti	Tiptur	HP	13.294	76.489	24-05-2012	8.4	890	15	171	156	22	32	0.51	0.10	28	31	200	105	11.0	0.003
37	Hulihalli	Tiptur-outside	HP	13.362	76.417	22-05-2012	8.8	1780	33	354	298	70	56	1.42	0.10	52	44	310	207	99.3	0.065
38	Khaimara Junction	C.N.Halli	HP	13.441	76.484	23-05-2012	8.2	1150	0	360	129	18	70	1	0.12	24	17	130	202	2.7	0.002
39	Kodagihalli	Tiptur	HP	13.403	76.476	24-05-2012	8.0	1430	0	116	355	40	74	0.22	0.07	40	94	490	100	4.3	0.002
40	Kaval/Shantiniwas estste	Tiptur	HP	13.306	76.522	26-05-2012	8.3	480	9	152	50	20	10	0.73	0.04	20	12	100	61	2.2	0.002
41	Kodalagara	C.N.Halli	HP	13.370	76.602	25-05-2012	8.4	530	15	201	28	10	18	0.4	0.005	40	2	110	68	2.6	0.002
42	Kuppuru	C.N.Halli	PZ/DMG	13.422	76.531	25-05-2012	8.0	1450	0	152	355	28	64	0.45	0.03	32	75	390	148	7.6	0.042
43	Kuppuradoddahalli	Tiptur	HP	13.286	76.439	23-05-2012	8.4	1110	18	274	135	70	46	0.77	0.02	24	68	340	88	12.5	0.002
44	Madihalli	C.N.Halli	HP	13.388	76.529	24-05-2012	8.3	1660	9	183	334	70	126	0.3	0.07	80	87	560	116	11.0	0.001
45	Manchasandra	C.N.Halli	HP	13.410	76.530	24-05-2012	7.7	1320	0	220	248	20	98	0.5	0.018	56	39	300	144	34	0.004
46	Manjunathapura	Tiptur	HP	13.358	76.434	22-05-2012	8.2	940	0	366	64	35	40	1.3	0.11	16	44	220	110	6.4	0.002
47	Mayagondanahalli	Tiptur	HP	13.385	76.467	24-05-2012	7.8	1520	0	91	341	60	138	0.99	0.1	52	41	300	205	7.7	0.001
48	Radrapura	Tiptur	HP	13.406	76.414	23-05-2012	8.1	2340	0	299	511	98	114	1.1	0.12	44	89	480	310	4.2	0.001
49	Radrapura	Tiptur	DW	13.406	76.412	23-05-2012	8.2	1620	0	378	263	60	68	1.2	0.11	100	27	360	203	3	0.003
50	Saratvalli	Tiptur	HP	13.330	76.456	22-05-2012	7.7	1000	0	262	163	23	30	0.48	0.20	24	46	250	110	6.6	0.001
51	Saratvalli Gollarhatti	Tiptur	HP	13.333	76.431	22-05-2012	8.0	770	0	268	64	42	32	1.0	0.22	20	31	180	89	6.1	0.001
52	Sasalu	C.N.Halli	HP	13.355	76.569	26-05-2012	8.1	680	0	201	92	16	24	0.54	0.07	20	29	170	75	2.9	0.002
53	Savsettihalli colony	C.N.Halli	HP	13.432	76.593	25-05-2012	8.4	850	12	165	142	37	34	0.46	0.03	24	27	170	112	4.5	0.002

