CHAPTER I
INTRODUCTION

1.1 Introduction

The present days’ advancement and development of the world is directly linked with the harnessing and utilizing of natural resources from the river basins. India is gifted with a river system comprising more than 20 major rivers with several tributaries. Many of these rivers are perennial and some of these are seasonal (Raghunath, 1983). Besides, large number of surface water bodies is also being part of the water ecosystem and play the vital role to fulfil the requirement of water for various utilizations. In the recent decades, surface water has utilized fully due to increasing demand on water is a result of from many factors; especially the demographic increase and industrialization. It makes the world depend upon the largest available source of quality fresh water which lies underground and it is referred to as Groundwater. It is held in the subsurface within the zone of saturation under hydrostatic pressure below water table (Ariyo and Banjo, 2008). Hence, groundwater is gaining greater importance by time in many parts of the world, particularly in the arid and semi-arid zones of the continent where it is often the only source of water available. Moreover, groundwater is generally preferred for domestic uses due to its relative purity and the absence of contaminants that are found typically in surface waters and known to cause several serious water borne diseases. India, as one of the countries affected by both population explosion and the Green Revolution, hardly sees a day without some problem related to water figuring in the news. It is also evident that certain regions of the country, especially in the south and northwest, are more prone to drought due to dries up of surface water within 2 to 3 months after monsoon. The water demand during remaining lean period is managed with the groundwater. Groundwater has become an important resource for
meeting the water requirements for irrigation, industrial and domestic uses. Groundwater is a crucial productive resource in both Tamilnadu and India as a whole. Similarly, we could find that the domestic water in general and drinking water in particular, is supplied from ground water sources. Hence we need to seriously look at the groundwater situation not only for sustainable development but also for the balance between the demand and the availability of water resources.

Intensive groundwater use in agriculture has become a dominant, yet under perceived aspect of contemporary water use. While the use of groundwater has its roots in many ancient civilizations, it has grown exponentially in scale and intensity over recent decades. Global abstraction of groundwater grew from a base level of 100–150 cubic kilometers in 1950 to 950–1,000 cubic kilometers in 2000 (http://www.ramsar.org). Heavy use of groundwater was not made possible until there had been advances in geological knowledge, well drilling, pump technology and rural electrification, which for most regions dated from the 1950s. Today, a global withdrawal of 600-700 km³/a (cubic kilometers per year) makes groundwater the world’s most extracted raw material. In arid regions, where fossil groundwater is a primary source of water for all uses, intensive groundwater irrigation may threaten future water security. Approximately one-third of the world’s population roughly 2.4 billion people, live in water-stressed countries and by 2025 the number is expected to rise to two-thirds (UN-FAO, 2007).

In addition, with anticipated shifts in precipitation patterns induced by climate change, groundwater’s value as a strategic reserve is set to increase worldwide. Moreover, the value of groundwater to society should not be gauged solely in terms of relative volumetric abstraction. Compared to surface water, groundwater use often brings large economic benefits per unit volume, because of local availability, drought reliability and good quality requiring minimal treatment.
At the same time, groundwater contained in coastal aquifers represents a vital component of the freshwater resources available for urban, agricultural and industrial activities. Population increase and protracted periods of below-average rainfall have led to an enhanced dependency on coastal groundwater resources. Hence, getting freshwater in the coastal aquifers is being a big task and one of the major agendas for the benefit of the present and future generations.

In general, to delineate the fresh water in the sedimentary and coastal aquifers, geophysics and hydrogeochemical techniques are practiced commonly. Geophysical techniques are widely used to locate the freshwater aquifers and among geophysical exploration techniques, the electrical resistivity imaging method has been increasingly applied in geo-environmental investigations. This method provides information about resistivity distribution within the subsurface structures. It is commonly used by researchers for ground water exploration and seawater intrusion, and proved to be successful in detecting the fresh/salt-water interface in coastal aquifers (Abdul Nassir et al., 2000; Abdul Rahim et al., 2002; Vincent et al., 2002; Mohsen et al., 2006; Ekingi et al., 2007; Dushiyanthan et al., 2011).

