CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

The earth is also known as the "water planet," as approximately 70 percent of its surface is water. Water is found in rivers, ponds, lakes, oceans, ice caps, clouds and as groundwater. All these forms of water are part of a dynamic and interrelated flow called the hydrologic cycle in which each part of the cycle shares a portion of the total amount of water on the planet.

It is important to appreciate the fact that only 3 per cent of the world's water is fresh and roughly one-third of it is inaccessible. The rest is very unevenly distributed and the available supplies are increasingly contaminated with wastes and pollution from industry, agriculture and households.

Over the years, increasing population, growing industrialization, expanding agriculture and rising standards of living have pushed up the demand for water. Efforts have been made to collect water by building dams and reservoirs and creating ground water structures such as wells. Recycling and desalination of water are other options but cost involved is very high.

However, there is a growing realization that there are limits to 'finding more water' and in the long run, we need to know the amount of water we can reasonably expect to tap and also learn to use it more efficiently.

1.2 AVAILABILITY OF WATER RESOURCES IN INDIA

The availability and the quality of the fresh water resources is the most demanding of the many environmental challenges in India. The stress on water resources is from multiple sources and the impacts can take diverse forms. Increase in population together with rapid urbanization, industrialization and agricultural development has resulted in great effect on quality and quantity of water. Of the 121 crore Indians, 83.3 crore live in rural areas while 37.7 crore stay in urban areas, said the Census of India's 2011 Provisional Population Totals of Rural-Urban Distribution in the country. One of the noticeable features of urbanization in India is the skewed distribution of population with as much 28.3% of urban population in 35 metro cities alone. Unregulated growth of urban areas, particularly over the last two decades, without infrastructural services for proper collection, transportation, treatment and disposal of domestic wastes led to increased pollution & health hazards. The local civic authorities have not been able to cope up with this huge task which may be attributed to several reasons.

The situation warrants immediate attention through radically improved water resource and water quality management strategies. Depletion of available freshwater resources, falling ground water levels and deteriorating water quality are all posing a variety of challenges in managing India’s water resources. Competing demands from the diversified needs of a growing population are quite often leading towards disputes among users. The per capita water availability in India is raising concerns. The annual per capita availability of renewable freshwater in the country has fallen from around 6042 cubic meters in 1947 to 1845 cubic meters in 2007.Given in projected increase in population by the end of 21st century, the per capita availability is likely to drop below 1000 cubic meters a situation labeled as water scarcity.

On an average, the combination of rainfall, surface and groundwater resources have been sufficient in proViding adequate water to the Indian population. Rise in demand and development pressures are changing the characteristics of water in India. Erosion in the watershed due to the fast growing development and poor land management practices is increasing siltation and changing stream hydraulics. Groundwater resources are becoming depleted as surface water sources have become too polluted for human use. Water security is emerging as an increasingly important concern for India. Many Indian cities are experiencing water scarcities, brought on by the concurrent effects of agricultural growth, industrialization and urbanization. These shortages would be further aggravated by receding of glaciers and dwindling fresh water resources. Population stress, irrigation requirements and industrialization are the major pressures for water insecurity.

1.3 DISTRIBUTION OF RAINFALL

Almost 80 per cent of the rainfall occurs in the four monsoon months from June to September. Even within these four months, most of the rainfall occurs as few spells of intense rain.

It is estimated that in Himalayan Rivers, where there is some flow due to snowmelt also, about 80 per cent of the total annual flow takes place within these four monsoon months. In peninsular rivers, where there is no contribution from snowmelt, monsoon flow accounts for more than 90 per cent of the annual flow. In this context, retention and storage of water becomes important.

