CHAPTER-I

INTRODUCTION

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1.1 Water

Water forms one of the basic components of our living environment next to air. The existence of human culture and civilization are vitally linked with water. Both surface and subsurface water is essential for realizing full potential of the agriculture sector and the country’s development. India is enviably endowed in respect of water resources. The country is crisscrossed with rivers and blessed with high precipitation mainly due to the South-West Monsoon, which accounts for 75 percent of the annual rainfall. The major river basins account for almost 91 percent of the country’s entire drainage area. In spite of nature’s bounty, paucity of potable water has been an issue of national concern. With the runaway increase in population and urbanization along with rapid industrialization, water is becoming a scare resource. Effluent and pollutions are taking their toll in our river. To conserve this resource, it is essential to ensure people’s involvement in planning, implementation and management of all aspects relating to water management. It is increasingly realized that water will be the most strategic resource guiding the course of development of a nation in the 21st century. This is primarily because, on one hand more and more areas in the world are facing an increasing shortage of water, while on the other hand, wide spread pollution of ground water resource limits its use in areas where it is available. What is more worrying is that the decreasing well yields and lowering ground water levels have stated affecting even small rural communities, creating social tensions between neighbouring villages and even individuals within the same village.

While availability is one side of the problem, the deteriorating quality of water resources is the other side, and equally vexing. Pollution of groundwater due to external contaminants such as industrial, urban and agricultural activities is quite well documented (Todd, 1980; Freeze and Cherry, 1979). One of the aspects on which enough attention has not been focused is the degradation of groundwater quality controlled by natural and environmental factors such as geology, soil coverage etc are the influence of changes in chemical parameter like fluoride, calcium, magnesium, TDS etc. Ground water is the only replenishable natural mineral resource available to man. Use of ground water has been growing steadily over the years for domestic, agricultural and industrial purposes. In large parts of India, in the geographical areas away from surface water resources (rivers, lakes
and man made dams), it remains as the only source of water. In these areas, its exploitation has increased manifold in the last two to three decades. The report of the Groundwater resources committee (GWRC, 1997), has estimated that in India, during the period 1951-92, the number of dug wells increased from 3.86 million to 10.12 million, while the number of shallow tube wells increased from 3,000 to 538 million. The total area irrigated by ground water increased from 6.5Mha in 1951 to 35.38Mha in 1993. In the hard rock areas of India, where recharge is limited, such large-scale abstraction has resulted in failure of shallow wells / bore wells creating over exploited zones. Of the 7163 blocks (mandals in A.P. taluks in Gujarat and watershed in Maharastra) in the country, 250 (3.5%) are over exploited, while 179 (2.5%) are dark areas (GWREC, 1997).

Advanced technologies like Remote Sensing and GIS provide tools for effective mapping of natural resources economically than these on the conventional methods and yield better results. In recent years, the increasing use of satellite remote sensing data has made it easier to define the spatial distribution of different ground water prospect classes on the basis of geomorphology and other associated parameters (Sinha et al., 1990; Rao, 1991; Prakash and Mishra, 1991; Tiwari and Rai, 1996). Analysis of remotely sensed data along with Survey of India topographical sheets and collateral information with necessary file checks help in generating the base line information for groundwater targeting.

1.2 Groundwater in hard rock terrain

Geologically, Indian continent is an enormous and dissimilar series of lithological formation, ranges from old crystalline hard rock to recent unconsolidated sedimentary deposits. Karnataka state exhibits a number of greenstone belts which consist of metavolcanics and meta-sedimentary rocks. The variation of geological formation (rock type, linear structures etc), geo-morphological and hydro-morphological signature tends to variation of groundwater quality and water level factors. The word hard rock in geo-hydrological parallance is the rocks that occur in Archean terrain. These rocks are called as aquifers if they have sufficient porosity and permeability and occur under water table condition or confined condition. These formations act as storage and media for movement
of water which is received from surface by infiltration. The infiltration that occurs in any hydrological unit area (may be a watershed or a river basin) will be the main source for the groundwater potential of the basin. The alternative source for the potential is through aqueferous lineaments linking the area from different basin which has excess potential (Murthy KSR, 2000).