Id	Location	Taluk	Type of well	Latitude	Longitude	Date	pH	EC (µS/cm-25°C)	CO3--	HCO3-	Cl-	NO3	SO4	F-	PO4	Ca++	Mg++	TH	Na+	K+	B
54	Settikere	C.N.Halli	DW	13.383	76.553	24-05-2012	7.8	1580	0	104	369	59	121	0.34	0.07	144	39	520	120	5.1	0.072
55	Somalapura	C.N.Halli	HP	13.365	76.572	24-05-2012	8.1	480	0	116	50	40	36	0.41	0.07	36	14	150	39	3.5	0.001
56	Tammadihalli	C.N.Halli	HP	13.414	76.507	24-05-2012	8.2	920	0	183	177	16	40	0.4	0.06	20	58	290	75	4.4	0.078
57	Tarabenahalli	C.N.Halli	BW	13.374	76.634	25-05-2012	8.3	730	12	140	106	29	48	0.31	0.01	16	29	160	90	4.5	0.001
58	Vasudevarahalli	Tiptur	HP	13.299	76.442	23-05-2012	8.0	1300	0	250	227	49	72	0.4	0.11	40	56	330	139	10.2	0.001
59	Lakshmanapura	Tiptur	HP	13.343	76.489	24-05-2012	8.0	1230	0	256	199	43	82	0.64	0.10	24	29	180	191	7	0.001
60	Madapurahatti	C.N.Halli	HP	13.437	76.501	23-05-2012	8.0	1270	0	91	277	65	108	0.45	0.10	56	48	340	125	9	0.002
61	Makuvalli	C.N.Halli	HP	13.372	76.557	24-05-2012	8.5	1030	18	232	149	26	54	0.46	0.032	40	27	210	138	2.0	0.004
62	Manakikere	Tiptur	HP	13.337	76.482	24-05-2012	8.6	1320	21	274	199	35	80	0.77	0.09	12	56	260	123	101.0	0.002
63	Muddanayakanpalya	Tiptur	DW	13.415	76.427	23-05-2012	8.4	720	15	171	57	40	74	1.24	0.06	20	22	140	97	2.3	0.002
64	Muddanayakanpalya	Tiptur	HP	13.418	76.426	23-05-2012	8.3	620	9	122	78	42	40	1	0.03	24	10	100	94	2.7	0.001
65	Muddenahalli	Tiptur	HP	13.372	76.469	24-05-2012	7.9	640	0	171	85	42	16	1.4	0.06	20	19	130	74	21.2	0.52
66	Nelagondanahalli	Tiptur	HP	13.339	76.444	22-05-2012	7.6	650	0	226	57	21	38	0.5	0.19	24	46	250	29	5.3	0.003
67	Sasival	Arasikere-outside	DW	13.447	76.394	23-05-2012	8.4	960	18	378	64	20	24	0.9	0.10	44	34	250	101	7.1	0.002
68	Sasival	Arasikere-outside	HP	13.441	76.401	23-05-2012	8.7	1750	39	213	383	49	44	0.38	0.09	64	114	630	107	6.7	0.006
69	Siddaramanagara	C.N.Halli	HP	13.384	76.584	25-05-2012	8.5	900	21	268	114	17	14	0.88	0.007	48	27	230	96	6.3	0.001
70	Suragondanhalli	Tiptur	HP	13.406	76.432	23-05-2012	8.5	1010	15	177	185	45	34	0.33	0.11	24	36	210	132	3	0.001
71	Tagachaghata Colony	C.N.Halli	HP	13.431	76.517	23-05-2012	8.4	730	12	201	64	42	46	0.75	0.06	20	27	160	91	3.1	0.004
72	Tigalannahalli	C.N.Halli	HP	13.328	76.609	25-05-2012	8.0	660	0	110	142	22	16	0.13	0.43	40	29	220	41	14.2	0.044
73	Vaddarahalli	C.N.Halli	HP	13.386	76.576	25-05-2012	8.2	460	0	140	57	26	10	0.4	0.007	16	17	110	51	3.5	0.021

Annexure 3.8: Seasonal variation of ground water quality (September 2011 vs. May 2012)