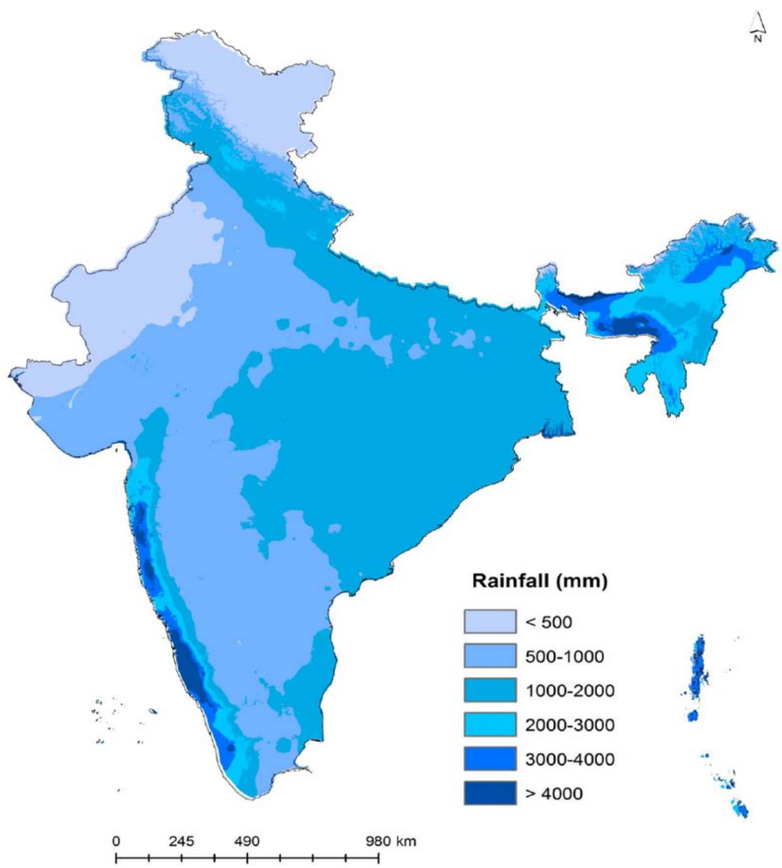

Fig. 1.1 Distribution of Rainfall in India

(Source: Sudhakar Reddy C., 2015)

Precipitation in India is not uniformly distributed and varies from less than 100 mm/year in Rajasthan to more than 2,500 mm/year in Assam. Consequently, despite the current availability, water is not evenly distributed or used around the country. Brahmaputra and Barak basin, with 7.3 per cent of the geographical area and 4.2 per cent of the country’s population, have 31 per cent of the annual water resources.

Table 1.1 Ground Water Quality Scenario of India

Water Statistics of Country	
Average Annual Precipitation (including snowfall)	4000 BCM
Geographical Area	328.7 Million Hectare
Census Population – 2001 - ii) Census Population – 2011	1028.74 Million 1210.19 Million
Estimated Annual Rainfall 2011	3669.35 BCM
Average Annual Water Resources Potential	1869 BCM
Per Capita Water Availability (2001) Per Capita Water Availability (2011)	1816 Cubic Meter 1544 Cubic Meter
Estimated Utilisable Water i) Surface ii) Ground iii) Total	i) 690 BCM ii) 431 BCM iii) 1121 BCM

(Source: Ground Water Quality Scenario: CGWB Report)

1.4 STATE OF WATER ENVIRONMENT, GUJARAT

Nature has endowed Gujarat with limited fresh water. The annual replenishable ground water resource of the state for 2008-09 has been estimated as 18.43 billion cubic meters (BCM). (GoI, 2010). Net Annual Ground Water Availability is 17.35 billion cubic meters and the Annual Ground Water Draft is 12.99 billion cubic meters

Agriculture sector remains the predominant consumer of ground water resources by drafting about 92% of total annual ground water draft i.e. 11.93 billion cubic meters while only 1.05 billion cubic meters is for Domestic & Industrial use which is about 8% of the total draft. The figure for net draft of groundwater considering the present utilization indicates that a substantial portion of the total potential (about 23 per cent) still remains untapped. There has been an increase of 36 percent in the net utilizable groundwater in 2009 as compared to 1997 (17.35 BCM to 12.8 BCM).

The total renewable fresh water available, including the annual runoff from within the state and that allocated from the neighboring states, and all the natural recharge of groundwater, is 54,593 MCM (IRMA, 2001). This gives a per capita renewable fresh water availability of 1137 m3 per annum for the year 2001 (IRMA 2001) and 830 m3 per annum for the year 2011 (Nawlawala 2011). Therefore, as per water stress index, the state reached the status of "water stressed" in the year 2001 itself and over the decade per capita availability has decreased significantly. It is also predicted that the availability will be 738 M^3 in 2015 and 601 M^3 in 2025. But it needs to be noted that the availability of water is heavily uneven towards south and central Gujarat, which has 69.5% of the total renewable fresh water.

The study by Amarasinghe et.al.(2005) confirms these observations. The study has used disaggregated data at the river basin level to assess the water supply and demand across the river basins of India. According to this, Saurashtra, Kachchh and North Gujarat falls under the river basin named as westerly flowing river group 1 (WFR 1), which is the only basin of the country having physical water scarcity with an highest degree of development (132%) and Ground water abstraction ratio (194%), with a depleted fractions of 92 percent. A broad picture of the distribution of the arid and semi-arid blocks support the above mentioned water scarcity, as 17 blocks in the state are arid and 79 blocks are semi-arid bringing the total to 96 blocks of the total 192 blocks.

