CHAPTER-1

INTRODUCTION

1.1. General

"Water is precious save every drop of it"

This single sentence, when obeyed, is the only way which can save life and environment of the modern civilization on the earth.

Among the States of India, alphabetically, Andhra Pradesh finds place at the top. Likewise, the district in which the study area falls, also finds first place. The district is located in the extreme north of Andhra Pradesh adjoining Maharashtra State. Its location with dense forests consisting of rich fauna and flora and bounded by major rivers gives an auspicious feeling and an aesthetic sense. The area enjoys a sub-tropical to semi arid type of climate. The geographical demarcation of Adilabad district is made by Penganga and Wardha rivers in the north, Pranahita in the East and Godavari all along the south. Total geographical area of the district is 16,105 Sq.Kms. which is divided administratively into 52 mandals and organised into five revenue divisions viz., Adilabad, Utnoor, Nirmal, Asifabad and Mancherial. (CPO, 1991). The density of population as per 2011 census is 170 persons per sq.km, lowest in the State. Out of the total area; 5,220 Sq.Kms, constituting 32.36%. Overall literacy per cent of the district is 32.96 and rural literacy percent is 25.78. As per norms less than 50 percent literacy indicates under-developed conditions of an area, which requires special and area specific attention of the planners.

Adilabad district is rich in fauna and flora. About 47 per cent of the total geographical area is forest area with teak [Sagawan] and bamboo as main species. The fossil remains of dinosaurs and petrified wood found at Chennur area in the eastern part of the district indicate that there has been a complete evolutionary continuity of life in Adilabad district from Palaeozoic era to Cenozoic era. Wild life inhabiting these forests includes tigers, leopards, deers, bears, hyenas and wild boars.

Although three major rivers bound the district, very limited area comes under Saraswati canal command of Sriramsagar major irrigation project, in Nirmal revenue division. Three medium irrigation and 750 minor irrigation projects are the source for surface water irrigation in the district, the most important among them being Saathnala project which has its catchment in the study area. All these are located in plain areas. Mathadi vagu basin mainly constituted by hilly terrain, so surface water irrigation sources are minimum and dependence is mainly on groundwater resources. Out of the total cropped area of the district, 9.2% is irrigated. This can be attributed to low density of population, want of infrastructure like electricity and road network and also lack of planning to create more surface irrigation sources in the past. However, as per the present plan of Medium Irrigation Department, out of 25 medium irrigation projects proposed in the state the highest number 7 are to be completed by the year 2008, one of the main project is Mathadi vagu project constructed at south of Thamsi town (PHOTO 2.11).

1.2. AIMS AND OBJECTIVES OF THE STUDY

Availability of stream water in plenty in the past never compelled human community to plan and use the resource. However, with passage of time and development of agriculture surface water became scarce and the un-harnessed groundwater resource was not available to the farmer, thereby affecting the agriculture activity. As rightly said, "Necessity is mother of invention" ensuring required quantity of water source throughout the year is essential for proper planning of irrigation, industrialization and overall development of the area.

Streams and rivers which are perennial in plain areas generally contain water throughout the year. On hilly and rocky terrains any amount of monsoon precipitation rushes down as run-off to the foot hills, except a small part of it infiltrating into the rock formation and seeping down as groundwater. Such areas, rich in natural environment, are the dwelling places of human population. But, due to lack of awareness, their socio-economic condition is generally poor.

The Mathadi vagu basin area is characterised by hilly terrain with elevated plateau, having steep to moderate slopes with good annual rainfall and luxuriant forests. In general, the area is suitable for development of groundwater resource. Main occupation of people of this area is agriculture. The area has a culture of growing single rainfed crop. During non-monsoon months of the year, the tribal farmers are engaged in collection of forest produce and some migrate to neighboring major irrigation project command areas of Nizamabad, Karimnagar and Warangal districts to work as agricultural labour. The streams, springs and waterfalls in these forest areas are utilized as drinking water sources in summer months with very limited use for the production of second crop.

In recent past, due to inconsistent monsoon, the water sources are getting dry, thus causing acute drinking water problem especially during summer. Groundwater development and its use for agriculture take first priority for economic improvement of population, particularly the tribes. The following Objectives and methodologies are adopted for the present research work:

Objectives

- Understanding the geological and geomorphological setup of the area
- Morphometric analysis
- Determination of aquifer characteristics
- Deleniatin of different layers i.e. weathered zone, depth to bed rock etc
- Identification of ground water potential zones
- Analysis of the surface and groundwater samples to establish water quality and their characterization in the study area
- Identification of ground water polluted areas

Research plan and methodology (Field and Laboratory)

- Preparation of geological and geomorphological maps with field checks.
- Literature survey and secondary data collection
- Topographical and Hydrogeological investigations
- Water level monitoring of selected wells and well inventory in the study area
- Geophysical investigations to identify aquifer depth, clay zones, groundwater potential zones.
- Observation wells data collection to know the water level fluctuations i.e. of Pre and Post monsoons.
- Conduct of Pumping tests to establish aquifer parameters
- Water sample collection and analysis to findout the major and trace elemental concentration.

1.3. HISTORICAL DEVELOPMENT AND PREVIOUS LITERATURE

Varied hydrometeorological conditions, under different geological formations, convert surface water into groundwater, which form a part of hydrological cycle. Hindu literature contains hymns relating to water and energy since the days of Vedas and Upanishads. As early as in 6th century, Varahamihira in his work called Brihat Samhita provided names of Bio-indicators which helped decipher occurrence and movement of groundwater, (E.A.V. Prasad. 1980). Varahamihira also indicated the rain making theory in his ancient work (Koteswaram 1976).

The knowledge of occurrence of groundwater under artesian conditions and the means to bring it to surface is known since the great epic Mahabharata days, as manifested by the way Arjuna struck an arrow on the ground to provide water to Bhishma lying on "Ampasayya" (Bed of arrows) and Moses smiting a rock with his rod and creating water. As surface water was available in plenty, human race since early period, confined it self to using rivers and perennial streams flowing through dense forests. However, with passage of time, in times of dire necessity, the search and exploration for sub-surface water (groundwater) hidden in sand bed of rivers and streams, forced people to resort to its exploitation and then the practice spread to other upland areas also. The contribution of Aristotle (384-322 B.C.) Pluto (427-349 B.C.), Karats of Persia and Egypt, the huge groundwater tunnels of 800 B.C. (Tolman, 1937) are the works earliest known on groundwater. The science of groundwater resources and its significance in development of civilisation is pre-historical. There are references in ancient Greek and Roman literature also.

Pierre Perrult (1608-1680), Edme Mariotte (1620-1684) and Edme Halley (17421856) are pioneers of hydrology. The mathematical formulae on laminar flow of groundwater, "Darcy's Law" is known to follow basic of groundwater flow, developed steady state formula for the flow of water into a well. Theim (1906) developed a method to determine permeability of aquifers in the field. Slichter (1906) derived an equation to find out specific capacity of dug well from recovery data. O.C. Meinzer (1923) was the founding father of Groundwater Hydrogeology who explained the Artesian Flow Theory. Theis (1935) gave basis for groundwater evaluation from non-equilibrium conditions, Mikels et al (1956) described the induced infiltration. Hantush (1964), Jacob (1970) described the flow of groundwater to collector well (Dug well). Larson (1983), Black J.H (1994), gave a model of disposition of aquifers in hard rock terrain, Podgorney and Ritzi (1997) discussed capture zone geometry of fractured aquifers, and Mead Mayer defined the utilisation of mathematical models, statistical methods, systems approach and digital simulation model, application of probabilistic and stochastic theories in hydrology in 20th century.

Study on Groundwater chemistry in correlation with hydrologic and geologic units gave rise to Hydrogeochemistry. B.M.Larsch of Germany and T.H.Hunt of Canada have early works on this subject. F.W. Clarke published his water quality work in North America during early 20 Th Century. Gorham (1958) dealt with factors influencing the major ions in water, Katz Lindner and Ragone (1980) gave a comparison of nitrogen from shallow groundwater from sewered and non-sewered areas, while Gold et.al (1990), Flipse et.al (1984) and Yates (1985) studied Nitrate-Nitrogen in groundwater and relation with sanitation, Cronin (2003) gave an account of Temporal variations in the depth-specific hydrochemistry and sewage-related microbiology of an urban sandstone aquifer, gave a mechanisms controlling world water chemistry, Gascoyne and Karnineni (1994) dwelt on hydrochemistry of fractured plutonic rocks in the Canadian shield, Gall et.al (1994) gave the Correlation between bedrock Uranium and dissolved Radon in Groundwater of a fractured carbonate aquifer in Southwestern Ohio; Trojan et.al (2003) dealt on effects of land use on groundwater quality drinking water guidelines were given by WHO (WHO, 1984).

Work on groundwater flow in fractured rocks was recorded by Hantush (1964), and Streltsova (1976), Toth (1987) has extended techniques of groundwater investigations to petroleum field. Scanlon and used water budget and changes in storage using mass balance to compute recharge to groundwater. Has updated the world water i.e., the quantities in different points and areas on the earth. Strenger has developed table for run-off (Subrahmanyam K 1997).

In India during early 20 Th Century groundwater related problems were tackled by Geological Survey of India (G.S.I.), Groundwater Wing was formed in Geological Survey of India in the year 1945 with increasing demand to cater to the needs of water supply. With more and more developmental programmes in the Country, Exploratory Tube well

Organisation (E.T.O) was formed in the year 1954. Subsequently, in the year 1972, the Groundwater wing in Geological Survey of India merged with the Exploratory Tube well Organisation forming an apex body at national level 'Central Groundwater Board' (C.G.W.B.) under the Ministry of Irrigation. Contribution of National Geophysical Research Institute (N.G.R.I.), Hyderabad, Center for Exploration Geophysics and Geology Department, Osmania University, Hyderabad towards groundwater research paved the way for vast development in different geological formations. Most of the universities in various parts of the country have taken up groundwater studies under different projects. Thangarajan, M. (2000) approached the groundwater studies in hard rock aquifer system with emphasis on modelling. Andhra Pradesh State Ground Water Department (2002) using ground water estimation methodology of Ministry of Water Resources (GEC 1997) have computed and compiled groundwater resources of the state.

Goswami P and Mandal A (2004), dealt with long-range, High-resolution Forecast of Monsoon Rainfall: Onset and distribution of weekly and monthly rainfall CSIR Centre for Mathematical Modelling and Computer Simulation Since 1960 onwards, to keep pace with the groundwater exploration and exploitation particularly for rural drinking water and minor irrigation schemes, many state Governments have formed their own Ground Water Departments for systematic and successful implementation of the programmes. In Andhra Pradesh, the Ground Water Department was established in the year 1971, which has been making remarkable contribution in exploration, development, evaluation and management of groundwater resources through systematic and detailed groundwater investigations. The Department has been laying emphasis on development of Ground Water in undeveloped/under and remote areas.

Apte (1972) took up groundwater studies in hard rocks of Peninsular India, while Shanmugam and Krishna Murthy (1972) studied aquifer characteristics of hard rocks. Karanth (1973) and Srinivas Srinivasan (1973) studied significance of fractures and joints. Seshu Babu (1978) in Andhra Pradesh and Rajurkar et al (1990) in Madhya Pradesh and Maharashtra applied aerial photo interpretation and remote sensing techniques in preparing hydrogeological maps. Athavale (1979) gave an integrated approach of geohydrological investigations during Lower Manair Basin studies in Andhra Pradesh, with digital modeling.

Deshmukh (1969) determined the groundwater potential in parts of Telangana Region, while Panduranga Rao (I974) conducted aquifer characteristic studies in granitic terrain of Telangana Region.

Again Shankar Narayana and Ravindra (1981) studied Kalvar river basin. Ananth Reddy (1983) studied specific capacities of wells in granites of Ranga Reddy district. Prakash Goud (1984) worked on ground water conditions in Koilsagar Project Area, Mahaboobnagar district. Lakshmaiah (1989) emphasized the need assessment and development of groundwater in tribal tracts of Warangal district.

Subsequent to the work of W.King (1881), H.E.H. The Nizam's geologist, P.V. Rao (1952) mapped areas in Adilabad district and gave brief account of geology. And Ramkishan Desai (1984) detail study of Ground water investigation, development and management in tribal tracts utnoor area. Through the present study area was not covered, the surrounding areas were covered by G.S.I. Geologists J.P. Dias (1965), K. and T. Ajith Kumar Reddy (1974).

Hydrogeological conditions of Chennur taluk, Adilabad district was studied by M.Hanumantha Reddy (1980) of the State Ground Water Department. The groundwater investigation works in remote parts of the district were mostly taken up by State Ground Water Department and Central Ground Water Board since 1973.

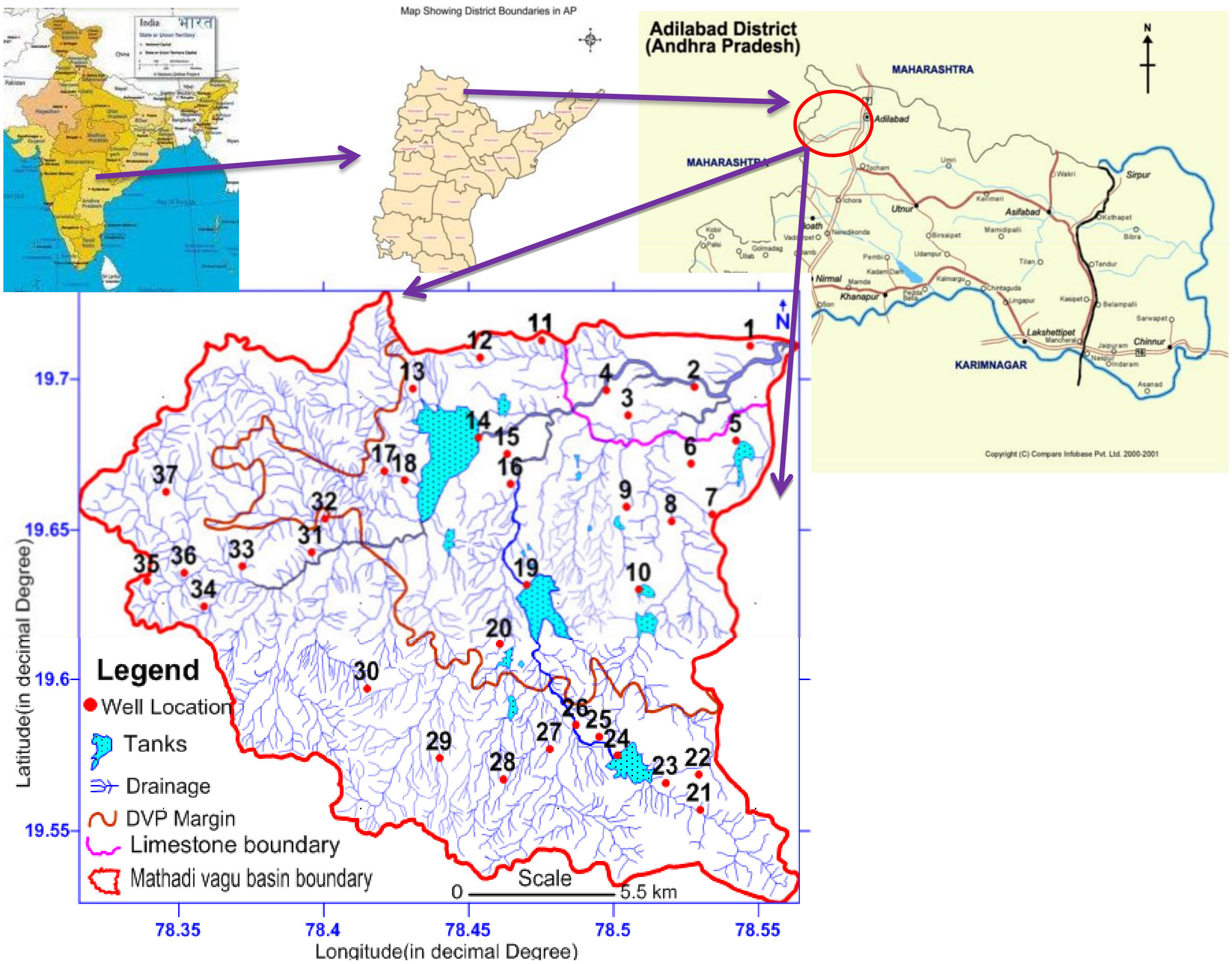


Fig: 1.1 Location map of Mathadi vagu basin area

1.4.1. LOCATION

Mathadi vagu basin is located in the north part of Adilabad District .Mathadivagu is a tributary of Sathnala River which is a tributary of the Penganga River. The study area is located Western part of Saathnala River in Adilabad town. The area falls in the Survey of India toposheet Nos 56 I/06, 56I/10. And the major part covers in 56 I/06 only. There are more than 80 habitats in the basin. Thamsi and Thalamadugu are the main Mandal Head quarters, situated in this basin. The basin trends NW-SE and situated about 12-15 Kms from Adilabad town. (Figure 1.1). The study area lies between latitudes 19°50'28" to 20°13'35" North and Longitudes 78°28'25" and 78°58'00" East. The total Geographical area covered is 525 Sq. Kms. with 43 villages in 4 mandals of the district.

1.4.2. COMMUNICATION AND APPROACH

Adilabad, the district headquarters, is located in the study area and can be reached by Adilabad - Mukhed (Maharashtra State) broad gauge railway line in the north. Delhi-Kazipet broad gauge railway line which passes through Sirpur Kagaznagar- Mancherial railway stations, is about 150 km east of study area, connecting Hyderabad-Chandrapur (Maharashtra State). National Highway (NH-7) connecting Bangalore, Nagpur passes through the study area, touching Gudihathnoor Mandal head quarters. Basar (Gnyanasaraswathi temple) is connected by Hyderabad - Manmad broad gauge railway line.

1.5. PHYSIOGRAPHY

The study area is a plateau, with number of ridges and flat-topped hills is called Mesa and Butte, characterised by rugged to undulatory topography interpreted by plains and valleys. The major hill range, known as Sahyadri parvat or Saatnala hill ranges, trends in and East-West directions. The hillocks slope moderately due southwest and steeply due East, which drain out the run-off water forming ephemeral streams. The maximum height of 523 m. is to the North of Palsi-(B) Thanda village and lowest elevation of 358 m. is to the Southwest of Thamsi town. Many other locally elevated features in the area are not uncommon.

The Research studies incorporated in this thesis for creation of permanent Groundwater sources to the peoples of the area is the continuation of fulfillment of their ambitions.

1.6. FLORA AND FAUNA

Major portion of Mathadi vagu basin with luxuriant vegetation is covered under reserve forest, constituting about 47% of total geographical area of study area. Flora of the area has developed to its complete form ranging from small shrubs to tall timber trees. The plant kingdom offers very favourable ecology. the common dry deciduous type flora occurring in the area are Tectongrandis (teak or Sagwan), pterocarpus marsupium (pedda-vegi), Salamalia-malabarcium (Burugu), Acaciasundra (Sandra), Aegle morpnolos (Maredu), Cleistanthus collinus (Kodisa), Cassiaqurculata (Tangedu) and a few other local species such as Jetrogim, Usiri, Sarapappu, Bamboo. Thick forests play important role precipitating good rainfall resulting in abundant ground water resources in an area.

These forests are dwelling place for wild animals such as tigers, leopards, bears, hyenas, nilgiri smabar, spotted deer, wolves, wild boars and wild dogs, along with peafolws, peacocks, jungle fowl, parrot, myna etc.

1.7. SOILS

The Deccan traps and Archaean granites on weathering give black cotton, and red loamy soils respectively. More than 80 per cent of the area is covered by deep to moderate black cotton soils ranging in thickness from 0.5 to 3.0 m. Isolated patches of red and red loamy soils also observed around Thamsi. Besides chemical character, physical properties like texture, water retaining capacity, structure have a lot to do the capacity and ability of the soil to produce crops under irrigated and rainfed with in conditions.

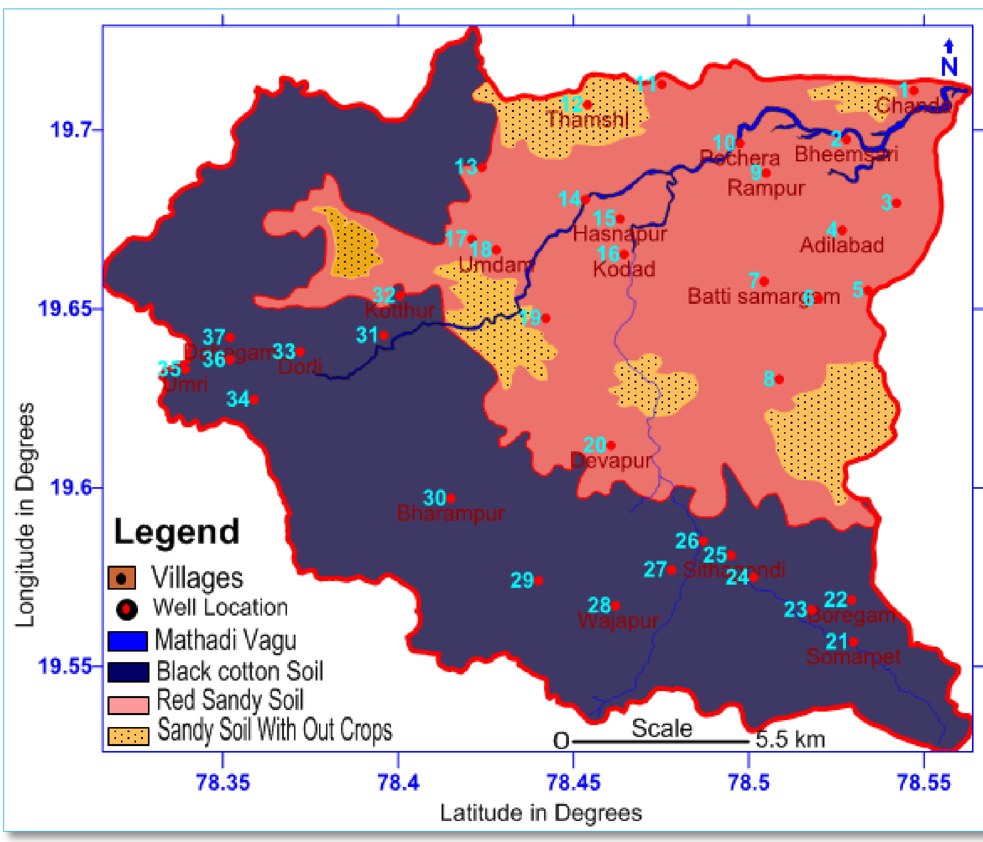


Fig: 1.2 Soil map of Mathadi vagu basin area,

1.7.1. Black cotton soils

Black cotton soils in the area are deep to moderate, with low to moderate permeability, moderate drainage and runoff resulting in low to moderate rate of infiltration and water transmission within the soil. The water holding capacity is high to moderate. Since these soils possess high water holding capacity, moisture is capable of sustaining more dry crops for longer durations and hence are more suited for rain fed crops, (Fig: 1.2).

1.7.2. Red soils

The red earths are medium in colour and coarse to medium in texture with fine loamy and clay sub-soil. The moisture holding capacity of these soils is medium to low, the field capacity varying between 12 to 16%, and low soil moisture. Frequent water use at small intervals is necessary. More suited for commercial irrigated dry crops.

CHAPTER-2

GEOLOGY AND GEOMORPHOLOGY

2. GEOLOGY

2.1 Previous work:

The earliest reference to the geology of the area is by W.King (I881) memoir entitled "the geology of Pranahita-Godavari valley".

The pre-Cambrian sediments between Penganga and Godavari River were named as the Penganga series by Heron (1949). Syed Abdul Kareem (1926) also mapped southwest and southern part of the district comprising Archaean granite and gneisses, infra-trappeans, limestones, sandstones and Deccan traps. P.V.Rao (1952) mapped and gave a brief account of geology. J.P.Dias (1965) and K.Ragunathan (1966), had studied parts of Chanda District (Maharastra state) and Adilabad District (Andhra Pradesh). T. Ajit Kumar Reddy (1974) studied geology of eastern and southeastern parts of Adilabad district.

Because of mineral economics and paleontological importance, the eastern part of the Adilabad district was thoroughly covered by systematic geological mapping by various geologists, whereas the central part, forming the present study area, has covered and the studies are as follows.

2.2 Geology of Adilabad district:

Unlike other districts, Adilabad district comprises major sequence of the rock types as classified in Indian stratigraphy. Considering the geological succession, the district can be called as a Miniature of Stratigraphy of Andhra Pradesh state, which ranges from Archaean granites and gneisses to recent alluvium, on a traverse taken from Adilabad in the northwest to Chennur in the southeast.

The district is underlain by Archaean granite and gneisses in southern part. The northern part is occupied by puranas comprising limetones and shales. Central and western parts are covered by Deccan traps, and the eastern and south eastern part are significantly underlain by gondwana formation.

Geological succession of Adilabad District table is given below, as per the revised stratigraphic nomenclature of Geological Survey of India, (Ramkishan Desai 2006).

