CHAPTER 2

REVIEW OF LITERATURE

2.1 GENERAL

During the eighteenth century fundamentals in geology were established that provided a basis for understanding the occurrence and movement of groundwater. During the first half of the nineteenth century many artesian wells were drilled in France, stimulating interest in groundwater. The French hydraulic engineer Henry Darcy (1803 – 1853) studied the movement of water through sand. His Treatise of 1856 defined the relation, now known as Darcy’s law, governing the groundwater flow in most alluvial and sedimentary formations. Later European contributions during nineteenth century emphasized the hydraulics of groundwater development. In the twentieth century, further development in all phases of groundwater hydrology has occurred.

Raghunath et al (2004) have stated that information of soils is a prerequisite to agricultural planning. Conjunctive use of remote sensing data and collateral information like lithology, physiography, has enabled mapping soils at different scales, ranging from 1:25,000 to 1:50,000. High-resolution stereo data are found useful for generating information on soil resources at 1:25,000 scales necessary for micro level optimal land use planning.

Sharma (2007) has stated about the importance of GIS to help farmers for improving soil fertility. The Indian Institute of Soil Science (IISS)
at Bhopal has developed the digitized soil fertility map for Bhopal district using GIS and GPS. He has reported that this map will be more helpful to farmers to improve the soil fertility, decide to apply seeds, use fertilizers and micronutrients for getting high yield in the agriculture sectors.

2.1.1 Remote Sensing and GIS

The groundwater occurrence in any terrain is largely controlled by the prevalence of primary and secondary porosity and as such in conventional exploration methods delineation and mapping of different lithological, morphological units are difficult to map the linear features like lineaments which is possible in remote sensing due to its synoptic view. In addition to quantitative surfacial phenomenon like drainage network and geomorphology, the study have a unique capsule of integrating with the high geophysical resistivity domains with respect to map the depth to basement configuration (Consolidated rocks). To understand the prevailing groundwater condition, nowadays, satellite based remote sensing techniques are being regularly employed for terrain resources mainly for delineating hydrogeomorphological units (Anonymous, 1979, 1988; Aravindan et al 1996 and Krishnamoorthy, 1996), but only very few studies have been attempted by integrating all the groundwater controlling parameters like geophysical resistivity, geology, geomorphology, lineaments, quantitative morphometric characteristics, etc., especially using Geographical Information System (GIS) as a tool.

The GIS is a computer automated spatial data management software that simplifies the input, organizing, analysis and mapping of large sets of complex georeferenced information (Burrough, 1986). GIS may be used to build input data sets as well as to view and manipulate model output. The GIS can also help to investigate spatial relationships between model input and output. GIS has been widely used for several years in the field of natural
resources management, digital mapping, cartographic modeling and the analysis of spatially referenced data sets. Lillesand and Kiefer (1994) defined GIS as a computer base system that can deal with virtually any type of information about features that can be referenced by geographical locations. This system is capable of handling both location data and attribute data about such features. GIS permits the automated mapping or display of the locations of features, but also these systems provide a relational database capable of recording and analyzing descriptive characteristics about the features.

Remote sensing techniques have been widely applied for preparation of different thematic maps for analyzing groundwater resources of the study area. Remote sensing coupled with GIS techniques is very fast in analyzing the spatial and non-spatial data and getting near accuracy in the analysis of vast area when compare to the conventional method (Kalyan Raman, 1999). Ground truth verifications followed by hydrogeological, geophysical and geochemical analysis and surveys forms the main aspects of the present study. Groundwater potential and recharge zonation maps indicating potential and non-potential areas are identified using GIS analysis. Identifying the land use degradation, wasteland areas, water quality affected areas and suitable locations for introducing artificial recharge structures are the final outcomes of this study. Methodology adopted by various Social organizations and research scholars on geological and hydrogeological investigations using remote sensing and GIS techniques are reviewed.

Lillisand et al (2004) have stated that the success of many application of remote sensing is improved considerably by taking a multiple view approach to data collection. The application of remote sensing helps in providing information quickly the growth of remote sensing applications in various resource management systems. Colwel (1978) has reported that the advent of remote sensing technology has paved the way to gather information
about the earth’s resources and various phenomenons more accurately than conventional methods in time and cost effective manner.

Samant et al (2005) have reported that there is substantial research and development underway in the area of hyperspectral remote sensing, which involves systems that sense in literally hundreds of very narrow spectral bands simultaneously. This approach greatly increases the information and detail that can be obtained about objects on the earth’s surface.

Xue Cao et al (2006) have described that in recent years the rapid development of satellite remote sensing and image processing technology provides an effective way for acquisition of true, accurate and real time land use information.

Seelan et al (2007) has reported that the satellite imagery has proven to be potential in farm level application, especially in the Upper Midwest of United States of America. They have suggested that farmers are to be educated in remote sensing technology to improve their productivity and income. Training of farmers and researchers in use of satellite imagery is started at the University of North Dakota in 2000. They have reported that over 500 farmers, ranchers, crop consultants and other end users have been trained through this programme and the results are beginning to show through the success stories of cost savings and environmental benefits that have emerged.

2.1.2 Hydrogeophysical Investigation

Numerous geophysical investigations have been done in various locations over the globe to demarcate the potential zones of groundwater and thick and low resistivity horizons have been marked as favorable zones for the
groundwater development. Sharma (1982) and Sharma et al (1986) are the few notable works published in India relating to such studies in sedimentary rock terrains. Sathyamoorthy (1991) in his integrated studies on groundwater in and around Tiruchirappalli, TamilNadu, has presented a groundwater development map in which based on the type and thickness of the saturated aquifer, he has delineated suitable zones for various kinds of abstraction structures such as filter points, dug wells, dug-cum-bore wells and bore wells. Muralidharan (1996) attempted a non-conventional way of examining the apparent resistivity data of soundings conducted over different rock terrains. The interpretation yielded a factorial depth relation with the yielding aquifer zones hidden in the bed rock signal and the novel finding is by using the factor arrived at actual aquifer depths can be recommended for bore wells especially in the alluvial area.

The primary objectives of conducting soundings are to transform the field data into subsurface geology or hydrogeology and this can be achieved by adopting suitable interpretation techniques. Depending upon the details required the field data could be interpreted by qualitative and quantitative methods. Zhody et al (1974) and Patangay et al (1984) have described the various techniques of qualitative and quantitative interpretations.