Shivani watershed is a part of hard rock terrain of peninsular India. The foremost portion of the study area lithologically covered by Banded Gneiss, Migmatites and Granodioritic to tonalitic gneisses and tonalite and the remaining portion contains Banded Gneiss, Conglomerate, Channagiri Ultramafic-Mafic complex, Ultramafic enclaves, Granite (Sensu Lato), Limestone, Migmatites and granodioritic to tonalitic gneisses, Quartzite, Tonalite and V-Ti Magnetite. The detailed geological information of the study area is discussed in the forthcoming chapter. In the present study, an attempt has been made to evaluate the effect of improved spatial resolution offered by using standard filtering and enhancement techniques applied to IRS-1D LISS-III false composite image data for the interpretation of major faults and linear features.

1.3 Executive summary

Occurrence of groundwater in hard rock is confined to secondary permeable structures i.e. fractured and weathered horizons and in upper unconsolidated materials. The traditional methods of locating sites for drilling of bore hole have not only had a poor success rate but even the places where such efforts have succeeded, the bore wells are known to have dried up in a short period of time due to the effect of over exploitation of groundwater. The concept of integrated remote sensing and GIS has proved to be an efficient tool in groundwater studies (Saraf et.al. 1998, Krishnamurthy et.al 1996 and Murthy 2000). Inclusion of hydro-geological information inferred from geo-electrical survey can give more realistic picture of groundwater potentiality of an area. Keeping this in view, the present study attempts to delineate suitable locations for groundwater exploration by using integrated approach of hydro-geological, hydro-geochemical and geo-electrical studies aided by applications of GIS and Remote sensing techniques.
The area under investigation (Fig: 1.1) lying in Chikkamagalore and Davanagere districts of Karnataka State has been selected for qualitative and quantitative evaluation of different hydro-geological parameters by using some components of Geographical information system and Remote sensing technologies. The study area comes under one of the drought prone zone of Karnataka State. The overall ground water potential of the area is generally poor. The area covered by hard rock formations faces acute water scarcity problem both for irrigation as well as drinking purposes. The irrigation in this area is principally depends on rain and groundwater. The entire watershed area comes under dry land irrigation system. More than two thousand bore wells exist within the study area. That means 4 to 5 bore wells per square km. The foremost purposes of these wells are agriculture and drinking water purposes. The average depth of the bore well is about 700 to 1000 feet. The density of the bore well is increasing day by day. Maximum exploitation of groundwater causes the water table dropdown up to more than 1000 feet. Due to this reason the percentage of groundwater dependent agricultural activities are reduced and the quality of the groundwater varies considerably.

Hydro-geological, hydro-chemical and geo-electrical investigations have been undertaken with the help of geospatial information technology to find out the fatally affected areas interrelated to groundwater quality and groundwater resources variation. satellite data IRS-1D LISS-III has been used to interpret the spatial features such as lineaments, land use / land cover, soil, hydro-geomorphology, geological contact zones using ERDAS (Earth Resources Data Analysis System) Imagine 8.5 Image processing software. The main aim of the present research is integrated hydrological studies governed by several factors such as topography, detailed geology, depth of weathering, extent of liner features, slope aspects, flow accumulation, flow length, flow direction, slope aspects, drainage density, drainage frequency, land use / land cover, hydro-chemical analysis and classifications. This can be effectively achieved through Remote Sensing and GIS techniques. References to integrated approach for study of hydro-geological aspects using Remote Sensing and GIS techniques are many in recent literature.
1.4 Geographical setup

1.4.1 Geographical location

The study area is spatially located in Channagiri, Kadur and Tarikere taluks of Davanagere and Chikkamagalore Districts of Karnataka State (Fig 1.1), covering an aerial extent of 593.56 sq. km and geographically extends between 13° 36' to 13° 55' North latitude and 75° 53' to 76° 12' East longitudes, and the area is covered in Survey of India Topo sheet No. 48 O/13, 48 N/16 and 57C/1.