Similar to the geophysical electrical resistivity method, hydrogeochemical methods also been used to delineate freshwater aquifers. Because water is such an excellent solvent it can contain lots of dissolved chemicals. Since groundwater moves through rocks and subsurface soil, it has a lot of opportunity to dissolve substances as it moves. For that reason, groundwater will often have more dissolved substances than surface water will. However, in the freshwater, concentration of the dissolved elements are normally low when compare to saline water. The freshwater gained concentration of the elements from dissolvable elements present in its travel path and have become saline or lead to contamination.
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The risk of contamination is greater for unconfined (water-table) aquifers than for confined aquifers because they usually are nearer to land surface and lack an overlying confining layer to impede the movement of contaminants. Because, groundwater moves slowly in the subsurface and many contaminants absorb to the sediments, restoration of a contaminated aquifer is difficult and may require years, decades, centuries, or even millennia. Any interference in the aquatic ecosystem is related in the changes in its physical and chemical characteristics. Measurement of physic-chemical characteristics is therefore, a convenient way to examine the changes in water quality (Gautam, 1990). Hence, knowledge of hydrogeochemistry is very essential as it seeks to determine the origin of the chemical composition of groundwater and the relationship between water and rock chemistry, particularly as they relate to groundwater movement (Zaparozec, 1972). Many researchers have studied geochemical facies and identification and utilization of groundwater based on its quality in different terrain conditions (Jain 1996, 1997; Madan Mohan et al., 1996; Panigrahy et al., 1996; Ramanathan et al., 1996; Atwia et al., 1997; Fischer and Mullican, 1997; Anandhan et al., 2000; Ramappa et al., 2000; Ramanathan and Others 1998; Srinivasamoorthy et al., 2005; Jeyavel Rajakumar, 2007; Abbasi Tasneem et al., 2009; Shankar et al., 2011; Mohammed Muthanna, 2011; Dushiyanthan et al., 2014).

1.2 Groundwater potential and development in India-An outline

The hydrogeological setup in the country varies widely. The lofty mountain chains in the north with high runoff, offers little scope for groundwater storage. However, they play an important role in recharging the vast Indo-Ganga-Brahmaputra plains flanked southwards. Multi-aquifer systems, explored down to 600 m, promises extensive and productive groundwater reservoirs. The peninsular shield in the south comprises discontinuous aquifers of limited potential in weathered and fissured
consolidate sedimentary, basalts and crystalline rocks. The coastal areas have a thick cover of Pleistocene to Recent alluvium with potential aquifers but associated with risk of sea water intrusions. The arid and semi-arid regions of Rajasthan and Gujarat with scanty rainfall and practically no recharge have restricted occurrence of deep aquifers tapping fossil water.

As far as groundwater development is concerned, it has a long history in India. Groundwater use in this country started dates back to ancient limes and is being found in literature more than 5000 years old. Relicts of brick-lined dug wells have been recorded in the excavations of ancient historical sites of Harappa and Mohenjo-Daro. For centuries dug wells have served the drinking water needs of the rural population and limited irrigation (Subhajyoti Das, 2008).