Locations	Taluk	pH		Differ-ence	EC		Differ-ence	CO3--		Differ-ence	HCO3-		Differ-ence	Cl-		Differ-ence
		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012	
Agasarahalli	C.N.Halli	7.7	8.4	-0.7	650	630	20	0	15	-15	152	201	-49	114	50	64
Anekatte	C.N.Halli	7.5	8.1	-0.6	1480	420	1060	0	0	0	390	128	262	192	43	149
Ankasandra	C.N.Halli	7.7	8.4	-0.7	1320	870	450	0	15	-15	213	171	42	256	156	100
Aralikere	C.N.Halli	7.2	8.2	-1.0	1870	550	1320	0	0	0	122	146	-24	341	71	270
Bandegate	Tiptur	7.5	8.1	-0.6	860	540	320	0	0	0	238	140	98	128	85	43
Banjar thanda	C.N.Halli	7.8	8.2	-0.4	690	2320	-1630	0	0	0	323	159	164	36	582	-546
Bommanahalli	Tiptur	7.4	7.9	-0.5	870	870	0	0	0	0	323	274	49	71	85	-14
Chattasandra	C.N.Halli	7.6	7.7	-0.1	910	2270	-1360	0	0	0	128	207	-79	220	511	-291
Dasanakatte	Tiptur	8.5	7.9	0.6	900	860	40	15	0	15	140	299	-159	170	78	92
Dasikere	C.N.Halli	7.7	8.6	-0.9	1960	1650	310	0	30	-30	549	213	336	213	298	-85
Gerahalli	C.N.Halli	7.3	8.1	-0.8	850	540	310	0	0	0	220	128	92	135	92	43
Gaudanahalli	C.N.Halli	7.7	8.3	-0.6	970	810	160	0	12	-12	128	146	-18	220	114	106
Gopalanahalli	C.N.Halli	7.3	8.6	-1.3	2570	1290	1280	0	27	-27	518	250	268	398	206	192
Gatakanakere	Tiptur	7.6	8.2	-0.6	970	790	180	0	0	0	183	305	-122	199	71	128
Hosur	Tiptur	7.4	8.1	-0.7	1070	1330	-260	0	0	0	506	146	360	57	270	-213
Kallakere	Tiptur	7.7	8.5	-0.8	740	610	130	0	12	-12	354	226	128	28	43	-15
Kallenahalli	C.N.Halli	7.7	8.4	-0.7	820	1620	-800	0	15	-15	323	165	158	57	305	-248
Kamlapura	C.N.Halli	7.6	8.2	-0.6	1020	1400	-380	0	0	0	396	287	109	92	241	-149
Kerehalli	C.N.Halli	8.2	8.2	0.0	630	570	60	0	0	0	274	122	152	28	99	-71
Khaimara Junction	C.N.Halli	7.8	8.2	-0.4	830	1150	-320	0	0	0	354	360	-6	64	129	-65
Kodagihalli	Tiptur	7.7	8.0	-0.3	1940	1430	510	0	0	0	360	116	244	440	355	85
Kuppuru	C.N.Halli	7.6	8.0	-0.4	2070	1450	620	0	0	0	238	152	86	454	355	99
Kuppuradoddahalli	Tiptur	7.2	8.4	-1.2	1230	1110	120	0	18	-18	467	274	193	85	135	-50
Madihalli	C.N.Halli	7.6	8.3	-0.7	1860	1660	200	0	9	-9	470	183	287	312	334	-22
Manchasandra	C.N.Halli	7.8	7.7	0.1	1030	1320	-290	0	0	0	140	220	-80	227	248	-21
Manjunathapura	Tiptur	7.9	8.2	-0.3	840	940	-100	0	0	0	220	366	-146	135	64	71
Mayagondanahalli	Tiptur	7.5	7.8	-0.3	850	1520	-670	0	0	0	281	91	190	85	341	-256
Saratvalli	Tiptur	7.7	7.7	0.0	800	1000	-200	0	0	0	232	262	-30	92	163	-71
Sasalu	C.N.Halli	7.6	8.1	-0.5	1670	680	990	0	0	0	311	201	110	248	92	156
Savsettihalli colony	C.N.Halli	7.4	8.4	-1.0	1260	850	410	0	12	-12	397	165	232	121	142	-21
Settikere	C.N.Halli	7.4	7.8	-0.4	1030	1580	-550	0	0	0	178	104	74	192	369	-177
Somalapura	C.N.Halli	7.2	8.1	-0.9	1490	480	1010	0	0	0	329	116	213	262	50	212
Tammadihalli	C.N.Halli	7.6	8.2	-0.6	1740	920	820	0	0	0	372	183	189	348	177	171
Tarabenahalli	C.N.Halli	7.3	8.3	-1.0	1290	730	560	0	12	-12	226	140	86	248	106	142
Vasudevarahalli	Tiptur	7.4	8.0	-0.6	1050	1300	-250	0	0	0	384	250	134	78	227	-149