1.4.2 Accessibility

Shivani watershed forms part of Chikkamagalore and Davanagere districts and comprises several villages and three densely populated village-Panchayat like Shivani, Bukkambudi and Ajjampur having good facilities of communication and accessibility. The area is well connected by roadways. Apart from this a number of un-metalled road, cart track exist within the study area. These un-metal roads and cart tracks link one village to another. A broad gauge railway line connecting Bangalore and Hubli, passing through the area. In general the area has a good transportation network (Fig 1.2).

1.4.3 Topography

Topographically, the area is mainly flat and undulatory. Topographic information has been collected from Survey of India topographical sheets of 1:50,000 scales. Elevation contours have been digitized at 20m intervals and spot height / triangular height are also plotted. Most part of the area shows more or less flat to undulating topography. The minimum and maximum elevations of the area are 680 to 1080m from MSL. The northern part of the study area is highly elevated and southern part is generally low. Shivani watershed is a tributary of Vedavathi River (Plate: I, Fig: a) and ultimately joins to the Vanivillas Sagar / Marikanive dam. The contour map of the area has been prepared to understand general topography of the watershed (Fig 1.3).
Fig 1.1: Location Map of Shivani Watershed, Davanagere - Chikmagalur Districts: Karnataka State, India.
Soil is defined as a thin layer of earth's crust which serves as a natural medium for growth of plants. It is the unconsolidated mineral matter that has been subjected to and influenced by genetic and environmental factors; parent material, climate, organisms and topography, all acting over a period of time. Soil differs from the parent material in the morphological, physical, chemical and biological properties. Also, soils differ among themselves in some or all the properties, depending on the differences in the genetic and environmental factors. Thus some soils are red, some are black; some are deep and some are shallow; some are coarse textured and some are fine-textured. They serve as a reservoir of nutrients and water for crops, provide mechanical anchorage and favourable tilth. The components of soil are mineral matter, organic matter, water and air, the proportions of which vary and which together form a system for plant growth.

Soil characteristics are unstable based on the climatic condition, existing geology of the area. The classification of soils is based on colour, mineralogy, structure and texture. Soil colour is primarily influenced by soil mineralogy. The extensive and various iron minerals in soil are responsible for an array of soil pigmentation. Colour development and distribution of colour within a soil profile result from chemical weathering, as the primary minerals in soil-parent material weather, the elements combine into new and colourful compounds. Iron forms secondary minerals with a yellow or red colour; organic matter decomposes into black and brown compounds; and manganese forms black mineral deposits. These pigments give soil its various colours and patterns and are further affected by environmental factors. Aerobic conditions produce uniform or gradual colour changes while reducing environments result in disrupted colour flow with complex, mottled patterns and points of colour concentration.

Soil structure is the arrangement of soil particles into aggregates. These may have various shapes, sizes and degrees of development or expression. Soil structure influences aeration, water movement, erosion resistance, and root penetration. Observing structure gives clues to texture, chemical and mineralogical conditions, organic content, biological activity, and past use, or abuse.
There are mainly five types of soils in Shivani watershed which have been identified by supervised classification of the IRS-ID LISS-III satellite data in conjunction with limited field data collected from field visits and general information collected from the village panchayat. The major portion of the area is covered by red sandy soil. Most of the agricultural soils usually lose the top horizon either due to construction of terraces or erosion. In the terraced hillside, the down slope drift of mineral matter is sharply reduced and the soil is stabilised. On steep slopes, soils are generally shallow and usually have a thin surface horizon and medium to coarse texture. Sub-soils are deep and heavily textured. Top surface horizon with a high content of organic matter is a characteristic feature of the area. Top soils are highly leached and acidic in nature. Valley soils are developed from the colluvium brought down from the upslope. Soils of the valley bottom on stream terraces comprise of partly alluvium, brought and deposited by streams in the process of aggradations. The soil types identified in the study area are Red Sandy soil (Plate: II, Fig. c) + Pediments, black Cotton Soil (Plate: II, Fig. d) with alkaline content, mixed soil, red soil and sandy soil (Table 1.1). The spatial variation of soil formation of the area has been shown in Fig 1.4.