In the modern India, the mission of groundwater development project was launched in 1934 for the construction of 1500 public Tube wells for irrigation in Uttar Pradesh. The success of this project led to the constitution of a Sub-Soil Water Section in the Government of India in 1944, which was converted later into the Central Ground Water Organisation which functioned till 1949. In post Independence India, US - aided Technical Co-operation Mission with the collaboration of Geological Survey of India and Exploration Tube wells Organisation embarked on a project for exploring the scope of large diameter deep tube wells in the Indo-Gangetic plains and other alluvial areas in the country during the fifties. Till mid- sixties, the emphasis was on large and medium irrigation projects based on surface water for augmenting irrigation potential and food grain production. Since mid-sixties, however, realization dawned on the importance of groundwater, especially in areas of low rainfall and aridity. Side by side, several project studies by the Central Ground Water Board (CGWB) with foreign collaboration proved the feasibility of bore wells in Deccan traps and crystalline complex.
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Since 1987, minor irrigation census is undertaken every ten years by the government of India in all states to enumerate groundwater structures and irrigation potential based on groundwater along with other minor irrigation components, which form the basis for estimation of progressive groundwater utilization. In 1990, CGWB received a fresh mandate as per recommendations of the High Level Swaminathan Committee set up by the Ministry of Water Resources, Government of India, with stress on reappraisal hydrogeological surveys, deep exploration, groundwater regime monitoring, resource estimation and special problem studies like pollution, conjunctive use, artificial recharge, also research and development.

The continuous implementation of the groundwater development and management programmes witnessed that at present, more than 85% of domestic water supply in rural areas, about 50% of water requirements for urban areas and industries and more than 55% of irrigation water requirements are being met from ground water (www.planning commission.nic.in). In spite of the importance of groundwater in maintenance of India's economy it does not find its due share in planning processes for scientific development and management. Groundwater development is mainly done by private enterprises, witnessed in a phenomenal growth of groundwater abstraction structures during the last five decades. The stage of groundwater development in 2004 was estimated as 57.75%. It has exceeded 100% in the states of Punjab, Haryana, Rajasthan and Delhi, and is more than 70-85% in Uttar Pradesh, Gujarat, Karnataka and Tamil Nadu. The eastern and northeastern states present a picture of groundwater development less than 45%.

1.3 Groundwater development in Tamil Nadu

In Tamil Nadu, Tamil Nadu Water and Drainage Board (TWAD) and State Public Work Department (PWD) are the two state organisations which look after groundwater development and management. The PWD started its
investigation long back in the year 1965. During the period between 1965 and 1972, investigations were carried out with the assistance of UNDP groundwater project for assessment of groundwater potential in (1) Kortalaiyar and Araniyar basin (2) part of Palar basin (3) Neyveli area (mainly on the east of Panruti along Gadilam) and (4) Cauvery Delta. Since 1970, major programmes with the assistance of UNICEF for provision of drilled wells for rural water supply have been launched in the hard rock areas of Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu and Rajasthan. Apart from state government departments Central Groundwater Board (CGWB), a central government authority is actively implementing groundwater development and surface water management programmes particularly monitoring, artificial recharge and rainwater harvesting.

As far as Cuddalore district is concern, the state PWD has been conducting several activities such as continuous monitoring of water level and groundwater recharge to develop groundwater resources. Apart from this, it conducts remote sensing study, water quality study and consultancy service to farmers and public sectors related to groundwater resources development and management. Agricultural Engineering Department (AED) is promoting programmes for groundwater development by constructing check dams. National Bank for Agriculture and Rural Development (NABARD) has been supported watershed management related programmes in the district.

Neyveli Lignite Corporation Ltd, Neyveli (NLC) is a governmental organization in charge of important lignite fields and power generation supporting water shed development, artificial recharge, and rainwater harvesting programmes. A part from government departments, NGOs particularly, DHAN and Swaminathan Foundations are also contributing remarkable level for groundwater development in the district through management programmes.
1.4 Groundwater problem in sedimentary terrains

Aquifers are much less vulnerable to the pollution caused by man than surface water bodies, being naturally protected by soils or layers of impermeable sediment and rock. But, as a result of large storage and long residence times, when aquifers become polluted, contamination is persistent and difficult to remediate. Contaminants may enter aquifers relatively easily through large pores, but once diffused through and absorbed by the aquifer material are extremely difficult to remove.