Geophysical resistivity survey is necessary to ascertain the subsurface geological and hydrological condition of an area (Jaffrey et al (1994). It includes the interpretation of measurements to obtain useful information on the structure and composition of the concealed zones. In a broader sense, geophysical survey provides detail for studying the structure and composition of the earth’s interior. The different geological formations occurring at various vertical depths could be found out using geophysical
survey. The subsurface soil exploration can be studied by means of electrical measurement taken at the surface of the earth (Ramakrishanan 1998).

Sabnavis et al (1998) have stated that the electrical methods of prospecting comprise a wide variety of techniques, which utilize different electrical properties and their related phenomena to distinguish between different geological formations or to delineate structures.

The estimation of groundwater potential through geophysical method is an irreplaceable one as resistivity is the only physical property, which can give the moisture signal. Different authors have given comprehensive list of geophysical resistivity values for various rock types, minerals and soils. Using Schlumberger electrical soundings, Ashok and Srivastava (1991) have attempted the geohydrological characteristics through vertical Electrical sounding responses in different geomorphic units of Munger, Bihar. The study reveals that, the thickness of the aquifer in buried pediments and alluvial plain are 10 to 29 m and 17 to 54 m respectively.

Hydrogeophysical investigations carried out in Namagiripettai area (100 sq. km in extent), Namakkal district, Tamil Nadu by Ballukraya (2001) used data merging tool in the analysis of availability of groundwater, where the formation resistivity (low), total longitudinal conductance (high) and depth to bedrock (high), along with presence of lineaments are related. Integration of geophysical data using GIS was carried out for hydrogeological study over an area of 226 sq. km in Midnapur District, West Bengal, India by Shahid and Nath (2003).
2.1.3 Groundwater Investigation

Previous studies pertaining to groundwater potential, groundwater chemistry, modeling of groundwater have been attempted either individually or in-group by a number of researchers. The groundwater investigation in India was confined to the unconsolidated alluvial and semi-consolidated sedimentary areas. Worthington (1977) had attempted to evaluate groundwater resources of the Kalahari Basin, South Africa. Groundwater estimation is carried out using any one or a few methods (Karanth, 1987) namely, Geology and Hydrogeomorphology, etc.,); Surface geophysical methods (Electrical methods); Hydrogeologic well logging (Inventory of existing wells, rainfall infiltration, etc.,) and tracer techniques, as stated by Sharma and Sharma (1987). One should be very keen before the exploration of groundwater in an area viz., Identify and locate aquifer boundaries; extent of the aquifer system; hydraulic characteristics of aquifer; and relationship of fresh water, saline water interface.

Hodge et al (1988) have discussed the linkages of hydrographic Programme and water shed process model with the raster GIS. The linkage of hydrographic Programme and watershed (Version 3.0) was used to delineate water shed boundaries from digital elevation data stored in GRASS. The stream network and sub-basins for the watershed were also determined using GRASS. Jensen and Domingue (1988) have presented an approach for determining drainage direction, flow accumulation, watershed and sub-watershed delineation on regularly grided surface. These approaches are hinged around the concept of a grid point being surrounded by eight neighboring points. Source or watershed areas are determined for any grid square whose drainage subsequently flows through having abrupt changes in terrain elevation at any location. These procedures are built in the GRID based hydrologic modeling tool of ArcInfo.
Sahai et al (1991) and Krishnamurthy, (1993) have used this technique for groundwater prospective zone mapping. Sahai et al (1991) has pointed out that the best places for drilling bore well and digging dug well are the valley fills in Palghat mapping using hydrogeomorpholgy, drainage density, slope, geology, soil and lineament analysis in the parts of Karnataka between latitudes 13º N and 14º N using remote sensing techniques.

Krishamoorthy et al (1995) has described methodology to demarcate the groundwater potential zones of Marudhaiyar basin. The groundwater potential zones map generated through this model was verified with the yield data to ascertain the validity of the model developed. The verification showed that the groundwater potential zones demarcated through the model are in agreement with the bore well yield data collected in the field.

Christopher et al (1999) applied GIS to groundwater assessment of North West of Florida water management district. The principle purpose of the investigation is to determine the source of contamination lying outside local study area.

2.1.4 Hydrogeomorphological Studies

Hydrogeomorphological study is one of the most important aspects in the evaluation of water resources. It plays a vital role in management of natural resources and helps in various types of planning such as watershed management and developmental activities. The analysis of geomorphological conditions is essential prerequisite in understanding water-bearing characteristics of most crystalline rocks. In general, the groundwater distribution is not uniform and is subject to wide spatio-temporal variations, depending on the underlying rock formation, their structural fabric, geometry, surface expression, etc. as explained by Thomas et al (1995).
Geomorphological map is very effective tool in management of natural resources and helps in various types of planning and developmental activities. The geomorphological maps portray the forms of the surface, the nature and properties of the surface materials and indicate the kind of magnitude of the process involved. Thomas et al (1998) have reported that geomorphological mapping allows an improved understanding of watershed management, groundwater exploration, land use planning, landscape ecological planning etc. He has also stated that a detailed geomorphological map is one of the principle means of studying the morphology, genesis, distribution and age of forms, to help interpret the geomorphic history of any evolved landscape.

In recent years, the use of remotely sensed data and GIS applications has been found increasing in a wide range of resource inventory, mapping, analysis, and monitoring and environmental management. Remote sensing data provides an opportunity for better observation and systematic analysis of terrain conditions (Obi Reddy et al 2002). Remotely sensed data serves as vital role in identifying favourable geomorphological landform for locating groundwater-prospecting zone as reported by Chatterjee et al (1995), Tiwari et al (1996) and Ravindran (1997).

Javed (2000) has stated that remote sensing data is very useful for identifying various geomorphic landforms and for understanding the river morphology of Ganga and Yammuna river basin in India. Kumar et al (1998) have described that the remote sensing data helps in fairly accurate geomorphological analysis and identification and delineation of landforms.

Allison (2002) had illustrated that geomorphologists and geomorphology have not made a conspicuous contribution to the methodology or implementation of Environmental Impact Assessment (EIA). Yet other impacts of some human activities, such as acceleration of erosion
by water and wind in response to dry land agriculture practices, are manifestly amenable to geomorphological research.