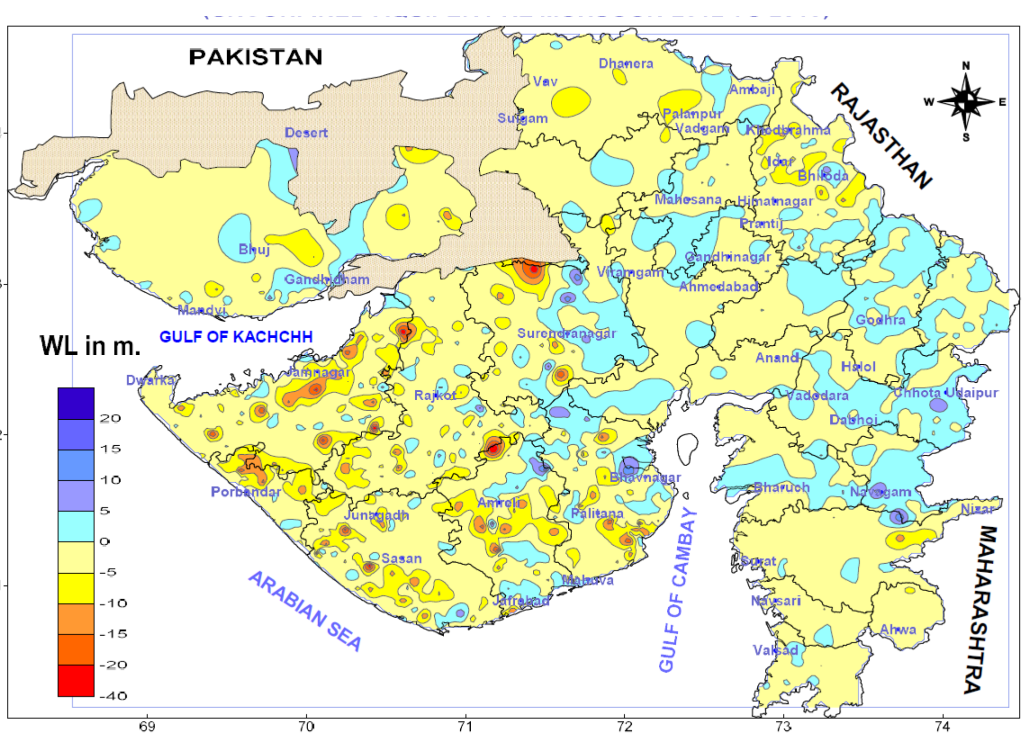

Fig. 1.2 Annual Change in Water Level 2013

(Source: CGWB)

Studies conducted by the State Ground Water Board in several regions of the state also draw attention to the severe water scarcity. Again, the report of the Ground Water Management Investigation Centre of the Government of Gujarat (2011) has revealed that water tables in Gujarat are declining rapidly even from “confined” water tables.

The average water table form the confined water tables was 51.86 meters in 2001, and it went to 65.89 meters in 2011. This trend was observed in Central Gujarat, North Gujarat as well as in the Eastern Gujarat. Uncontrolled withdrawal of ground water by farmers has been responsible for this trend (CGWB 2011). According to the assessment of Central Ground Water Board as on March 2009, in 5 out of 26 districts all belonging to North Gujarat, the gross annual drafts has exceeded the available groundwater resources and they are categorized as “over-exploited” districts. Kutch is the only district where groundwater development is greater than 90 percent and is categorized as critical districts. Sabarkantha and Porbandar are categorized as semi-critical while the remaining 17 districts are considered safe as the level of development is less than 70 percent and there is scope for further exploitation in these districts. CGWB has also assessed 223 talukas/units for computing the stage of ground water development. Out of the 223 assessment units (Taluka), 27 have been categorized as “Over-exploited”, 6 as Critical, 20 as Semi- critical, 14 as Saline and 156 as safe.