Development of groundwater in coastal regions unlike hard rock terrains, groundwater in the coastal area occurs under unconfined to confined conditions in wide range of unconsolidated, semi-consolidated and consolidated geological formations. Increasing exploitation and reduction of coastal fresh water outflow upset the dynamic equilibrium in the coastal aquifers. The groundwater salinity in coastal areas can be attributed to several reasons such as inherent salinity, land inundation due to creeks, tidal actions, irrigation by saline water, upcoming and finally the lateral sea water ingress or sea water intrusion.

The salinity found in some pockets is because of leaching of soil from the aquifer material (in situ) and not due to sea water ingress. Though, the saline-fresh water interface could not be observed in these prolific aquifers, it should be exploited optimally with a caution and intensive monitoring is required. At the same time, there is an urgent need to undertake integrated hydrogeological research to study the dynamics of saline-fresh water interface, which will ultimately help in scientific development of both shallow and deeper fresh water in these areas.

In the state of Tamil Nadu, coastal salinity is quite alarming in certain parts especially in the Minjur area of Thuiruvallur district, it has been observed that the seawater-freshwater interface has moved 2 to 9 km since
1969, The reason could be intensive development of groundwater in these areas, resulting into sharp decline in groundwater levels and changing the complete hydrodynamics of the area (Rao et al., 2004).

1.5 Need for the study

The technology of drilling and lifting devices increased the exploitation of groundwater in many folds. The uncontrolled groundwater development has proven to be a curse and has resulted in over exploitation in many parts of the country leading to steep decline in water table, large scale failure of tube wells, fall in well yields, and increase in cost of water lifting and decline in food production. As on 2004, a total of 839 assessment blocks (blocks/mandals/taluks) in the country are categorized as overexploited and 239 others as critical (www.cgwb.gov.in). In contrast, lack of groundwater development in canal commands has resulted in rise of water table, rampant water-logging and soil salinisation. It is only through harmonious development of both surface water and groundwater that such adverse fallouts on environment may be avoided. Technological developments and induction of fast rotary cum percussion drilling rigs capable of drilling to deeper levels saw proliferation of deep bore wells in the peninsular states. Use of sophisticated tools like remote sensing, geophysical probing also aided groundwater exploration and its enhanced exploitation.

It is estimated that at the present rate of development, all available water resources are likely to get exhausted by 2025, if timely action is not taken (www.infochangeindia.org). To meet the increasing targets of food grains production and requirement of water supplies and economic activities of the growing population in the country, groundwater needs to be optimally developed and augmented through rainwater harvesting and artificial recharge along with other water conservation measures to avoid the crisis. At the same time, saline water is the major threat in the coastal regions.
The present study area, the lower Vellar sub basin is one among the sub basin areas where the groundwater demand has been noticed in recent times. It is observed that the groundwater level has lowered in many existing bore wells and some have gone to dry yield condition. The increasing trend of drilling new bore wells and extensive exploitation of groundwater affected the shallow aquifers of the study area. In this scenario, it is necessary to understand the sub surface lithology and its characterization for identifying fresh groundwater potential zones and quality variations for sustainable development.

There is a growing awareness that integrated hydrogeological studies pertaining to the quality and quantity of groundwater resources, over a regional context and also within a systems framework are necessary to cope up with the present day water demand and scarcity problems.

1.5.1 Aim and Objectives

This study aims to analyze the groundwater resources of Lower Vellar basin of Cuddalore district, Tamil Nadu.

The major objectives of the present work are

- To understand hydrogeomorphological characteristics
- To understand the aquifer parameters by pumping test
- To delineate the fresh groundwater potential zone using electrical resistivity method
- To assess the groundwater quality and its suitability

1.6 Methodology

Research, in common parlance, refers to the search for knowledge. Simply, it is an endeavor to discover answers to problems (intellectual and practical) through the application of scientific methods to the known
universe. It is essentially, a systematic enquiry seeking facts through objective verifiable methods in order to discover the relationship among them and to deduce from them broad principles or laws. It is really a method of critical thinking. It comprises defining and redefining problems, formulating hypothesis or suggested solutions, collecting, organizing and evaluating data, making deductions and making conclusions, and at last, carefully testing the conclusions to determine whether they fit the formulated hypothesis. In the scientific research work, to fit into the hypothesis, particularly for the integrated study, a systematic approach is essential to arrive at a proper conclusion and propose suitable management strategy for the selected research problem. In order to achieve the objectives, the present study was carried out with a predefined methodology.