Sands and silt	**Alluvium**			**Recent to sub-recent**
Basaltic flows	Deccan trap			Mesozoic to lowerTertiary
Ferruginous sandstone	Chikiala	Upper	Gondwana	Upper Carboniferous to lower Cretaceous
Sandstone and red clay bands	Kota			
Calcareous sandstone and clay	Maleri			
------- Unconformity -------------				
Sandstone with shale and ferruginous material	Kamti	Lower		
Sandstone, clay and coal beds	Barakar			
Boulder bed	Talchir			
--------------- Unconformity ---------------				
Sandstone	Sullavai group	Upper proterozoic		
Sandstone	Penganga group			
Shale and limestone				
------------- Unconformity ---------------				
Granite (pink and gray) and gneisses				Middle Lower to middle proterozoic

2.3 Geology of the Study area:

The study area is mostly covered by crystalline rocks or hard rocks. About 60 percent of study area comprises basaltic lava flow i.e., Deccantraps. The central part comprises Archaean granite and gneisses and a small pocket in northeast is covered by limestone of Penganga series. Geological Map is given in (Figure-2.1)

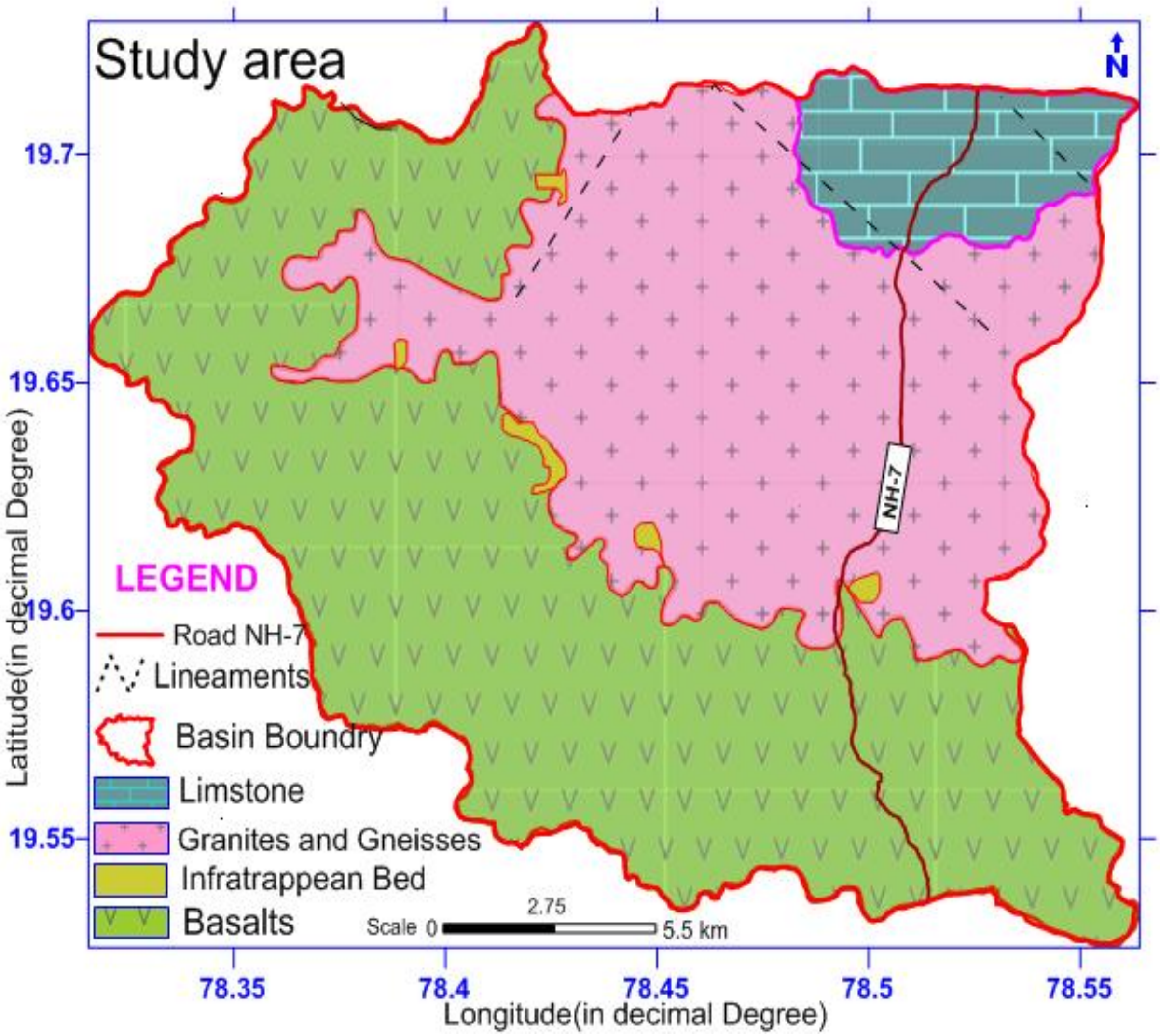


Fig.2.1 Geology map of Mathadi vagu basin

Geological succession, (Ramkishan Desai 2006).

Era	Period	Formation	Lithology
Mesozoic to lower tertiary	Upper cretaceous to Lower	Deccan traps with intertrappeans	Basaltic lava flows
---------------------- Unconformity ----------------------- **INFRATRAPPEANS**			
Palaeo zoic	Upper proterozoic	Pengangas	Pale to dark red lenticular, calcarious clay deposit with sand & silt intercalation
			Limestones, shales and sandstones
---------------------- Unconformity -----------------------------------			
Lower to middle proterozoic	Archaeans	Archaeans	Granite (pink and gray), gneisses, pegmatites, quartz vein and aplites

2.3.1 Penganga limestones:

Penganga formations, the equivalents of Cuddapah system of rocks are the consolidated metasediments. They commonly consist of Chanada limestones associated with shales and sandstones. In the study area only a small patch of limestone is present in the north east, near Chanada one of the mandal head quarters.

These formations are named after the Penganga River, which flows west to east in the northern part of Adilabad district. They are horizontally bedded or gently dipping due east with 12° to 15°. They are gray, buff and purple in colour, thinly bedded with well developed bedding planes giving rise to bedding joints with wide openings. The well developed joint pattern generally gives rise to secondary porosity. The limestones are seen with typical elephant skin weathering. Special features of limestone like elephant skin weathering, bedding joints, caverns, (Photos: 2.1 to 2.7).

2.3.2 Granites and Gneisses:

These Archaean crystallines occupy less than one third of central part of the area. Apart from pink granite, gray granite and gneisses the area is also characterized by the extensive presence of pegmatites and quartz veins and aplites of moderate length and width the granites and gneisses are significantly devoid of dolerite dykes. The granite rocks display two sets of well developed jointing system, giving rise to “tors" consequent to weathering and exfoliation. Out crops of rounded boulders stand amidst the soil cover. Good fracture Indications were observed along the shear zones developing secondary porosity. Graded weathering was seen to the south of Thamsi in Devapur village. (Photo: 2.1). Color of granite depends on color of felspars present. Pink or flesh red colour potash felspars with less mafic minerals give rise to pink granite and gray coloured felspars with more mafic minerals give rise to gray granite.

Pegmatites in granites with light coloured minerals and phenocrysts are common in the area, giving scope for good secondary features. A few quartz veins with limited length and width form small ridges at places. They are highly fractured and crumbled, light pink to white in colour. Granites and gneisses are found around Devapur, Kodad, Hasnapur of Thamsi mandal Battisamargam, Ramnagar of Adilabad mandal and Umdam, Sunkidi villages of Thalamadugu mandal.The granites show viens in granite as seen in Devapur ghat (Photo:2.9).

2.3.3 Infra-trappean Bed:

A pale to dark red, lenticular, calcarious clay deposit with intercalations of sandstones, and silt varying in thickness from fraction of a meter to a few meters is found at the contact of granite and traps (P.Prasad 1977). These formations have been mapped in area of Adilabad district by Syed Abdul Karim (1926 i.e. 1335 Fasli). Intratrappean bed exposed in North of Gudihathnoor mandal and western part of the Thalamadugu mandal.

They are correlated with "Lametas" and 'Bagh Beds" (M.S.Krishnan, 1960). In the study area they are exposed to surface in isolated patches along the granite and traps contact line striking in NW-SE direction. A big patch is exposed to the north of Somarpet covering an area of about 1 sq.km. Other 3 patches exposed between Bharampur and Dahegam villages.

2.3.4 Deccan traps:

As mentioned earlier about 60 percent of the study area is covered by Deccan traps, extending in all three directions except northeast direction. The bulk of Deccan volcanoes are of early tertiary age although the early flows may date back to the late cretaceous period (Pascoe, 1964). The stratigraphy of these basaltic flows has been extensively described by Oldham (1893). B.G.Dhokarikar (1991) called the horizontally disposed blanket sheet like basaltic lava flows as Deccan trap formations. There were numerous lava flows in the geological past each flow ranging in thickness from a meter to about 70 meters (A.Surya Prakash Rao -1975). Mentioned that each individual flow attained a thickness of 90 m. indicated each individual flow as 100 m thick. It is observed that the thickness of each flow is different and depended on the intensity of volcanic activity at different periods.

In the study area the Deccan traps un-conformably lie over Archaeans, pengangas and infra-trappeans. The trap area is characterised by flat topped hills and step like terraces and mesa like structures. Vesicular, non-vesicular, massive, spheroidal weathered column or jointed traps were observed. Highly weathered zeolitic traps with well developed cavities were also coming seen. The lava flows are separated from each other by inter-trappean beds consisting of conglomerates, clays, sandstones and limestones. At places, the red bole band is noticed between two successive flows. The hill ranges of traps exhibit varied trends locally. Between Gudihatnur and Bharampur village they show E-W trend, at Dahegam its trend changes to NW-SE. In SW area once again the trend is W- E. The Deccan traps are unique forming continental basaltic province with more or less uniform chemical composition.

The number of Deccan trap flows were identified by different authors. Vikarabad area of Rangareddy district (A.P.) is supposed to be the type area for Deccan traps with maximum number of flows. Sinha (1976) identified five different flows in Deccan traps, whereas Dutt (1976) classified all together 9 flows in the area.

S.M. Masoom (1989) in his studies in Bhokar and Billoli taluks of the neighboring Nanded district of Maharastra State, had identified 6 flows between 340 and 500 m above msl. Based on geological mapping and results of exploratory-cum-production drilling by the Central Ground Water Board, the author, for the first time, made an attempt at the micro level to identify potential zones in trap of Bharampur area.

2.4. GEOMORPHOLOGY

2.4.1. BASIC CONCEPTS OF GEOMORPHOLOGY:

Geomorphology means a "discourse of earth landforms" and it generally defined as a Science of Landforms". It is a systematic study of landforms in relation to the climatological, geological and structural aspects. Study of geomorphology is of particular importance to aerial photo-interpretation as it forms major criteria in deciphering lithology and structure.

The ten fundamental concepts are:

1) The same physical processes and law that are being operated throughout the geological time, although not necessarily with the same intensity as at present.

2) Geological structure is dominant controlling factor in the evolution of landforms and is reflected in them. This is the most important concept and has a direct bearing on the formation of a landform. It is an accepted principle that the geological structures of rocks are much older than the geomorphic forms developed.

3) The earth's surface possesses relief to a large extent because the geomorphic processes operate at differential rates. Though, the relief of the earth's surface may primarily be due to variation in lithology and structure, the influence of variation in temperature, moisuture, altitude, exposure, topographic configuration and vegetal cover are quite notable. This concept of differential weathering has been made use of, in developing the quantitative approach to geomorphic problems.

4) Geomorphic processes leave their distinctive imprint upon landforms and each geomorphic process develops its own characteristic assemblage of landforms and involves many physical and chemical changes due to which, the earth's surface undergoes changes. An outline of geomorphic processes and their various agents which shape earth's surface is given below, Ramkishan Desai (2006).

EXOGENIC PROCESSES	**AGENTS**
➢ Weathering	Mechanical & Chemical
➢ Massive Wasting or Gravitative Transfer	
➢ EROSIO (including Transportation)by	
• Running Water	Rivers *I* Fluvial
• Ground Water	
• Waves, currents, Tides, TSUNAMI	Coastal Features
• Wind	
• Glaciers	
➢ Work of organisms and Vegetation	
➢ Endogenic process	
➢ Diastrophism	
➢ Volcanism	
➢ Extraterrestrial processes	
➢ Meteorites etc	

5) The geomorphic process and their various agents give rise to characteristic land forms. However, shape of land form is also affected by climate. The complex of geomorphic processes and their agents which act under a particular set of climatic conditions have been termed as 'morphogenetic system". A landscape is usually a result of changing morphogenetic systems associated with changing climates through geological times, Ramkishan Desai (2006).

6) As the erosional agents act upon the earth's surface an orderly sequence of landforms is produced. The erosional agents such as running water, groundwater, waves, currents, wind

and glaciers acting on the earth's surface under a particular morphogenetic system over a period produce an orderly sequence of landforms. This principle has given rise to the concept of geomorphic cycle wherein the three stages of youth, maturity and old age are recognizable.

7) Complexity of geomorphic evolution is more common than simplicity. The earth's surface is not developed by a single geomorphic process or one geomorphic cycle of development. Though most of the present landforms are products of current cycle of erosion, the remanant of previous cycles are always present. Depending on the complexity of the development of landscape the classification of is in vouge. The list of completely developed landscapes would not be complete unless we add another concept, that of "Polyclimatic Landscape". The cyclic changes in climate during pleistocene period with repetitive periods of glaciation have left their marks on the land forms.

8) Little of earth's topography is older than Tertiary and most of it is not older than Pleistocene. It has been estimated that at least 90% of land surface has been developed in post Tertiary time and perhaps 99% is of post middle Miocene in age.

9) Proper interpretation of present day landscape is impossible without a full appreciation of the manifold influences of the geological and climatic changes during the Pleistocene.

10) An appreciation of world climate is necessary for a proper understanding of the varying importance of different geomorphic process.

2.5. GEOMORPHIC CONDITIONS OF THE AREA:

The geomorphological map of the areas has been prepared by using SURFER software, of 2cm = 1 km (Figure-2.2).

2.5.1. Phases in the interpretation:

Four phases are adopted while interpreting the Satellite data.

First Phase: Detection of features observable in the imagery mainly on its size, tone, texture, association in relation to the spatial resolution of the recording system and on its reflection and emission characteristics in the wave length bands used.

Second Phase: Observed features are identified and classified in known categories with basic knowledge and reference of the study area.

Third Phase: Analysis of the pattern formed by observable features and delineation of the boundaries.

Fourth Phase: Limited field check for induction and deduction of certain boundaries and areas. Ground checks integrated with hydrogeological and geophysical surveys were taken up to study the interaction of geomorphological units, tectonics and structure of the area and their recharge conditions for demarcation of groundwater potential areas and identification of feasible sites for groundwater development.

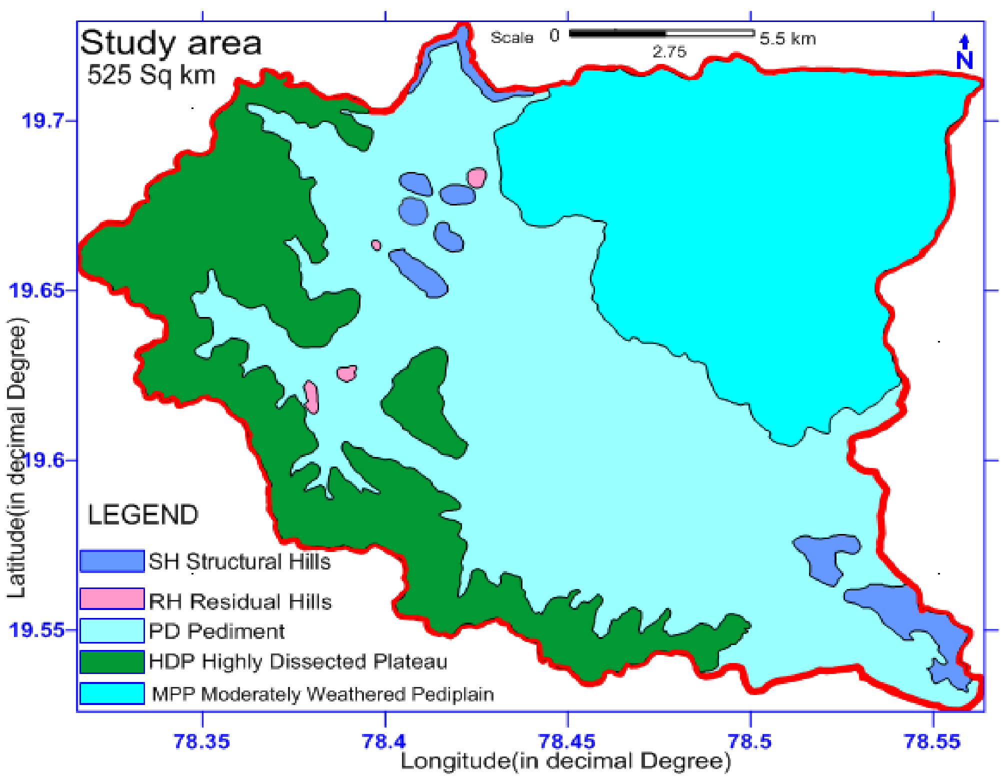


Fig: 2.2 Geomorphological map of Mathadi vagu basin

2.6. GEOMORPHIC UNITS

Five geomorphic units were demarcated viz.

1) Highly dissected plateau

2) Moderately weathered pediplain
3) Pediment
4) Residual Hills
5) Structural Hills.

Apart from these, all the major lineaments are also demarcated.
The uni- wise description is as follows:

2.6.1. Highly Dissected Plateau (HDP):

About 20 percent of the study area forms Highly Dissected Plateau, flat to gently sloping with basalt flow of 10 - 20m thickness followed by intertrapean clay bed. This clay / gray earth beds mark the contacts between the flows. Each individual flow is hard and massive at bottom and grading in to vesicular or tuffaceous at top. Scarp, hills and uplands dissected by deep and narrow valleys occupied by different flows of Deccan trap.

Weathered zones along narrow valleys with Limited potential are suitable for dug wells. Moderate to good potential zones located especially along the fractures and in the Vesicular/tuffaceous zones if any in this underlying trap flows are suitable for deep borewells Ramkishan Desai (2006).

2.6.2. Moderately Weathered Pediplain (MWP):

About 30 percent of the area forms Moderately Weathered Pediplain with moderate to steeply dipping, hard and compact limestones and shales, with fractures at places. Deep weathering, exhibits limited potential for ground water in the weathered zones. Moderate potential along fractures suitable for bore wells Ramkishan Desai (2006).

2.6.3. Pediment:

About 35 percent of study area is covered by pediment. The area is underlain by foliated gneiss and massive granite with joints / fractures rock cut surface. The weathered zone forms aquifer of limited potential and moderate potential along fractures suitable for bore wells.

2.6.4. Residual Hills (RH):

Isolated hill composed foliated gneiss with massive granite with joints and fractures occurring in the study area, forms about 3% of the total area. This is generally not suitable for groundwater exploitation due to high relief, resulting in less weathering and swift run off, poor infiltration etc.

2.6.5. Structural Hills (SH):

An area of about 12 percent is occupied by structural hills in SE part of the study area. Highly foliated, sheared, fractured group of massive hills with limited prospects of ground water in the weathered zone along valleys in granitic area.

2.7. INTERPRETATION OF LINEAMENTS:

The most successful use of remote sensing for the study of regional aquifers has resulted in mapping of 4 major lineaments in the study area. Exploration carried out along lineaments in less permeable Deccan traps and granites have revealed existence of deep weathered and fractured aquifers.

Deep weathering, graded weathering and fracturing is also observed during the ground surveys along lineaments. Lineaments concentrated areas are targeted for geophysical surveys to prove the potentiality of lineament zones.

2.8. SOIL MAP:

Soil Map prepared by National Bureau of soil survey and land use planning (ICAR) on 1: 2,50,000 scale were obtained.

The soil map of traditional soil classification (Fig-1.2) shows, irrespective of geological formation of limestone, granite and Deccan trap, the area is covered by black soils of shallow thickness locally known as black cotton soils. A small patch to the extreme north is covered by deep thick black soil, where the county rock is limestone and to the southwest rocky lands are also shown (Fig-2.2).

Photo 2.1: Contact between Granites and Deccantraps at Sithagondi

Photo 2.2: Bedded Limestones at Bheemsary

Photo 2.3: Purple Limestone at Rampur

Photo 2.4: Elephant skin weathering in Limestone, Near Adilabad

Photo 2.5: Limestone Bedding Planes, a Cross Section at Rampur

Photo 2.6: Cavernous Limestone at Bheemsary

Photo 2.7: Siliceous Limestone at Bheemsary

Photo 2.8: A View of Granite exposed at South of Sithagondi

Photo 2.9: Veins in Granites i.e. south of Devapur

Photo 2.10: Deccantrap Exposures in Somarpet

Photo 2.11: A View of the Mathadi Vagu Project constructed on Mathadi Vagu

Photo 2.12: Deccantrap, a 'Mesa' near Mathadi Vagu Project

Photo 2.13: Deccantrap, a 'Butte' near Mathadi Vagu Project

Photo 2.14: Fertile Land in Deccantrap

Photo 2.15: Deccantrap, a 'Butte' near Thamsi

Photo 2.16: Massive grey granite rock in stream bed near Devapur

Photo 2.17: Deccantrap, a 'Mesa' near Thamsi

CHAPTER-3

HYDROGEOLOGY

3.1 HYDROGEOLOGY

This Chapter deals in detail with the hydrogeology, groundwater occurrence, well inventory, and future scope of groundwater development in the study area. The area under study has three stratigraphic units. About 40% of the area is underlain by granites and granite gneisses of Archaean age, covering major portion of Adilabad, Thamsi and parts of Thalamadugu modals.

Limestones occur in the eastern most part of the study area, covering parts of Chanda, Bheemsari and Pochera villages in Adilabad mandal, constituting about 10% of the study area.

Deccan traps and Infratrappeans of Mesozoic to Proterozoic era cover about 50% of the geographic area. The entire Gudihathnoor mandal and , parts of Thalamadugu, Thamsi Mandals, Gudihatnoor, Thalamadugu and Thamsi mandals underlain by these basaltic flows.The basatlic flows are vescicular to massive, exhibiting Spheroidal weathering. They are completely massive and devoid of any weathering and fracturing.

The Reconnoitory surveys were condcuted from time to time by Central Ground Water Board and State Ground Water Department for different purposes. Very few geologists have done extensive work on different aspects of geology in the area.

Over the years, the State Groundwater Department has been engaged in the area in various groundwater resources developmental activities such as systematic hydrogeological mapping, well inventory, hydrological and geophysical studies followed by Exploratorium-production drilling and also water resource management, (Ramkishan Desai, 20060)

Rainfall is the main source of recharge to groundwater. Major part of the study area being hilly, very little recharge takes place on account of surface run-off.

The geological units like granite and Deccan trap have undergone weathering from 2 to 12m depth. The weathered zone and the secondary porosity facilitate groundwater recharge at some places.

The fractures developed due to structural disturbances in granite and trap and the vesicular nature of the basaltic flows at various depths form potential aquifers in the study area. The solution cavities and other karst features in limestones also constitute potential aquifers.

3.2. WELL INVENTORY

A total of 18 dug wells and 107 bore wells were inventoried in the three formations in the basin, i.e., Limestone, Granite and gneisses and Deccan Traps and the data is given in Table3.1.

The objective was to obtain a clear view of the geological formations, lithological sections, the depth to water levels and their fluctuations during post monsoon and pre - monsoon seasons, productivity levels of the wells vis-a-vis the geological formations and topography, the type of wells predominant in certain areas, the cropping pattern and the extent of acreage under the wells. Pumping discharge rates were also measured, (Photo: 3.1). Water from two types of wells, i.e., dug wells and bore wells is extracted in the study area. The well inventory data collected from 125 wells from tree terrains is given in Table 3.1.

3.2.1. DUG WELLS

Specific groundwater conditions and hydrogeoloigcal aspects can be studied and analysed with the available data of wells being utilised for drinking water, irrigation, industry and protected water supply. The study of total depth, water level, well dimensions, topography, geology, mode of lift, cropping pattern, area irrigated during Kharif and Rabi period helps to understand very clearly the hydrogeological and hydrological features of the area under investigation for future planning of groundwater development.

Well inventory data from 18 dug wells in the study area is collected, analysis of well inventory data indicates that the general range of total depth is 3.6 to 19m. and depth to water level is 1.6 to 12.4. Below ground level with a seasonal fluctuation of 2 to 8m. Almost all the wells inventoried are circular in shape, with domestic dug wells having 1 to 2 m. and irrigation dug wells having 6 to 8m. diameter. Area under cultivation ranges between 0.5 to 1.5 Ha. With 4 to 8 hours of pumping. Crops grown are Cotton, Turmeric, Paddy, Maize and Vegetables.

3.2.2. BORE WELLS

Exploitation of groundwater through bore wells is limited in the area under study. The details of bore well inventory are given in Table 3.1.

a) The 107 bore wells inventoried in the study area fall in the following depth categories.
Well inventory data from 107 bore wells is collected and given in Table 3.1. Depth range and number of bore wells is given here under.

