CHAPTER 1
INTRODUCTION

1.1 GENERAL

“Water is the most basic of all natural resources. Civilizations grew or withered depending on its availability”.

Dr. Nathan W. Snyder

Water, an indispensable constituent of everyday life, is widely distributed in nature so that it may be available quickly and easily. Water system, being the life supporting factor a healthy water system, is essential for a robust economy and a good quality of life. However, with the increasing population and rapid urbanisation trend, along with the advent of modern technologies, the usage of water has increased tremendously. Hence the need for an early rational and practical policy for the development, use and the conservation of water resources for the growth of the country.

The world’s total water resources are estimated at $1.36 \times 10^8$ M ha-m. Of these global water resources about 97.2 % is salt water found mainly in the oceans and only 2.8 % is available as fresh water at any time on the planet earth. Fresh water constitutes about 2.2 % of surface water resource and 0.6 % from groundwater resource. More so, of the 2.2 % of surface water, 2.15 % of fresh water is found in glaciers and icecaps and only 0.01 % of fresh water is found in lakes and streams and the remaining 0.04 % of fresh water is from other sources. Of the total groundwater stored (0.6 %) only 0.25 % can be economically extracted with the present drilling technology (the remaining being at greater depths). It can be said that the groundwater potential of the Ganga Basin is roughly about forty times the flow of water in the River Ganga (Raghunath, 1990).
The importance of water resources management through adequate watershed rehabilitation and conservation is increasing. Watershed development and management is evolving as a useful mechanism to address the most common water resource problems in India. Firstly, it aims to address the problem of water availability resulting from an increased demand on a resource rendered fragile due to irregular and erratic rainfall. Secondly, watershed management is required to mitigate the effects of flood and drought and to provide a livelihood for the large number of ethnic minority groups living in the country.

Watershed is a hydrologic unit, and the term is defined as “the total area of land above a given point on a waterway that contributes runoff to the flow at that point” (Hanson, 1954). The watershed characteristics such as size, shape, slope, drainage, vegetation, geology, soil, geomorphology, climate and land use pattern affect the disposal of water from the watershed. The watershed management is to protect the proper utilization of all land, water and natural resources of the watershed. The concept of watershed management is as old as the concepts of crops grown under irrigated conditions and this has led to the development of tanks and reservoirs for increasing the production to meet the demands of the overgrowing population.

Land and water are two wide-ranging components on which the entire biotic community increases. The available surface water resources are inadequate to the whole water requirements for all purposes (Praveen Raj Saxena et al. 2004). Therefore, land and water resources management has been identified as one of the priority areas for achieving sustainable food security by raising land productivity, reversing and degradation and water loss, and increasing the bio-diversity and the quality of the environment (Aditi Sarkar, 2008).

In India, Pandey and Sahu (2002) pointed out that the land use/land cover was an important parameter input of the SCS-CN model. Nayak and Jaiswal
(2003) found that there was a good correlation between the measured and estimated runoff depth using GIS and CN. Runoff is one of the most important hydrological variables in water resources applications (Beven, 2001). Reliable prediction of quantity and rate of runoff, from land surface into streams and rivers, is difficult and time consuming one in the case of ungauged watersheds (Huggins and Monke, 1968). However, this information is vital in dealing with many watershed development and management problems. GIS based SCS - CN method for computing runoff from the watershed, using daily rainfall data, has proved to be efficient for ungauged watersheds.

An integrated approach is the need of the hour to improve the quality of watersheds of countries to plan and monitor the best use and management of their water and land resources to increase agricultural productivity while maintaining land and environmental quality. Watersheds have assumed importance for preserving the ecological balance between natural resource development and conservation, particularly, in the fragile and heterogeneous erosion-susceptible hilly ecosystems. Watershed management is required for planning, developing, managing and conserving the water and land resources besides efficient irrigation scheduling.