In order to achieve the proposed aim and objectives, the work has been planned in a systematic way of map preparation, literature collection, primary and secondary data collection, data analysis and interpretation. The methodology of the present study is presented as flow chat (Figure 1.1).

1.6.1 Map preparation

The base map of the study area is prepared from the survey of India topo sheets No. 58M/7, 10 and 14, 11 and 15. The maps of drainage, soil, geology, geomorphology and land use maps (1:50000 scale) were prepared from thematic map generated by the Institute of Remote Sensing (IRS), Anna University, Tamil Nadu, India and digitization were done in ArcGIS9.2 platform.

1.6.2 Literature survey

The literature collection was done for different aspects of groundwater exploration, aquifer studies and groundwater chemistry. The relevant works done at national and international level has been collected and presented in a systematic manner.
Figure 1.1 Flow Chart of Methodology

METHODOLOGY

Primary Data (Field study)

Hydrogeological Study

Groundwater sample collection (Precipitation, Post monsoon)

Major element analysis

Assessment and suitability of groundwater quality

Secondary Data

Literature Collection

Rainfall and Water Level Data from PWD Department

Water Level Fluctuation Summer and Winter Season

Thematic Maps
1. Drainage
2. Geomorphology
3. Geology
4. Soil
5. Land Use

Resistivity Survey VES, Resistivity scanning and well inventory questionnaire

Data interpolation and Analysis

Isostaticity & thickness map and scanning image

Resistivity pseudo section

Correlation with well lithology and bore hole screening

Data integration and Analysis

Demarcation of fresh groundwater Potential and groundwater quality
1.6.3 Data generation and collection

According to the proposed methodology, the data collection has been done from two kinds such as primary data and secondary data. The primary data were generated from filed studies and the secondary data such as rainfall and water level were collected from various government departments.

1.7 Primary Data

In the primary data generation, pumping tests were conducted in 8 different locations to evaluate the aquifer characteristics. The collected data was interpreted in a basic language programme APE developed by Balasubramanian (1989). The aquifer parameters were analysed and spatial maps also prepared for different aquifer parameters. Further, well inventory study also been conducted at 53 locations in which the bore hole details particularly the depth of screening position was collected.

To delineate the freshwater aquifer zones and understand the sub surface lithological variation of the study area, geophysical electrical resistivity survey was conducted by employing Schlumberger configuration. The resistivity measurements were collected using SSR-MP-AT-ME model resistivity meter. Totally, 69 VES were carried out in the study area in which the AB/2 spreading of 100m was done in 64 locations and in 5 locations AB/2 spreading extended up to 200m. The obtained apparent resistivity data were analyzed by using IPI 2WIN software. From the interpreted data, isoresistivity and isolayer thickness maps were generated to delineate the shallow fresh groundwater potential zones.

Apart from the VES, multi electrode electrical resistivity scanning was carried out at 14 locations and total length of 250m was scanned using 50 electrodes at an interspacing distance of 5m. The obtained data were transferred using IGIS scan software and analyzed with IPI 2WIN software.
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From the interpreted resistivity data, freshwater aquifer zones and subsurface lithology have been evaluated by preparation of pseudo sections. To understand the reliability of the resistivity study in the area, it has correlated to the existing borehole lithology and screening position (slotted pipe) of the boreholes.