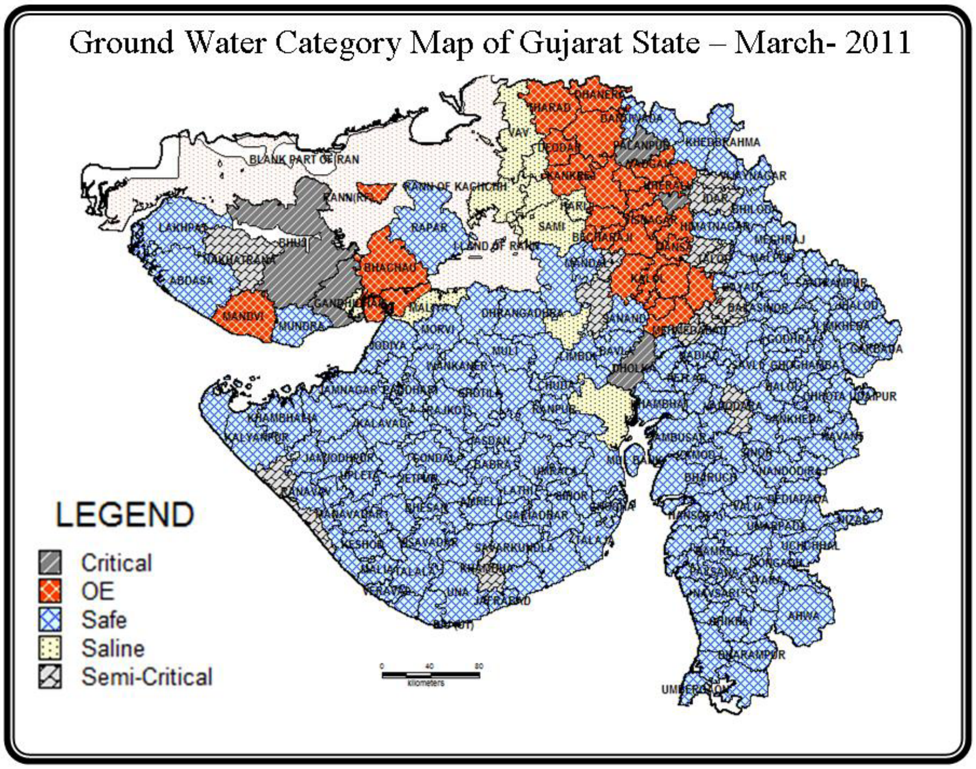

Fig. 1.3 Groundwater Category Map of Gujarat, 2011

(Source: CGWB)

1.5 STATE OF WATER ENVIRONMENT IN KUTCH

The Kutch district stretches roughly from 22°44'11" to 24°41 '25" north latitudes and 68°09'46 to 71°54'47" east longitudes. It is the border district of India and forms the northwestern region of India as well as the Gujarat state. It has a very large portion of its area (about 26000 km2) covered by a desert (known as Great Rann and Little Rann). It has a grass land of 2144 km2 the largest in Asia. The district has a coastline of 322 km, which is about one-fifth of the total coastline of the state. It is bounded on the north and north-west by Sindh (Pakistan), on the north-east by Rajasthan, on the east by the districts of Banaskantha and Mehsana, on the south-east by Surendranagar district, on the south by the Gulf of Kutch and the Rajkot district and on the south-west and west by the Arabian Sea.Kutch is an arid region with low rainfall and scarce water resources. In spite of having the largest geographical area amongst all districts of Gujarat and the maximum number of rivers in a single district for Gujarat, it has the least water potential. The Kutch district has a geographical area of 45652 km2 which is about 23.29 % of the total area of Gujarat. It also has 97 rivers or streams which is the highest number for any district in Gujarat. Further, with Kutch having the largest coast line of Gujarat, there are number of ports in the region .Therefore, the demand for industrial use of water is also increasing by each day. The region offers tremendous development potential and it can only be realized when the available resources are optimally used.

1.6 RATIONALE

Kutch district located in a crescent-shaped peninsula of Gujarat state of Western India is an arid region with water crisis and repetitive drought cycles. It is the largest district in Gujarat and has an area of 45,612 sq km constituting 23 per cent of the state. Kutch is like an island as it is bound by the sea in the South and West and by the Ranns (salt marshlands) in the East and North. Kutch was a princely state ruled by the Maharao of Kutch and was integrated into the state of Gujarat only in 1961. Kutch has 887 inhabited villages with a population of 1.2 million. It has ten Taluka or administrative sub-districts: Bhuj and Nakhatrana in the North; Lakhpat and Abrasa in the West; Mandvi, Mundra,Gandhidham and Anjar in the South and Bachau and Rapar in the East.

Kutch's geology, climate and topography are intriguing, making it a fascinating and challenging place to study water resources management. Legend has it, that much of Kutch was a navigable lake during the time of Alexander's conquest of Sind (Thakker: 1988).

The landscape comprises an array of tectonogenic geomorphic elements in the form of uplifts and residual depressions. Elevated landforms are occupied by Mesozoic and Tertiary rocks, whereas the residual depressions or low-lying regions between the uplifts consist of Quaternary sediment successions marked alluvial river terraces in the rocky mainland and the mud-flats and salt pans in the Great and Little Ranns and Banni Plains. The general forms of the uplifts are marked by domes and asymmetric anticlines. All major uplifts are bounded, at least on one side, by a fault or a sharp monoclinal flexure, and on the other side by gently dipping peripheral plains, the strata (Tertiary) in which dip gently into the surrounding residual depression (Biswas, 1980).