1.2 WATER RESOURCES DEVELOPMENT AND MANAGEMENT

Sufficient quantity and quality of water is an essential resource not only for agriculture, industry, and tourism, but also for everyday life in cities and villages. Water resources, distributed in time, are the heart of sustainable development in many regions of the world and their availability varies seriously from time to time and place to place. An unexpected change and imbalance in the hydrological cycle put the necessity to quantify the available water resources with the objective of managing the resources environmentally as well as ecologically. As such, the approach towards the management of watershed assures greater importance in the recent years (Somashekar et al. 2011).
The rapid growth of urban population has been the character of Indian urbanization. The urban population in the country has increased more than 8 times, since the turn of the century and around 3 fold since Independence. The level of urbanization was 11-12 % during the first three decades of this century. Only 17.3 % of the Indian population, in 1951, was living in urban areas which have risen to 25.7 % in 1991. The urban population growth rate, significantly, is higher (3.1 %) than the overall population growth rate (2 %) as the urban population is projected to be about 658 million by the year 2025. Groundwater plays a very important role in meeting the water demands of Indian cities. The support, by groundwater regulation, would enable overall improvement of the water resources in the cities and urban areas in India. In addition to this, there is a need for demand management, which the urban policy makers have to emphasize (CGWB Report, 2011).

Water resources are sources of water that are useful or potentially useful. Uses of water include agricultural, industrial, household, recreational and environmental activities. Virtually, all of these human uses require fresh water. Totally, 97 % of the water on the Earth is salt water. Of the 3 % is fresh water available slightly over two third is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is found as groundwater, with only a small fraction present above the ground level as surface water or in the air. Fresh water is a renewable resource, yet the world's supply of clean, fresh water is steadily decreasing (Figure 1.1).
The demand for water has already exceeded the supply in many parts of the world and as the population continues to rise the demand for water is also in the rise. Awareness of the global importance of preserving water for ecosystem services, emerged during the 20th century, identified that more than half the world’s wetlands have been lost along with their valuable environmental services for water education. The framework for allocating water resources to water users (where such a framework exists) is known as water rights (Figure 1.2).

Surface water is the water in a river, lake or fresh water wetland. Surface water, naturally is replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and sub-surface seepage. Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water, in that system, at any given time is also dependent on many other factors.
Figure 1.2 Need for Water resources management

These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss. Human activities can have a large and sometimes devastating impact on these factors. Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed.

Groundwater is one of the most valuable natural resources, which supports human health, economic development and ecological diversity. Groundwater is precious and the most widely distributed resource of the earth unlike any other mineral resource. Because of its several inherent qualities (consistent temperature, widespread and continuous availability, excellent natural quality, limited vulnerability, low development cost, drought reliability, etc.), it has become an immensely important and dependable source of water supplies in all the climatic regions, including urban and rural areas of the developed and the developing countries (Preeja et al. 2011).
1.3 WATERSHED MANAGEMENT

A watershed is the area covering all the land that contributes the runoff water to a common point (Majed Subhi Abu Sharkh, 2009). It is a natural physiographic or ecological unit composed of interrelated parts and functions (Ashish Pandey et al. 2003). The watershed approach enables the planners to harmonize the use of soil, water and vegetation in a way that conserves these resources and maximize their productivity. The watershed is the appropriate hydrological unit for technical efforts to manage water and soil resources for production and conservation. But watershed management is complicated by the fact that watersheds rarely correspond to human-defined boundaries (Bharat R. Sharma et al. 2005).

Community watersheds are growth engines for the development of dry land areas. Since the beginning of watershed programs, the approach has been constantly evolved in India. Today, watershed projects do not focus on water conservation solely. Integrated watershed management plays an important role in ensuring food security, reducing poverty, protecting the environment and addressing issues such as equity and improved livelihoods (Suhas P Wani et al. 2009).

A watershed, simply is the land on which water flows across or through on its way to a common stream, river, or lake. The watershed can be very large (e.g. draining thousands of square miles to a major river or lake or the ocean), or very small, such as a 20-acre watershed that drains to a pond. A small watershed that nests inside of a larger watershed is sometimes referred to as a sub-watershed (Sivanappan, 2006).

Human activities on land have a direct and cumulative impact on water and other natural resources within a watershed. Upstream activities influence river flows and water quality downstream. Channelizing rivers, removing riparian vegetation along watercourses, paving recharge areas, filling in
wetlands, and consuming groundwater at rates faster than it can be replenished can have severe, and in some cases, irreversible effects on natural systems. These effects, in turn, usually impair water quality, degrade aquatic and terrestrial habitat, contribute to a loss of biodiversity, contaminate underground aquifers, and increase risks of flooding and erosion damage.