Aslam et al (2003) have described that hydrogeomorphological units have been mapped using the IRS-1C, LISS III False Color Composite (FCC) imagery and the satellite image characteristics have also been identified and assessed in a part of Cauvery river basin around Manchanahalli, Karnataka State, India. The study area exhibits diverse hydrogeomorphological conditions where the ground water regime is controlled mainly by topography and geology. The main hydrogeomorphic units found in the area are alluvial plain, Pediplain, pediment, valley fill, meander scar and water bodies.

Rinklebe et al (2007) have explained about the characteristics of flood plain soils identified in the Central Elbe River in Germany which are semi terrestrial soils of reverines with aquic or epiaquic moisture regimes. They are formed by various aquatic sources including groundwater, static water, return seepage and floodwater as well as various rates of sedimentation with deposits ranging from gravel to clay. The quality of flood plain soil in the study area is good and fit for irrigation use and no such harmful heavy metals are present in the flood plain.

2.1.5 Pump Test Analysis

There are numerous techniques proposed to analyze the pumping test data of wells. The classical methods are mostly graphical in nature and there is no room for error in individual judgement (Papadopoulos et al 1967); Raju et al (1967); Cooper et al (1946); Narasimhan, 1968; Das (1972); Streltsova (1974); Newman (1975); Boulton et al (1976); Black et al (1977), Fenske (1977); Walton (1979); Rushteon et al (1983). Many computer
methods have been proposed and successfully utilized during the last two decades, for analyzing the pumping test data Walton, (1970); Saleem, (1970); Rayner, (1980); Mc Elwees, (1980); Bradbury et al (1985); Mukhopadhyay, (1985) and Balasubramanian, (1986).

Walton (1962) introduced the concept of specific capacity index, which is obtained by dividing the Slichter’s specify capacity (average) by the saturated thickness of the aquifer (lpm/m drawdown / m thickness of aquifer tapped). Zeizel et.al, (1962), Nauttyal and Gopalappa, (1980), Sharma (1982), Sastri et.al, (1983) and Prased (1984) have used this index in determining the relative productivity of different units in predicting aquifer yields.

A number of techniques are available to analysis the pumping test data of wells. Both manual and computer methods are commonly used for this analysis. The graphical and iso line representations of permeability, transmissivity and specific capacity indices were adopted by many authors (Adyalkar et al 1966, Sammel, 1974, Nightingale and Bianchi, 1980 and Ruston et al 1983). Chabtler and Whorter (1975) have estimated the salt water intrusion in Indus river basin through permeability and anisotropic analysis by applying pumping test methods.

Several authors have investigated the reasons for groundwater fluctuation. Using transmissivity and storage coefficient (numerical methods), Moeach (1981) identified groundwater fluctuation in a single well test in Illinois. Karanth (1987) has also pointed out that water level fluctuation maps are indispensable for estimation of storage changes in an aquifer.

Anonymous (1986) have compared the groundwater level and different geomorphological features. It is observed that, the wells located in the erosional valley have deeper water level, varying from 3.4 to 6.5 m below
ground level as compared to other landforms. By analyzing the patterns of lineaments, geomorphologic features, etc., different authors have attempted to find out the depth-yield relationship existing between depth and yield (Hegde and Puranik 1990). But when the yield of a well is compared with the geomorphologic features, certainly there exist direct relationships (Anbalagan et al 1991).

Al-Ahamadi et al (1994) has studied about the aquifer performance of Wajid aquifer in Southwestern region of Saudi Arabia,. He had concluded that large draw down and declining regional water levels and decreasing bore hole yields is observed in the aquifer which is mainly due over exploitation of groundwater. Al-Ahamadi (1991) has described that there are few recent measurements of water levels in the Quaternary aquifer are studied. From the study, it is observed that the lowering of water levels found to occur in many parts due to the lowering of pumps and deepening of boreholes. Depletion of groundwater level and methods of preventing the depletion have been discussed and presented by several researchers during nineties such as Prihar et al (1990), Saleth (1991), Moench (1992), CGWB (1994 a) and Dhawan (1998).

2.1.6 Hydrogeochemical Analysis

By taking into account the nitrate as an individual factor, Herman Bouwer (1978) has pointed out that more than 30 PPM of nitrate causes severe problem of fruit cultivation. Handa (1979) has given a clear picture of crop analysis in his attempt on the quality criteria for groundwater. The study has given the guidelines of crop tolerance level for different crops by using Electrical conductivity (E.C). Exchangeable sodium percent (ESP) and Boran concentration and the requirement of gypsum for high sodium water during irrigation.
Hydrogeochemical modeling is an important study which helps to identify the dominant chemical ion present in the water. Barr and Newland (1977) have recommended the partial correlation coefficients to investigate or predict the geochemical relationship of waters. Using Factor analysis Lawrence and Upchurch (1982) have identified the recharge areas in Live oak area of Florida with the help of different ion constituents present in the groundwater.

Gupta (1987) has attempted to find out the groundwater quality of northern part of Meerut District of Utter Pradesh. He used Collin’s bar graph, trilinear diagram, Durov’s diagram and U.S.S.L. diagrams to delineate different water quality zones. The study infers that more than 90 percent of water in the study area is suitable for drinking and irrigation.

Stiff and bar diagrams were used to analyze the groundwater quality of Dejima upland by Changyan Tang (1989). Based on these methods Groundwater was classified into five groups in the study area as very good, good, moderate, poor and bad. Hydro geochemistry and its relationship to agriculture have been attempted by many authors. It has been observed that water classified as suitable particular use may not reach the same classification tag of another worker because of differences in the parameters chosen for classification. It is felt that by considering the entire chemistry rather than the individual ionic or grouped ionic character in pairs. The results obtained would be better (Doneen 1966, Handa 1979).

Using the regression analysis, the relationship between the electrical conductivity of groundwater and its anions and cations has been worked out by Balasubramanian et al (1989). It is interesting to note that based on the model derived from varimax factor model, the pictorial output of different ions present in the groundwater could be identified. Based on this,
one can develop the agricultural regions with reference to the chemistry of groundwater of different zones (Kumaraswamy et al (1996).

Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes. The chemical quality of groundwater is significant in the present day context, as it concerns with taste, health and sustainable development (WHO 1983). Karnath (1987) has reported that the quality of groundwater varies from place to place. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities. The chemical composition of groundwater is a measure of its suitability as a source of water for human and animal consumption, irrigation, and for industrial and other purposes. The groundwater resources are under great risk due to the drastic increases in population, modern land use applications (agricultural and industrial) and demands for water supply, which endanger both water quality and quantity (Babiker et al 2007). Different uses require different standards of water quality. Therefore, assessing and monitoring the quality of groundwater is important to ensure sustainable and safe use of these resources for the various purposes. Many researches in India and abroad has assessed the groundwater quality to find its suitability for drinking and irrigation purposes Melian et al (1999) and Lee et al (2003).

Ahmed et al (2002) have compared the analytical results of groundwater in Rajshahi city of Bangladesh with recommended limits suggested by World Health Organisation (WHO 1971) and they have classified groundwater into various types. Anbazhagan et al (2004) have used the geographical information system (GIS) to represent and understand the spatial variation of various geochemical elements in Panvel Basin, Maharastra, India.
2.1.7 Land Use and Waste Land Studies

Anderson (1970) has concluded that the large percentage of impervious cover due to urban land use in the form of buildings and roads reduce the infiltration capacity in a basin causing proportional increase in the amount of surface runoff. The shape of the settlement and its spectral response make the category separable from other classes.

Cohen (1985) has stated that groundwater is an increasingly important component of the water resources of the United States. He has reported that as groundwater withdrawal, land use and wasteland management problems intensify with continued agricultural, industrial and population growth, effective management of the water quality and quantity of groundwater will be necessary.

Das (1990) has stated that the various thematic layers generated using remote sensing data like lithology, geomorphology, land use, lineaments etc., can be integrated with slope, drainage density and other collateral data in a GIS framework for groundwater targeting, management and conservation of groundwater resources that ensures optimum and judicious use of groundwater and in identification of artificial recharge sites.

Mathur et al (1998) have made an attempt to study Database management and analysis for Crop Acreage and production Estimation (CAPE) Using Remote sensing and GIS in Punjab. They have described that the integrated approach of remote sensing and GIS can open new vistas in using data base generated under CAPE project and support for planning and decision making at village level.
Singh (1997) has described that the land use varies from time to time and place to place. Land use pattern at any given time is determined by several factors including size of human and live stock population, the demand pattern, the technology in use, the cultural traditions, the location and capability of land etc. Planning for development of natural resources without endangering the environment is a crucial issue as reported by Kachhwaha (1985). Sharma et al (1989) and Khorram et al (1991). Brown (2006) has described that land use / land cover change research that focuses on explanation and understanding land-related decision-making processes and their implications and to characterize the spatial patterns of landscapes through the calculation of metrics that describe the composition and configuration of land cover in a particular area. The land use is therefore become a very important tool in the hands of planners of urban, rural and region to assess and forecast land use requirements and to assign proper use to land resources.

Dhiwniwa et al (1992) have reported that land use degradation is a global phenomenon and India ranks very high among the developing countries in respect of both the extent and severity of land use degradation over a period of time. Anon (1992) has stated that land use planning and management is an important strategy for development of any region and these techniques are being used in the developed and developing countries for land resources evaluation programme with the modern techniques of remote sensing and GIS.

With the capabilities of the remotely sensed data and GIS techniques, numerous databases can be integrated to produce conceptual model for delineation and evaluation of groundwater potential zones of an area as reported by Krishnamurthy et al (1995), Khan (2002) and Sikdar et al (2004).
Kolarkar et al (1996) have reported that the characteristic of electromagnetic spectrum, sensors and platforms, remotely sensed products and techniques of interpretation / analysis is essential pre-requisite for land use study. The visual interpretation techniques can be used for land use classification by interpreting the satellite data on 1:50,000 and 1:25,000 scales. Singh (1977) has stated that the interpretation on satellite imagery, involves identification, classification and mapping of natural resources and other terrain features. Various methods of image interpretation such as detection, recognition and identification, analysis, classifications, deductions and idealization are reviewed for preparation of land use map.

Singh (1997) has reported that the National Commission on Agriculture (NCA) in 1976 had looked at the problem of land reclamation and development in all its dimensions and made valuable suggestions in this regard. Since then the awareness of the need of wasteland development has grown tremendously in the country culminating in the setup of the National Wasteland Development Board (NWDB) in 1985. When the wastelands are restored as productive land by proper reclamation technology, each hectare of wasteland can yield 3 to 5 tones of food grains per year. Wastelands development would help in generating more income and employment for the marginal farmers and the landless labours. It is therefore, imperative that the wastelands are to be reclaimed and put under adequate vegetative cover to preserve the environment of this study area.

Remote sensing and GIS were used to study the changes in mangrove ecosystem between Muthupet and Pichavaram during 1990 and 1996 in Tamil Nadu and Andaman and Nicobar Islands, India by Ramachandran et al (1998). The authors discuss the changes in the Mangrove wetlands in the light of the degradation caused by the human influence and emphasize the need for conserving wetlands.
On a global scale and over a longer time period, nearly 1.2 million km² of forest and woodland and 5.6 million km² of grassland and pasture have been converted to other uses during the last three centuries, according to Ramankutty and Foley (1999). During this same time period, cropland has increased by 12 million km².

Sudhakar et al (1999) have studied land use / land cover with special reference to forest type mapping in West Bengal. In the present study visual interpretation technique is mainly applied to classify the land use data. The role of remote sensing in agriculture sector described by Brisco et al (1992), Ehrlich et al (1980) and Hudson (1987) are reviewed for preparation of land use map.

Navalgund et al (2002) have reported that although remotely sensed data have been used in many national level application projects, greater efforts needed to derive full benefits of currently available remote sensing and GIS technology for natural development is still a perspective and priority. It involves integration of remote sensing derived information into user information, collection, processing and decision making process.

Shivaraj et al (2000) have illuminated that an attempt has been made to develop a comprehensive Groundwater Information System (GWIS) with extensive capabilities of GIS through a case study of river basin. The space technology has clearly demonstrated its usefulness in understanding the factors responsible for maintaining hydrological cycle, mainly the vegetal cover, surface bodies, litho types and land form. Supply of groundwater even in the dry month is very much essential for sustainable development. He has also concluded that the satellite remote sensing alone cannot produce information regarding confined aquifers, then geophysical and drilling data
have to be consulted for acquiring subsurface information and decision file shall be created through overlay by GIS techniques.