Locations	Taluk	pH		Differ-ence	EC		Differ-ence	CO3--		Differ-ence	HCO3-		Differ-ence	Cl-		Differ-ence
		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012	
Positive values				**2**			**22**			**1**			**25**			**17**
Negative values				**31**			**12**			**11**			**10**			**18**
No change				**2**			**1**			**23**			**0**			**0**

Contd. - Annexure 3.8: Seasonal variation of ground water quality (September 2011 vs May 2012)

Locations	Taluk	NO3		Differ-ence	SO4		Differ-ence	F-		Differ-ence	PO4		Differ-ence	Ca++		Differ-ence
		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012	
Agasarahalli	C.N.Halli	19	41	-22	14	14	0	0.83	0.7	0.13	0	0.039	-0.039	52	20	32
Anekatte	C.N.Halli	52	37	15	94	10	84	0.68	0.25	0.43	0	0.07	-0.07	112	16	96
Ankasandra	C.N.Halli	58	12	46	66	34	32	0.80	0.67	0.13	0	0.039	-0.039	108	44	64
Aralikere	C.N.Halli	190	22	168	180	28	152	0.70	0.46	0.24	0	0.01	-0.01	200	24	176
Bandegate	Tiptur	15	19	-4	34	14	20	0.79	0.66	0.13	0	0.03	-0.03	52	16	36
Banjar thanda	C.N.Halli	5	50	-45	18	152	-134	1.60	0.59	1.01	0	0.16	-0.16	36	52	-16
Bommanahalli	Tiptur	32	25	7	38	60	-22	1.04	0.9	0.14	0	0.11	-0.11	56	28	28
Chattasandra	C.N.Halli	8	91	-83	22	160	-138	0.97	0.64	0.33	0	0.16	-0.16	56	72	-16
Dasanakatte	Tiptur	25	60	-35	36	16	20	1.5	1	0.50	0	0.06	-0.06	12	40	-28
Dasikere	C.N.Halli	77	65	12	140	118	22	1.14	0.52	0.62	0	0.07	-0.07	104	28	76
Gerahalli	C.N.Halli	19	12	7	30	20	10	0.57	0.3	0.27	0	0.01	-0.01	76	28	48
Gaudanahalli	C.N.Halli	12	35	-23	54	64	-10	0.76	0.67	0.09	0	0.04	-0.04	56	40	16
Gopalanahalli	C.N.Halli	150	29	121	160	70	90	0.69	0.55	0.14	0	0.04	-0.04	108	60	48
Gatakanakere	Tiptur	15	30	-15	30	14	16	1.10	0.99	0.11	0	0.12	-0.12	28	20	8
Hosur	Tiptur	17	81	-64	22	87	-65	0.75	0.4	0.35	0	0.01	-0.01	60	72	-12
Kallakere	Tiptur	5	12	-7	24	24	0	1.20	0.8	0.40	0	0.07	-0.07	40	20	20
Kallenahalli	C.N.Halli	6	45	-39	48	172	-124	1.10	0.41	0.69	0	0.03	-0.03	44	48	-4
Kamlapura	C.N.Halli	34	62	-28	20	68	-48	1.00	0.36	0.64	0	0.09	-0.09	60	36	24
Kerehalli	C.N.Halli	4	33	-29	38	10	28	1.20	1	0.20	0	0.01	-0.01	48	16	32
Khaimara Junction	C.N.Halli	10	18	-8	16	70	-54	0.89	1	-0.11	0	0.12	-0.12	72	24	48
Kodagihalli	Tiptur	10	40	-30	30	74	-44	0.40	0.22	0.18	0	0.07	-0.07	48	40	8
Kuppuru	C.N.Halli	28	28	0	160	64	96	0.30	0.45	-0.15	0	0.03	-0.03	112	32	80
Kuppuradoddahalli	Tiptur	55	70	-15	58	46	12	0.87	0.77	0.10	0	0.02	-0.02	60	24	36
Madihalli	C.N.Halli	16	70	-54	74	126	-52	0.65	0.3	0.35	0	0.07	-0.07	72	80	-8
Manchasandra	C.N.Halli	18	20	-2	56	98	-42	0.85	0.5	0.35	0	0.018	-0.018	56	56	0
Manjunathapura	Tiptur	29	35	-6	24	40	-16	0.3	1.3	-1.00	0	0.11	-0.11	48	16	32
Mayagondanahalli	Tiptur	20	60	-40	48	138	-90	1.15	0.99	0.16	0	0.1	-0.1	52	52	0
Saratvalli	Tiptur	15	23	-8	56	30	26	0.77	0.48	0.29	0	0.20	-0.2	36	24	12
Sasalu	C.N.Halli	88	16	72	140	24	116	0.73	0.54	0.19	0	0.07	-0.07	148	20	128
Savsettihalli colony	C.N.Halli	60	37	23	70	34	36	1.04	0.46	0.58	0	0.03	-0.03	90	24	66
Settikere	C.N.Halli	32	59	-27	64	121	-57	0.81	0.34	0.47	0	0.07	-0.07	64	144	-80
Somalapura	C.N.Halli	5	40	-35	86	36	50	0.68	0.41	0.27	0	0.07	-0.07	108	36	72
Tammadihalli	C.N.Halli	7	16	-9	50	40	10	0.61	0.4	0.21	0	0.06	-0.06	60	20	40
Tarabenahalli	C.N.Halli	36	29	7	66	48	18	0.65	0.31	0.34	0	0.01	-0.01	84	16	68
Vasudevarahalli	Tiptur	10	49	-39	76	72	4	0.92	0.4	0.55	0	0.11	-0.11	36	40	-4