Table: 3.1 Well inventory data collected in different terrains

3.1.A. Limestone terrain in Mathadi vagu basin

S. No	Name Of The Beneficiary	Village/Mandal	Well Type	Total Depth (m)	Dtw (m) December,2011	Dtw (m) June, 2012	Dimensions	Mode Of Lift	Geology
1	2	3	4	5	6	7	8	9	10
1	T Vijay Kumar	Chanda/Adilabad	Bw	40	7.2	16.01	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
2	M Sathanarayana	Chanda/Adilabad	Bw	40	7	15.08	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
3	S Ravinder	Chanda/Adilabad	Bw	40	7.3	15.9	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
4	Markendaya Temple	Bheemsary/Adilabad	Bw	40	8.01	14.4	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
5	Bus Stand	Bheemsary/Adilabad	Bw	33	8.9	14.2	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
6	B Narasaiah	Bheemsary/Adilabad	Bw	40	8.4	14.3	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
7	Bus Stand	Rampur/Adilabad	Bw	40	12	13.4	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
8	L Pochenna	Rampur/Adilabad	Bw	33	9.1	11.1	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
9	M Raju	Rampur/Adilabad	Bw	35	12.3	13.9	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
10	N Satyanarayana	Rampur/Adilabad	Bw	40	12.66	13.9	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
11	G Vinay Kumar	Rampur/Adilabad	Bw	40	12.5	13.7	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
12	Hanuman Temple	Bandal Nagapur/Adilabad	Bw	60	10.5	12.85	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
13	Bus Stand	Pochera /Adilabad	Bw	40	11.06	5.7	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
14	R Ramarao	Pochera/Adilabad	Bw	35	11.2	5.4	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
15	N Suman	Pochera/Adilabad	Bw	40	11.8	5.7	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone
16	P Surender	Pochera/Adilabad	Bw	40	11.4	5.1	6 $^{1/2}$ dia	Submersible 1 Hp	Limestone

Contd…,

3.1.B. Granitic Terrain

Sl No	Name Of The Beneficiary	Village/Mandal	Well Type	Total Depth(m)	Dtw (m) December,2011	Dtw (m) June, 2012	Dimensions	Mode Of Lift	Geology
1	2	3	4	5	6	7	8	9	10
1	Gandi Nagar	Gandi Nagar / Adilabad	Bw	50	8.6	14.25	6 1/2 dia	Submersible 1 Hp	Granites
2	Collector Office	Collector Office / Adilabad	Bw	45	8.7	14.56	6 1/2 dia	Submersible 1 Hp	Granites
3	Ravinder Nager	Hanuman Temple / Adilabad	Bw	50	8	14.71	6 1/2 dia	Submersible 1 Hp	Granites
4	Thantholi Road	Thantholi Road / Adilabad	Bw	50	8.25	13.2	6 1/2 dia	Submersible 1 Hp	Granites
5	Icecrime Factory	Thantholi Road / Adilabad	Bw	60	8.01	13.05	6 1/2 dia	Submersible 1 Hp	Granites
6	Aprtw School	Aprtw School, Boys / Adilabad	Bw	45	8.2	13.78	6 1/2 dia	Submersible 1 Hp	Granites
7	Adilabad Park	Adilabad Park / Adilabad	Bw	50	8.53	14.2	6 1/2 dia	Hand pump	Granites
8	M Narsimha	Ramnagar / Adilabad	Bw	35	8.26	14.803	6 1/2 dia	Submersible 1 Hp	Granites
9	Ramnagar	Ramnagar / Adilabad	Bw	50	8.16	14.45	6 1/2 dia	Submersible 1 Hp	Granites
10	Cci Adilabad	Cci / Adilabad	Bw	45	8.71	14.56	6 1/2 dia	Hand pump	Granites
11	Railway Station	Railway Station / Adilabad	Bw	40	7.85	14.5	6 1/2 dia	Submersible 1 Hp	Granites
12	Bus Stand	Bus Stand / Adilabad	Bw	50	7.95	12.85	6 1/2 dia	Submersible 1 Hp	Granites
13	Narsimlu	Dubbaguda / Adilabad	Bw	40	7.65	12.9	6 1/2 dia	Submersible 1 Hp	Granites
14	Bati Samargam	Bati Samargam / Adilabad	Bw	40	7.2	10.5	6 1/2 dia	Hand pump	Granites
15	Bus Stand	Dubbaguda / Adilabad	Bw	45	7.45	10.45	6 1/2 dia	Submersible 1 Hp	Granites
16	Nalanda College	Adilabad	Bw	50	7.48	10.23	6 1/2 dia	Submersible 1 Hp	Granites
17	Govt Degree college	Adilabad	Bw	50	7.45	10.56	6 1/2 dia	Submersible 1 Hp	Granites
18	Pippalkoti Busstand	Pippalkoti / Thamsi	Bw	40	11.5	7.75	6 1/2 dia	Submersible 1 Hp	Granites
19	M Rajanna	Pippalkoti / Thamsi	Bw	35	11.4	7.75	6 1/2 dia	Submersible 1 Hp	Granites
20	Bus Stand	Jamri / Thamsi	Bw	45	4.5	6.5	6 1/2 dia	Hand pump	Granites
21	Mini Water Tank	Thamsi / Thamsi	Bw	40	1.8	3.3	6 1/2 dia	Submersible 1 Hp	Granites
22	Bus Stand	Thamsi / Thamsi	Bw	40	1.6	3.5	6 1/2 dia	Submersible 1 Hp	Granites
23	M Ramarao	Thamsi / Thamsi	Bw	40	1.7	3.4	6 1/2 dia	Submersible 1 Hp	Granites
24	Hanuman Teple	Thamsi / Thamsi	Bw	40	1.6	3.2	6 1/2 dia	Hand pump	Granites

Contd…,

Sl No	Name Of The Beneficiary	Village/Mandal	Well Type	Total Depth(m)	Dtw (m) December,2011	Dtw (m) June, 2012	Dimensions	Mode Of Lift	Geology
25	K Narayana	Kapparla / Thamsi	Bw	45	2.5	12.25	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
26	M Gangu	Kapparla / Thamsi	Bw	50	2.6	12.3	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
27	Bus Stand	Hasnapur / Thamsi	Bw	33	2.5	4.9	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
28	Bus Stand	Kodijam / Thamsi	Bw	40	2.8	5.5	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
29	Hanman Temple	Ponnari / Thamsi	Bw	40	2.9	5.3	6 $^{1/2}$ dia	Hand pump	Granites
30	Primary School	Ponnari / Thamsi	Bw	40	2.9	5.2	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
31	Bus Stand	Kajjarla / Thalamadugu	Bw	40	2.6	6.5	6 $^{1/2}$ dia	Hand pump	Granites
32	Primary School	Kajjarla / Thalamadugu	Bw	40	2.5	6.6	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
33	Bus Stand	Kodad / Thalamadugu	Bw	35	9.35	11.9	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
34	R Nagaraju	Kodad / Thalamadugu	Bw	40	9.45	12.3	6 $^{1/2}$ dia	Hand pump	Granites
35	Hanuman Temple	Kodad / Thalamadugu	Bw	40	9.55	12.4	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
36	G Ramaiah	Sunkidi / Thalamadugu	Dw	10, No Lining	4.3	6.65	2.2(m)	Rope And Bucket	Granites
37	Bus Stand	Sunkidi / Thalamadugu	Bw	40	4.25	6.6	6 $^{1/2}$ dia	Hand pump	Granites
38	M Rajanna	Sunkidi / Thalamadugu	Bw	35	4.56	6.53	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
39	R Muthyam	Sunkidi / Thalamadugu	Bw	33	4.59	6.58	6 $^{1/2}$ dia	Hand pump	Granites
40	Hanuman Temple	Umdam / Thalamadugu	Bw	40	3.75	6.8	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
41	Opposite Hotel	Umdam / Thalamadugu	Bw	33	3.6	6.5	6 $^{1/2}$ dia	Submersible 1 Hp	Granites
42	Bus stand	Umdam / Thalamadugu	Bw	40	3.65	6.7	6 $^{1/2}$ dia	Hand pump	Granites
43	Abdul Aziz	Devapur / Thalamadugu	Dw	12, Lined Up To 2m	4.1	7.85	2.2(m)	Rope And Bucket	Granites
44	Water Tank	Devapur / Thalamadugu	Dw	15, Lined Upto 3	4.5	7.3	4(m)	Electric Motor 1 Hp	Granites
45	Hanuman Temple	Devapur / Thalamadugu	Dw	15, Cement Rings Upto Bottom	4.6	7.1	2.5(m)	Rope And Bucket	Granites

Contd…,

3.1.C. Basaltic terrain

Sl No	Name Of The Beneficiary	Village/Mandal	Well Type	Total Depth(m)	Dtw (m) December,2011	Dtw (m) June, 2012	Dimensions	Mode Of Lift	Geology
1	Bus Stand	Somarpet / Gudihathnoor	Dw	19	6.4 Lined Up To 10	12.4	6 1/2 dia	Rope And Bucket	Traps
2	Hanuman Temple	Somarpet / Gudihathnoor	Bw	40	4.5	4.7	6 1/2 dia	Submersible 1 Hp	Traps
3	G Suryabhanu	Boregam / Adilabad	Bw	35	6	7.8	6 1/2 dia	Submersible 1 Hp	Traps
4	Thirupathi	Boregam / Adilabad	Bw	40	6.1	7.9	6 1/2 dia	Submersible 1 Hp	Traps
5	P.Dev Rao	Garkampet / Gudihathnoor	Dw	15	4.65 Lined Up To 12	7.3	2(m)	Rope And Bucket	Traps
6	P.Dev Rao	Garkampet / Gudihathnoor	Dw	12	4.58 Lined Up To 12	7.4	2(m)	Submersible 1 Hp	Traps
7	Shek Masud	Sithagondi / Gudihathnoor	Bw	40	1.6	7.2	6 1/2 dia	Submersible 1 Hp	Traps
8	T Ramnarayana	Sithagondi / Gudihathnoor	Dw	10	5.2lined Up To 5	6.8	4.9(m)	Hand pump	Traps
9	G Narayana	Sithagondi / Gudihathnoor	Dw	12	5.4 Lined Up To 3	6.5	4.9(m)	Submersible 1 Hp	Traps
10	M Narayana	Sithagondi / Gudihathnoor	Bw	35	5.2	7.3	6 1/2 dia	Submersible 1 Hp	Traps
11	M Kabeer	Sithagondi / Gudihathnoor	Bw	40	5.15	7.2	6 1/2 dia	Submersible 1 Hp	Traps
12	Jeedipally	Jeedipally / Gudihathnoor	Bw	40	5.85	7.65	6 1/2 dia	Submersible 1 Hp	Traps
13	K Vittal	Kamlapur / Gudihathnoor	Dw	15	3.95 Lined Up To 5	7.3	2.5(m)	Submersible 1 Hp	Traps
14	R Ramesh	Kamlapur / Gudihathnoor	Bw	33	4.1	7.35	6 1/2 dia	Submersible 1 Hp	Traps
15	K Kishan	Kamlapur / Gudihathnoor	Dw	15	4.6 Lined Up To 3	9.6	2.5(m)	Submersible 1 Hp	Traps
16	Primary Shool	Kamlapur / Gudihathnoor	Bw	40	4	7.33	6 1/2 dia	Submersible 1 Hp	Traps
17	Hanuman Temple	Kamlapur / Gudihathnoor	Bw	40	4.1	7.45	6 1/2 dia	Hand pump	Traps
18	M Ramu	Laxmipur / Gudihathnoor	Bw	35	5.3	8.9	6 1/2 dia	Submersible 1 Hp	Traps
19	M Hanmanthu	Gidipally / Gudihathnoor	Bw	40	5.4	8.75	6 1/2 dia	Submersible 1 Hp	Traps
20	Hanman Temple	Vijapur / Gudihathnoor	Bw	40	5.6	8.85	6 1/2 dia	Submersible 1 Hp	Traps
21	K.Rajanna	Waghapur / Adilabad	Bw	33	5.8	10.65	6 1/2 dia	Submersible 1 Hp	Traps
22	Primary School	Waghapur / Adilabad	Bw	40	5.6	10.55	6 1/2 dia	Submersible 1 Hp	Traps
23	Hanuman Temple	Waghapur / Adilabad	Bw	50	5.45	10.5	6 1/2 dia	Submersible 1 Hp	Traps
24	Tadka Ganganna	Peddapally / Thalamadugu	Bw	45	4.95	8.75	6 1/2 dia	Hand pump	Traps
25	Tadka Rajanna	Peddapally / Thalamadugu	Bw	40	4.8	8.68	6 1/2 dia	Submersible 1 Hp	Traps
26	R Muthyalu	Peddapally/ Thalamadugu	Bw	33	4.9	8.91	6 1/2 dia	Submersible 1 Hp	Traps

Contd…,

Sl No	Name Of The Beneficiary	Village/Mandal	Well Type	Total Depth(m)	Dtw (m) December,2011	Dtw (m) June, 2012	Dimensions	Mode Of Lift	Geology
27	Near Bus Stand	Bharampur/ Thalamadugu	Bw	60	9.2	15.6	6 1/2 dia	Submersible 1 Hp	Traps
28	Near Bus Stand	Bharampur/ Thalamadugu	Bw	50	9.1	15.5	6 1/2 dia	Submersible 1 Hp	Traps
29	Near Bus Stand	Bharampur/ Thalamadugu	Bw	60	9.3	15.7	6 1/2 dia	Hand pump	Traps
30	Cherlapally	Cherlapally/ Thalamadugu	Bw	60	9.75	15.68	6 1/2 dia	Submersible 1 Hp	Traps
31	P Deepak	P Deepak,Jari/ Thalamadugu	Dw	15	9.5	10.8	2.5(m)	Submersible 1 Hp	Traps
32	Bus Stand	Bus Stand, Jari / Thalamadugu	Bw	65	9.85	16.25	6 1/2 dia	Submersible 1 Hp	Traps
33	Kottagudem	Kottagudem / Thalamadugu	Bw	65	10.2	16.95	6 1/2 dia	Submersible 1 Hp	Traps
34	Mandaguda	Mandaguda/ Thalamadugu	Bw	70	10.5	17.3	6 1/2 dia	Submersible 1 Hp	Traps
35	Durgapally	Durgapally/ Thalamadugu	Bw	70	10.56	17.56	6 1/2 dia	Submersible 1 Hp	Traps
36	Rathnapur	Rathnapur / Thalamadugu	Bw	70	10.85	15.88	6 1/2 dia	Hand pump	Traps
37	Sukanpur	Sukanpur / Thalamadugu	Bw	50	9.85	10.5	6 1/2 dia	Rope And Bucket	Traps
38	Raowdri	Raowdri / Thalamadugu	Bw	40	6.5	9.85	6 1/2 dia	Hand pump	Traps
39	N Naresh	Madnapur/ Thalamadugu	Bw	60	10.25	16.56	6 1/2 dia	Submersible 1 Hp	Traps
40	M Muthyalu	Sukanputr / Thalamadugu	Bw	45	10.3	16.88	6 1/2 dia	Submersible 1 Hp	Traps
41	Muthyalamma Vada	Thalamadugu	Bw	50	5.5	11.8	6 1/2 dia	Submersible 1 Hp	Traps
42	Hanman Temple	Thalamadugu	Bw	45	5.4	11.9	6 1/2 dia	Hand pump	Traps
43	M Rajesh	Thalamadugu	Bw	45	5.6	11.75	6 1/2 dia	Submersible 1 Hp	Traps
44	MRO Office	Thalamadugu	Bw	50	5.3	11.8	6 1/2 dia	Electric Motor 2 Hp	Traps
45	Linga Reddy	Kottur / Thalamadugu	Bw	33	6.75	12.2	6 1/2 dia	Electric Motor 1 Hp	Traps
46	E Thirupathi	Kothur / Thalamadugu	Bw	45	7.2	11.3	6 1/2 dia	Electric Motor 2 Hp	Traps
47	J Raju	Kothur / Thalamadugu	Bw	40	7.6	11.5	6 1/2 dia	Submersible 1 Hp	Traps
48	M Naveen	Kothur / Thalamadugu	Bw	33	7.7	11.4	6 1/2 dia	Electric Motor 2 Hp	Traps
49	M Naveen	Kottur / Thalamadugu	Bw	40	7.8	11.56	6 1/2 dia	Electric Motor 1 Hp	Traps
50	Near Hanman Temple	Dorli / Thalamadugu	Bw	50	9.45	7.5	6 1/2 dia	Hand pump	Traps
51	Ashanna	Dorly / Thalamadugu	Bw	33	9.55	11.3	6 1/2 dia	Submersible 1 Hp	Traps
52	Primary Shool	Dorli / Thalamadugu	Bw	50	9.4	7.8	6 1/2 dia	Electric Motor 2 Hp	Traps

Contd…,

Sl No	Name Of The Beneficiary	Village/Mondal	Well Type	Total Depth(m)	Dtw (m) December,2011	Dtw (m) June, 2012	Dimensions	Mode Of Lift	Geology
53	Bus Stand	Dorly / Thalamadugu	Bw	45	9.86	7.68	6 $^{1/2}$ dia	Electric Motor 1 Hp	Traps
54	K Triembak Rao	Kppar Devi / Thalamadugu	Dw	15	8.15	9.2	2.3 (m)	Rope And Bucket	Traps
55	K Dattu	Kppar Devi / Thalamadugu	Bw	40	8.2	9.25	6 $^{1/2}$ dia	Submersible 1 Hp	Traps
56	Bus Stop	Indra Nagar / Thalamadugu	Dw	15	4.45 Cement Rings Upto Bottom	4.8	4.9(m)	Electric Motor 2 Hp	Traps
57	Temple	Indranagar / Thalamadugu	Bw	15	4.25 Cement Rings Upto Bottom	4.86	6 $^{1/2}$ dia	Hand pump	Traps
58	Hanman Temple	Umri(T) / Thalamadugu	Dw	15	8.3 Lined Up To 6	9.1	2.9(m)	Rope And Bucket	Traps
59	Hanuman Temple	Kosai / Thalamadugu	Bw	50	8.85	9.85	6 $^{1/2}$ dia	Submersible 1 Hp	Traps
60	Durwa Ashok	Dahegam / Thalamadugu	Dw	15	7 Lined Upto 5	7.1	2.5(m)	Rope And Bucket	Traps
61	K Bheem Rao	Dahegam / Thalamadugu	Dw	15	6.9 Lined 5	7.2	2.5(m)	Rope And Bucket	Traps
62	M .Nagu	Dahegam / Thalamadugu	Dw	15	6.7 Lined 5	7.5	2.5(m)	Rope And Bucket	Traps
63	Bus Stand	Lingi / Thalamadugu	Bw	40	9.56	11.2	6 $^{1/2}$ dia	Hand pump	Traps
64	Bus Stand	Kuchlapur / Thalamadugu	Bw	45	9.5	11.5	6 $^{1/2}$ dia	Electric Motor 2 Hp	Traps

Range of depth to water level and number of bore wells is given here under.

i)	<5.0m. bgl	9 bores
ii)	5.0-10.0m. bgl	50 bores
iii)	10.0-15.0m.bgl	42 bores
iv)	15.0-20.0m.bgl	6 bores

Analysis of bore well depths and depth to water levels clearly indicates that there is no extraction of water from the deeper aquifers as manifested by the very shallow water level of less than 10m. in 91% of the bores .Due to various constraints and lack of infrastructural facilities such as power line, technicious repair submersible pumps, ignorances of the farmers to put to optimum use, the utilisation of groundwater from deeper aquifers has not reached the levels desired.

3.3. GROUNDWATER CONDITIONS

3.3.1. Structural Controls

Groundwater occurs under phreatic or water table conditions in the weathered zone and under semi-confined conditions in the fractured zones in the study area. The areas generally potential for groundwater exploitation are located in the topographic lows and along lineaments developed due to structural controls like faults, folds and along fissure zones foliations and liniations.

3.3.2. Lithological units

(a) Granite

In granitic terrain groundwater mainly in weathered zone in low lying areas under water table conditions with moderate to good yields. The area between Thamsi, Hasnapur and kodad has undergone weathering in continuous stretches ranging in depth from 6 to 12 m. The area is covered by coarse grained, weathered pink granite with grey granite boulders at places, and certain areas are seen with the progressive. (Photo: 2.8).

Occurrence of groundwater in fractured granite is controlled by the presence of joints, lineaments and hydrological gradient. Such zones are encountered in very limited areas. It was observed during the study that, coarse grained pink granites are more susceptible for weathering and facilate recharge to groundwater resulting in considerably high yields, of the productive irrigation dug wells and bore wells.

(b) Deccan Traps

Groundwater occurs under water table conditions in traps in the weathered zone ranging from 2 to 10m. in the top layer. Due to limited weathered zones thickness, groundwater saturation is very limited. These pockests exist in isolated topographic low lying patches. On the other hand, extensive and continuous extents of massive traps are exposed at surface, resulting in poor groundwater recharge in these high rainfall (> 1000 mm per annum) areas. Therefore it is common to observe patches of 10 to 50 Sq.Km. not potential for large scale groundwater development for irrigation purpose. Such terrains are seen in the entire Thamsi mandal. Such an extensive patch of massive trap near Waijapur and Waghapur (V) is shown in Photos: 2.12 to 2.15. Deccan trap a 'mesa' step-like topped basaltic land form near Mathadi vagu project photos: 2.12, 2.13, and 2.14 and 2.17. Deccan trap a 'butte' small step-like topped basaltic land form near Mathadi vagu project, photos: 2.13 and 2.15. Two to five lava flows of different geological periods are encountered in this area. In most of the places the lava flows are alternatively massive and vesicular in nature with varying thickness. Vesicular basalt with abundant vesicules interconnected or filled with secondary Zeolites, Quartz, Calcite retain groundwater, offering very productive aquifers and such areas are highly suitable for drilling of medium to deep bore wells.

The secondary structural features such as joints, fissures and shear zones in Deccan traps are limited in their density, extent and depth as traps are harder and resistant. Alternate lava flows are separated by 1 to 3m. thick sedimentary beds comprising conglomerates, limestone and sand stones termed as intertrappeans. The intertrappeans at the depth of 20 m. give rise to semi-confined aquifers, but less productive than infratrappeans.

The basaltic flows, generally being horizontally disposed, are not subjected to much of tectonic activity and hence are poor aquifers. The Red bole, being clayey in nature occurring as a contact zone between trap and granite, hinders any vertical flow of groundwater due to its very fine grained and sticky nature.

(c) Limestones

A small patch in extreme eastern part of the study area comprises lime stone formation, from the Chanda to Rampur village in the study area weathering in limestone extends to a depth of 3 to 5m followed by cavernous lime stone. Penganga limestone formation with thin bedded shale intercalations are characterised by extensive and numerous secondary structural features by well developed interconnected solution channels giving rise to cavernous lime stones. Massive lime stone has undergone typical elephant skin weathering, at the surface Photo 2.4, exhibits elephant skin weathering in limestones of Rampur village. Tectonic activity in the geological past in the area caused structural deformation resulting in anticlines and synclines and series of step faults, leaving the limestone with dense and numerous secondary structures such as sheared bedding planes and voids at the nose of anticline which form potential aquifers Photo2.2. And some defferent types of limestones are present in the area are purple limestones, and silicious limestones, (photos: 2.3 and 2.7).

3.4. OBSERVATION BORE WELLS

Monitoring of groundwater table (Phreatic) conditions for a period of 1 year from 18 dug wells in all the three geological formation gives in the Mathadi vagu basin general idea of the recent past with limited aquifer condition.

Micro level drainage pattern, geological features with special attention on primary and secondary structural control helps in understanding the area properly and very clearly for the future plan of action for groundwater development, management and conservation programme. In the present detailed groundwater monitoring study plan in the study area, the drainage pattern and geology, consisting 3 to 6 villages in each formations.

Depth to water levels were measured for post monsoon (December 2011) and pre monsoon (June 2012) periods for one hydrological year from December 2011 to June 2012.

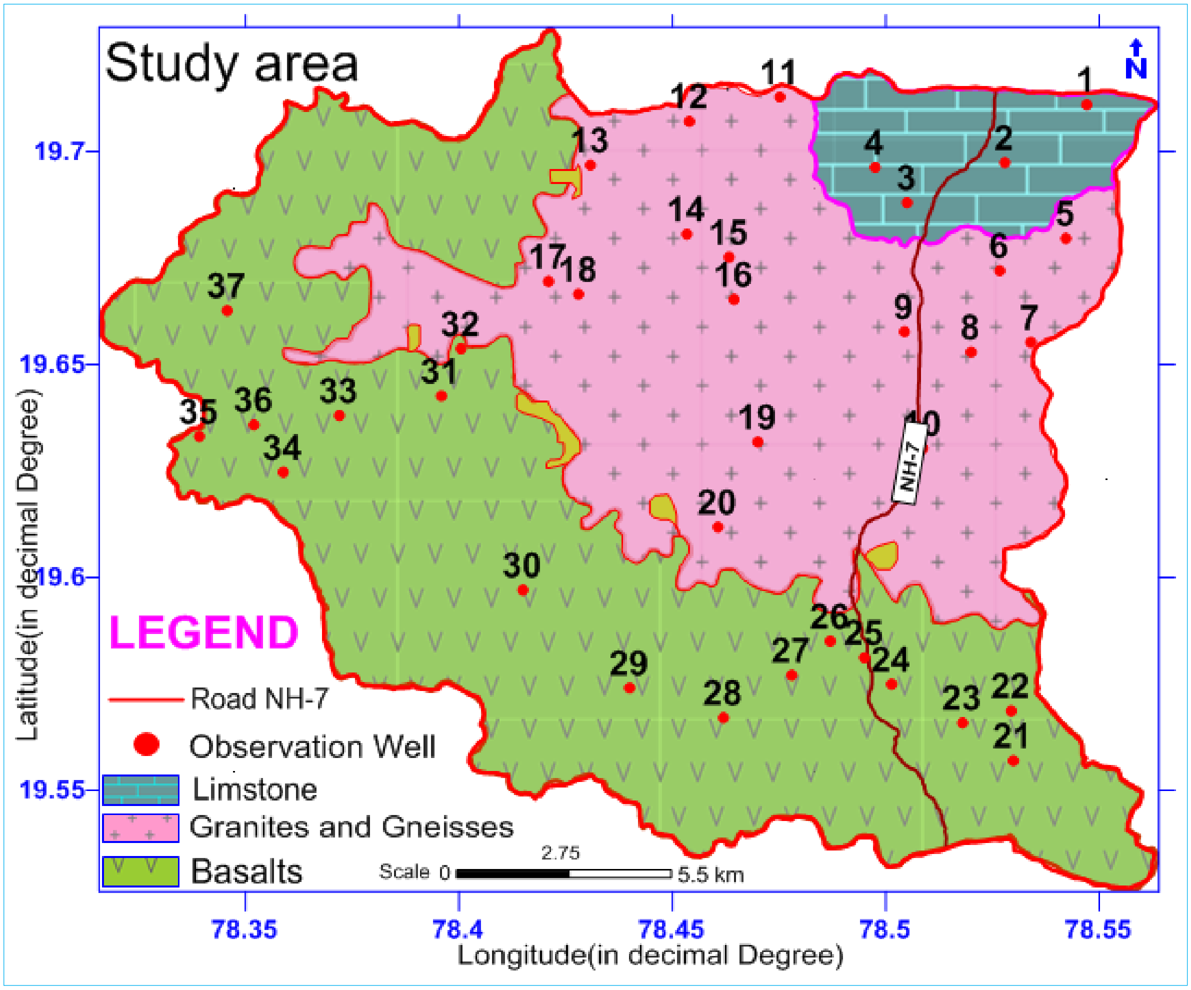


Fig: 3.1 Observation Well Location map of Mathadi vagu basin,

3.4.1. Depth to water level:

The depth to water level data was collected 2 times in all the 107 observation bore wells which are classified into four categories.

Category - I: More than 15m. and less than 20m bgl (15 - 20m.)

Category - ll: More than 10m. and less than 15 m bgl. (10 - 15m.)

Category - Ill: More than 5m. and less than 10m. bgl. (5 -10 m)

Category - IV: More than 5m. and less than 10m. bgl. (0 -5 m)

Category I (15 - 20m.): In the Mathadi vagu basin 107 observation bore wells recorded depth to levels in this category during December, 2011 and June, 2012. The in basin observation bore wells falling in this category range about 0% to 6% in December, 2011, and 0% to 0% in June,2012 .

Category II (10 to 15m): In the Mathadi vagu basin 107 observation bore wells recorded depth to levels in this category during December, 2011 and June, 2012. The in basin observation bore wells falling in this category range about 16% to 15% in December, 2011, and in June, 2012.

Category - III (5 to 10m): In the Mathadi vagu basin 107 observation bore wells recorded depth to levels in this category during December, 2011 and June, 2012. The in basin observation bore wells falling in this category range about 59% to 47% in December, 2011, and in June, 2012.

Category IV (0 to 5m): In the Mathadi vagu basin 107 observation bore wells recorded depth to levels in this category during December, 2011 and June, 2012. The in basin observation bore wells falling in this category range about 25% to 8% in December, 2011, and in June, 2012.

3. 5. DRAINAGE ASPECTS AND MORPHOMETRY

3. 5.1. Introduction

A drainage basin is defined as a portion of the earth's surface, which is bounded by topographic slopes that divert all run off to one drainage outlet. The physical boundary of the drainage basin is defined by the direction in which surface runoff will drain and follows the ridgeline between hydrologic units. The boundary is called the drainage divide (Vijay P.Singh 1997).

The pioneer to conceive the idea of quantitative expression of drainage basin were Playfair (1802) developed the concept of drainage analysis, subsequently Zernitz (1932) projected the relation between drainage pattern and structural control.