Temperature fairly remains average in the district. Highest temperature goes up to 44.8 degree centigrade in summer and lowest temperature comes down to 3.7 degree centigrade in winter season. Rainfall is very low in Kutch district as low as 350 to 375 mm during the whole monsoon. Rainfall is erratic and variable.

The Kachchh peninsula is characterized mostly by ephemeral streams which carry water during monsoon only (Merh, 1995). The internal high land forms the main watershed with numerous streams draining the slopes in the radial pattern. Most of the rivers are of small length and having low sediment carrying capacity.

All of Kutch's 97 rivers are non-perennial and have a high run-off rate. It has therefore very low potential of surface and potable groundwater resources. However, overall resource potential of the region, mainly coastal resources becomes one of the most added attractions and ideal regions for industrial development. Along with industrialization, population and basic infrastructure have also grown. This has resulted in manifold increase in industrial and domestic water demands and put groundwater resource of the region under tremendous stress. As the area is adjoining the seacoast, over exploitation of groundwater has also resulted in seawater intrusion in the aquifers thus, having considerable environmental implications. The Geomorphology of the Kutch district is just similar to "Reverse Bowl". Hence, precipitated water immediately flows away by the rivers either in Rann or in Arabian Sea.

A decline in the groundwater causes crop failures, seawater intrusion in coastal aquifers; land subsidence etc. This problem is particularly observed in area between Sakar and Sang rivers of Kutch. More over the salinity add to this problem, as most of the dug wells in the area turn saline soon after their development.

Thus, there is an urgent need for artificial recharge of groundwater by augmenting the natural infiltration of precipitation into subsurface formation by some suitable method of recharge. For this, understanding of the hydro-geological framework and delineation of the fresh water zones is essential and important. In order to arrest the depletion in groundwater potential and to achieve sustainable development, several measures including artificial groundwater recharge can be suggested. In an effort to maintain the water table condition in balance, artificial recharge schemes are being implemented in various parts of the world. The selection of sites for artificial recharge is a very important task in recharge studies. The present study will therefore focus on the selection of suitable artificial recharge structures based on hydro-geomorphic approach.

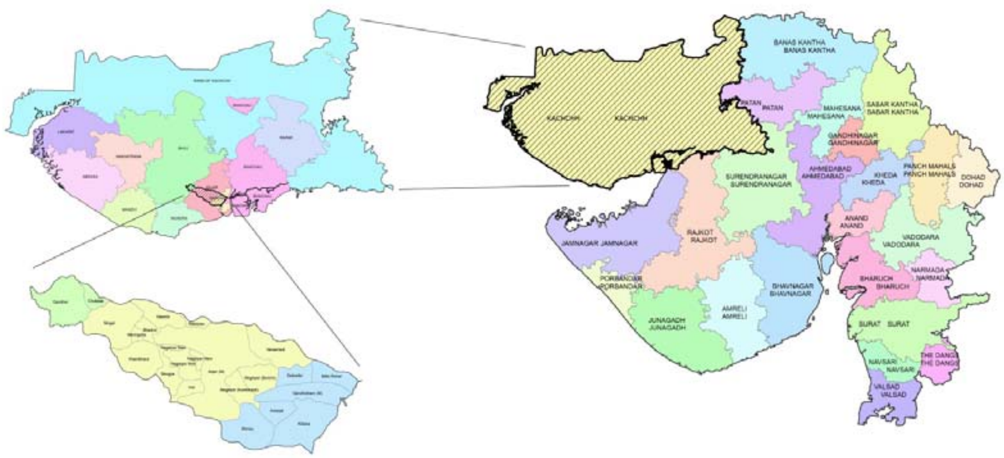

Fig. 1.4 Map of Study Area

(Source: Census Book 2011)

The study area comprises of Sakar & Sang river basin of Kutch. It comprises of parts of Anjar Bhuj and Gandhidham Taluka occupying a total area of 324.25 sq.km. Sang river originates from near Gandher village of Bhuj Taluka, while Sakar originates near Vidi, in Anjar Taluka. Both the rivers are east flowing and disappear into Gulf of Kutch near the mouth of little Rann. The basin lies between 22°59’ and 23°11’ N latitude 69 °47’ and 70°13’ E longitude.