1.4 WATERSHED MANAGEMENT – A MULTI DIMENSIONAL APPROACH

This study proposed a multidimensional approach for a suitable watershed management. These multidimensional approaches for watershed management analyzed the data using conventional and GIS techniques. Using this technique, Assessment of surface runoff by SCS-CN method, Groundwater potential by GEC Norm 1997, Land Use/Land Cover change detection analysis in GIS environment, Evaluation of soil resources and Primary data generated to delineate the subsurface lithology and to identify groundwater potential using Geo-Physical method will be done.

The need for watershed management has the underlying philosophy that "everything is connected to everything else". Watershed components are interrelated and interdependent, like the links of a chain or the spokes of a wheel. Damage to any one of the watershed components runs the risk of damage to all. The health of upstream components, directly, determines the health and function of the areas in the downstream. This multidimensional approach will give a stable watershed. The main problems associated with the watershed are: Flooding, Unstable slopes / Landslides, Erosion from denuded land, Deficient water supplies, Energy and food shortage, Poor quality drinking water, Polluted streams / Reduced fishing, Sedimentation of navigation tracks, Timber shortage (for Dwelling purposes) (Figure 1.3).
1.4.1 Hydrological Factors in Relation to Watershed Management

The hydrological factors which are related to watershed management are as follows:

**Precipitation and Interception**

Precipitation (also known as one of the classes of hydrometeors, which are atmospheric water phenomena) is a product of the condensation of atmospheric water vapour that falls under gravity. The main forms of precipitation include drizzle, rain, sleet, snow, and hail. Precipitation occurs when a local portion of the atmosphere becomes saturated with water vapour and enables the water condenses and "precipitates". Interception refers to precipitation that does not reach the soil, instead it is intercepted by the leaves and branches of plants and the forest floor.

**Evapotranspiration and Soil moisture storage**

Evaporation from soils, plant surfaces, and water bodies together with water transpired through plant leaves is called evapotranspiration. Larger canopied plants transpire larger amounts compared to bare soil or plants with
smaller stature. The ET affects the water yield and largely determines the proportion of precipitation input of which becomes stream flow. In the tropical watersheds the ET component reaches up to 80%.

**Infiltration Runoff and Stream flow**

Surface runoff is the water flow that occurs when the soil is infiltrated to full capacity and excess water from rain, melt water, or other sources flows over the land. This is a major component of the water cycle, and the primary agent in water erosion.

**Groundwater**

Groundwater is referred to as the water that is accumulated beneath the soil surface in saturated zones. It is very important to maintain the watershed wetness but it seldom occurs where it is most needed. Groundwater is often used as a source of fresh water and important for vegetation sustenance and/or vegetation revival. Groundwater that seeps into streams provides the base flow of streams. Therefore, any unmanaged use would create a heap of environmental problems.

**Soil erosion and Sedimentation**

Soil erosion is the process of dislodgement and transport of soil particles by wind and water. The factors affecting soil erosion are: climate, topography, soil characteristics, vegetative cover, and land use etc. The major concern throughout the World (especially in the tropics) is the soil erosion by water.

**1.5 APPLICATION OF REMOTE SENSING AND GIS**

Remote sensing (RS) is the technique of deriving information about objects on the surface of the earth without physically coming into contact with them. This process involves making observations using sensors (cameras, scanners, radiometer, radar etc.) mounted on platforms (aircraft and satellites), which are at a considerable height from the earth's surface and recording the
observations on a suitable medium (images on photographic films and videotapes or digital data on magnetic tapes). Satellite remote sensing is widely used as a tool in many parts of the world for the management of the resources and activities within the continental shelf containing reefs, islands, mangroves, shoals and nutrient rich waters associated with major estuaries (Ramachandran, 1993).

Remote sensing data can be used in conjunction with conventional data for delineation of ridge lines, characterization, priority evaluation, problem identification, assessment of potentials and management needs, identification of erosion prone areas, evolving water conservation strategies, selection of sites for check dams and reservoirs, etc. (Somashekar et al. 2011). The functions of GIS also include data entry, data display, data management, information retrieval and analysis. The applications of GIS include mapping locations, quantities and densities, finding distances and mapping and monitoring change.