**Table 1.1 Soil types of the Shivani watershed area.**

<table>
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<tr>
<th>Sl. No</th>
<th>Soil Type</th>
<th>Area in Sq km</th>
<th>Total area in %</th>
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<td>Red Sandy soil + Pediments</td>
<td>251.30</td>
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<td>2</td>
<td>Black Cotton Soil + Alkaline Content</td>
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<td>3</td>
<td>Mixed Soil</td>
<td>109.11</td>
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<td>4</td>
<td>Red Soil</td>
<td>72.16</td>
<td>12.16</td>
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<td>5</td>
<td>Sandy Soil</td>
<td>35.99</td>
<td>6.06</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>593.56</strong></td>
<td><strong>100.00</strong></td>
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</table>
Fig. a: Vedavathi River, near confluence point of Shivani tributary & Vedavathi River

Close view

Fig. b: Synoptic view of Masanikere tank
Fig. a: Variation of soil from red sandy soil to black cotton soil.
Location: Between Channapura-Giriyapur.

Fig. b: Black cotton soil
Location: 5 km south of Hirekanavangala towards Ajjampura.
1.4.5 Meteorology

Meteorology is the basic science to understand the recharge of surface and subsurface water through the process of precipitation, run-off and infiltration which depends on the temperature, humidity, evaporation, relative humidity, wind velocity and other related meteorological factors. Hence these hydro-meterological factors play a vital role in the occurrence and distribution of groundwater and also provide basic tool to understand the hydrologic cycle.

Rainfall, temperature, humidity, evaporation and wind velocity data on the study area were gathered from Indian Meteorological Center, Bangalore and Ministry of Water Resources, Geomatics Center, Bangalore. Based on the data collected, average monthly and yearly rainfall, temperature, humidity, evaporation and wind speed were calculated for each meteorological station. These data were represented in graphical format.

Climate: It describes changes in the variability or average state of the atmosphere over time scales ranging from decades to millions of years. These changes can be caused by processes internal to the earth, external forces (e.g. variations in sunlight intensity) or anthropogenic factors (acts by humans) that change the environment and influence climate. The Shivani watershed experiences sub-tropical to tropical climatic condition.

Rainfall: Is a product of the condensation of atmospheric water vapour that is deposited on the Earth's surface. It forms when separate drops of water fall to the Earth from clouds. Not all rain reaches the surface; some evaporates while falling through dry air. When none of it reaches the ground, it is called virga, a phenomenon often seen in hot, dry desert regions. Rainfall is classified into six types, this classification mainly based on amount of precipitation per hour (Cerveny and Balling; 1986).

- Very light rain (when the precipitation rate is < 0.25 mm/hour).
- Light rain (when the precipitation rate is between 0.25 mm/hour to 1.0 mm/hour).
- Moderate rain (when the precipitation rate is between 1.0 mm/hour to 4.0 mm/hour).
- Heavy rain (when the precipitation rate is between 4.0 mm/hour to 16.0 mm/hour).
• Very heavy rain (when the precipitation rate is between 16.0 mm/hour to 50 mm/hour).
• Extreme rain (when the precipitation rate is > 50.0 mm/hour).

Convectional, frontal or cyclonic and orographic or relief rainfall are the three distinct types of rainfall.

Convectional rainfall usually occurs in places with warmer or tropical climates, and in countries close to the equator. Convection is the condition where rising currents of warm or heated air is separated by larger areas of gradually dropping air, and is commonly the cause of particularly powerful thunderstorms that occur in summer or in hot regions. Convectional rain is caused when convection occurs where the surface of the atmosphere becomes heated or hotter than normal, which in turn causes the damp air to rise.