Further, Horton (1932 and 1945), Long bein (1947), Smith (1958) and Maxwell (1960) have contributed to the development of different aspects of drainage evolution. Morisawa (1962) established the relation of discharge to run off intensity in watersheds in Appalachian plateau, Carlston (1963) has studied the relation between drainage density, surface water runoff and ground water movement and inferred that they are part of single hydraulic system controlled by the transmissivity and soil. Classification and type of drainage pattern based on stream network as per Zernitz (1932) and Howard (1967) is shown in Figure VI.1. Karanth K.R. and Srinivas Prasad (1979) determined rainfall infiltration factor from base flow analysis. Shanker Narayan and Sudhakar Reddy (1981) made detailed study on morphometry of Chittoor river basin, Shankar Narayana and Ravindra (1981) attempted morphometric analysis of Kalvar river basin. Shankar Narayana and Narsimlu (1991) gave elaborate account on drainage analysis of Manjira river sub basin.

General morphological classification of drainage pattern is given in Fig: 3.2 and drainage map of Mathadi vagu basin in Fig: 3.3.

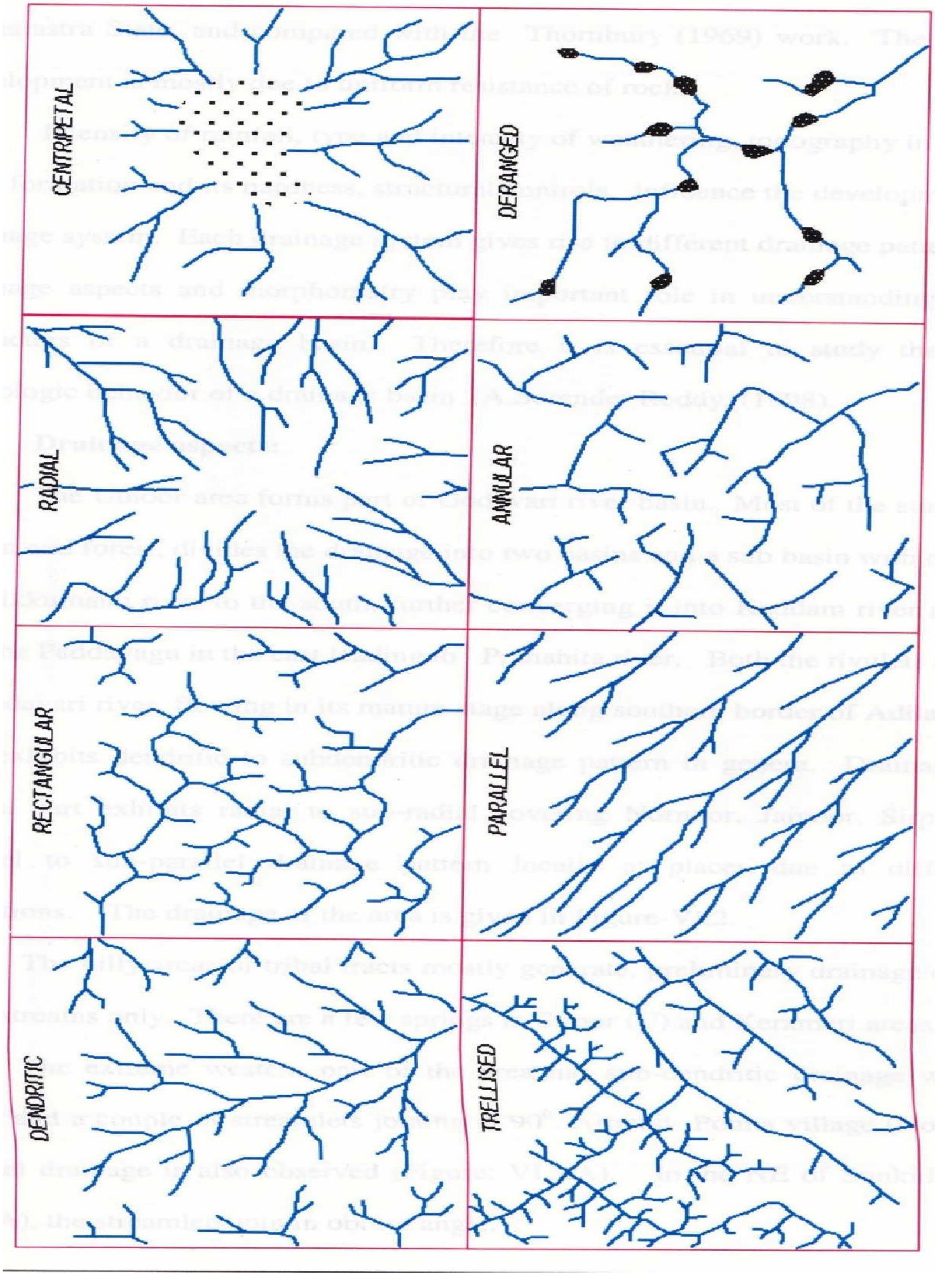


Fig: 3.2 Morphological classification of drainage pattern

Masoom (1989) studied drainage pattern of Godavari river basin in Nanded District of Maharastra State, and compared with the Thornbury (1969) work. The dendritic drainage development is mostly due to uniform resistance of rocks.Intensity of rainfall, type and intensity of weathering, topography in an area, nature of rock formation and its hardness, structural controls, influence the development of a particular drainage system. Each drainage system gives rise to different drainage patterns. The study of drainage aspects and morphometry play important role in understanding the hydrological characters of a drainage basin. Therefore it is essential to study them to understand hydrologic behavior of a drainage basin (A.Surender Reddy, (1998).

3.5.2. Drainage aspects

The Mathadi vagu basin is a part of Saatnala river basin, saathnala is a tributary of Penganga River, and it is a part of the Godavari river basin. Most of the study area is hilly and covered by forest. The area exhibits dendritic to subdendritic drainage pattern in general. Drainage pattern in the central part exhibits radial to sub-radial covering Devapur, Bharampur, Umdam and Waghapur converting to parallel to sub-parallel drainage pattern locally at places due to different geological formations. The drainage pattern of the area is given in Figure 3.4.

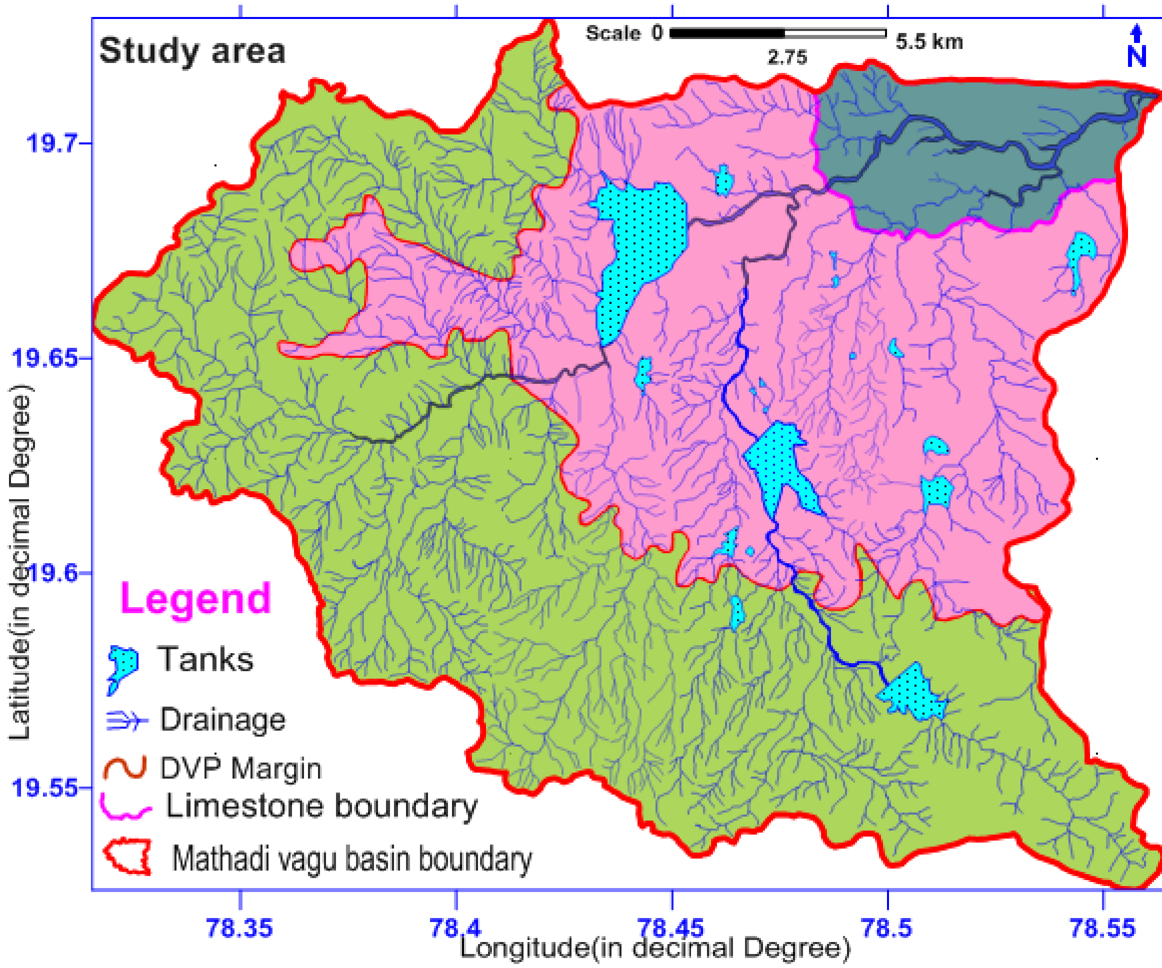


Fig: 3.3 Drainage map of Mathadi vagu basin,

The hilly areas of study area mostly generate preliminary drainage of 1st, 2nd and 3rd order streams only. There are a few springs in Kappardevi and Jhari areas.

The extreme western part of the area has sub-dendritic drainage with a few sharp bends and a couple of streamlets joining at 90°. Around Ponna village (Northeast and East) parallel drainage is also observed (Figure: 3.4.A). In the NE of Batti Samargam village (Figure: 3.4.A), the streamlets join in obtuse angle.

Even a relatively higher order Mathadi vagu shows 90° sharp bends, and also to the South of Somarpet repeated sharp bends at short distances, giving rise to rectangular pattern drainage (Figure 3.4.B). Dominant drainage flow directions are W to E in the West and West to East in the Eastern area. Mainstream flow at Umdam and Sunkidi is towards WSW, taking a sharp bend between Waijapur and Waghapur before joining the main stream, which flows towards north. This confirms that the general flow direction in the west is towards the north. Whereas, in the eastern part general flow direction is from west to east is maintained. The drainage pattern at Dahegam, Umri, Kappardevi and Dorli (Figure3.4.C) strongly suggest evolution of youthful drainage system under process, largely controlled by underlying geology and structures. To the south of Kottur, Mathadivagu stream shows two "V" bends, reflecting tectonic control. The disproportionate size and shape of the drainage pattern to the east of study area suggests "Misfit" stream (Figure 3.4.D)

The complete drainage system observed in the area indicates:

a. Structural control, such as faulting of the strata and the joint pattern
b. Geological boundaries and contact between different flows.
c. Contact between lava flows and the basement granite rock.

To understand the above in more detail Morphometric analysis of the study area is taken up separately. Three drainage systems are existing with three outlets, within same Climatological combination of different geological formations. They are:

1. Limestones: Nortrh-Eastern part of the area comprising Penganga Limestones that is Siliceous Limestones, Purple Limestones and Gray Limestones.
2. Granites, Gneisses: Eastern part of the area comprising Granites, Gneisses.
3. Deccan traps: Western and souther parts of the area with only Deccan traps.

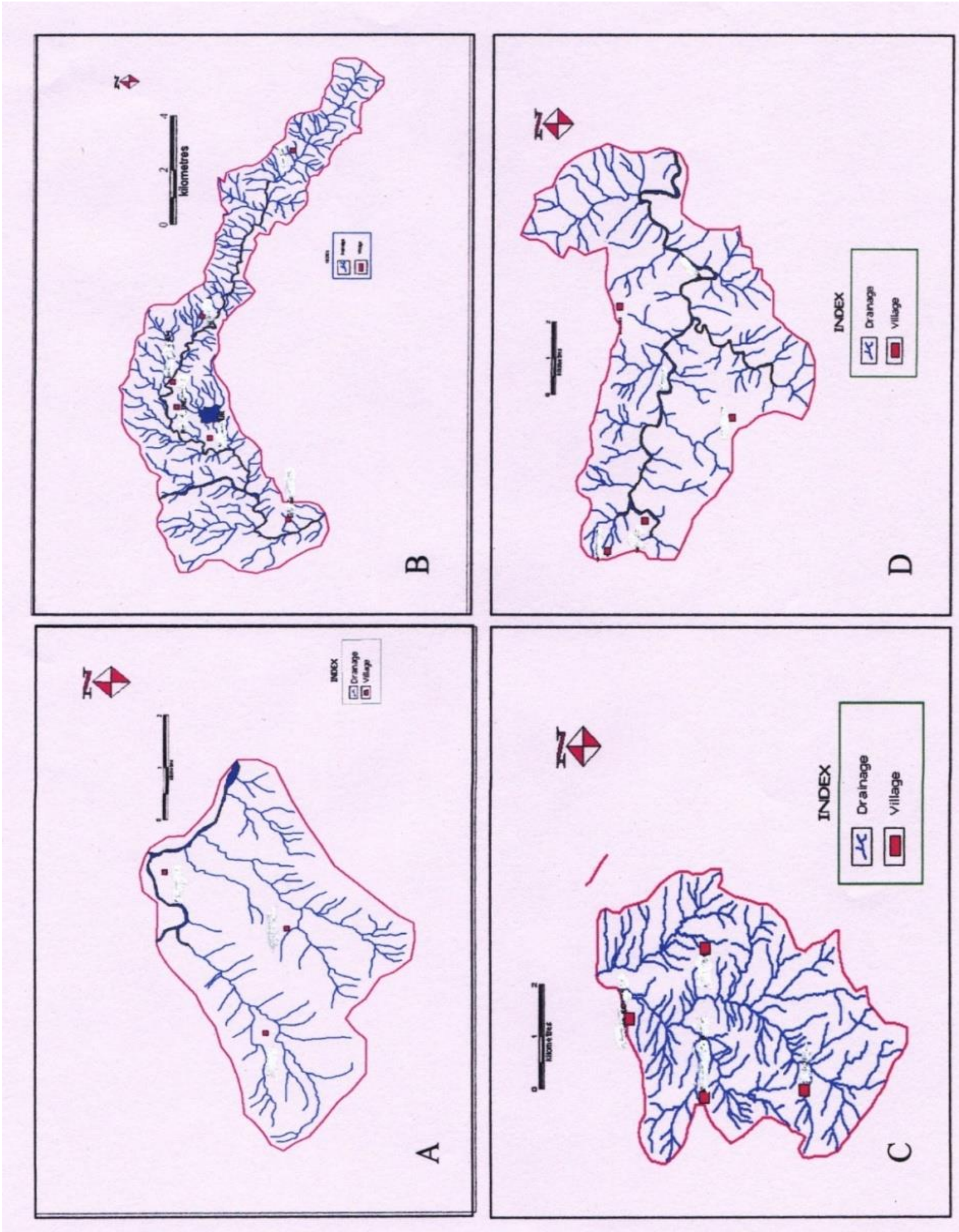


Fig: 3.4 Drainage pattern of Mathadi vagu basin,

3.6. MORPHOMETRIC ANALYSIS

Drainage basin geometry is understood properly by the analysis of drainage network; its stream channel system requires measurement of linear aerial and relief aspects with ground slopes. First two parameters are derived by measurement with planimeter and the third parameter is by vertical variation. The analysis shown in this work is done on 1:50,000 scale drainage map, and for convenience presented in 1:2, 50,000 Scale.

3. 6.1. LINEAR ASPECTS OF DRAINAGE SYSTEM

3. 6.1. (a) STREAM ORDER

Study of stream orders is the first component in the analysis of linear aspects of drainage network. Stream order marking helps in rapidly designing any stream or its segment quantitatively. Proposed a method for stream order marking but the one proposed by Horton (1945) is popularly adopted. In this system, each fingertip tributary is designated as first order stream, two first order streams combine to give second order and two second order streams combine to give a third order and so on. After this initial order marking is completed, the highest order stream is projected back to the headwaters along the stream which involves least deviation from the main stream direction (Figure 3.5.A).

Strahler (1952) assumed that in a channel network all intermittent and permanent flow lines are located in clearly defined valleys. He designated the smallest fingertip tributary as first order, two first order convergences produce a second order segment, two second order to provide a third order and so on. The trunk stream through which discharge of water and sediment takes place is marked the highest order (Figure 3.5.B). Schumm (1956) designated the main stream as first order and smaller tributary streams are designated in increasing order. Melton (1959) gave the mathematical aspects involved, which has an advantage of designating all unbranched segments as same order and giving the highest order to one segment rather than to the pole trunk stream. Sometimes order of the trunk stream (order 'n') may remain unchanged by addition of tributary stream of lower order (n-I, n-2 etc.). While sometimes addition of a single first order stream could rise the order of trunk stream (Figure

3.6.A). Further small changes of network can also lead to differences in the order of the trunk stream (Figure 3.6.B).

Shreve (1967) proposed modifications to Strahler's system of stream ordering, where each outer link or first order segment is designated as magnitude one and each subsequent link is designated as a magnitude equal to the sum of all the first order streams which are tributaries to it (Figure 3.5.C). Almost a similar method of stream ordering was evolved by Scheidegger (1965) (Figure 3.4.D).

In contrast, the law of stream ordering postulates the algebra of stream segment combination, which is cumulative and associative. According to these postulates, the stream order magnitude $G=\log_2 2$ M, where M is the magnitude of exterior links considered as magnitude one. In this, 2 becomes 1, 4 become 2 and so on. Stream order number is directly proportionate to size of the contributing watershed, channel dimensions and stream discharge at that place. The ratio of number of stream segments of a given order (Nu) to the number of stream segment of higher order (N_{u+1}) is termed as the bifurcation ratio (R_b) and is arrived at by the formula.

$$\mathbf{R_b = N_u / N_{u+1}}$$

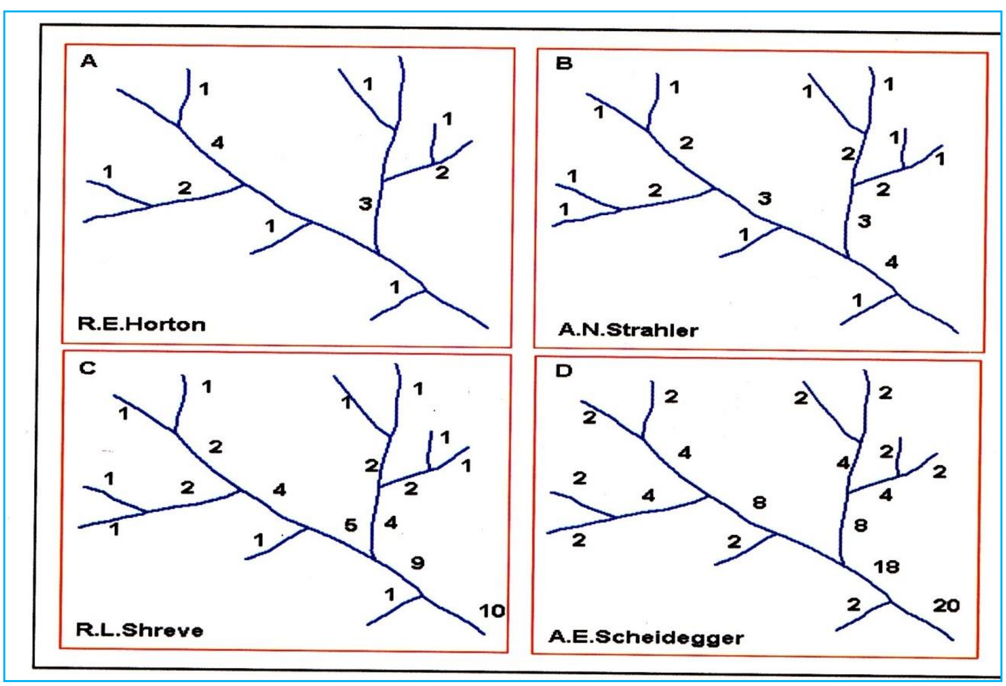


Fig: 3.5 Methods of stream and segment ordering

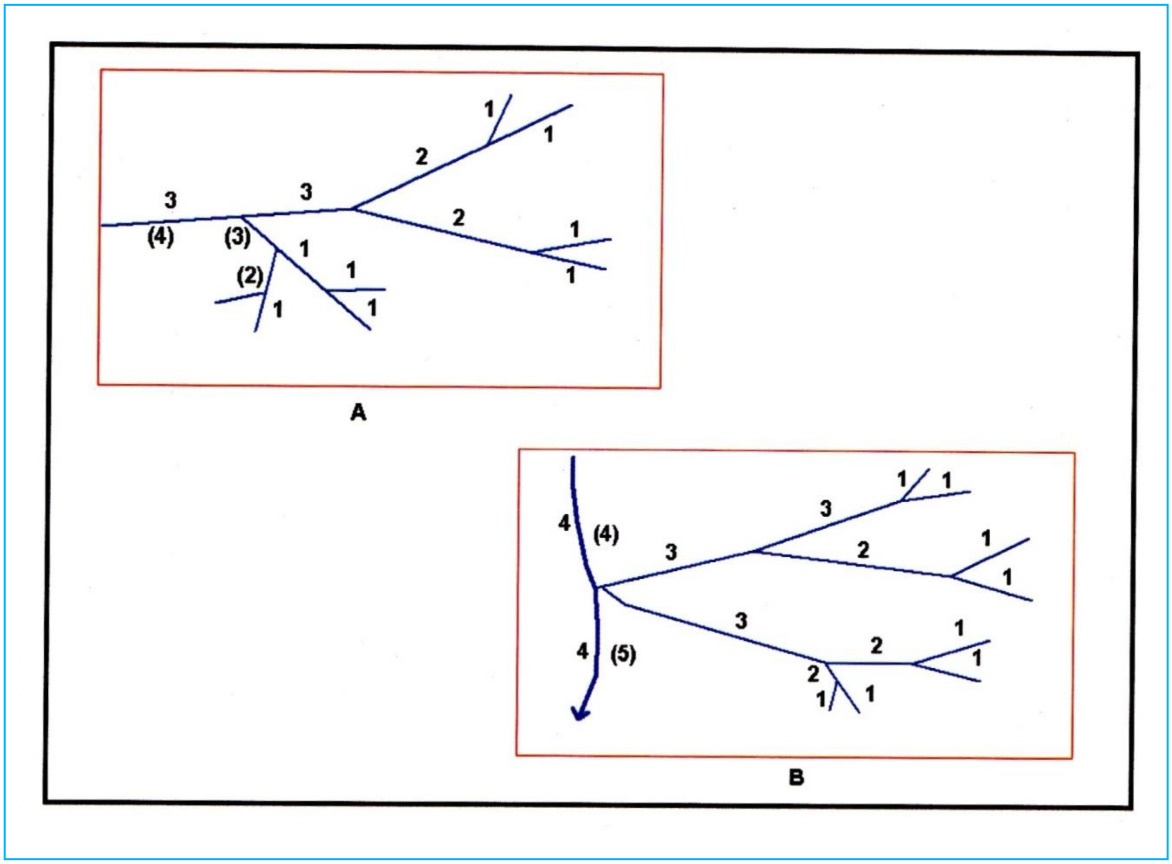


Fig: 3.6 Limitation in Stralers system of stream and segment ordering

In the present study, Strahler's (1906) method of stream ordering has been adopted. Stream order (u), total number of streams of each order (Nu) and bifurcation ratio (Rb) are computed for three formations and one basin area and are presented in Table 3.2. It can be seen that the number of stream segments decrease with the increase of stream order. The stream segment of any given order will be less than the stream segments of next lower order and more than the stream segment of higher order. Further it is observed that bifurcation ratio (Rb) with respective different stream orders vary as follows for the basin. The Mathadi vagu basin variation of bifurcation ratio is 2.00-7.00, Mean bifurcation is 4.44.

Table: 3.2 Stream order, number of streams and bifurcation ratio of

Mathadi vagu basin Adilabad District A.P.

<table>
<tr><td rowspan="11">Mathadi vagu basin</td><td>Steam Order</td><td>No. of Streams

N_u</td><td colspan="2">Total length of streams in km
L_u</td><td>Log N_u</td><td colspan="2">Log L_u</td></tr>
<tr><td>1</td><td>1129</td><td colspan="2">337.5</td><td>3.052</td><td colspan="2">2.528</td></tr>
<tr><td>2</td><td>274</td><td colspan="2">122.5</td><td>2.437</td><td colspan="2">2.088</td></tr>
<tr><td>3</td><td>49</td><td colspan="2">57</td><td>1.690</td><td colspan="2">1.755</td></tr>
<tr><td>4</td><td>14</td><td colspan="2">49</td><td>1.146</td><td colspan="2">1.690</td></tr>
<tr><td>5</td><td>2</td><td colspan="2">12.5</td><td>0.301</td><td colspan="2">1.096</td></tr>
<tr><td>6</td><td>1</td><td colspan="2">10</td><td>0</td><td colspan="2">1</td></tr>
<tr><td>Total</td><td>1469</td><td colspan="2">588.5</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="6">Bifurcation ratio R_b</td><td>Mean Bifurcation</td></tr>
<tr><td>1st /2nd order</td><td>2nd/3rd order</td><td>3rd /4th order</td><td colspan="2">4th / 5th order</td><td>5th/6th order</td><td></td></tr>
<tr><td>4.12</td><td>5.59</td><td>3.5</td><td colspan="2">7</td><td>2</td><td>4.44</td></tr>
</table>

The bifurcation ratios (Rb) will not be the same for different stream orders on account of variation in the geometry of the basin. Horton's law of stream numbers, states that the number of stream segments of each order forms an inverse geometric sequence with stream order number.

$$\mathbf{R_b = N_u / N_{u+1}}$$

Bb=No. of streams of given order/ No. of stream of next higher order

Where, Nu= Total number of stream segments of order 'u'

Nu+1 = Number of segment of next higher order

Rb=Bifurcation ratio,

U=number of stream order.