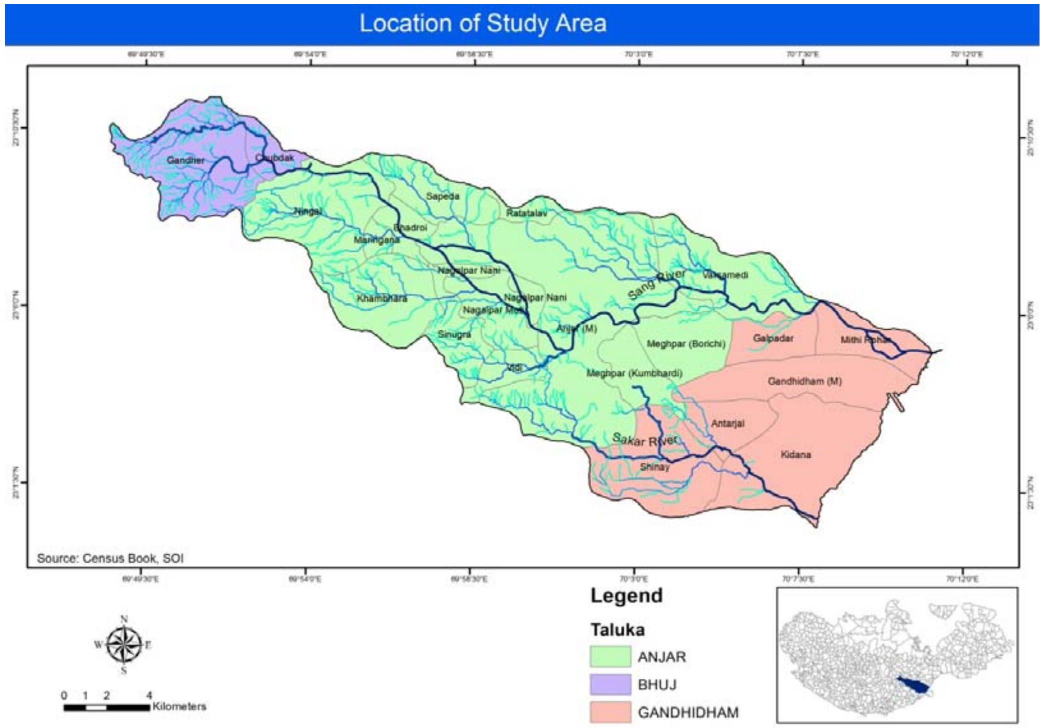

Fig. 1.5 Map of Study Area along with Sakar & Sang River basin

(Source: Census Book 2011)

1.7 OBJECTIVE AND SCOPE

The study aims at carrying out an in-depth study on hydro-geomorphic approach for identification of site specific groundwater artificial recharge techniques in Sakar and Sang river basin. The precise objects of the study are as follows:

1. To understand the hydro geological framework.
2. To delineate fresh water and brackish water aquifers in the study area.
3. To suggest areas favourable for recharge by integrating various themes with different recharge possibilities and to recommend suitable recharge structures.
4. Preparation of guidance manual for rapid reconnaissance of groundwater resources in arid and semi-arid environments.

1.8 DATA SET AND METHODOLOGY

The study incorporates primary and secondary data sets.

1.8.1 Primary data capture:

Extensive field work was done for the collection of the data related to water resources. Data related to various parameters like Groundwater level, Groundwater Quality, Soils, Geology, Socio-economics, Pump test, Resistivity survey, Geophysical Subsurface Logging etc. was collected from the field survey.

1.8.2 Secondary data capture:

Online journals were referred through-websites were accessed and articles were downloaded from the portal of The Maharaja Sayajirao University of Baroda through INFLIBNET.

District Census Handbooks, Statistical Abstract of Gujarat were collected from Census of India, Gandhinagar , Toposheets (Toposheet no. 41 E/16 and 41 I/4 with 1:50,000 scale), from Survey of India, Gandhinagar, Gujarat.

A detail regarding various other data which cannot be generated from the field was collected from various private agencies, NGOs and government agencies. Geological and Geomorphological maps were collected from GSI and Kutch Development Plan. Their field verification was done and data regarding the lineaments was generated from the satellite images as well. Meteorological data were collected from Data Center, Gandhinagar while the rainfall images were downloaded from the GSDMA website. Soil maps were collected from (NBSS) National Bureau of Soil science while their other properties were studied from the field sample. Groundwater Quality, water level and other related data was obtained from various government agencies like GWSSB, CGWB, District lab-Bhuj, Bhujal News -Quarterly Journals, Ground Water Year Books, Ground Water Monitoring Reports, District Ground Water Reports. Elevation data is obtained from satellite images of ASTER and updated with the data collected from the field survey wherever required. Land use maps are generated from the combination of satellite images of Landsat and Google earth Pro (Digital Globe/Geo eye). Landsat 7 and 8 images were obtained from the site of USGS. This images are very useful for the interpretation of Large features / events that cover major part of the images like Agriculture fields, Fallow lands, Rocky terrain, waste lands etc. while the finer objects or features like small water bodies, roads, settlements, industries etc. which require high resolution satellite images were downloaded from Google earth Pro i.e. digital globe and Geoeye.