Frontal or cyclonic rainfall is caused mainly by the occurrence of low pressure areas or lows, and happens when warm and often tropical air meets cooler air. When these two opposing masses of air meet, the warm air 'prevails' as such, over the colder air, and the two contrasting forces of air cause a front. Fronts cause sudden, enigmatic changes in general temperature, and the humidity and pressure in the air. Fronts can be either cold fronts or warm fronts. Warm fronts occur in the situation presented above, where the warm air and cold air meet, and the warm air 'overrides' the cooler air and moves upward. Warm fronts are usually followed by several days of intense rainfall, because, after the warm air rises above the cooler air (which sinks to the ground), it gradually cools, forms clouds, and causes rain. Orographic or relief rainfall is caused when masses of air pushed by wind encounter sizeable objects or land formations they cannot pass, such as large mountains (hence its name of orographic rainfall). This forces the air above the object/land form in question, and, if the air is pushed high enough, it is condensed and becomes cloud matter, which will then cause rain to fall. This type of rainfall is also known as relief rainfall.

Shivani watershed area comes under the categories of convectional rainfall type. The minimum and maximum average rainfall computed for last 30 years (1976 to 2006) is
496.8 and 818.4 respectively, and the average rainfall is 623.1 mm (Table 1.2). The spatial variation of rainfall within the study area (Fig 1.5) and the average rainfall for each station have been calculated and shown in bar graph (Fig 1.6).

### Table 1.2: Average Rainfall from last 30 years (1976-2006)

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<th>Year</th>
<th>Bukkambodi</th>
<th>Shivani</th>
<th>Ajjampur</th>
<th>Ubrani</th>
<th>Ganguru</th>
<th>Yagati</th>
<th>Kadur</th>
<th>Srirampura</th>
<th>Ramgiri</th>
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<td>806.1</td>
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<td>334.5</td>
<td>546.0</td>
<td>556.9</td>
<td>402.4</td>
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<td>541.2</td>
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<td>562.0</td>
<td>703.2</td>
<td>487.4</td>
<td>430.3</td>
</tr>
<tr>
<td>2003</td>
<td>403.6</td>
<td>488.8</td>
<td>432.0</td>
<td>815.0</td>
<td>554.2</td>
<td>592.4</td>
<td>602.0</td>
<td>551.8</td>
<td>501.1</td>
</tr>
<tr>
<td>2004</td>
<td>268.5</td>
<td>592.5</td>
<td>564.0</td>
<td>912.7</td>
<td>398.4</td>
<td>394.1</td>
<td>616.7</td>
<td>460.8</td>
<td>604.0</td>
</tr>
<tr>
<td>2005</td>
<td>425.0</td>
<td>592.5</td>
<td>532.5</td>
<td>653.2</td>
<td>752.0</td>
<td>584.8</td>
<td>497.9</td>
<td>352.6</td>
<td>367.0</td>
</tr>
<tr>
<td>2006</td>
<td>435.0</td>
<td>603.5</td>
<td>578.5</td>
<td>467.2</td>
<td>689.0</td>
<td>478.8</td>
<td>658.9</td>
<td>457.6</td>
<td>584.0</td>
</tr>
</tbody>
</table>

**Avg. Rainfall (30 Years)**

|            | 496.8 | 575.3 | 618.1 | 658.0 | 818.4 | 629.0 | 653.6 | 559.1 | 496.8 | 623.1 |