The interpretation of satellite data in conjunction with sufficient ground truth information makes it possible to identify and outline various ground features such as geological structures, geomorphic features and their hydraulic characters and these may serve as direct or indirect indicators of the presence of groundwater as reported by Sree Devi et al (2001) and Gopinath et al (2004).

Singh et al (2000) have classified and analyzed the wasteland category using remote sensing techniques in Loktak catchment in Imphal district. The wastelands have been classified through visual interpretation techniques. From the study it is concluded that a significant portion of Loktak lake catchments is under wasteland category (land with or without scrub). These are found in the western part of the upper catchment of Loktak, as a result of continuous practice of shifting cultivation and cutting of forest. In the present study also visual interpretation techniques is applied to classify the wastelands into different categories.

Mas (2004) has described that a common problem when classifying remotely sensed images in order to map land use / land cover is spectral confusion i.e. different land use / land cover classes present similar spectral signatures and are misclassified. He has presented a procedure for mapping land use / land cover combining the spectral information from a recent image and data about spatial distribution of land use / land cover types.

Daniel Brown (2005) has described about two distinct notations of accuracy of land-use models and highlighted a tension between them. A model can have predictive accuracy i.e. its predicted land-use pattern can
be highly correlated with the actual land-use pattern. They have also reported that a model can also have process accuracy i.e. the process by which locations or land-use patterns determined can be consistent with real world process. They have used an agent-based land-use model and using multi temporal land-use data collected for Washtenaw County, Michigan, USA. Based on the results, he has reported that researchers can improve their ability to communicate how well their model performs, the situations or instances in which it does not perform well, and the cases in which it is relatively unlikely to predict well because of either path dependence or stochastic uncertainty.

Nagaraja et al (2005) have reported that India’s average growing population is exerting enormous pressure on the per capita arable land availability. There is increasing demand for land for both agricultural and non-agricultural use. This results in creation of sizeable stretches of land that are not suitable for further agricultural use or offer uneconomical agricultural returns. It also causes reduction in per capita cultivable land, besides causing ecological imbalances. These wastelands suffer on account of land, degradation, soil fertility, water logging, desertification, soil erosion etc. It was also felt that the 13 fold wasteland classification systems could be modified to a 28 fold classification systems where more classes could be included like the severity of degradation.

Rao et al (2006) have enlighten that in the 1990s the growth rate of agriculture sector began to decelerate with emergence of problems like degradation of natural resources, stagnation in technical development and slowing down of investment in agriculture. Land use / Land cover change detection study carried out in Erimulli Vagu watershed in Andhra Pradesh has revealed that from 2001-2004; there is decrease in area used for agriculture purpose due to urbanization and change in land use of agriculture lands into residential areas / industries.
Lopez et al (2006) have analyzed the extent of migration patterns influence land-cover and land-use change at the watershed level in the basin of Lake Cuitzeo, Michoacan, in Central Mexico, and area of high emigration of the USA. They have stated that demographic changes introduced by migration strongly effect economic activities and may thus trigger land-use changes. A Remote sensing and GIS and statistical approach have been applied to quantify and analyze both land-cover change and change in population per spatial unit. It was hypothesized that migration should exert a strong effect on land-cover change. It has been concluded that the expansion of scrubland areas at the expanse of rain-fed agricultural land is associated with the abandonment of agricultural land with poor soils. As a consequence, vegetal succession has been promoted and subtropical scrubland increased.

Chen et al (2006) have reported that Global warming has obtained more and more attention because the global mean surface temperature has increased since the late 19th century. As more than 50% of the human population lives in cities, urbanization has become an important contributor for global warming. They have also reported that Pearl River Delta (PRD) in Guangdong Province, southern China, is one of the regions experiencing rapid urbanization that has resulted in remarkable Urban Heat Island (UHI) effect, which will be sure to influence the regional climate, environment, and socio-economic development. Landsat TM and ETM+ images from 1990 to 2000 in the PRD were selected to retrieve the brightness temperatures and land use / land cover types. A new index, Normalized Difference Bareness Index (NDBI), was proposed to extract bare land from the satellite images.

Jixian Zhanga et al (2007) have described that the Ministry of Land and Resources (MLR) of China launched the National Land Use Change Program especially to monitor the scale and distribution of urban expansion and the decrease in cultivated land through remote sensing technology. First,
the remote sensing data sources and other ancillary data used in this Program are presented. The approaches for image preprocessing, i.e. radiometric normalization, image geometric rectification and image registration. They have reported that land use change detection technique is the most critical and complex aspect of the program and the data of land use changes derived from remote sensing will be operationally used for local and central government, field validation and accuracy assessment are crucial to ensure the reliability of change detection results. The land use and change information derived from remotely sensed data has wide applications for land management, including land use database updating, verification of land use planning and monitoring of national high-tech parks.

Subramaniam (2007) has described about automatic feature extraction for land use – land cover mapping. He has reported that the main aim is to develop / extend texture analysis method for handling different spatial resolution, developing technique for the automatic correction of atmospheric effects in the WiFS / LISS III sensor data. Development of knowledge based intelligent application specific image analysis system, image information mining system for the effective use of archived data.

Shrama et al (2007) have reported that the sustainability of watershed development has been assessed through the quantitative of the recharge and evapotranspiration for 71 micro watersheds of Kharoad watershed located in Western India. They have also reported that the current water resources and land use / land cover scenario and envisaged changed water resources and land use / land cover after implementing all prescriptions for micro watershed development. Finally the water balance component, level analysis and comparison were done to see the impact and assess the sustainability of envisaged water shed development scenario.
Vander et al (2007) have described that groundwater investigations are multi disciplinary in nature. Geophysicists, geomorphologists, hydrogeologists, social scientists, remote sensing specialists and geologists all have potential role to play. GIS even if used at low technical level, provide an opportunity for integrating a great variety of data source to assists in integrated cross-discipline decision making during groundwater exploration work. They have also stated that in the groundwater investigation study conducted in Boteri area or the Khalhari region in Botswana, the GIS has performed a crucial role in integrating and updating scattered and outdated base map data and was highly instrumental in the production of essential contours. Integration of satellite imagery and selected scanned aerial photography with base map data, geological data and bore hole data assisted during the early phase of geomorphological interpretation and the selection of terrain units and then target areas of promising groundwater prospects in the large 29,000 sq. km. study area.