The data was tabulated and for analysis, statistical packages like IBM SPSS Statistics 22 was used. Three dimensional Sub-surface lithological modeling was done in Rockworks 15 (Evaluation Period) software. Arc GIS 10.1® software was used for the preparation of Land use / Landcover and various other thematic maps. The same software was also used for the tripping of data from the GPS Trimble YUMA 2 and Garmin eTrex. Aquaveo GMS software was used for Groundwater modelling. All the software were installed and run on Windows 10 ® operating system with Intel Core i5 3 GHz processor with 8 GB RAM and inbuilt graphics card support .

1.9 APPROACH AND METHODOLOGY

To achieve the above cited objectives a multi - disciplinary approach has been adopted. The envisaged methodology has dealt with following aspects

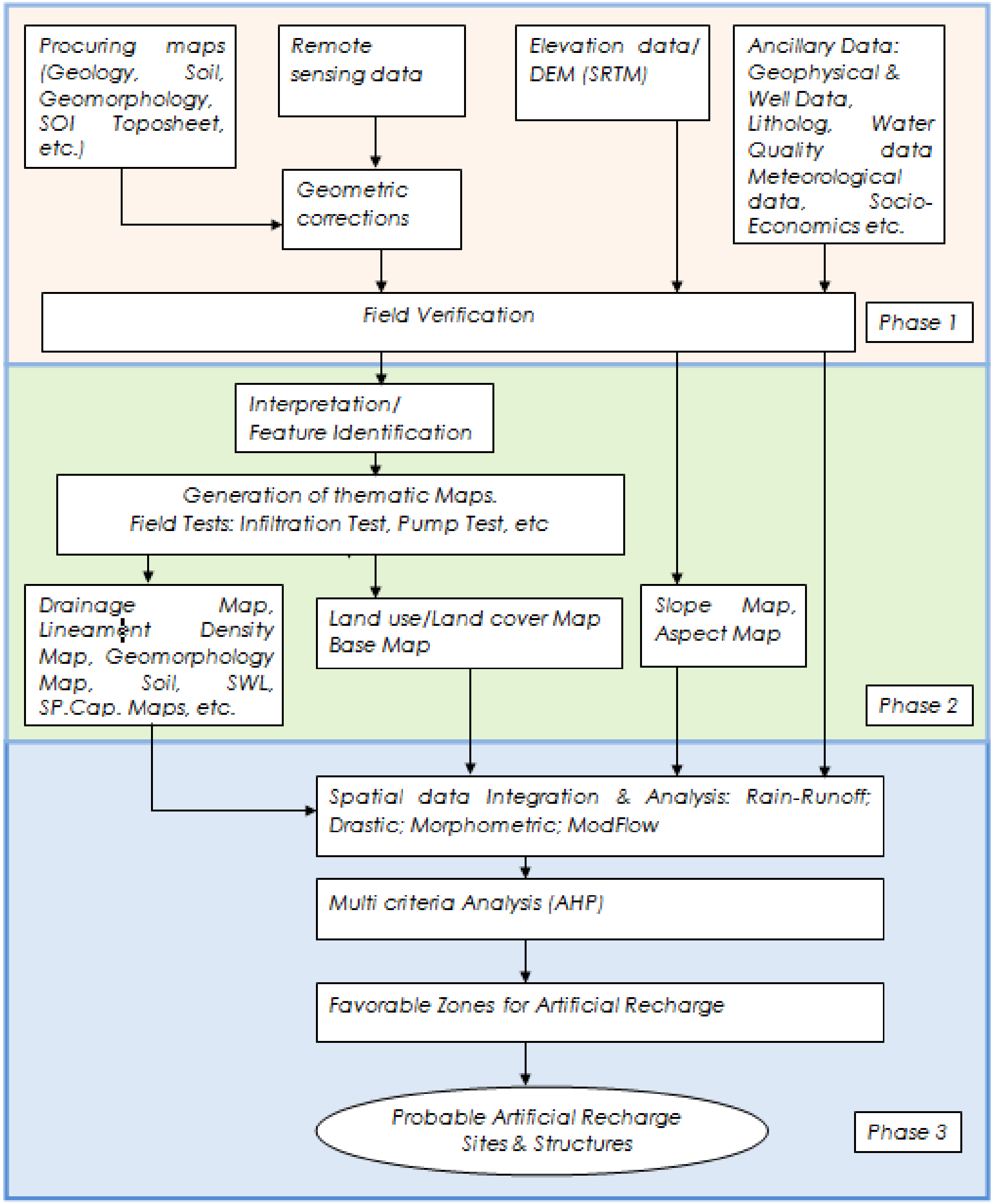

Fig. 1.6 Flow Chart of Methodology

Phase I: This phase deals with the collection of the data from various sources, its geometric correction and field verification for the accuracy and validation. Literature survey from libraries of The Maharaja Sayajirao University, Kutch University, online journals and articles are accessed. Secondary data from several sources like Census of India, Survey of India, Planning Atlas, Geology and Soil Survey maps , District Laboratory Bhuj, GWRDC, Data Centre ,Central Ground Water Commission Reports, Ground Year Books, Statistical and Economic Abstract Of Gujarat, Agriculture Census ,discussion with officers at Kutch and Personal observation.