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Temperature: Temperature is defined as the average energy of microscopic motions of a single particle in the system per degree of freedom. On the macroscopic scale, temperature is the unique physical property that determines the direction of heat flow between two objects placed in thermal contact. (Kittel, Charles; Kroemer, Herbert 1974). The maximum and minimum temperature of the study area is 30.5°C and 20.5°C. The seasonal trend of temperature has been shown in Fig 1.7.
**Humidity:** The term humidity is usually refers to relative humidity. Relative humidity is defined as the amount of water vapour in a sample of air compared to the maximum amount of water vapour the air can hold at any specific temperature in a form of 1 to 100%. Humidity may also be expressed as Absolute humidity and specific humidity. Relative humidity is an important metric used in forecasting weather. Humidity indicates the likelihood of precipitation, dew, or fog. Humid air is less dense than dry air because a molecule of water weighs less than molecules of nitrogen and oxygen. Humidity is a measure of the amount of water vapour dissolved in the air, not including any liquid water or ice falling through the air (Kittel, Charles; Kroemer, Herbert 1974). The relative humidity of Shivani watershed ranges from 61.3 % to 76.2 % and the seasonal trend of average Relative Humidity of the area has been shown in Fig 1.8.

![Figure 1.8: Seasonal Trend of Relative Humidity (2002-2006)](image)

**Wind Velocity:** Wind velocity is the speed of wind, the movement of air or other gases in an atmosphere. It is a scalar quantity, the magnitude of the vector of motion. Wind velocity has always meant the movement of air in an outside environment. The wind velocity of the study area ranges from 1.56 to 5.8 km / hour. The seasonal trend of average wind velocity is shown in Fig 1.9.
Evaporation: The evaporation of Shivani watershed is ranges from 15.2 to 20.9 mm. (Fig.2) Evaporation is the process by which water is converted from its liquid form to its vapor form and thus transferred from land and water masses to the atmosphere. Evaporation from the oceans accounts for 80% of the water delivered as precipitation, with the balance occurring on land, inland waters and plant surfaces. The rate of evaporation depends upon wind speed (the higher the wind speed, the more evaporation), Temperature (the higher the temperature, the more evaporation) and Humidity (the lower the humidity, the more evaporation). The evaporation of the study area ranges between 15.2 to 20.9 mm. The seasonal trend of average evaporation is shown in the Fig 2.0.
1.5 Review of related literature

Chitradurga schist belt is well known for low to high-grade reserves of iron and copper ores. As such it has attracted the attention of well-known geologists like B Chadwick (1978) and B.P. Radhakrishna (1977) and others. The study area forms a part of this schist belt. The literature/publications related to hydro-geological aspects of the study area are scanty. The TCS (Tata consultancy services, 2000) has done the Agriculture resources estimation of Shivani - Ubrani Area. It includes crop acreage estimation. Apart from this, Central Ground Water Board, Govt. of India and Department of Mines and Geology conducted the resistivity and hydro-geological studies on a regional scale.

The study area is scarce

Naraynamurthy, J et.al., (1963) have given an account of geology and structural interpretation of the area around Channagiri – Shivani watershed area. Umapathi Rao, A et.al., (1967) have reported the geological significance of Shimoga district which includes the structural features in hard rock terrain. Jayaram.B.et.al (1915), have conducted geo-hydrological survey in of Shimoga district which includes Channagiri and Kadur taluks. Slater, H.K., (1905, 1906, 1908 & 1912) has carried out an investigation to know the establishment of general geology of Tarikere, Channagiri, Holalkere, Davanagere & Shimoga areas. Ballal, N.R.R. (1972) prepared geological map with hydrogeological correlations for parts of Kadur and Tarike areas of Chikmagalur districts.

1.6 Basic sources of information

Primary data has been collected from Survey of India Topographical Sheets of 1:50,000 scale (48 O/13, 48 N/16 and 57C/1). The satellite images were downloaded from Google earth plus website (www.googleearth.com). The Shivani watershed or catchment area has been demarcation based on the consideration of drainage networks, existing topography by using Survey of India topographical map. All the base layers are generated using the topographical map of 1: 50,000 scale. Chemical analysis of groundwater samples has been carried out in the hydro-chemical laboratory of Department of Studies in Geology, Karnataka University, Dharwad and Department of Environmental Science, Bapuji Institute of Technology, Davanagere. Vertical Electrical Sounding (VES) using Aqua-meter (Model: CRM-20) Low power version (4W), (Microprocessor based earth resistivity meter) has been conducted with aid of Dept, of Studies in Geology, Karnataka University. IRS-1D LISS-III satellite Image interpretation has been done at Geomatics Center Bangalore. Secondary data source such as hydro-meteorological data related to rainfall, temperature, evaporation, wind speed and wind direction has been collected from the Indian Meteorological Department, Bangalore.