3. 6.1. (b) Stream length:

Stream length is more influencing hydrological parameter, along with stream order and stream number in a basin or watershed. The Horton's (1945) analysis of mean length of stream orders, characterise the size of the component that comprise the drainage net channel lengths of each stream order (∑ Lu). All the segments of a given stream order within the specified drainage network are measured without pause and the cumulative length is read on the dial of the map measurer. Morisawa (1957) stated that the length measured represents the true length, slightly shortened by projection upon horizontal plane and the mean length of stream channel (Lu) of order (u) is a dimensional property, which is obtained by dividing the total length (∑ Lu) by the number of segments (Nu) of that order and is calculated by the formulae

$$\mathbf{R_L = Lu/Lu\text{-}1}$$

Where “length ratio" (R_L)

Lu= Total stream length of order

Lu-1=Stream length of next lower order.

The total length of the stream is measured using the (planimeter) map measurer. The stream length of the Mathadi vagu basin Environs comes around 588.5 km. given in Table 3.4.

3. 6.2. Features of drainage basin:

Area, shape and drainage texture of a basin in morphometry, throw more light in understanding its nature.

3. 6.2. (a) Area of the basin:

Drainage basin area is defined as the area of the curve obtained by projecting the catchment boundary on a horizontal plane. Area measurement on a map of known scale is done by counting number of squares covered by the drainage basin boundary on a plain graph paper and also by using planimeter or mechanical digits or scanning techniques.

Total study area: 525 sq. km.

Perimeter of total study area: 62 km.

Size, shape, relief, slope and drainage density of basin in the area. Sediment yield per unit area has been observed to decrease as catchment area increases in accordance with stream flow. Rate of erosion and runoff per unit of drainage area is inversely proportional to area of basin or watershed. Multiple regression analysis of sediment data for Missouri basin, Loess hills and for Columbia River basin indicated that the sediment production rate varies as 0.8 power of drainage area, while other researchers found sediment production to vary 0.6 to 1.1 power of the drainage area.

3. 6.2. (b) Shape of the Basin:

Stream discharge characteristics depend on the shape of the drainage basin. Probable shapes of basins and their corresponding bifurcation ratios are shown in fig 3.2. The elongated basins have high bifurcation ratio whereas, it approaches to minimum for rounded basins. The study area has bifurcation ratios between 2 and 7, considered to be of normal category according to Strahler (1964) norms.

3. 6.2. (c) Drainage texture:

Drainage texture also requires to be studied to understand geomorphology concept. Drainage lines are numerous over impermeable area rather than permeable area. Horton (1945) observed that the study of drainage texture includes both drainage density and stream frequency.

3.6.2. (d) Drainage density:

This expression was introduced by Horton (1932) to indicate the closeness of spacing of channels. Mathematically it is expressed as the ratio of total channel segment lengths cumulated for all orders to the basin area. Formula given in table 3.5.Further, combining the law of stream numbers and lengths, the drainage density can be computed by the formula

$$D = Lu/A$$

Where D = Drainage density in km/sq.km.

Where L = Mean stream length of 1[51] order

Lu= Total length of basin in km

A = Total area of the basin in sq.km.

Drainage density of Mathadi vagu basin obtained by the above formula, 1.12 km/sq.km.

Table 3.3: Classification of Drainage density (Smith, 1950)

Drainage Density	Texture
<2	Very Coarse
2-4	Coarse
4-6	Moderate
6-8	Fine
>8	Very fine

The drainage density of the Mathadi vagu basin is 1.12 km/sq, and classified as coarse in texture indicating thick vegetation, high infiltration, and permeable rock strata in the present case. Other contributory factors for coarse drainage texture are infiltration capacity and structural features. Drainage density measurements made over variety of geologic and climatic types are given in table 3.4. Drainage density is controlled by various factors like rainfall, type of rocks, relief, infiltration capacity, vegetative cover (forest) and surface roughness under the influence of runoff intensity index. The amount and intensity of precipitation directly influence the quantity and character of surface runoff. Other factors being equal, areas with high intensity of precipitation, such as thunder shower, looses greater percentage of rainfall as runoff, resulting in soil erosion and more surface drainage channels. Hilly terrains with steep slopes, as in the study area, with high order of precipitation also results in more number of drainage lines with short stream lengths. Density and kind of vegetation and rainfall absorption capacity of soils also influence the rate of surface runoff and affects the drainage texture of an area. Areas having similar lithology, geologic structure with semi arid climatic regions have fine drainage texture than tropical to sub tropical climatic regions. Low drainage density generally results in areas of highly resistant or permeable sub soil material, dense vegetation and low relief. High drainage density is resultant of weak or impermeable sub surface material. Low drainage density leads to coarse drainage texture, while high drainage density gives rise to fine drainage texture. Hypothetical shapes of basin with bifurcation values shown in fig: 3.7.and Quantification of different densities of drainage

Given in fig: 3.8.

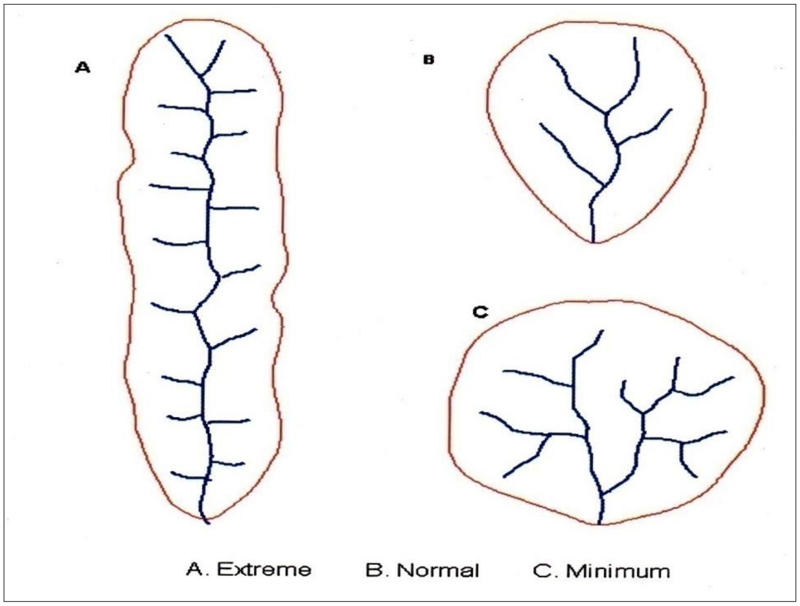


Fig: 3.7 Hypothetical shapes of basin with bifurcation values

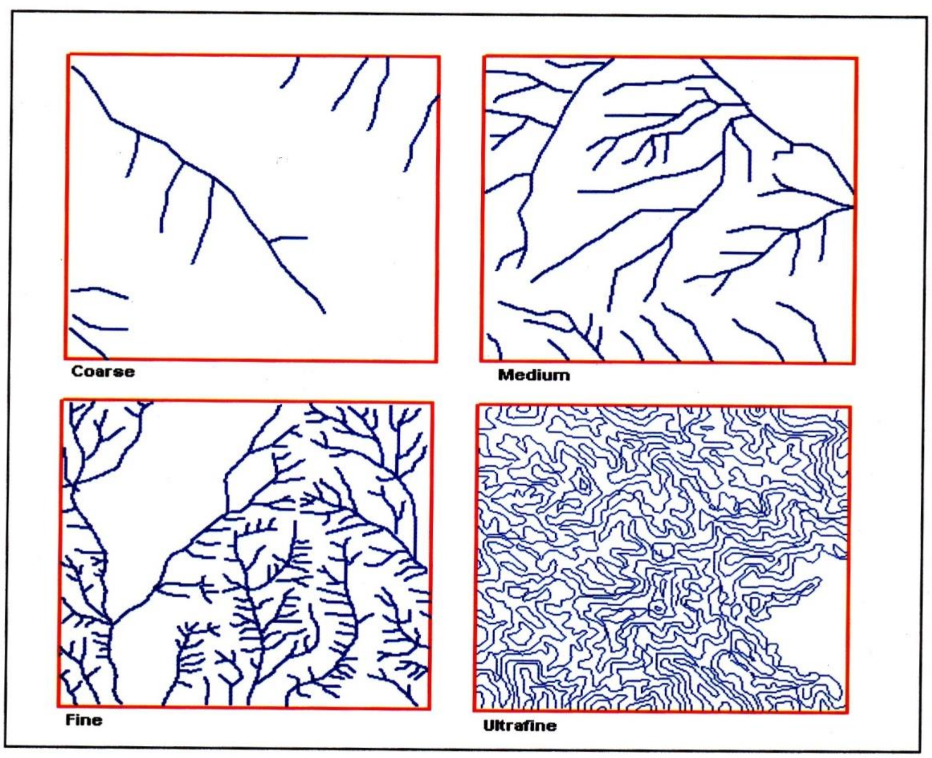


Fig: 3.8 Quantification of different densities of drainage

Table: 3.4 Morphometric parameters, Symbol/formula and Results of Mathadi vagu basin

Morphometric parameters	Symbol/formula	Results
Area(sq km)	A	525
Perimeter(km)	P	64
Drainage density(km/sq.km)	$D=L_u/A$	1.12
Stream frequency	$F_s=N_u/A$	2.79
Texture ratio	$T=N_1/P$	18.20
Basin length(km)	L_b	588.5
Constant channel maintenance	C=1/Dd	0.892
Circularity ratio	$R_C= 4\prod A/P^2$	53.21
Form factor ratio	$R_f= A/L_b^2$	0.44

L_u = Total stream length of all orders

N_u = Total no .of streams of all orders

N1 = Total no. of 1st^t order streams

$\prod$ = 3.14

3.6.2. (e) Constant of channel maintenance:

Schumm (1956) defined "constant of channel maintenance" as inverse of drainage density. The amount of drainage area needed to maintain one unit of channel length was termed as Constant channel maintenance by Schumm (1956) .Formula given in table 3.4.

C=1/Dd

C=Area of the basin/ Total stream length of all order

Constant channel maintenance=1/1469=0.892

The drainage density of the Mathadi vagu basin is calculated and the value is 1.12km/Sq km. The inverse of it is 0.892 Sq km. Hence the Constant channel maintenance comes to 0.892 Sq km. Indicating impermeable nature of sub surface formation.

3.6.2. (f) Stream frequency:

Stream frequency or channel frequency (F) defined by Horton (1932), is the ratio of number of streams to the area of the basin. Hypothetically it is possible to have basins of same drainage density differing in stream frequency and basins having same stream frequency differing in drainage density. Formula given in table: 3.4.

$$F = N_u / A$$

F= Total number of stream segments of all orders/Total area of the basin

Stream frequency of Mathadi vagu basin is 2.79 /km^2 .

3.6.2. (g) Texture ratio

Texture ratio defined by Horton (1945), Formula given in table: 3.4.

$$\mathbf{T = N1/P}$$

Where: N1= Total number of first order stream

P = Perimeter of basinTexture ratio of the Mathadi vagu basin is 18.20

3.6.2. (h) Circularity ratio

Circularity ratio Formula given in

$$\mathbf{R_C = 4^{\Pi} A/P^2}$$

Where: A=Area of watershed.

∏=3.14

P=Perimeter of watershed.

Circularity ratio of Mathadi vagu basin is 53.21

3.6.2 (i) Form factor ratio

Form factor ratio defined by Horton (1932), Formula given in table: 3.4.

$$\mathbf{R_f = A/L_b^{\,2}}$$

Where: A= Area of watershed

Lb= Basin length

Form factor ratio of Mathadi vagu basin is 0.44

3.7. DISCUSSIONS ON RELATION OF DRAINAGE ASPECTS, ORPHOMETRY AND HYDROLOGY:

Comprehensive picture of ground water resources available in an area is only possible by detailed study of geomorphic features along with hydrological aspects. Hydrology of a basin is directly related to total stream length, basin area and first order stream frequency and inversely related to stream gradient calculations and relief ratios (Morisawa, 1962). Geomorphic factors such as basin shape and slope depend on geology, structure, intensity of runoff and discharge in an area. Stream density and bifurcation ratio effect discharge. Such drainage pattern features are the typical characteristic of hard rock areas.

3. 8. SUMMARY:

The study area Mathadi vagu basin, Adilabad district is 525 sq.km. Based on the basin concept, the drainage pattern of the study area, the Mathadi vagu basin drainage outlet in the east converges in to Saatnala River. The geological formation of the entire study area are crystalline, but of different origin. The Central part of the area comprising Granites, Gneisses, Northeastern part of the area comprising Penganga Limestones, Western and Southern parts of the area with only Deccan traps.

In these three formations, with Deccan trap being common geological formation, which is associated with hard rock and soft rock formations in close by neighboring areas will form an ideal case for over all study of morphometric features and their correlation will give better understanding of impact of lithology on drainage characteristics.

The area is characterized by dendritic to sub-dendritic pattern in general. Drainage pattern in central part exhibits radial to sub-radial converting to parallel to sub-parallel drainage pattern, attributed to varied and different geology. Locally, 90^0 sharp bends giving rise to rectangle drainage pattern, sudden change in the flow direction, the process of youthful evolving drainage system, repetition of 'V' bends and misfit stream pattern are well observed in the area. They may be due to

a. Structural control, probably the joint system and faulting of the strata

b. Geological boundaries between different flows.

c. Contact between lava flows and the basement granite rock.

The area is covered by streams up to 5th and 6th order with 1469 streams measuring 588.5 km length with an average mean length ratio of 0.149 The average drainage density of the basin of the area is 0.56 sq/km, indicates coarse drainage texture caused by resistant geological formations and dense forest.

The average constant channel maintenance of the area is 0.44 sq / km. indicates that 0.44 sq.km area is needed to support each linear kilometer of channel. The average length overland flow is computed as 0.23, stream frequency as 2.79 stream segments/sq.km the relation of stream frequency to the drainage density is 1.12.

In the drainage pattern study and the morphometric analysis deduces that the area is of high intensity of precipitation with high run off resulting in more number of surface drainage channels due to steep slope hilly terrain. The drainage pattern reflects thick vegetation and local structural disturbances in the resistant geological formations.

Photo: 3.1 Shallow well near Sithagondi Village, Gudihathnoor mandal,

Photo: 3.2. Deepest well at Somarpet Village, Gudihathnoor mandal.

Photo: 3.3. Well inventory Data Collection at Pochera Village.

Photo: 3.4. Well inventory Data Collection at Kamlapur Village.

CHAPTER - 4
AQUIFER PARAMETERS

4.1. INTRODUCTION

To know the Groundwater saturation and sustainability, nine aquifer performance tests were conducted and are discussed at length in the ensuing paras.

Aquifer studies provide essential information for water-resource management and form an essential tool to assess and document the potential influences on local wells and to understand the local aquifer characteristics.

Hydraulic properties of aquifer are its hydraulic conductivity and storativity. Other parameters like transmissivity, leakage, etc., are derived parameters. Hydraulic conductivity (K) is defined as the rate of flow through unit area of an aquifer under unit hydraulic gradient at prevailing kinematic viscosity. Its dimensions are L't. Storativity is the volume of water that an aquifer can release from storage over a unit decline of head (or take into storage over a unit rise in head) per unit surface area, it is dimensionless. Transmissivity is an important derived parameter defined as the rate of flow through unit width of an aquifer under unit hydraulic gradient at prevailing kinematic viscosity. Its dimensions are L^2/t.

Since, there is a large variation in vertical characteristics of the aquifer and flow to a well occurs through entire thickness of the aquifer transmissivity is more appropriate representation of flow characteristics around a well. It is determined using various steady and unsteady flow equations. Theim (1908) derived his steady state equation from Darcy's law and used for determining transmissivity till Theim developed unsteady flow equations in 1935 (Theis, 1935). This equation was modified by many other workers to suit different conditions or to simplify the computations. Notable authors are Jacob (1950), Walton (1962), Boulton (1963) and others.

Knowledge of hydraulic properties of aquifer and associated rock properties of formations is essential in any scheme of ground water resource assessment. Pumping tests are an accepted means of acquiring data on hydraulic properties. In crystalline (hard) rocks, the development of porosity and permeability is due to fracturing and weathering. Weathering and fracturing are denser near the surface and hence the permeability of hard rocks generally decreases with depth. An aquifer test is designed to impose a hydraulic stress on the aquifer in such a way that measurements of response will fit in a theoretical model of aquifer response. However, in hard rocks the data obtained from pumping test need to be interpreted with a degree of caution as the system is highly anisotropic and heterogeneous. In a carefully controlled pumping test the following information can be obtained.

Transmissivity and (hydraulic conductivity), storage coefficient (specific yield in unconfined aquifer), leakage factor (of semi-confined aquifers), drainage factor (of semi-unconfined aquifers) and hydraulic resistance (of confining layers).

Distance, direction and nature of barrier (no-flow) or recharge boundaries and lateral gradation, thickening, pinching and interconnection of aquifers. From these parameters, effects of current and projected pumpage on the water levels on surrounding wells for one year period can be assessed if rate of rise or decline in water levels is monitored continuously.

The study can indicate if water quality changes are likely to occur as a result of future pumping demands.

Thorough understanding of the hydrogeological regime helps in interpreting the test data. In this study the objective was to assess transmissivity without incurring much cost over what would be needed for drilling a well, observation wells were dispensed with. As a result, only transmissivities could be roughly estimated.

4.2. METHODOLOGY ADOPTED FOR THE PUMPING TESTS

Initially pre-pumping water level data was collected for several hours from each of the tested wells. As continuous pumping for a long duration was needed diesel generator of

30 KV capacities along with a standby generator of 10 KV capacities were used as source of power for the pump used.

The discharge was kept constant (± 10%) by using a gate valve. It was monitored with an orifice plate, cross checked at suitable intervals of time by container method. A 230 litres barrel was used to make volumetric measurements and time required was noted with the help of stop watch. In early part of the study, only container method was used to monitor discharges. The depth to water level and changes in water levels with time (draw-down) during the test were- made with an accuracy of 1/2 cm using steel tapes and electronic drop-line indicators. The electronic drop-line indicators used in the study worked well and gave excellent results. For each log cycle of time at least 10 measurements were made although in the first log cycle sometimes only 8 measurements could be made. The data obtained was immediately plotted on a graph sheet showing depth to water level versus time and on semi log paper showing draw-down vs. time, (Ramkishan Desai 2006).

4.3. PUMPING TEST DATA ANALYSIS

Analysis of the pumping test data is a crucial phase in the determination of aquifer parameters. Obtaining reliable values depends to a large extent on the accuracy of the analysis. It comprises calculations and representations of the data on graphs from which aquifer types and flow conditions are understood, (M. Muralidhar 1988).

There are several methods and formulae for analysing the pumping test data in various aquifer conditions. Most of these are meant for analysing the pumping test data from bore wells with some modification, depending on the aquifer conditions and assumptions many hydrogeologists have successfully applied the same methods and formulae for large diameter wells in water table conditions (M. Muralidhar 1988).

Despite the ubiquitous distribution of crystalline igneous and metamorphic rocks over large parts of continents, the water bearing properties and behavior in the fractured media of these rock types are largely unknown and are sparsely documented (Kohut et al. 1983).

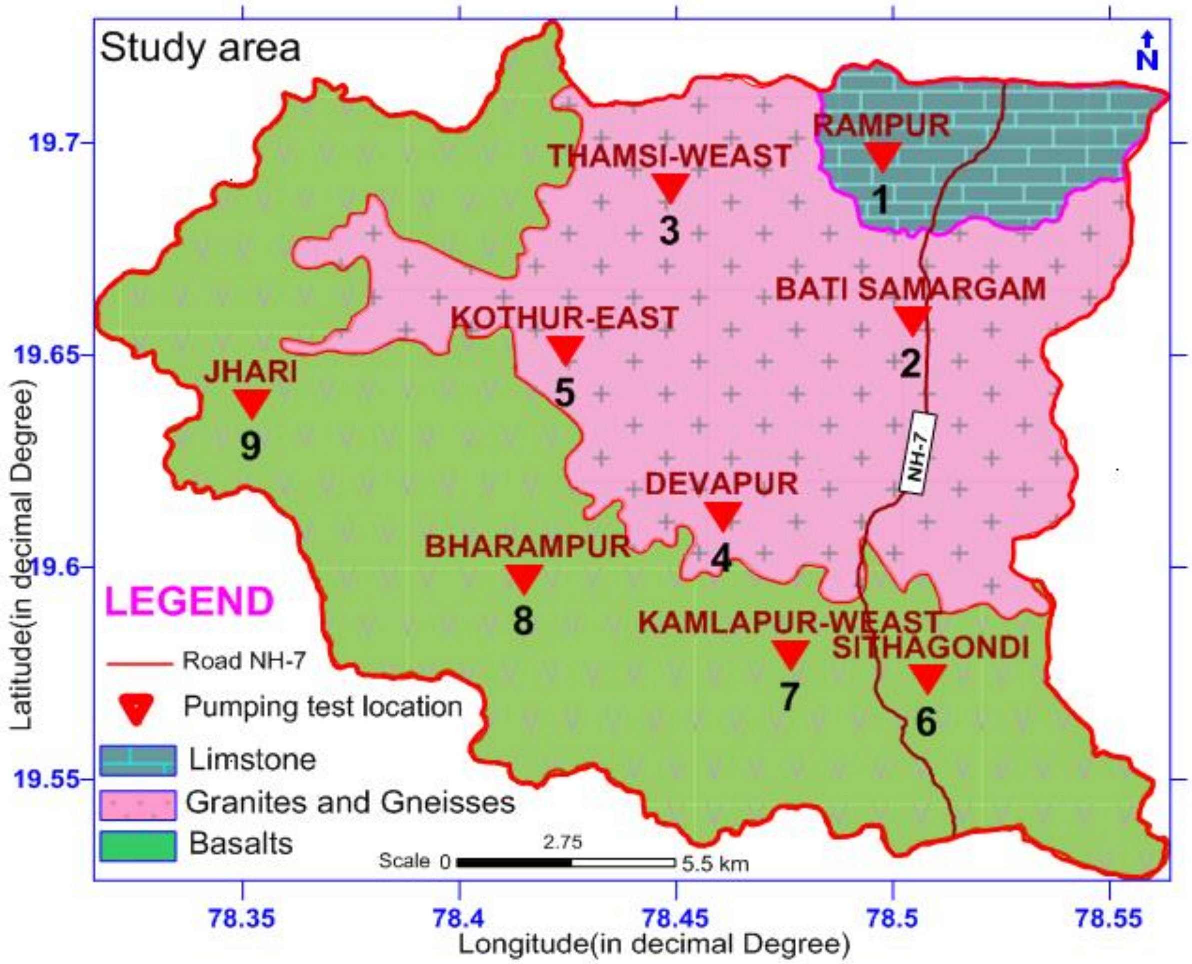


Fig: 4.1 Pumping test location in Mathadi vagu basin

In the present studies pumping tests were conducted at 9, Wells, fig 4.1. One of them is located in limestone, four of them are located in granitic terrain and the rest four are in basaltic area. Aquifer characteristics have been determined from the data collected and the results are analysed and interpreted.

Keeping in view the hydrogeological conditions. Theis method in determining the tranmissivity (T) and Storage Co-efficient (S) of the aquifers. And Slitcher's method is used for calculating specific capacity and unit area specific capacity.

Large diameter dug wells are the main source of water supply in many areas in the world. They are particularly useful in shallow aquifer conditions with low transmissivity. They are mainly used for domestic and agricultural supply. Since they are common and widely prevalent it becomes imperative to make use of these wells to determine the aquifer characters in these areas. This situation becomes more relevant in the case of hard rock terrains. In 1981, Herbert and Kitching stated that "there is no accurate method which will allow the calculation of transmissivity from recovery data obtained from partially penetrating large diameter wells" and situation is not much different even today.

Though several doubts are entertained, several workers in the field have used the Theis method in determining the tranmissivity (T) and Storage Co-efficient (S) of the aquifers, (Ramkishan Desai 2006).

4.4. Tranmissivity (T)

The transmittivity value in 4 tests conducted in granitic rocks is $3.06x10^{-5}$ m^3 /sec, $3.10x10^{-5}$ m^3 /sec, $4.06x10^{-3}$ m^3/sec and $4.09x10^{-4}$ m^3/sec during pumping phase and recovery phase determined by using Theis Method.

The transmittivity value in 4 test in basaltic is $2.19x10^{-3}$ m^3 /sec, $1.50x10^{-3}$ m^3 /sec, $1.97x10^{-5}$ m^3 /sec and$1.01x10^{-2}$ m^3/sec during pumping phase and recovery phase determined by using Theis Method .In one test limestone area the transmissivity is $3.29x10^{-3}$ m^3 /sec by using during pumping phase and recovery phase determined by using Theis method.

4.5. Storage Co-efficient (S)

Storage Co-efficient value in 4 tests conducted in granitic rocks is ranges $1.81x10^{-4}$, $1.55x10^{-6}$, $3.47x10^{-7}$ and $2.91x10^{-3}$ during pumping phase and recovery phase determined by using Theis Method.

The Storage Co-efficient value in 4 test in basaltic is ranges $3.91x10^{-2}$, $9.50x10^{-3}$, $1.51x10^{-4}$ and $1.01x10^{-2}$ during pumping phase and recovery phase determined by using Theis Method .In one test limestone area the Storage Co-efficient is $2.34x10^{-6}$ by using during pumping phase and recovery phase determined by using Theis method.