Jha et al (2007) have reported that the geographic information system (GIS) has emerged as an effective tool for handling spatial data and decision making in several areas including engineering, geology and environmental fields. Remotely sensed data are one of the main sources for providing information on land and water related subjects (Vitousek et al. 1997) stated that currently, humans have transformed significant portions of the Earth’s land surface: 10 to 15 percent is dominated by agricultural row crop or urban-industrial areas, and 6 to 8 percent is pasture

2.1.8 Groundwater Modelling

Ramalingam (1985) made an attempt to develop a groundwater model for better utilization of natural resources in water shed. In this study, the Kallar water shed has been chosen which lies in Tutticorin district, in the
southern part of Tamilnadu. A distributed parameter model (mathematical model) for the surface and subsurface systems has been developed. The various inflow components and outflow components and net recharge or discharge to the aquifer has been assessed. They were given as input to the each grid of the groundwater model. The water requirement has been assessed. The study is useful for planning suitable land use according to the availability of water to get the maximum benefit.

Even though, there is a limited role of GIS in hydrological applications such as groundwater resources assessments, planning, soil erosion and urban drainage system, and the remote sensing data derivation, it has gained popularity in recent times with raster and vector in GIS environment (Burrough, 1986). Several researchers have utilized the GIS technology and the remote sensing derived data for water resource management, groundwater assessment and modeling.

As described by Sathiamoorthy (1991), some of the chemical parameters could be successfully utilized to discuss the area of recharge, discharge and the residence time within the aquifer, suitability of water for irrigation, industry or domestic use. The mechanisms controlling the quality of groundwater modeling in order to find out the area of concentration of different chemical constituents present in the groundwater.

A number of groundwater modeling studies have been carried out around the world for effective groundwater management (Corbet and Bethke 1992; Strom and Mallory 1995; Gomboso et al. 1996; Strom 1998; Ganasundar and Elango 2000; Senthilkumar and Elango 2001; Selroos et al. 2002). Such a study was attempted for the lower Gadilam river sub basin.
2.1.9 Artificial Recharge Zones

Artificial recharge is the process of replenishing groundwater by augmenting the natural infiltration of rainwater or surface water into underground formation. Artificial recharge is also a process in which water is added to the zone of saturation by other than natural means, and is one method of storing surplus surface water for later use. With the increasing demands for water in Gadilam lower sub basin for both domestic and agricultural purpose, it is important to consider all avenues for enhancing groundwater recharge, and using the surface water that is available in the area either by spreading of the surface, using recharge wells, or altering the natural conditions to increase infiltration to replenish an aquifer. Artificial recharge depends upon the local conditions of climate, surface and subsurface geology. The artificial recharge water can be stored mainly during the wet season, which reduces flooding effects in some places. Artificial groundwater recharge is undertaken to increase the volume of fresh water recharging an aquifer, conserving and controlling groundwater levels and improving water quality in the study area.

Playa lakes in Texas, New Mexico and Colorado have been used in artificial recharge projects (O'Hare et al 1986). Many Playa lakes have tight clay deposits that restrict leakage of water. Most of the water is lost by evaporation or by non-beneficial growth of vegetation in the lake. Heavy clay soils can be broken up and the lake bottom regarded for maximum recharge. In a demonstration project near Lubbock, Texas, playa lakes were modified by excavating concentration pits and using the excavated soil to raise the elevation of some of the previously flooded lands.
Recharge rates in both shafts and pits may decrease with time due to accumulation of fine grained materials and the plugging effect brought about by microbial activity (O'Hare et al 1986).

The ditches could terminate in a collection ditch designed to carry away the water that does not infiltrate in order to avoid ponding and to reduce the accumulation of fine material (O'Hare et al 1986).

Several investigations were carried out on the impact of artificial recharge in Tamil Nadu by Ramalingam et al (1990) and Palanisamy (1991). The impact of percolation ponds in the different terrains is reviewed through the above literature. In Gadilam lower sub basin, the following sites are identified through remote sensing and GIS techniques for construction of percolation ponds.

Padmavathy et al (1993) have utilized the capabilities of a geographical information system (GIS), Arc/info, for the determination of potential sites for rainwater harvesting in Karnataka State of India. Various thematic maps such as soil, landuse, drainage, lineament and fracture map, drainage map of the area at 1:50,000 scale were derived from remotely sensed images and Survey of India topographic sheets. Second and third order streams were identified and selected to find out suitable sites for check dam construction. Different maps of the study area have been overlaid and sites for check dams were selected based on certain assumptions. A suitable ranking was carried out for the final selection of the check dam sites.

Moya (1994) has described that in a conjunctive use study of surface and groundwater for small scale irrigation conducted in Zimbabwe, surface water supplies are unreliable as they depend on the erratic and poorly distributed rainfall. The average sustained yields of bore hole and wells are
small. The collector wells constructed in Chiredzi have shown that it is possible to abstract sufficient water for basement aquifer to meet domestic and stock water requirements and still provide sufficient water to meet and requirement of an irrigation garden.

The study carried out by Elango et al (1997) showed that the percolation pond is an assured sustainable recharge method not only for irrigation but also for drinking water. A rough estimate indicated that about 7% of the recharged water would be sufficient to meet the drinking water requirements of the beneficiaries in the area.

Ramalingam et al (1999) applied GIS and Remote Sensing to delineate areas favorable for recharge both in hard rock and sedimentary environs, to recommend suitable recharge structures. Different thematic maps, such as geology, geomorphology, Soil, land use, etc., were prepared from satellite data and overlaid with suitable ranks and weights. For hard rock area, geomorphology is the highest influencing factor, whereas geology is for sedimentary formations. By integrating the various thematic maps, the favorable zones for recharge are identified and the suitable recharging structures are recommended based on field conditions.