Remote Sensing techniques have been used extensively to provide accurate and timely information describing the nature and extent of land resources and changes over time. In watershed research and hydrological sciences, RS has played a major role because of its ability to provide spatially continuous data, its potential to provide measurements of hydrological variables not available through traditional techniques, and its ability to provide long term, global-wide data, even in remote and generally inaccessible regions of the Earth (Santillan et al. 2010).

The Geographical Information System (GIS) provides efficient tools for data input into database retrieval of selected data items for further processing and software modules which can analyze and manipulate the retrieved data in order to generate desired information on specific form (Burrough, 1996). The GIS has proven ability to handle such spatial and non-spatial data analysis issues. The spatial data sets are heterogeneous in nature and may be derived
from text, maps, charts, ground information, organizations, aerial photographs and satellite imageries. The management and analysis of such large volumes of spatial data requires a computer based system called Geographic Information System (GIS), which can be used for solving complex geographical and hydrological problems (Agarwal and Garg, 2000).

Hydrological modeling is a well known technique of hydrologic system investigation for both research hydrologists and practicing water resources engineers involved in the planning and development of integrated approach for water resources management. The conventional models for prediction of river discharge require considerable hydrological and meteorological data. Collection of these data is expensive, time consuming and a difficult process. There are several approaches to estimate the runoff from ungauged basins. The Soil Conservation Service-Curve Number (SCS-CN) method [now called as Natural Resources Conservation Service - Curve Number method (NRCS-CN)] is widely used because of its flexibility and simplicity. The method combines the watershed parameters and climatic factors in one entity called the Curve Number. Many researchers (Gandini and Usunoff, 2004; Zhan and Huang, 2004) have utilized the GIS techniques to estimate runoff curve number value throughout the world.

Remote sensing technology can augment the conventional methods to a great extent in rainfall-runoff studies (Stuebe and Johnston, 1990). The role of remote sensing in runoff calculation, generally, is to provide a source of input data or as an aid for estimating equation coefficients and model parameters.

RS and GIS have been used for investigation of springs, which are an important groundwater source, to investigate new water sources by using remote sensing and GIS methods (Erhan Sener et al. 2005). The advantage of remote sensing technology and its great potential in the field of agriculture have opened newer possibilities of improving agricultural statistic system. In the last few
years, remote sensing technology has been increasingly considered for evolving an objective, standardized and possibly cheaper and faster methodology for crop production estimation (Randhir Singh et al. 2003).

The GIS can be used effectively for this purpose to combine different hydro geological themes objectively and analyze those systematically for demarcating the potential zone (Shahid et al. 2000). There are several urban applications where satellite based remotely sensed data are being applied, namely; urban sprawl/ urban growth trends, mapping and monitoring land use/land cover, urban change detection and updating, urban utility and infrastructure planning, urban land use zoning, urban environment and impact assessment, urban hydrology, urban management and modeling.

“The development of India lies in the development of villages”, said M.K. Gandhi, the father of the nation. This statement shows that the target of any development should be towards the rural. The development in rural areas must be followed with the agricultural development. According to the guidelines given by Ministry of Rural development, Government of India, the integrated approach for sustainable development of rural area lies in the development of land, water, and crop/agriculture with a view of social economic conditions. To evaluate all the rural development factors as said above, the study used the RS and GIS techniques on watershed basis. So the Government of India planned for utilizing all the natural resources with integrating all the developmental tools such as information technology because Information Technology acts as a collaboration tool for exploring data resources using other technology like GIS and helps to define the needs of rural people (Asadi et al. 2011).

One of the major requirements for rural development is to have the accurate and timely information – information in geospatial forms that allows generation and use of different maps, GIS data and applications. Information of rural areas that characterizes the social and economic environment, physical
environment and rural services and amenities are critical in planning and development of rural areas. These tasks or goals can be achieved by implementing a multi-dimensional approach on rural watersheds.

Remote sensing techniques offer benefits in the field of land use/land cover mapping and their change analysis. One of the major advantages of remote sensing systems is their capability for repetitive coverage. The changes in land use/land cover, due to natural and human activities can be observed by using current and archived remotely sensed data (Srivastava and Gupta, 2003). In the last few decades, the RS and the GIS techniques have been used in different fields of the sciences in which it provides an opportunity for better observation and more systematic analysis of various identification and demarcation of groundwater resources. The RS and GIS are playing a rapidly increasing role in the field of hydrology and water resource development. While developing accurate hydro geomorphological analysis, monitoring, ability to generate information on spatial and temporal domain and delineation of land features are crucial for successful analysis and prediction of groundwater resources.