Locations	Taluk	NO3		Differ-ence	SO4		Differ-ence	F-		Differ-ence	PO4		Differ-ence	Ca++		Differ-ence
		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012	
Positive values				**10**			**19**			**32**			**0**			**25**
Negetive values				**24**			**14**			**3**			**35**			**8**
No change				**1**			**2**			**0**			**0**			**2**

Contd. - Annexure 3.8: Seasonal variation of ground water quality (September 2011 vs May 2012)

Locations	Taluk	Mg++		Differ-ence	TH		Differ-ence	Na+		Differ-ence	K+		Differ-ence
		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012	
Agasarahalli	C.N.Halli	2	12	-10	140	100	40	81	95	-14	5.3	4.4	0.9
Anekatte	C.N.Halli	17	14	3	350	100	250	172	46	126	9.8	2.8	7.0
Ankasandra	C.N.Halli	24	27	-3	370	220	150	128	89	39	7.4	15.4	-8.0
Aralikere	C.N.Halli	29	14	15	620	120	500	136	65	71	13.0	8.5	4.5
Bandegate	Tiptur	17	19	-2	200	120	80	104	65	39	1.9	1.9	0.0
Banjar thanda	C.N.Halli	14	41	-27	150	300	-150	84	391	-307	5.2	5.0	0.2
Bommanahalli	Tiptur	17	34	-17	210	210	0	85	84	1	25.0	31.5	-6.5
Chattasandra	C.N.Halli	22	48	-26	230	380	-150	100	339	-239	4.5	5.6	-1.1
Dasanakatte	Tiptur	24	31	-7	130	230	-100	142	87	55	7.5	6.1	1.4
Dasikere	C.N.Halli	63	87	-24	520	430	90	208	172	36	4.9	8.4	-3.5
Gerahalli	C.N.Halli	17	24	-7	260	170	90	72	42	30	4.3	5.2	-0.9
Gaudanahalli	C.N.Halli	14	19	-5	200	180	20	122	99	23	10.7	6.2	4.5
Gopalanahalli	C.N.Halli	111	51	60	730	360	370	238	119	119	27.4	18.1	9.3
Gatakanakere	Tiptur	17	17	0	140	120	20	156	121	35	3.8	4	-0.2
Hosur	Tiptur	48	53	-5	350	400	-50	80	115	-35	1.6	9.8	-8.2
Kallakere	Tiptur	14	14	0	160	110	50	91	82	9	8.7	6.2	2.5
Kallenahalli	C.N.Halli	27	34	-7	220	260	-40	82	220	-138	7.9	48.8	-40.9
Kamlapura	C.N.Halli	48	80	-32	350	420	-70	72	120	-48	2.1	2	0.1
Kerehalli	C.N.Halli	14	22	-8	180	130	50	58	67	-9	5.5	5.6	-0.1
Khaimara Junction	C.N.Halli	17	17	0	250	130	120	72	202	-130	5.9	2.7	3.2
Kodagihalli	Tiptur	116	94	22	600	490	110	166	100	66	5.8	4.3	1.5
Kuppuru	C.N.Halli	102	75	27	700	390	310	151	148	3	2.9	7.6	-4.7
Kuppuradoddahalli	Tiptur	58	68	-10	390	340	50	98	88	10	8.2	12.5	-4.3