In recent years, the role of remote sensing and Geographic Information System (GIS) techniques has received much attention with regard to artificial recharge. Many scientists have suggested suitable sites for artificial recharge to groundwater on the basis of geological and geomorphological data, with less emphasis given to subsurface geological and hydrogeological data. Detailed aquifer parameters and subsurface geological information are needed to improve the results, and numerous studies have concentrated on the application of remote sensing and GIS for artificial

Choudhary et al (2001) demonstrated that moderately high resolution remote sensing data and GIS techniques are very useful for identifying artificial recharge sites. Anbazahagan et al (2005) identified suitable sites for artificial recharge of groundwater based on geological, geomorphological, and subsurface geological and water level fluctuation data. In this study integrated remote sensing and GIS techniques are use based on the various aquifer parameters and subsurface geological and geomorphological information. Percolation pond is one of the most popular artificial recharge methods in India to augment groundwater reservoirs both quantitatively and qualitatively.

Kaledhonkar et al (2003) have reported that in the state of Haryana, the present availability of water is 2 million hectare meters, which includes 1.1 million hectare meters of surface water and 0.9 million hectare meters of groundwater. Yearly fluctuations in water Table depths in the north-east region of the state indicate the declining trends of fresh groundwater resources. In the districts of Ambala, Kurukshetra and Karnal, groundwater withdrawal, mainly from the fresh water zone, is at the rate of 19.2%, 15.8% and 72.5% of the annual recharge, respectively. They have concluded that artificial recharge structures are to be constructed at suitable locations to improve the groundwater resources and safeguard the freshwater aquifer zones. Saraf et al (1997) have demonstrated that moderately high-resolution remote sensing data and GIS techniques are very useful for identifying artificial recharge sites.

Rasoulzadeh et al (2006) have reported that due to decreasing precipitation in recent years, lack of perennial surface water resources, and the
high volume of groundwater extraction in the vicinity of Tashk Lake, the groundwater level decreases, and as a result, salt water from Tashk Lake intrudes into the fresh water groundwater coastal aquifers. Several technical counter measures are used to prevent or retard the groundwater salinisation process. Once of them is to increase (artificial) recharge in upland areas to enlarge the outflow of fresh groundwater through the coastal aquifer, and thus, to reduce the length of saltwater wedge.

Amiri et al (2006) have reported that remote sensing and GIS systems are effective and efficient techniques in watershed management. In a case study conducted in South Isfahan provinces of Iran, soil, slope and land function maps were prepared and water feeding sites were identified using a GIS system. This site is located at 2750 meters above mean sea level, which experience a along dry period a year because of its rainfall distribution regime. The following information such land use map, slope map, soil texture map, streams map and climate information have been incorporated and analysed in the water feeding project.


Jastoria et al (2007) have reported that with the increasing demands for water due to increasing population, urbanization and agricultural expansion, groundwater resources are gaining much attention, particularly in the Kandi region of Jammu district, which faces acute shortages of drinking water throughout the year. This study used integrated remote sensing and geographic information system (GIS) techniques to provide an appropriate
platform for convergent analysis of multidisciplinary data and decision making for artificial recharge to groundwater. Thematic maps were constructed using merged Linear Imaging Self Scanner (LISS)-III and Panchromatic (PAN) remote sensing data and aquifer parameter thematic layers were prepared from conventional field data. The thematic layers of the aquifer parameters were integrated and a map showing the potential zones for artificial recharge to groundwater has been generated. They have concluded that by superimposing the drainage network map over this artificial recharge zone map, and also considering the terrain conditions for artificial recharge, suitable sites for replenishing groundwater.

In riverbeds where there is no exploitation of groundwater in the upstream, the groundwater blocked by a subsurface dam enhances either the storage of water in the reservoir created above it or substantial base flow in the downstream. In the latter case, the additional flows will be a boon for water-starving canals particularly located in the coastal tracts. A subsurface dam across the Ganga River upstream of the Farakka barrage helps Kolkata to become an all-weather port, while people in parts of Bangladesh could have subsistence agriculture and fishing even during summer. A subsurface dam across the Godavari River upstream of the Dowleswaram barrage ensures no shortages of water for the Rabi crop in the Godavari delta. A subsurface dam across the Krishna River upstream at the Krishna barrage at Vijayawada or across the Cauvery ensures adequate water for two crops in the delta irrespective of the vagaries of surface runoff. Such subsurface dams could be constructed across every small river joining the sea to put the associated groundwater presently joining the sea into use without the danger of any saltwater intrusion (Rao 2003).

The artificial recharge to ground water aims at augmentation of ground water reservoir by modifying the natural movement of surface water utilizing suitable civil construction techniques.
2.2 PREVIOUS WORK IN GADILAM SUB BASIN

Central Groundwater Board, Government of India has carried out systematic hydrogeological surveys by establishing its own observation wells to study groundwater fluctuation and groundwater exploration by electrical logging at regional level for the whole Cuddalore district and designed well fields out of it, three of the bore wells were within the study area to tap semi confined aquifer. Since early eighties Agriculture Engineering department takes care of ryots of small and marginal land owners for groundwater exploration and construction of wells at Taluk level in Cuddalore district.

In the first instance Engineering Geology and Ground-Water Division, paid a short visit sometime in February, 1950, in order to get an idea of the area, as well as to study the geological aspects in connection with the hydrological conditions of the lignite bearing beds and the associated formations. In the middle of March 1951, Geological Survey of India, came to the lignite field and studied the geological and hydrological conditions of the area.

Previous work on lignite and groundwater in this area has been discussed and the original studies in the data regarding the artesian beds by several officers of the Geological Survey of India. The last report was entitled ‘Geological Note on Lignite and Ground Water in the South Arcot District (1950)’.

The lithological data collected from the number of deep and shallow boreholes drilled by the Geological Survey of India (GSI), the Central Ground Water Board (CGWB), the Neyveli Lignite Corporation (NLC), and the State Ground Water Department (SGD) in the eastern sedimentary tract of the district are the main sources of data pertaining to the study of the sub-
surface geology of the area The following are the salient features of the sub-
surface configuration, as inferred from the available data.

1. The coastal alluvium around Cuddalore and along the
   Cuddalore – Alappakkam road is not more than 45.7 m in
   thickness.

2. The alluvium consists of granular beds of 3 to 21.33 m in
   thickness, separated by the clay beds, and are significant one
   in the groundwater development.

3. The maximum thickness of the Tertiary sediments in the
   central part of the area, as a whole is not less than about
   411.5 m.