1.6 NEED AND SCOPE OF THE PRESENT STUDY

Although India occupies only 3.29 million km$^2$ geographical area, which forms 2.4% of the world’s land area, it supports over 15% of the world population. The population of India is 1027.015 million persons as on 2001 census and thus, India supports about 1/6$^{th}$ of world population, 1/50$^{th}$ of world’s land and 1/25$^{th}$ of world water resources. India also has livestock population of 500 million, which is about 20% of the world’s total livestock population. More than half of these are cattle, forming the backbone of Indian agriculture. The total utilizable water resources of the country have been assessed as 1086 km$^3$.

In view of the existing status of water resources and increasing demands of water for meeting the requirements of the rapidly growing population of the country as well as the problems that are likely to arise in future, a holistic, a well
planned long-term strategy is needed for sustainable water resources management in India. The water resources management practices may be based on increasing the water supply and managing the water demand under the stressed water availability conditions. Data monitoring, processing, storage, retrieval and dissemination constitute the very important aspects of the water resources management. These data may be utilized not only for management but also for the planning and design of the water resources structures.

Effective watershed management is also considered an appropriate approach for addressing food security and poverty alleviation. Watershed management is being seen as a major component of soil, water and vegetation cover conservation, rural communities’ living standards improvement and better environmental conditions. So, watershed management is one of the important topics of this present study. For the development of a country, its natural resources must be conserved, utilized and managed properly. This can be achieved efficiently by considering watershed as a basic workable unit and it has been proved by a number of researchers (David A.Eash 1994, Greene and Cruise, 1995).

Watershed management is required for planning, developing, managing and conserving the water and land resources besides efficient irrigation scheduling. Water management may be carried out efficiently by knowing surface and sub-surface runoff from the watershed. Nowadays, researchers emphasize the need for watershed-based water resource planning and development for successful management practices. The developed participatory watershed management policy and relevant action plans should be adopted in developing countries.

1.7 OBJECTIVES OF THE PRESENT STUDY

Effective implementation and monitoring of watershed practices are essential and require the service of technical personnel. The efficient watershed
management and development programme based on multidimensional approach for water and land resources are to be developed. The following are the identified objectives of the present study:

- To assess the quantity of surface water and groundwater resources of the study area.
- To delineate the areas of favorable zones for groundwater recharge in the study area.
- To delineate the subsurface geology and also to identify the contact zone between hard rock and sedimentary rock regions using geo-physical method.
- To analyze the nature and extent of Land Use/Land Cover Changes for the past 25 years (1972 – 2007) and to identify the major components that influence the changing trend in land uses in the study area.
- Assessment of Soil resources and Prioritization of mini watersheds for soil and water conservation of the study area.
- To create Watershed Management Information System (WMIS) of the study area.
- To study the socio-economic aspects and to suggest the suitable watershed management strategies based on multidimensional approach.

1.8 ORGANIZATION OF THE THESIS

The thesis consists of six chapters. The First chapter is the introduction that contains general facts about Water Resources Development and Management, Watershed Management, Application of Remote Sensing and GIS, Need for Present Study, Scope and Objectives of the present study.

The Second chapter is the Review of Literature, which focuses attention on the studies about Watershed Management and Modeling, Surface water Management, Groundwater Management, Watershed Management – A Multi
dimensional Approach, Application of Remote Sensing and GIS, GIS based SCS-CN Method, Groundwater Resources, Land use/Land cover Change detection, Soil Resources and the Socio-economic studies of watershed management.

The Third chapter of this study deals with the Study Area, which contains Codification of Watershed, Location and Extent, Climate and Rainfall, Physiography and Drainage Pattern, Geology and Geomorphology, Hydrogeology, Soil and Land Use Pattern.


The Fifth Chapter has the Results and Discussion. It encloses the results and discussion on the outcomes of the study. It also consists of some recommendations for better watershed management. This chapter throws more light on the multidimensional approach required for the watershed management.

The Sixth chapter comprises the Conclusions and Recommendations for further study.