Madihalli	C.N.Halli	138	87	51	750	560	190	81	116	-35	1.9	11.0	-9.1
Manchasandra	C.N.Halli	24	39	-15	240	300	-60	124	144	-20	2.6	34	-31.4
Manjunathapura	Tiptur	17	44	-27	190	220	-30	100	110	-10	4.3	6.4	-2.1
Mayagondanahalli	Tiptur	19	41	-22	210	300	-90	94	205	-111	7.6	7.7	-0.1
Saratvalli	Tiptur	22	46	-24	180	250	-70	97	110	-13	5.9	6.6	-0.7
Sasalu	C.N.Halli	10	29	-19	410	170	240	176	75	101	30.5	2.9	27.6
Savsettihalli colony	C.N.Halli	14	27	-13	290	170	120	156	112	44	7.0	4.5	2.5
Settikere	C.N.Halli	22	39	-17	250	520	-270	117	120	-3	7.4	5.1	2.3
Somalapura	C.N.Halli	43	14	29	450	150	300	131	39	92	6.9	3.5	3.4
Tammadihalli	C.N.Halli	46	58	-12	340	290	50	237	75	162	8.3	4.4	3.9
Tarabenahalli	C.N.Halli	12	29	-17	260	160	100	173	90	83	5.7	4.5	1.2
Vasudevarahalli	Tiptur	53	56	-3	310	330	-20	87	139	-52	18.3	10.2	8.1

Locations	Taluk	Mg++		Differ-ence	TH		Differ-ence	Na+		Differ-ence	K+		Differ-ence
		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012		Nov 2011	May 2012	
Positive values				**7**			**22**			**20**			**18**
Negative values				**25**			**12**			**15**			**16**
No change				**3**			**1**			**0**			**1**

FIELD PHOTOS

Dry tank near Halkurike village

Dry tank near Marasandra village

Exposure of schist in dug well near Hosur village

Boulder checks observed on Vaderahalli – Chunganahalli road

Water scarcity scenario in Vasudevarahalli village

Ragi crop in Rudrapura village

Check dam constructed accorss 3rd order stream on Settikere – Dasihalli village

Small kalyani near Dasanakatte village

Major check dam at Ankasandra village

Water conservastion structure on Hesarahalli – Gowdanahalli road

Construction of bunds at parcel on Bharanapura – Hosur road

A farmer with his bullocks at in Karehalli village

Existing dug well at Arlikere village

A progressive farmer with his agriculture land in Kodigehalli village

Field inspection by Regional Director

Exposure of Quartizite vein on Settikere – Madihalli road

Granite quarrying near Bandegate village

Drip irrigation adopted for Banana plantation in Dasikere village

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