To identify the groundwater quality a total number of 80 groundwater samples were collected from bore wells in the study area where 40 samples were collected during pre monsoon season of June 2012 and 40 samples were collected during post monsoon season of January 2013. The samples were collected in a clean polythene bottles as prescribed by Hem (1970), Brown et.al (1970) and APHA (1995). The analysis has been carried out in the department of Earth Sciences, Annamalai University, Tamil Nadu for the parameters of pH, Electrical conductivity (EC), major cations Ca$^{2+}$, Mg$^{2+}$, Na$^{+}$, K$^{+}$ and anions HCO$_3^-$, Cl$^-$ and SO$_4^{2-}$. Total hardness, Total Dissolved Solids (TDS), Sodium Absorption Ratio (SAR) were calculated using software WATCLAST (Chidambaram et al., 2004). The data were plotted in Piper’s trilinear, Gibb’s plot and USSL diagrams for understanding the water facies, controlling mechanism and its irrigational suitability. Besides, Permeability Index (PI), Sodium Percentage (Na%), Chloride classification and corrosivity ratio also done. Spatial maps have been prepared to understand the variation of hydrogeochemical parameters.

1.8 Secondary Data

1.8.1 Rainfall

The present study, rainfall data were collected from the data centre, state Public Works Department, Chennai. Only four rain gauge stations namely, Bhuvanagiri, Portonovo, Sethiyathope, and Kothavacheri, are within the sub basin. The rainfall data of the mentioned rain gauge stations collected for the period of 23 years from 1990 to 2012. The collected data were analysed and represented in the graphical diagrams.
1.8.2 Water level

Water level data were collected from the data centre, state Public Works Department, Chennai to evaluate the water level trend and fluctuation in the study area. Totally 8 observation wells were identified within the boundary of the study area and data were collected during the period between January and May for 23 years from 1991 to 2012.

Besides, spatial/ contour maps of rainfall and water level also prepared for better understanding. The rainfall and water level fluctuation were correlated seasonal wise for establishing the rainfall and water level relations and other hydrometeorological parameters.

1.8.3 Data analysis and Integration

To delineate the fresh groundwater potential zones and quality variations, the analysed primary and secondary data were integrated in a systematic way.

1.8.4 Organization of the Thesis

In order to discuss and evaluate the proposed study through an elaborate discussion of all the objectives, this research work is conveniently divided into 6 chapters as given below;

Chapter – I INTRODUCTION

The outline of groundwater potential and development in India and Tamil Nadu has been discussed. The groundwater problem in sedimentary terrain, particularly in coastal regions has highlighted. The aim and objectives of the study and detailed methodology adopted in the study also presented in the chapter.

Chapter – II STUDY AREA

The important features of the study area such as geology, geomorphology and soil are discussed with necessary thematic maps and the sub basin geometrical parameters are also presented in this chapter.
Chapter – III HYDROMETEOROLOGY AND HYDROGEOLOGY

Hydrometeorology and hydrogeological parameters of the district and the study area are discussed. Water level and water level fluctuation are analysed for 23 years between 1990 and 2012. The rainfall of the study area is analysed for the same period. The hydrogeology of the sub basin has been discussed and with the help of a BASIC language computer program the aquifer Transmissivity, storage coefficient, specific yield and optimum yield have been calculated for the study area.

Chapter – IV GEOPHYSICS

The basic concept of electrical resistivity technique and scanning is presented in this Chapter with existing literature. The freshwater aquifer zones and sub surface lithology have been discussed from the interpretation of vertical electrical resistivity sounding and scanning. From the interpretation output iso resistivity and iso layer thickness maps were prepared. Besides, existing borehole lithology and aquifer screening position has been correlated to the resistivity pseudo sections.

Chapter – V HYDROGEOCHEMISTRY

The chapter deals with the Hydrogeochemistry and quality of groundwater of this sub basin and existing literature. Regional quality behavior of groundwater with reference to TDS, SAR, USSL, Gibb’s and hydrochemical facies has been discussed.

Chapter – VI SUMMARY AND CONCLUSION

In this chapter, important inferences are summarized chapter wise and bring out the conclusions from the parameters employed to analyse the present study. It is followed by the reference cited all through work in alphabetical order.