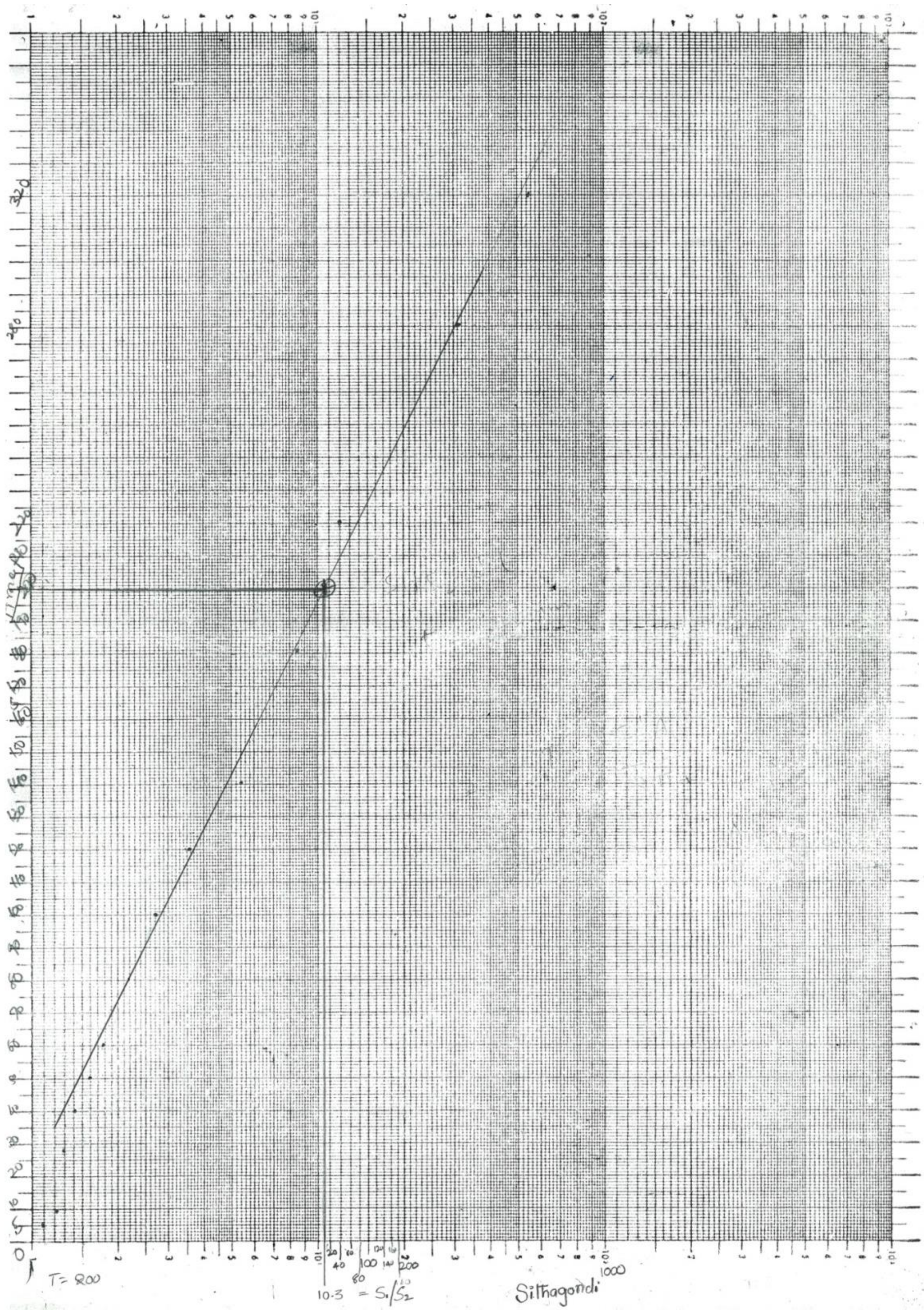


Fig: 4.2 Plot of log S1 / S2 Vs t (Slitchers Method) for determining specific capacity (C) at well no 6.in Sithagongi village.

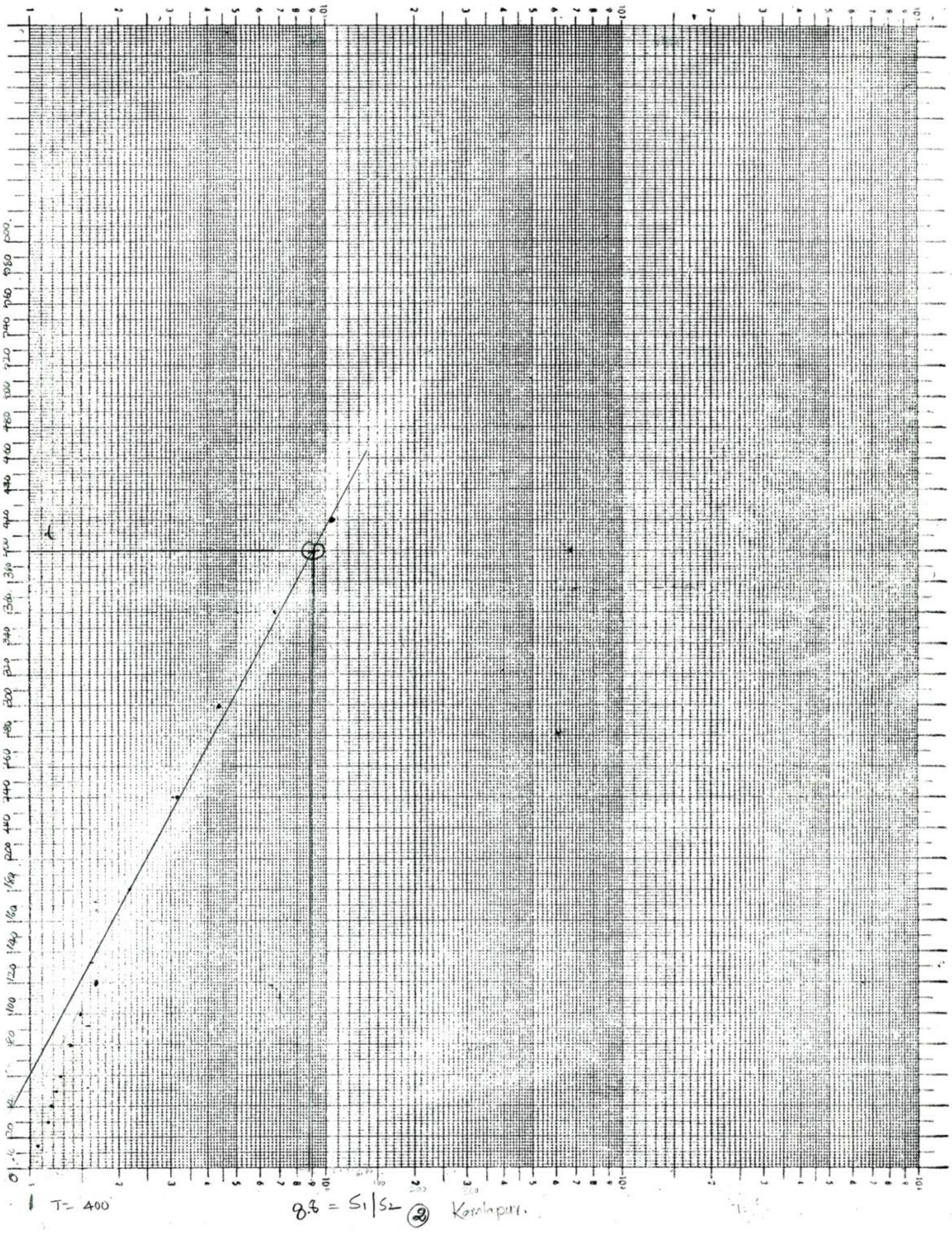


Fig: 4.3 Plot of log S1 / S2 Vs t (Slitchers Method) for determining specific capacity (C) at well no 7.in Kamlapur village.

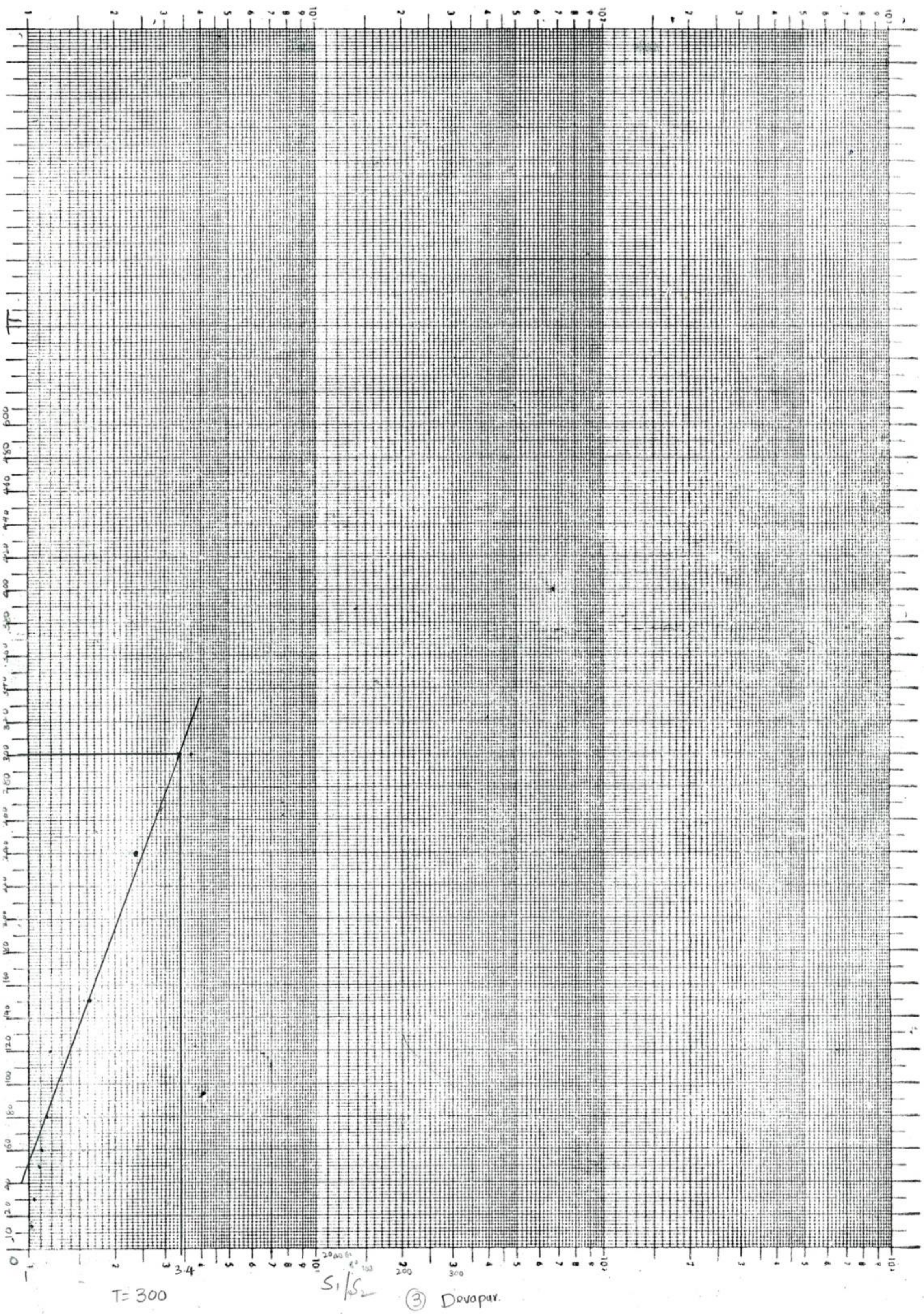


Fig: 4.4 Plot of log S1 / S2 Vs t (Slitchers Method) for determining specific capacity (C) at well no 4.in Devapur village.

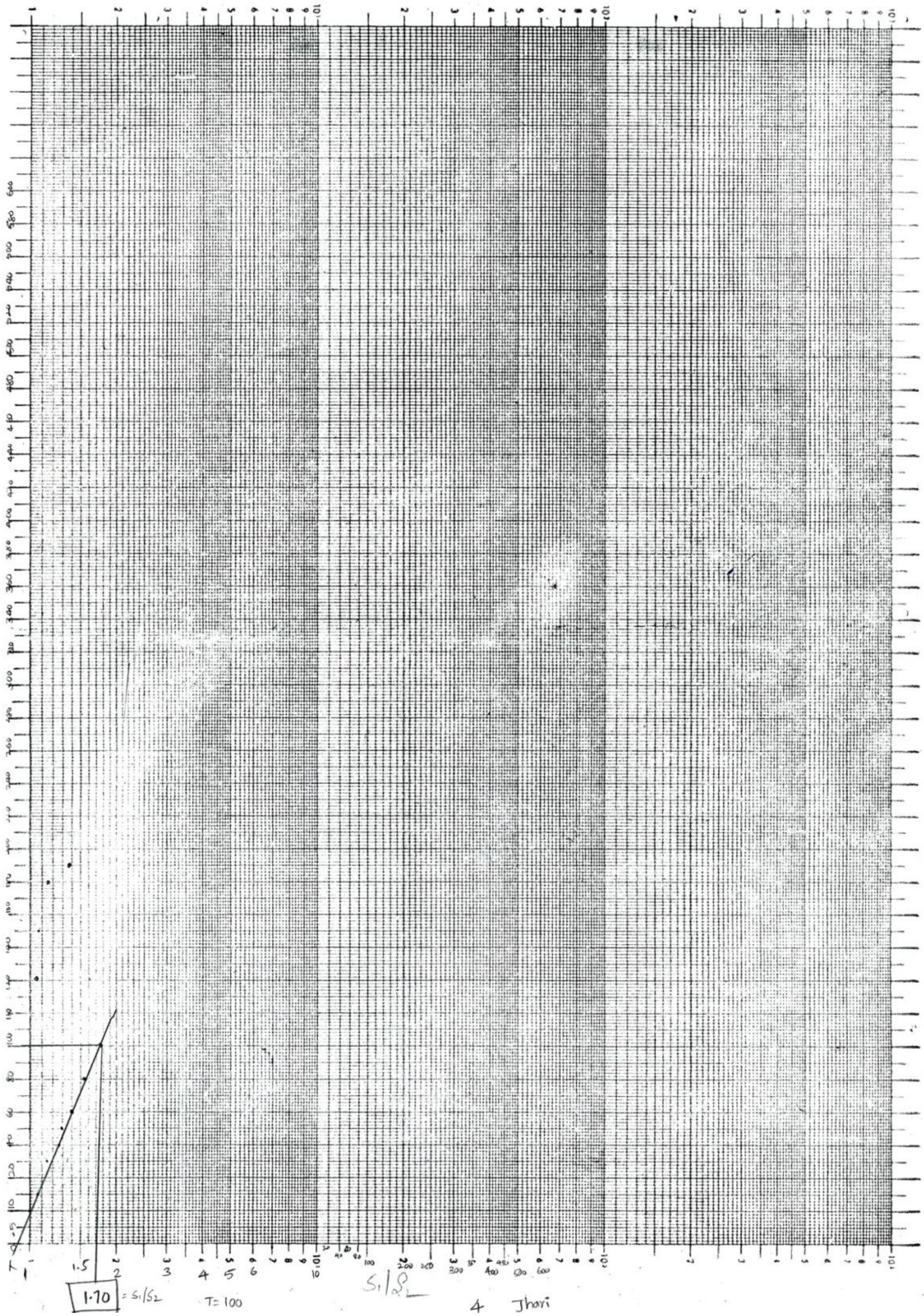
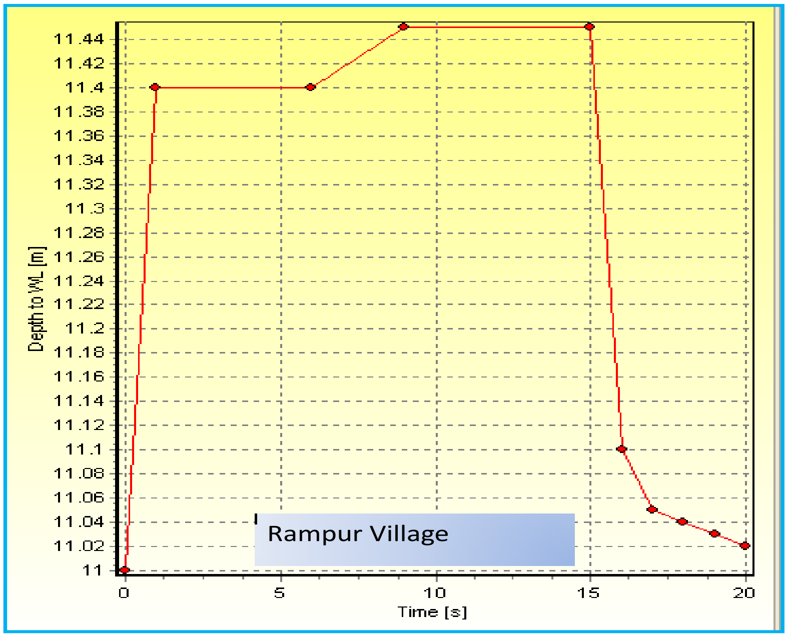


Fig: 4.5 Plot of log S1 / S2 Vs t (Slitchers Method) for determining specific capacity (C) at well no 9.in Jhari village.



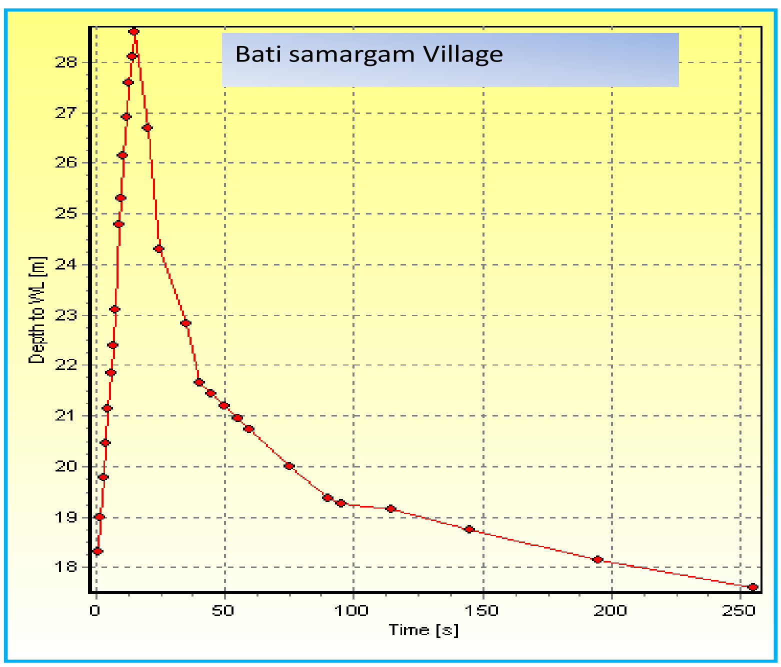
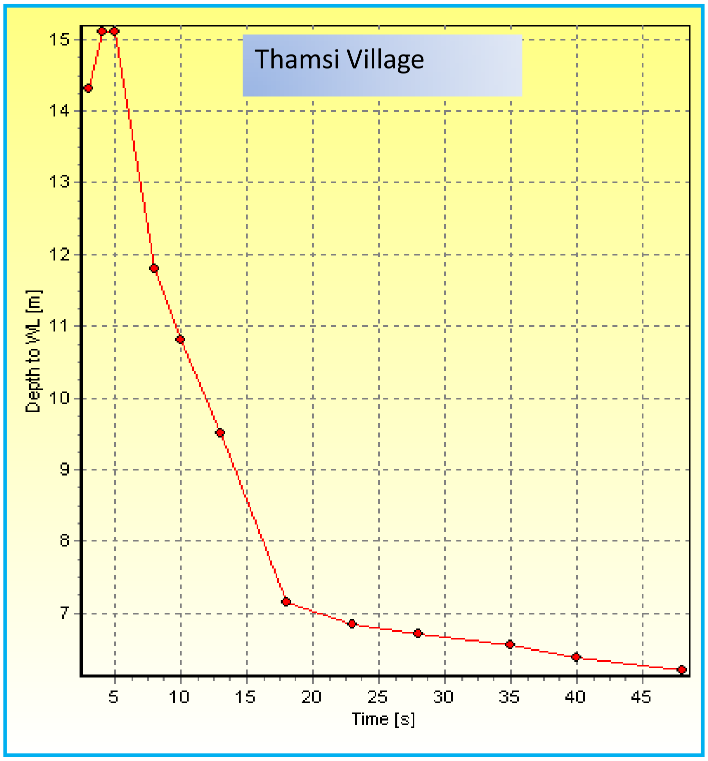


Fig: 4.6 Hydrographs of pumping wells, Mathadi vagu basin.



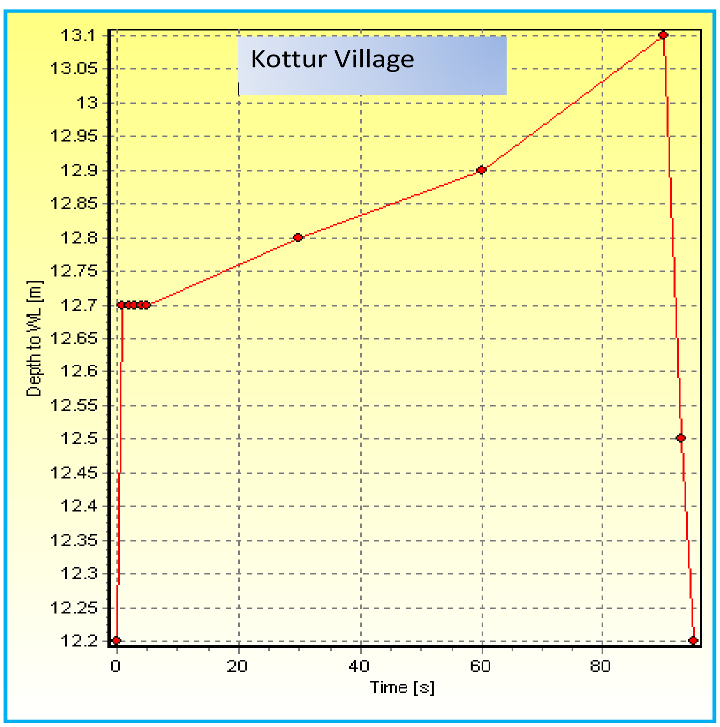
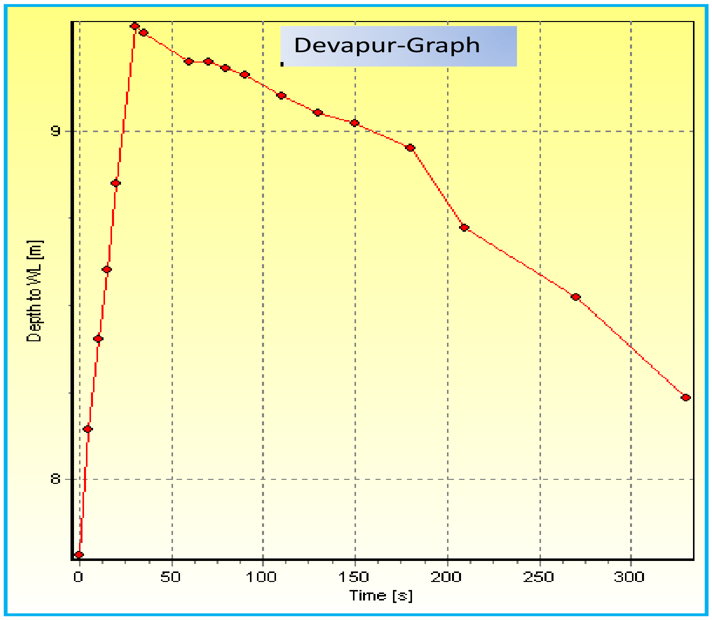
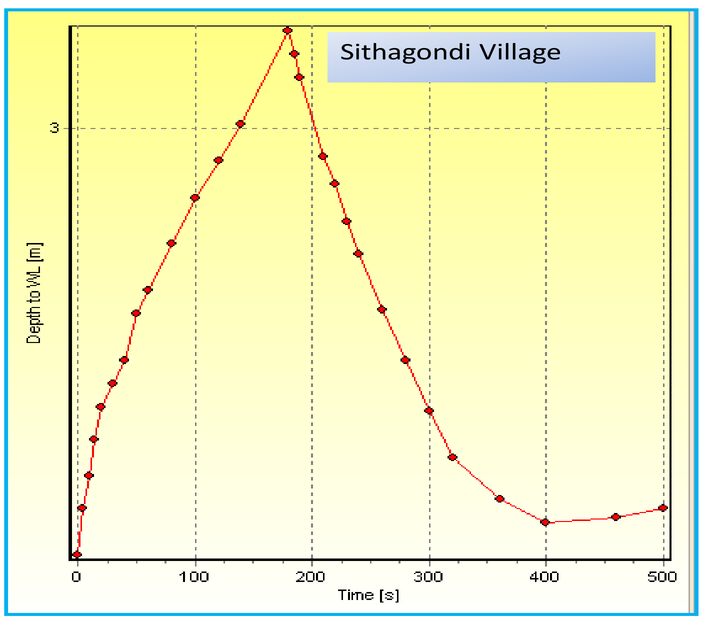
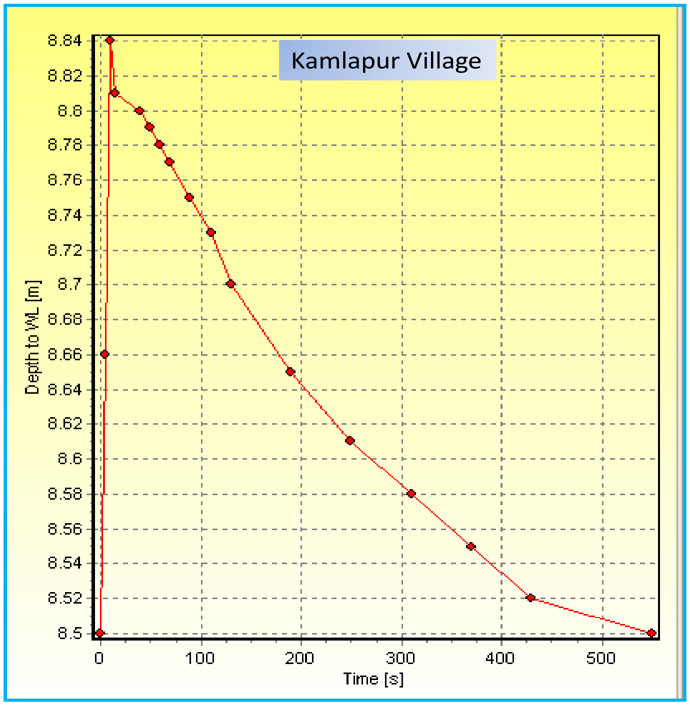


Fig: 4.7. Hydrographs of pumping wells, Mathadi vagu basin.





Fig; 4.8. Hydrographs of pumping wells, Mathadi vagu basin.



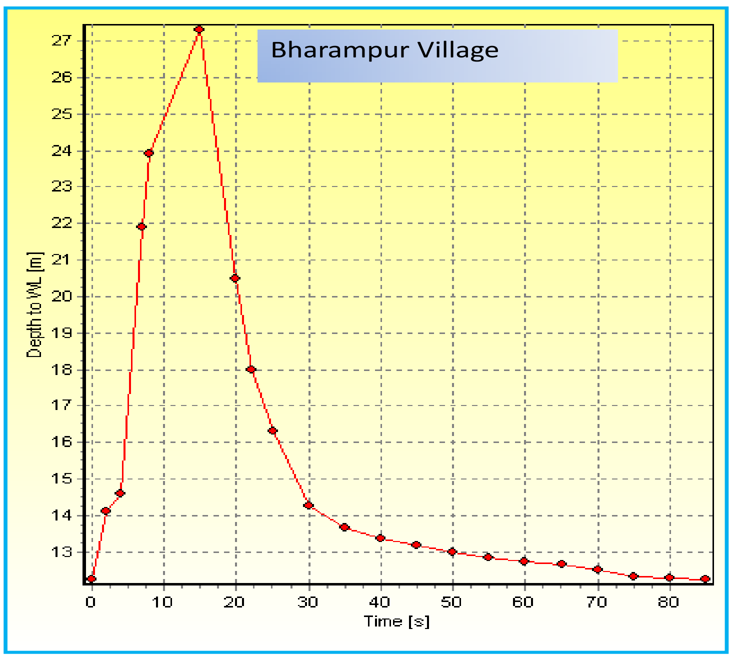


Fig: 4.9. Hydrographs of pumping wells, Mathadi vagu basin.