Phase II: Deals with the delineation of hydro geomorphic units considering parameters influencing the hydro geological properties. It consists of creation of thematic layers of Hydrology like Drainage, water bodies, canals, irrigated areas, well data and rainfall data. Lithology, geomorphology, Land use/land cover, Slope and Aspect Maps along with base map details based on the visual interpretation of satellite data in conjunction with field data and existing secondary data are also generated.

Fieldwork: Participatory survey for well inventory, Sampling and on-site analysis, pump test, infiltration test and ground checks of satellite image analysis.

Phase III: Deals with spatial data integration and its analysis. It consists of a) estimation of ground water prospects by taking into account the well observatory data, b) Probable sources of pollution and c) identification of suitable locations for constructing recharge structures.

1.10 OUTCOME

The study will help in understanding the following:

1. Identification of sites with specific groundwater exploration potential and selection of suitable structures for improving the groundwater regime of the area.
2. Identification of possible pollutions and sources.
3. Predict the trend of groundwater in the future.
4. Hydro geological framework of the area and delineation fresh and saline water areas.
5. Guidance manual for rapid reconnaissance of groundwater resources in arid and semi-arid environments.

1.11 FUTURE SCOPE

Extensive field investigation is expected before implementing any water-harvesting program. Further, the groundwater resource estimation has to be taken up at the regular intervals to know the net balance available for future use.

1.12 STRUCTURE OF THE THESIS

The study has been organized into seven chapters. All chapters highlight relevant literature.

The first chapter is an overview of the research work undertaken. It deals with the introduction to the subject, rationale and relevance of research topic in present context, research objectives, data base and methodology.

In the Second Chapter, the brief characteristics of physical and socio-economic setup of the study area is outlined. The physical aspects of the study area associated with physiography of the region, hydrogeological setup, drainage, soil, climate, aquifer and vegetation. The socio-economic setup focuses upon demographic pattern, agriculture and irrigation, industry, transport and connectivity, water facility and landuse/land cover pattern of the district

Chapter Three illustrate the geo-hydrological setting of the study area: The Geology and Tectonic history, Geological formation, Structural features and geomorphology and emphasizes the importance of the hydrogeology and describes the different geomorphic units falling in the basins.

In the Fourth Chapter, Hydro-Metrology of the area is discussed. Rainfall data for the year 1878 to 2015 is analyzed for Anjar and Bhuj Taluka while for Gandhidham it was only available for the last 18 years from 1998. The determination of the runoff value is necessary for designing of dams, reservoir management and prediction of risks and potential losses caused by flooding. Also determining amount of the runoff is very important in projects related to sediment and erosion processes.

The Fifth Chapter explains the hydro-geo-chemistry and elucidates groundwater Quality. Secondary data from District Bhuj Lab and GWRDC Gandhinagar is used for the year 2009, 2015, 2016. About 40 samples for Pre and Post monsoon period are analyzed. Parameters like pH, TDS, Hardness, Iron, Fluoride, Nitrate, Chloride, Calcium, Magnesium, Sulphate, Alkalinity, Carbonate and Bicarbonate are studied.

The Sixth Chapter briefly explains the procedure for the delineation of suitable zones for the artificial recharge structures. Map prepared by KDP in 2003 was used for delineation of geomorphic unit and was modified based on the field survey and latest data available from the government authority. Ground Water Modeling using AHP, DRASTIC and MODFLOW are explained in this chapter.

AHP technique helped in delineating the suitable zones for artificial recharge structures while the sources of possible pollutants were studied through DRASTIC model. MODFLOW model helped in predicting the future scenarios for better understanding and planning. Based on the results obtained by the analysis in the sixth chapter, the tentative sites for construction of recharge structures such as percolation tanks, check dams, recharge tube wells and the de-siltation of tanks concludes the sixth chapter.

Conclusion and recommendations are presented in Chapter Seven

1.13 RESUME

Present chapter summarizes the main structure of research addressing the background and availability of water resources in country and Gujarat state, rationale, purpose of the study undertaken, data base and methodology. The next chapter will look into the brief characteristics of physical and socio-economic setup of the study area.

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