4. Beds of sands, pebbles and gravel in the Cuddalore
   sandstones range between 9 and 169 m in thickness and are
   of ground-water worthiness.

The pioneering work of GSI during 1950’s in Neyveli lignite field
and its environs which forms part of Gadilam basin formed the basis for
further studies of groundwater regime (Subramanyam 1969). Subsequently,
Subramanian et al (1970) have conducted a quantitative reassessment of the
Neyveli groundwater system on the basis of the data collected between 1967
and 1969. As a part of GWC (Groundwater Control) programme, Neyveli
Lignite Corporation has put up control wells, which forms a part of the
Gadilam river basin to monitor groundwater fluctuations and water quality. It
has also carried out geological investigations for Lignite deposits in the
sedimentary tract of then composite South Arcot district (Sengupta et al
Under the United Nations Development Programme (UNDP), the groundwater potential of the sedimentary in and around Panruti was studied by drilling four exploratory boreholes ranging in depth from 250 to 300 m bgl. The salient data of the exploration are presented in Table 2.1. The average vertical permeability of the aquifers, determined as per the Hantush formulae works out 3.5 m\(^3\)/m\(^2\)/d. State Groundwater Department (SGD) has drilled exploratory bore well in the University Campus at Chidambaram to a depth of 457 m. and constructed a well-field tapping the different aquifers screening by four wells. The free-flow from the bore well tapping the zone between 274 and 335 meter below ground level is around 15 lpm.

Table 2.1 Hydrogeological Data of Selected Tubewells in Panruti Area

<table>
<thead>
<tr>
<th>Location</th>
<th>Aquifer Depth Range (m.bgl)</th>
<th>Discharge (lpm)</th>
<th>Drawdown (m)</th>
<th>Transmissivity (m(^2)/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panruti</td>
<td>100 – 200</td>
<td>1155.00</td>
<td>1.74</td>
<td>2713.75</td>
</tr>
<tr>
<td></td>
<td>200 – 300</td>
<td>637.50</td>
<td>-----</td>
<td>213.75</td>
</tr>
<tr>
<td>Tiruvadigai</td>
<td>Less than 100</td>
<td>993.75</td>
<td>0.95</td>
<td>3503.70</td>
</tr>
<tr>
<td></td>
<td>150 – 200</td>
<td>1155.00</td>
<td>5.13</td>
<td>436.80</td>
</tr>
<tr>
<td>Kuchipalayam</td>
<td>100 – 150</td>
<td>937.50</td>
<td>1.68</td>
<td>3094.79</td>
</tr>
<tr>
<td></td>
<td>150 – 250</td>
<td>982.20</td>
<td>4.93</td>
<td>1013.01</td>
</tr>
<tr>
<td>Krishnapuram</td>
<td>250 – 350</td>
<td>1331.25</td>
<td>12.5</td>
<td>2788.10</td>
</tr>
</tbody>
</table>

Under the United Nations Development Programme, Public Works Department, Government of Tamil Nadu has carried out Groundwater investigation by systematic hydrogeological surveys, groundwater exploration and evaluation of groundwater resources of Gadilam river basin, since 1970. P.W.D. is regularly monitoring control wells for groundwater quality and for groundwater fluctuation. TWAD board has carried out extensive exploration work in groundwater for selection of suitable areas to drill bore wells to
provide the protected drinking water supply under Rural Water Supply Scheme.

Aquifer performance study in Kadampuliyr village of Gadilam basin has been carried out by Amaranth (1992). He has done both long duration pumping test and recuperation test to study the Tertiary aquifer of the basin. A study on the seawater intrusion in the Ponnaiyar- Gadilam coastal tract in Tamil Nadu was conducted by Kumaraswamy et al (1994). They employed various hydrogeochemical methods like Durov’s diagram and various ionic ratios spatially with socio economic survey to identify the intrusion of seawater in coastal areas. Gnanasundar (1995) has done resistivity investigations by Vertical electrical sounding in 20 locations for demarcating Geological contacts in Ulundurpet area. By detailed resistivity Surveys he delineated the contact zones between various lithologic units (Archacan Vs Cretaceous and Tertiary Vs Cretaceous).

2.2.1 **Impact of Artificial Recharge Structure (ARS)**

Impact of ARS constructed in Alluvial and Tertiary formation in and around the study area by TWAD board RWS in Cuddalore.

At Kattamuthupalayam in Annagramam block, a check dam was constructed during 2006 August and at that time the water level observed near the well is 33 m bgl. Thereafter the water level is steadily increasing from September 2006 to August 2007.

In Thirumanikuzhi of Cuddalore block another check dam was constructed in August 2006 and the water level in nearby well was measured as 26 m bgl. From this period the water level was monitored every month and it was found that rise in water level upto August 2007.
The check dams are also constructed in the following locations such as Kilmampattu, Melliruppu and Virasingankuppam of Panruti block are also showing rise in water level from the period of construction and the details were furnished in the Table 2.2. The check dam at Kilmampattu and percolation pond at Silambinathanpettai is shown in Plate 2.1 and 2.2 respectively.

Plate 2.1 Check dam at Kilmampattu

Plate 2.2 Percolation pond at Silambinathanpettai
Table 2.2  Impact of Artificial Recharge Structure-Water Level in m (BGL)

<table>
<thead>
<tr>
<th>Location</th>
<th>SWL in m Before completed</th>
<th>SWL in m After completed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aug. 06</td>
<td>Sep. 06</td>
</tr>
<tr>
<td>Kattamuthupalayam</td>
<td>33.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Thirumanikuzhi</td>
<td>26.7</td>
<td>26.7</td>
</tr>
<tr>
<td>Meliruppu</td>
<td>57.4</td>
<td>57.4</td>
</tr>
<tr>
<td>Reddipalayam</td>
<td>56.2</td>
<td>56.2</td>
</tr>
<tr>
<td>Kilmampattu</td>
<td>62.5</td>
<td>62.5</td>
</tr>
<tr>
<td>Virasingankuppam</td>
<td>63.1</td>
<td>63.1</td>
</tr>
</tbody>
</table>

Source: TWAD Board, RWS, Cuddalore

Keeping the above literature in mind, an attempt has been made to study the hydrogeological conditions of the Gadilam River lower sub basin through groundwater modeling approach.