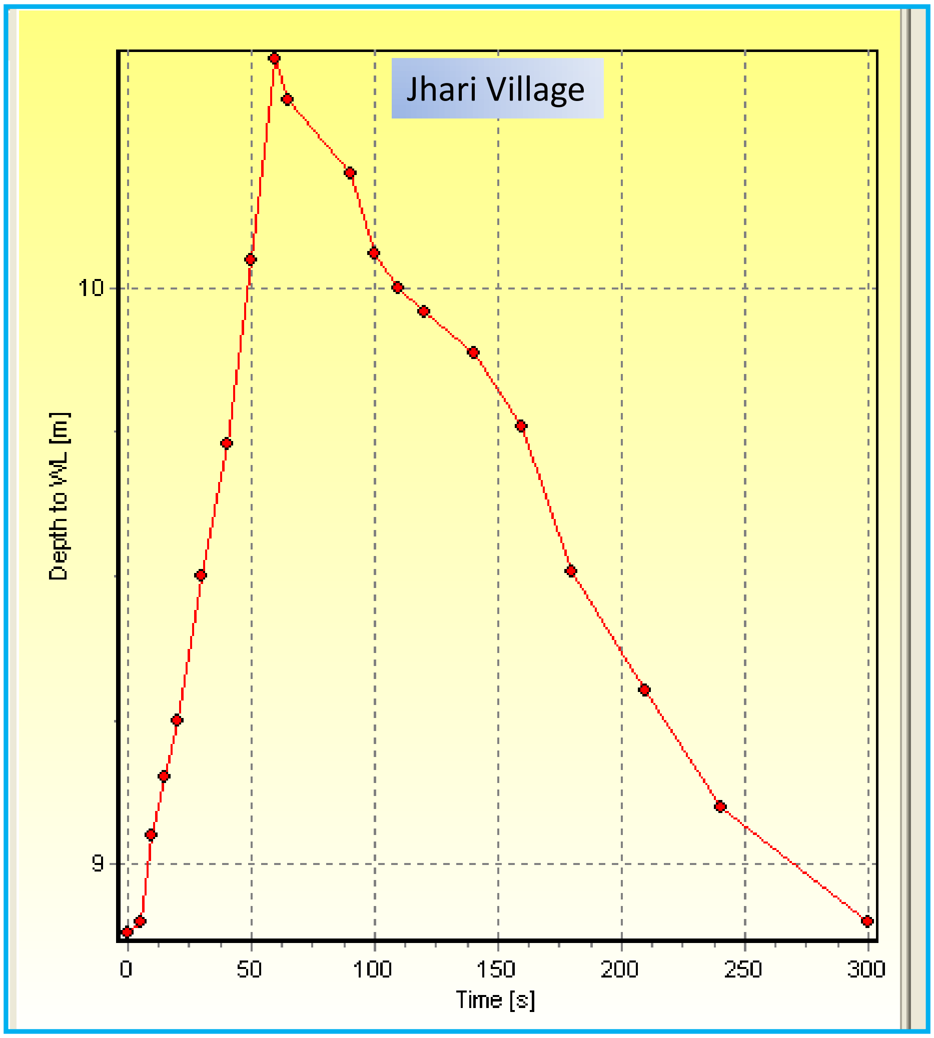
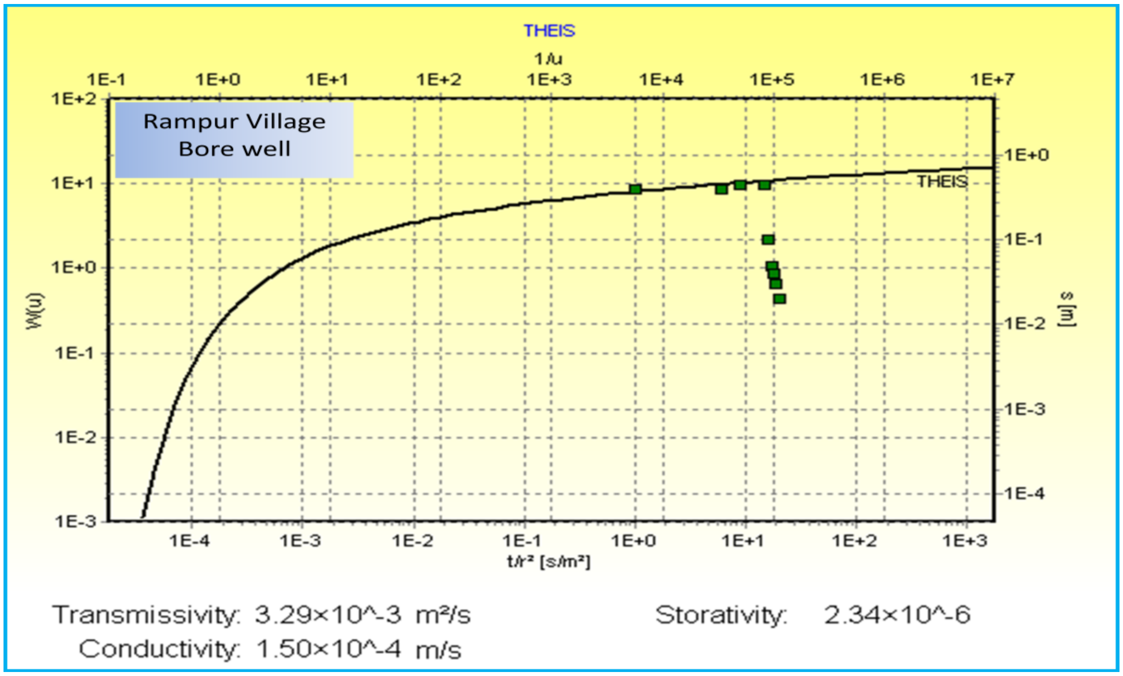


Fig: 4.10. Hydrograph of pumping wells, Mathadi vagu basin.



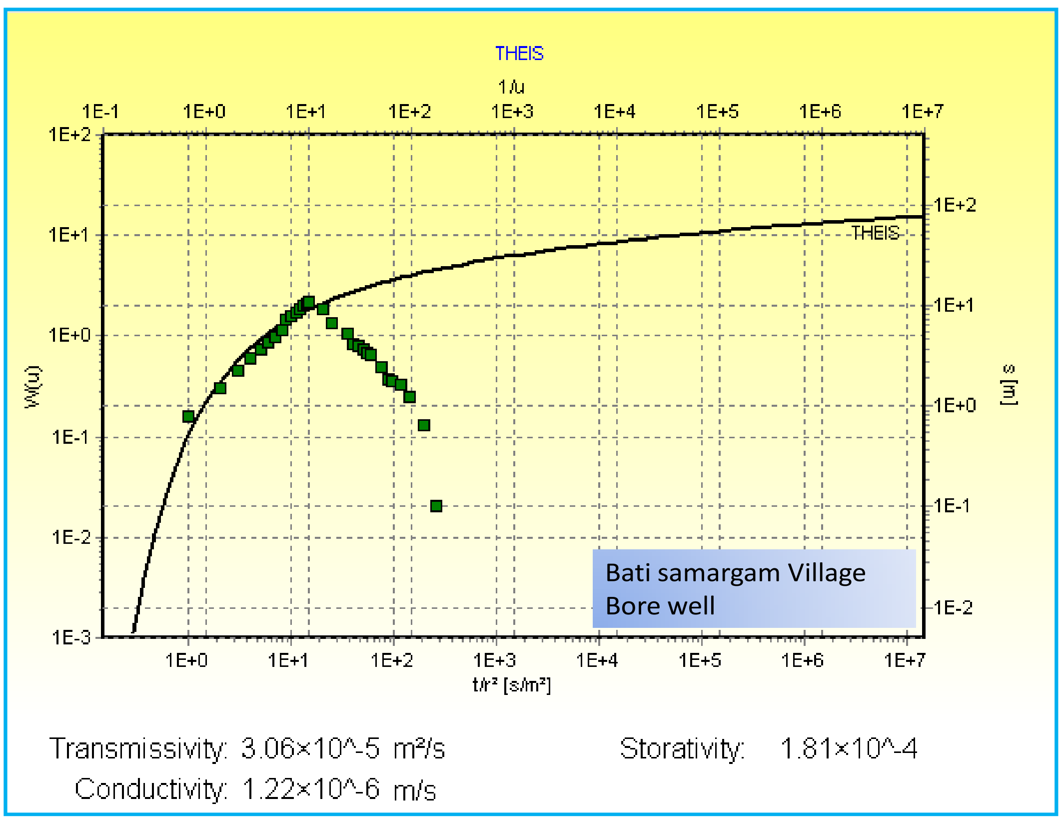
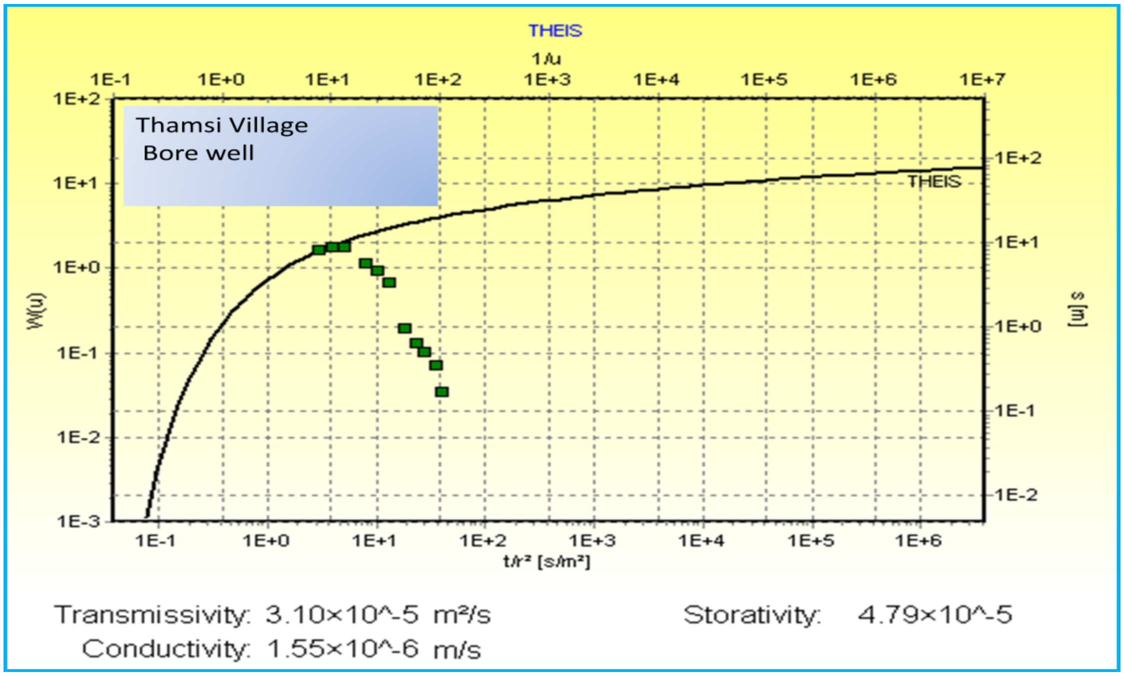
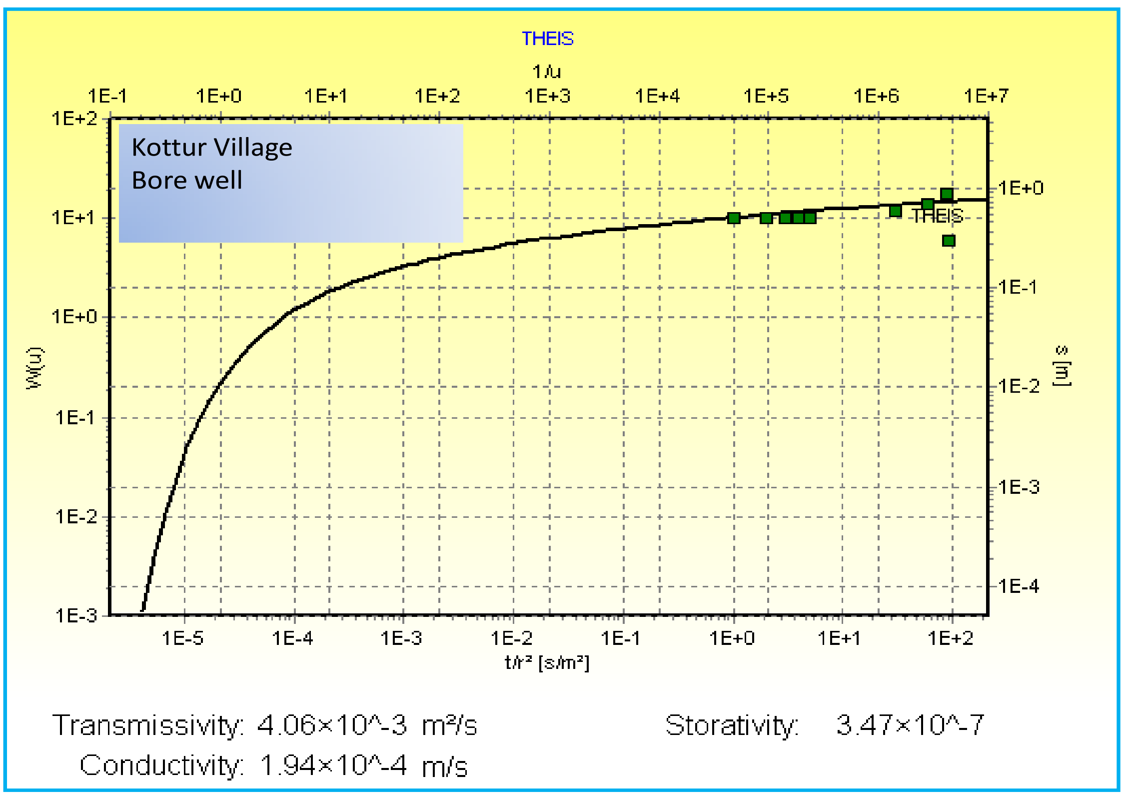
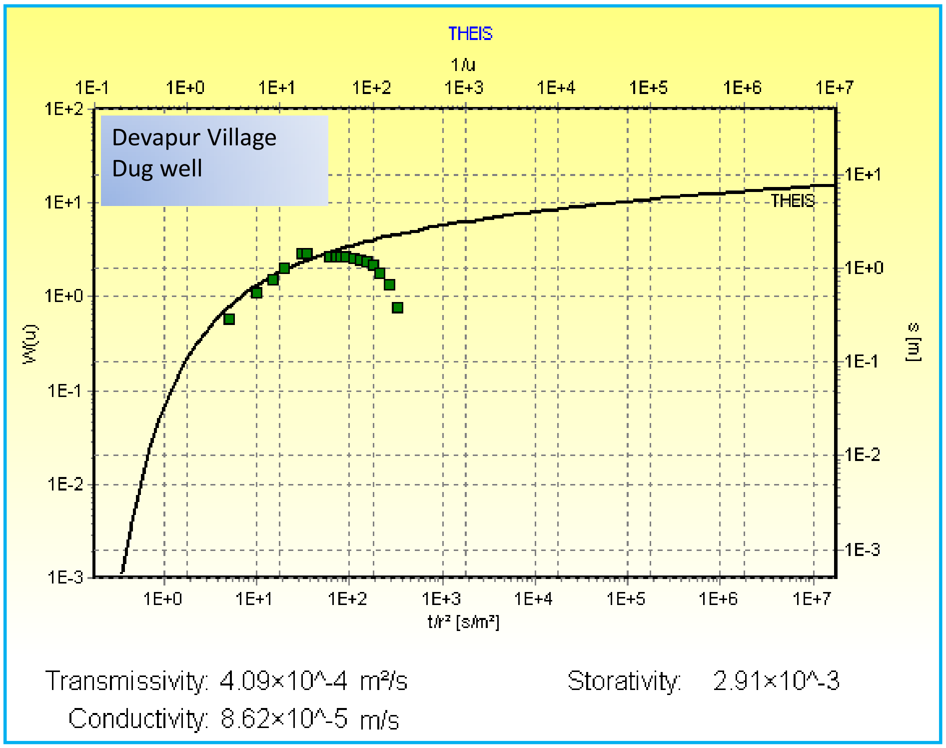


Fig:4.11 pumping well semi-log plot of time Vs drawdown (Theis Method), Mathadi vagu basin.





Fig; 4.12. Pumping well semi-log plot of time Vs drawdown (Theis Method), Mathadi vagu basin.



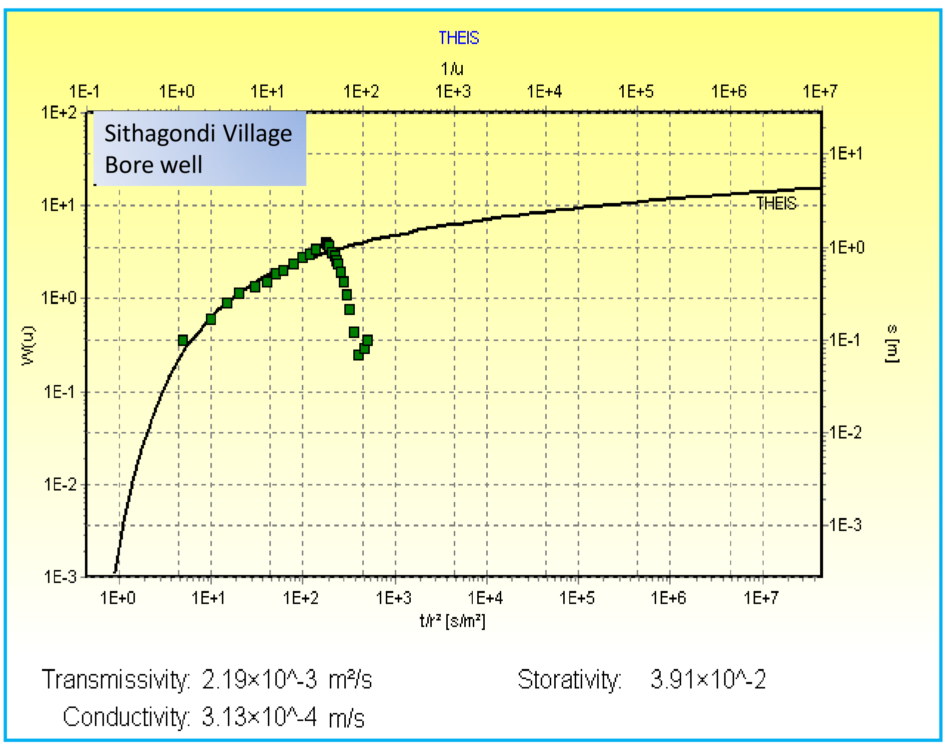


Fig: 4.13. Pumping well semi-log plot of time Vs drawdown (Theis Method), Mathadi vagu basin.

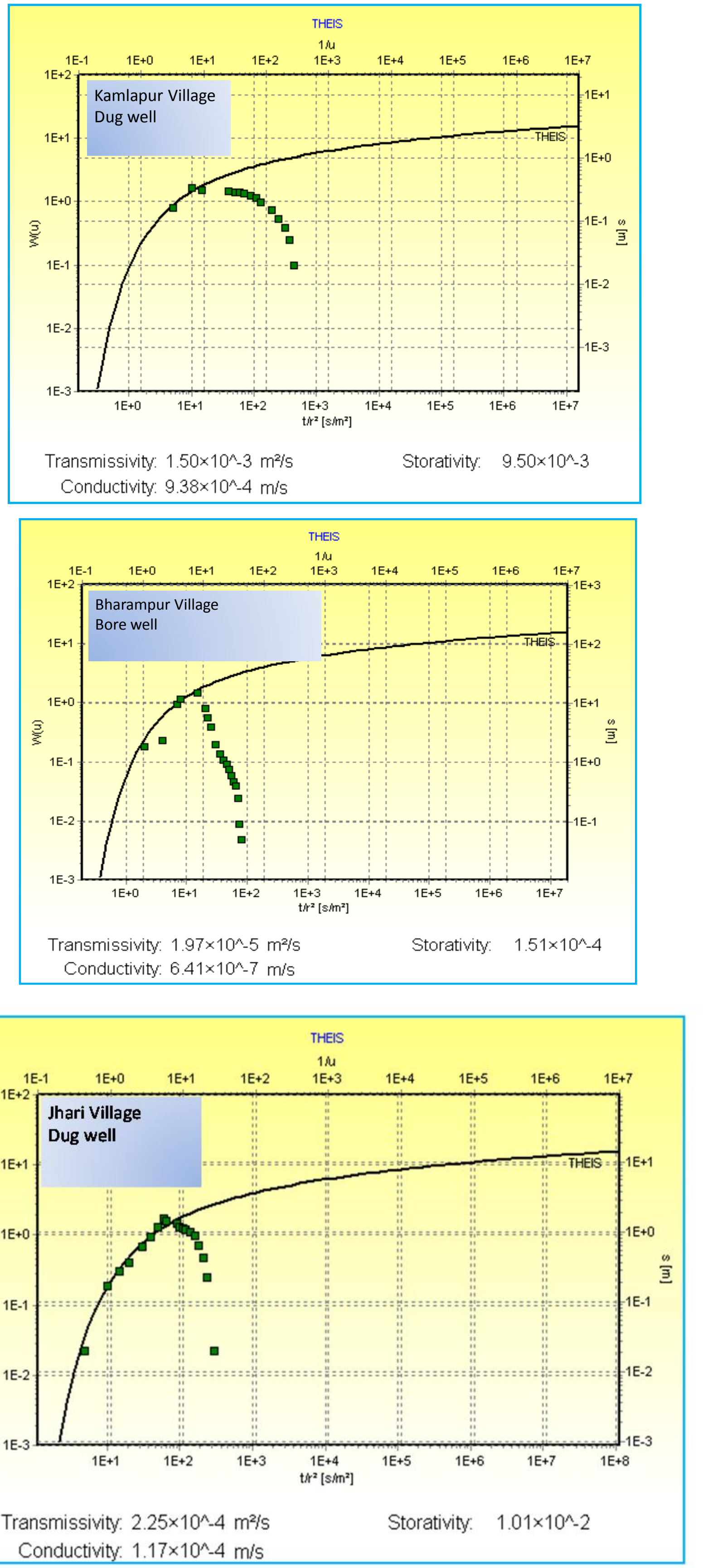


Fig: 4.14. Pumping well semi-log plot of time Vs drawdown (Theis Method), Mathadi vagu basin.

4.6. SPECIFIC CAPACITY

Specific capacity of a water well is the ratio of its discharge to drawdown (Q/St) and is usually expressed in liters per minute per meter. This is a measure of the productivity of a well. Obviously, the larger the specific capacity the better the well. It is not constant because the drawdown varies with a number of factors including the pumping time, rate of pumping, well characteristics and aquifer parameters. Specific capacity is a quantitative measure of yield of a well. In other words it is a measure of the effectiveness of a well.

High specific capacity usually indicates, a high co-efficient of transmissibility and low specific capacity a low transmissibility. It cannot be an exact yardstick of the coefficient of transmissibility because it is often affected by partial penetration, well logs and hydrogeologic boundaries. In most cases these factors adversely affect the specific capacity and actual co-efficient of transmissibility is found to be greater than the same computed from the specific capacity data. And for rough estimates of T an examination of the relation between co-efficient of transmissibility and specific capacity will be helpful, (M. Muralidhar 1988).

Specific capacity decreases with the period of pumping, because the drawdown continually increases with time as the cone of influence of the well expands. For this reason, it is important to state the duration of pumping period for which a particular value of specific capacity is computed (Walton, 1970).

Specific capacity is useful in proper designing of well. In dug wells it depends on the permeability and thickness of the aquifer tapped, cross-sectional area of the well and frictional resistance at the entrance to the well (Krupanidhi et al., 1973).

Nevertheless, wells in the same aquifer, constructed in the same way, are pumped for essentially the same period of time and essentially at the same rate, specific capacity becomes a measure of the variation in the hydraulic character of the aquifer and hence aquifer yield. Theis, Brown and Meyer (1963) relate the co-efficient of storage and transmissibility to the specific capacity, (M. Muralidhar 1988).

In hard rocks, the zone of saturation comprises, water in cracks, joints fractures or faults or along contacts between rocks of various types. As a result, the groundwater potential of the rocks depends upon the number, depth, size and degree of interconnectedness of such features. Thus the yield (and specific capacity) of dug/bore wells in these formations to a great extent depend upon the number, depth, shape, size and network of the fracture penetrated. Krupanidhi et al. (1973), Vishwanathaiah and Sastry (1978) determined the specific capacity of wells in some hard rock's of Karnataka.

According to Summers (1972) specific capacity of wells is inversely proportional to the

a. Thickness of the rock penetration below the water table
b. Depth of the wells below the land surface.

The larger yields and specific capacities of wells at shallow depths indicate that the wells intercepted a number of open fractures near the surface. Intermediate yield occur at both shallow and medium depths, because only a small number of fractures are penetrated at shallow depths, but sometimes the number of fractures penetrated increases considerably by digging/drilling deeper, (M. Muralidhar 1988).

Low yields and low specific capacity occur at all depths, when the total number of fractures penetrated is small. In such cases drilling or digging deeper will not increase the number of joints, fractures intercepted.

Obviously, if just a few fractures are penetrated at shallow depth, drilling/digging deeper will increase the number of fractures penetrated only by a small number. Therefore, deepening of wells with low specific capacities in all probability will have little or no affect on the ultimate specific capacities of the wells, (M. Muralidhar 1988).

4.7. YIELD AND DEPTH OF WELLS

Yields are related to well depths. The relationship between yield and depth in hard rocks. However, optimal depth of wells in most crystalline hard rocks is generally in the range of 15 to 30 meters.

Determination

Specific capacity is determined by constant rate or variable rate (step-drawdown) pumping test. In the former case the well is pumped at constant rate of discharge for a period of at least 7 hours and water levels are recorded at frequent intervals. In the variable rate, well Production test, the production well is operated during successive periods, usually about one hour in duration, at constant fractions of full capacity and water levels in the well are recorded at frequent intervals.

In the present studies specific capacities of dug wells have been determined to know the performance of the wells in the area, the affect of saturated thickness, the cross-sectional area and the depth of the wells on the specific capacity.