1.7 Objectives

The specific objectives set for the work are as follows

1. To establish hydro-chemical information system of the Shivani watershed in geospatial information system (GIS) platform.

2. To study the drainage basin morphometry and analysing the same using GIS and Remote sensing softwares to establish the evolution of the basin and to identify geo-morphological features.

3. To select suitable artificial recharge sites for the construction of check dam, vegetative check considering the slope, drainage density, soil type, Geology and lineaments.

4. To have spatial analysis of the hydro chemical parameters and evaluate the chemical variation of groundwater, the anthropogenic influence on water quality
and to identify likely sources of possible influence of the watershed with the aid of GIS technology.

5 To study the subsurface geo-electrical layer parameters and to prepare resultant thematic maps using GIS.

6 To establish a detailed numeric and thematic database of physico-chemical parameters of groundwaters of the watershed with the aid of GIS.

1.8 Methodology

1. An intensive literature survey has been conducted on the study area to know the general and geological aspects and relevant literature were collected and indexed.

2. Transforming maps / sheets, images into Raster format has been carried out by using EKONICS scanner.

3. Using GARMIN II PLUS: 76CSX (12 Channel) Global Positioning System (GPS) ground control Points (GCP’s) were collected and same were downloaded by using Waypoint+ Version 1.8.00 Software with datum of WGS 84 and DMS / UTM Mode.

4. With reference to GCP’s, geometric correction / rectification and mosaic of Survey of India topographical map (1:50,000 Scale), satellite image (year 2004) were done using ERDAS IMAGE 8.5 Software.

5. After rectification process, Shivani watershed area (Area of interest: AOI) has been demarcated based on the topography and catchment area confluence point.

6. Data Conversion (Raster to vector data conversion) has been done using CAD Overlay: All the base layers within the AOI (Area of interest) such as streams of first to sixth order, surface water bodies, contours of 20m interval, triangulation points / spot heights, settlements and transportation network are digitised by using SOI topographical map. Some of the thematic maps are verified during the field checks. The thematic details thus finalized were transfer to the base maps prepared from Survey of India topographic sheet.
7. Exporting all the digital layers from CAD Overlay 14 to ERDAS IMAGINE 8.5 software. These layers are superimposed on rectified satellite image and necessary correction have been applied.

8. Topology process has been applied to obtain accuracy for the spatial entities.

9. After the topology process, all the layers are exported to MapInfo Professional 8.5 software for creating the tabular / attribute data (Data Base) pertaining to each thematic layer class.

10. Satellite image interpretation was done by applying various filtering and enhancement techniques, Lineament / linear features and land use / land cover pattern of the study area are extracted.

11. The preparation of TIN, 3D Model, hydrological analysis and hydrochemical analysis (Point interpolation method) has been done using MapInfo Professional 8.5 and ArcView 3.2a Spatial analyst extension.
Flow Chart: The methodological approach using GIS and Remote sensing techniques

SECONDARY DATA COLLECTION (Various Organizations)

PRIMARY DATA PREPARATION

SPATIAL

NON - SPATIAL

SUB-SURFACE WATER SAMPLE COLLECTION

DATA STANDARDIZATION

WATER SAMPLE ANALYSIS

DATA INTEGRATION

BASE LAYER

GROUND TRUTH & CROSS CHECK

BASE LAYER UPDATION

SPATIAL ANALYSIS / MODELING

PREPARATION OF FINAL THEMATIC MAPS

RESULT

TOPOHEET

CADESTRAL MAP

IMAGE INTERPRETATION

SATELLITE IMAGE