In total 9 pumping tests (4 each in granites and traps and 1 in limestone) were conducted for a period of 5 minutes to 9 hours (Table 4.2) While conducting the tests residual drawdown data of recovery phase was collected and the residual drawdown value of 255 minutes, 330 minutes, 460 minutes and 550 minutes are used for calculating average specific capacity values by using Slitcher's formula which is given as

Slitcher's formula

$$C= A/t\ 2.303 \log10\ S1/S2$$

Where C= Specific capacity of the well in cubic meters per minute for a drawdown of one meter.

A =Cross sectional area of the well in sq. meters.

T= time in minutes after pumping stopped

S1=drawdown of the water level just before pumping stopped in meters

S2=residual drawdown in meters at time't'

A convenient method for using the above, formula is to plot the ratio S1/S2 for different values of t on a semi-logarithmic graph sheet taking't' in the arithmetic scale and S1/S2 on the logarithmic scale. The best fitting straight line is drawn with the help of which a convenient value of S1/S2 and the corresponding value of't' are extrapolated. These values are substituted in the equation. The pumping tests were conducted at a time of the year when water levels were moderate and beginning to decline.

4.8. SPECIFIC CAPACITY OF THE STUDIED WELLS

The specific capacity of the wells studied range in general from 0.00586 to 0.53 m3/min/m. The yield of the wells with higher specific capacities is found to be higher. Lithologically though there are three types of formations in the area no marked difference in relationship is found in the specific capacity values.

4.9. Yield factor

The Yield factor of the wells studied range in general from 0.038 to 9.38. The low Yield factor values found in Rampur village and highest values found at Kottur village.

Formula

Yield factor =Specific capacity / Aquifer thickness

4.10. WELLS FOR THE AREA

From the field experience, it is found that both dug wells and bore wells have their own role in extracting groundwater. In the area under investigation only open wells are mostly used for agriculture. However, taking the local hydrogeological conditions into consideration suitable wells should be established so as to utilise the groundwater potential of the area to the maximum possible extent. The relative merits of dug wells and bore wells in hard rock terrain are given in table 4.1.

4.11. Summary

The results show that granitic rocks in the area are more transmissivity than the limestone area, Basaltic rocks less transmissivity than the both granitic and limestone area.

The results show that limestone rocks in the area are more Storage Co-efficient values and Specific Capacity values than the granitic rock and Basaltic rocks. The results show that granitic rocks in the area are more yield factor than the limestone and Basaltic rocks. Summary results of the tests are given in table 4.2.

Table: 4.1 Relative Merits of Dug Wells and Bore Wells in Hard Rock Terrains (Muralidhar, 1988).

Dug wells	Bore wells
Difficult to protection from pollution	Easy to protection against pollution
Require more time for constructions	Can be constructed fast
Labor intensives	Capital intensive
Pumping costs per unit volume of water are low because water is pumped from storage in the well and drawdown cannot exceed well depth	Pumping costs per unit volume of water are high because of high lifts
Wells can be pumped intermittently by centrifugal pumps, which are cheap and easy to maintain	Require submersible or jet pumps which are costly and difficult to maintain.
Water can be derived intensily to irrigated land without surface storage	Water can be derived intensily to irrigated land without surface storage
Centrifugal pumps can be electrical or disel	Submergible pumps require electrical power
Well capacity larger are	Occupy very little area
Wells may go dry during prolonged dry cycles	Less effected by seasonal fluctuations and consequently more reliable during dry cycles
Desirable for irrigation under prevailing conditions	Desirable for both irrigation and domestic uses
Can be revitalized	Revitalization is not possible
Hand or mechanical construction	Drilling equipment required

Table: 4.2 Results of aquifer performance tests in Mathadi vagu basin.

S No	Type of well	Village	Longitude	Latitude	Total Depth (m)	Initial Water level	Dia (m)	Water colum(b)	Saturated (L)	r	R	Pumping duration (minutes) **t**	Re-coupe ration (minutes)	Pumping discharge LPM
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	BW	Rampur	78.505	19.688	30	11	0.165	19	22	0.0825	0.0827	15	5	115
2	BW	Battisamarg am	78.5044	19.658	40	17.50	0.165	22.50	25.0	0.0825	0.0827	15	240	115
3	BW	Thamsi	78.2735	19.433	30	6.20	0.165	23.8	20.00	0.0825	0.0827	5	43	115
4	DW	Devapur	78.461	19.658	12	7.85	1.20	4.15	4.75	0.60	1.00	30	300	153
5	BW	Kottur	78.401	19.64	30	12.20	0.165	5.60	21.0	0.0825	0.0827	90	5	153
6	DW	Sithagondi	78.2949	19.3442	5	2.08	6.50	2.92	2.60	3.25	3.31	180	320	460
7	DW	Kamlapur	78.2903	19.3506	9.60	8.50	3.20	1.10	1.60	1.60	2.10	10	540	230
8	BW	Bharampur	78.2735	19.4330	40	12.25	0.165	27.75	30.75	0.0825	0.0827	15	70	153
9	DW	Jhari	78.2154	19.36499	10.80	8.88	2.10	1.92	1.92	1.05	1.65	60	240	153

S. No	M^3/sec	Draw down phase		Recovery phase		Transmissivity m2/sec (Theis Methad)	Storativity(Theis Method)	Conductivity m/se (Theis Methad)	Specific Capacity M^3/min/m	Yield factor	Aquifer
		Time (minutes)	Draw down (**m**)	Time (minute**s)**	Residual Draw down (**m**)						
	16	17		18		19	20	21	22	23	24
1	0.0019166	15	0.50	5	0.02	$3.29x10^{-3}$	$2.34x10^{-6}$	$1.50x10^{-4}$	0.25	0.010	Weathered Limestone
2	0.0019166	15	11.06	240	0.06	$3.06x10^{-5}$	$1.81x10^{-4}$	$1.22x10^{-6}$	0.047	2.69	Weathered Granites
3	0.0019166	4	8.90	43	0	$3.10x10^{-5}$	$1.55x10^{-6}$	$4.79x10^{-5}$	0.013	5.48	Weathered Granites
4	0.0025500	30	1.45	30	1.45	$4.06x10^{-3}$	$3.47x10^{-7}$	$1.94x10^{-4}$	0.00586	0.0038	Weathered Granites
5	0.0025500	60	0.90	5	0	$4.09x10^{-4}$	$2.91x10^{-3}$	$8.662x10^{-5}$	0.167	9.38	Weathered Granites
6	0.0076666	180	1.13	320	0.02	$2.19x10^{-3}$	$3.91x10^{-2}$	$3.13x10^{-4}$	0.53	0.181	Weathered Deccan traps
7	0.0038333	10	0.34	540	0	$1.50x10^{-3}$	$9.50x10^{-3}$	$9.38x10^{-4}$	0.055	0.09	Weathered Deccan traps
8	0.0025500	15	15.05	70	0.05	$1.97x10^{-5}$	$1.51x10^{-4}$	$6.40x10^{-7}$	0.010	4.39	Weathered Deccan traps
9	0.0025500	60	1.52	240	0.02	$2.25x10^{-4}$	$1.01x10^{-2}$	$1.17x10^{-4}$	0.0234	0.0122	Weathered Deccan traps

Table: 4.3 Pumping test for aquifer performance study in Rampur (v), Adilabad (M)

1	Village		:	Rampur
2	Mondal		:	Adilabad
3	Geographic Co-ordinates	North Latitude	:	19.688
		East Longitude	:	78.505
4	Geology of the area		:	Granites and gneisses
5	Type of well		:	Bore well
6	Diameter of the well in mm		:	165
7	Depth of pumping well in m		:	35
8	Static water level in m. bmp		:	11.00
9	Measuring point in mgl		:	0.4
10	Pumping discharge in Ipm		:	115
11	Pumping discharge in m^3/ day			165

Pumping test data

	Time in hours	Time since pumping started **t** in minutes	Water level in **m** bmp	Drawdown in **m (S)**	Discharge **Q** in lpm	
	1	2	3	4	5	
Pumping phase	08.00	0	11.00	0	115	
		1	11.40	0.40		
		2				
		3				
		4				
		5				
		6	11.40	0.40	115	
		7				
		8				
		9	11.45	0.45		
		10				
		11				
		12				
		13				
		14			115	
		15	11.45	0.45	Pump stopped	
				Residual D D(s_2)	t^1 *	t/t^1
Recuperation phase		15	11.45	0.00	0	0.00
		16	11.10	0.10	1	16.00
		17	11.05	0.05	2	8.50
		18	11.04	0.04	3	6.00
		19	11.03	0.03	4	4.75
		20	11.02	0.02	5	4.00
* t^1 Time since pump stopped						

Table: 4.4 Pumping test for aquifer performance study in Battisamargam (v), Adilabad (m) Adilabad district.

1	Village		:	Battisamargam
2	Mondal		:	Adilabad
3	Geographic Co-ordinates	North Latitude	:	19.658
		East Longitude	:	78.5044
4	Geology of the area		:	Granites and gneisses
5	Type of well		:	Bore well
6	Diameter of the well in mm		:	165
7	Depth of pumping well in m		:	35
8	Static water level in m. bmp		:	17.54
9	Measuring point in mgl		:	0.6
10	Pumping discharge in lpm		:	153
11	Pumping discharge in m^3/ day			220

Pumping test data

	Time in hours	Time since pumping started **t** in minutes	Water level in **m** bmp	Drawdown in **m** **(S)**	Discharge **Q** in lpm	
	1	2	3	4	5	
Pumping phase	08.00	0	17.54	0	153	
		1	18.30	0.75		
		2	19.00	1.46		
		3	19.78	2.24		
		4	20.45	2.91		
		5	21.15	3.16	153	
		6	21.85	4.13		
		7	22.40	4.86		
		8	23.10	5.56		
		9	24.80	6.46		
		10	25.30	7.70		
		11	26.15	8.61		
		12	26.90	9.36	153	
		13	27.60	10.06		
		14	28.10	10.56		
	08.15	15	28.60	11.06	Pump stopped	
				Residual D D(s_2)	t^1 *	t/t^1
Recuperation phase		15	28.60	0.00	0	0.00
		20	26.70	9.16	5	4.00
		25	24.30	6.76	10	2.50
		35	22.83	5.29	20	1.75
		40	21.65	4.15	25	1.60
		45	21.45	3.91	30	1.50
		50	21.20	3.66	35	1.43
		55	20.95	3.41	40	1.38
		60	20.72	3.18	45	1.33
		75	20.00	2.46	60	1.25
		90	19.36	1.82	75	1.20
		95	19.26	1.72	80	1.19
		115	19.16	1.52	100	1.15
		145	18.75	1.62	130	1.12
		195	18.15	1.21	180	1.08
		255	17.60	0.61	240	1.06
* t^1 Time since pump stopped						

Table: 4.5 Pumping test for aquifer performance study in Thamsi (v), Adilabad (m) Adilabad district.

1	Village		:	Thamsi
2	Mandal		:	Thamsi
3	Geographic Co-ordinates	North Latitude	:	19.433
		East Longitude	:	78.2735
4	Geology of the area		:	Granite and gneisses
5	Type of well		:	Bore well
6	Diameter of the well in mm		:	165
7	Depth of pumping well in m		:	30
8	Static water level in m. bmp		:	6.28
9	Measuring point in mgl		:	0.5
10	Pumping discharge in lpm		:	115
11	Pumping discharge in m^3/ day			165

Pumping test data

	Time in hours	Time since pumping started **t** in minutes	Water level in **m** bmp	Drawdown in **m (S)**	Discharge **Q** in lpm	
	1	2	3	4	5	
Pumping phase	08.00	0	6.20	0.00	115	
		1	8.00	1.80		
		2				
		3	14.30	8.10		
		4	15.10	8.90	115	
		5	15.10	8.90		
					Pump stopped	
				Residual D D(s_2)	t^1 *	t/t^1
Recuperation phase		5	15.10	**0.00**	0	0.00
		8	11.80	5.60	3	2.66
		10	10.80	4.60	5	2.00
		13	9.50	3.30	8	1.62
		18	7.15	0.95	15	1.20
		23	6.83	0.63	20	1.15
		28	6.70	0.50	25	1.12
		35	6.55	0.35	30	1.16
		40	6.37	0.11	35	1.14
		48	6.20	0.00	43	1.11
* t^1 Time since pump stopped						

Table: 4.6 Pumping test for aquifer performance study in Devapur (v), Thalamadugu (m) Adilabad district.

1	Village		:	Devapur
2	Mondal		:	Thalamadugu
3	Geographic Co-ordinates	North Latitude	:	19.658
		East Longitude	:	78.461
4	Geology of the area		:	Deccan traps
5	Type of well		:	Dug well
6	Diameter of the well in m		:	1.20
7	Depth of pumping well in m		:	10.50
8	Static water level in m. bmp		:	7.85
9	Measuring point in mgl		:	0.60
10	Pumping discharge in lpm		:	153
11	Pumping discharge in m^3/ day			220

Pumping test data

	Time in hours	Time since pumping started **t** in minutes	Water level in **m** bmp	Drawdown in **m** **(S)**	Discharge **Q** in lpm	
	1	2	3	4	5	
Pumping phase	08.00	0	7.78	0.00	153	
		5	8.14	0.36		
		10	8.40	0.62		
		15	8.60	0.82		
		20	8.85	1.07		
		30	9.30	1.52	153	
					Pump stopped	
				Residual D D(s_2)	t^1 *	t/t^1
Recuperation phase		30	9.30	0.00	0	0.00
		35	9.28	1.50	5	7.00
		60	9.20	1.42	30	2.00
		70	9.20	1.42	40	1.75
		80	9.18	1.40	50	1.60
		90	9.16	1.38	60	1.50
		110	9.10	1.32	80	1.38
		130	9.05	1.27	100	1.30
		150	9.02	1.24	120	1.25
		180	8.95	1.17	150	1.20
		210	8.72	0.94	180	1.17
		270	8.52	0.74	240	1.13
		330	8.23	0.45	300	1.10
* t^1 Time since pump stopped						

Table: 4.7 Pumping test for aquifer performance study in Kottur **(v), Thalamadugu (m) Adilabad district.**

1	Village		:	Kottur
2	Mondal		:	Thalamadugu
3	Geographic Co-ordinates	North Latitude	:	19.64
		East Longitude	:	78.401
4	Geology of the area		:	Granite and gneisses
5	Type of well		:	Bore well
6	Diameter of the well in mm		:	165
7	Depth of pumping well in m		:	30
8	Static water level in m. bmp		:	12.20
9	Measuring point in mgl		:	0.5
10	Pumping discharge in lpm		:	151
11	Pumping discharge in m^3/ day			220

Pumping test data

	Time in hours	Time since pumping started **t** in minutes	Water level in **m** bmp	Drawdown in **m** **(S)**	Discharge **Q** in lpm	
	1	2	3	4	5	
Pumping phase	08.00	0	12.20	0.0	153	
		1	12.70	0.50		
		2	12.70	0.50		
		3	12.70	0.50		
		4	12.70	0.50		
		5	12.70	0.50		
		30	12.80	0.60	153	
		60	12.90	0.70		
		90	13.10	0.90		
					Pump stopped	
				Residual D D(s_2)	t^1 *	t/t^1
Recuperation phase		90	13.10	0.00	0	0.00
		93	12.50	0.20	3	31.0
		95	12.20	0.00	5	
* t^1 Time since pump stopped						

Table: 4.8 Pumping test for aquifer performance study in Sithagondi (v), Gudihathnoor (m) Adilabad district.

1	Village		:	Sithagondi
2	Mondal		:	Gudihathnoor
3	Geographic Co-ordinates	North Latitude	:	19.3442
		East Longitude	:	78.2949
4	Geology of the area		:	Deccan traps
5	Type of well		:	Dug well
6	Diameter of the well in m		:	6.50
7	Depth of pumping well in m		:	5.00
8	Static water level in m. bmp		:	2.08
9	Measuring point in mgl		:	0.10
10	Pumping discharge in lpm		:	460
11	Pumping discharge in m^3/ day			661

Pumping test data

	Time in hours	Time since pumping started **t** in minutes	Water level in **m** bmp	Drawdown in **m** **(S)**	Discharge **Q** in lpm	
	1	2	3	4	5	
Pumping phase	08.00	0	2.08	0.00	460	
		5	2.18	0.10		
		10	2.25	0.17		
		15	2.33	0.25		
		20	2.40	0.32	460	
		30	2.45	0.37		
		40	2.50	0.42		
		50	2.60	0.52		
		60	2.65	0.57		
		80	2.75	0.67	460	
		100	2.85	0.77		
		120	2.93	0.85		
		140	3.01	0.93		
		180	3.21	1.13	460	
					Pump stopped	
				Residual D D(s_2)	t^1 *	t/t^1
Recuperation phase		180	3.21	0.00	0	0.00
		185	3.16	0.08	5	37.00
		190	3.11	1.03	10	19.00
		210	2.94	0.88	30	7.00
		220	2.88	0.80	40	5.50
		230	2.80	0.72	50	4.60
		240	2.73	0.65	60	4.00
		260	2.61	0.53	80	3.25
		280	2.50	0.42	100	2.80
		300	2.39	0.31	120	2.50
		320	2.29	0.21	140	2.29
		360	2.20	0.13	180	2.00
		400	2.15	0.07	220	1.82
		460	2.16	0.03	280	1.64
		500	2.18	0.02	320	1.56
* t^1 Time since pump stopped						

Table: 4.9 Pumping test for aquifer performance study in Kamlapur (v), Gudihathnoor (m) Adilabad district.

1	Village		:	Kamlapur
2	Mondal		:	Gudihathnoor
3	Geographic Co-ordinates	North Latitude	:	19.3506
		East Longitude	:	78.2903
4	Geology of the area		:	Deccan traps
5	Type of well		:	Dug well
6	Diameter of the well in m		:	3.20
7	Depth of pumping well in m		:	9.60
8	Static water level in m. bmp		:	8.50
9	Measuring point in mgl		:	0.0
10	Pumping discharge in lpm		:	230
11	Pumping discharge in m^3/ day			330

Pumping test data

	Time in hours	Time since pumping started **t** in minutes	Water level in **m** bmp	Drawdown in **m** **(S)**	Discharge **Q** in lpm	
	1	2	3	4	5	
Pumping phase	08.00	0	8.50	0.00	230	
		5	8.66	0.16		
		10	8.84	0.34		
					Pump stopped	
				Residual D D(s_2)	t^1 *	t/t^1
Recuperation phase		10	8.84	0.00	0	0.00
		15	8.81	0.31	5	3.00
		40	8.80	0.30	30	1.33
		50	8.79	0.29	40	1.25
		60	8.78	0.28	50	1.20
		70	8.77	0.27	60	1.17
		90	8.75	0.25	80	1.13
		110	8.73	0.23	100	1.10
		130	8.70	0.20	120	1.08
		190	8.65	0.15	180	1.06
		250	8.61	0.11	240	1.04
		310	8.58	0.08	300	1.03
		370	8.55	0.05	360	1.03
		430	8.52	0.02	420	1.02
		550	8.50	0.00	540	1.02
* t^1 Time since pump stopped						

Table: 4.10 Pumping test for aquifer performance study in Bharampur (v), Thalamadugu (m) Adilabad district.

1	Village		:	Bharampur
2	Mandal		:	Thalamadugu
3	Geographic Co-ordinates	North Latitude	:	19.4330
		East Longitude	:	78.2735
4	Geology of the area		:	Deccan traps
5	Type of well		:	Bore well
6	Diameter of the well in mm		:	165
7	Depth of pumping well in m		:	35
8	Static water level in m. bmp		:	12.25
9	Measuring point in mgl		:	0.5
10	Pumping discharge in lpm		:	151
11	Pumping discharge in m^3/ day			220

Pumping test data

	Time in hours	Time since pumping started **t** in minutes	Water level in **m** bmp	Drawdown in **m** **(S1)**	Discharge **Q** in lpm	
	1	2	3	4	5	
Pumping phase	08.00	0	12.25	0.00	153	
		1				
		2	14.10	1.85		
		3				
		4	14.60	2.35		
		5			153	
		6				
		7	21.89	9.64		
		8	23.90	11.65		
		9				
		10			153	
		11				
		12				
		13				
		14				
	08.15	15	27.30	15.05	Pump stopped	
				Residual D D(s_2)	t [1] *	t/t[1]
Recuperation phase		15	27.30	0.00	0	0.00
		20	20.50	8.25	5	4.00
		22	18.00	5.75	7	3.14
		25	16.30	4.05	10	2.50
		30	14.25	2.00	15	2.00
		35	13.65	1.40	20	1.75
		40	13.35	1.10	25	1.60
		45	13.17	0.92	30	1.50
		50	13.00	0.75	35	1.43
		55	12.85	0.60	40	1.38
		60	12.73	0.48	45	1.33
		65	12.65	0.40	50	1.30
		70	12.50	0.25	55	1.27
		75	12.34	0.09	60	1.25
		80	12.30	0.05	65	1.23
		85	12.25	0.04	70	1.21
* t [1] Time since pump stopped						

Table: 4.11 Pumping test for aquifer performance study in Jhari (v), Thalamadugu (m) Adilabad district.

1	Village		:	Jhari
2	Mandal		:	Thalamadugu
3	Geographic Co-ordinates	North Latitude	:	19.36499
		East Longitude	:	78.2154
4	Geology of the area		:	Deccan traps
5	Type of well		:	Dug well
6	Diameter of the well in m		:	2.10
7	Depth of pumping well in m		:	10.80
8	Static water level in m. bmp		:	8.88
9	Measuring point in mgl		:	0.60
10	Pumping discharge in lpm		:	150
11	Pumping discharge in m^3/ day			220

Pumping test data

	Time in hours	Time since pumping started **t** in minutes	Water level in **m** bmp	Drawdown in **m** **(S)**	Discharge **Q** in lpm	
	1	2	3	4	5	
Pumping phase	08.00	0	8.88	0.00	153	
		5	8.90	0.02		
		10	9.05	0.17		
		15	9.15	0.27		
		20	9.25	0.37	153	
		30	9.50	0.62		
		40	9.73	0.85		
		50	10.05	1.17		
		60	10.40	1.52	153	
					Pump stopped	
				Residual D D(s2)	t^1 *	t/t^1
Recuperation phase		60	10.40	0.00	0	0.00
		65	10.33	1.45	5	13.00
		90	10.20	1.32	30	3.00
		100	10.06	1.18	40	2.50
		110	10.00	1.12	50	2.20
		120	9.96	1.08	60	2.00
		140	9.89	1.01	80	1.75
		160	9.76	0.88	100	1.60
		180	9.51	0.63	120	1.50
		210	9.30	0.42	150	1.40
		240	9.10	0.22	180	1.33
		300	8.90	0.02	240	1.25
* t^1 Time since pump stopped						

CHAPTER- 5
GEOPHYSICAL INVESTIGATIONS

5.1. Introduction

Electrical resistivity methods of geophysical prospecting are well established are the most important methods for groundwater investigations. The electrical resistivity method is one that has been widely used because of the theoretical, operational and interpretational ease. The advantages of electrical methods also include control over depth of investigation, portability of the equipment, availability of wide range of simple and elegant interpretation techniques, and the related software etc. Direct current (D.C.) resistivity (electrical resistivity) techniques measure earth resistivity by driving a D.C. signal into the ground and measuring the resulting potentials (voltages) created in the earth. From the data obtained, the electrical properties of the earth (the geoelectric section) can be derived. In turn from those electrical properties we can infer the geological characteristics of the earth.

In geophysical and geotechnical literature, the terms "electrical resistivity" and 'D.C. resistivity" are used synonymously. Several geological parameters which affect earth resistivity (and its reciprocal, conductivity) include clay content, soil or formation porosity, and degree of water saturation.

The theory and practice of this method for groundwater investigations is well documented. The interpretation of resistivity data and its application to groundwater studies has been given in detail by Zohdy (1965 and 1975). D.C. resistivity techniques may be used in the profiling mode (Wenner surveys) to map lateral changes and identify near-vertical features or they may be used in the sounding mode (Schlumberger array) to determine depths to geoelectric horizons (Ex. depth to saline groundwater). Both profiling and vertical electrical sounding (VES) has been successfully applied to various geological formations. Common applications of the D.C. resistivity method include, delineation of aggregate deposits for quarry operations, estimating depth to water table and bed rock or to other geoelectric boundaries, and mapping and/or detecting other geologic features (Verma et al. 1980).

5.2. Electrical properties of geological formation

The electrical resistivity of a geological formation is physical characteristic, determines the flow of electric current in the formation. Resistivity varies with texture of the rock, nature of mineralization and conductivity of electrolyte contained within the rock. Resistivity not only changes from formation to formation but even within a particular formation (Sharma 1997). Resistivity increases with grain size and tends to maximum when the grains are coarse (Sharma and Rao 1962), also when the rock is fine grained and compact. The resistivity drastically reduces with increase in clay content and which are commonly dispersed through out as coatings on grains or disseminated masses or as thin layers or lenses. In saturated rocks low resistivity can be due to increased clay content or salinity. Hence the resistivity surveys are the best suited for delineation of clay zone.

Further, combining resistivity data with in situ total dissolved solids (TDS) or electrical conductivity measurements in wells can help identify shallow contaminated zones. A combination of hydrogeological, geophysical and geochemical investigations can be very effective in the detection of contaminant migration, (Sankaran et a1. 2005).

5.3. Electrical Resistivity Method

In resistivity method of electrical prospecting an electric field is artificially created in the ground by means of either galvanic batteries (DC) or low frequency AC generators. The energizing current is sent in to the ground by means of two grounded electrodes, called the current electrodes designated as 'A' and 'B' placed at two selected points. The potential in the area is measured by another two more grounded electrodes called the potential electrodes designated as 'M and' N'. Electrical resistivity is defined as the resistance offered by a unit cube of material for the flow of current through its normal surface. If 'L' is the length of the conductor and 'A' is its cross-sectional area, then the resistance (R) is defined as

$$\mathbf{R=\rho\ L/A}$$

Where ρ is constant of proportionality and is called resistivity. In MKS system the unit of resistivity is Ohm-meter (Ω-m).

5.3.1. Apparent resistivity

For a homogeneous and isotropic conducting medium ρ is independent of the position of electrodes on the surface and electrode configuration while measuring the potential difference between any two points in a four electrode array comprising a pair of current and potential electrodes. Hence it is designated as true resistivity of the medium (Sharma 1997).

For heterogeneous medium the resistivity is called the apparent resistivity. The apparent resistivity of geologic formation is equal to the true resistivity of fictitious homogeneous and isotropic medium in which, for a given electrode configuration and current strength, I, the measured potential difference ΔV is equal to that for the given heterogeneous and anisotropic medium. The apparent resistivity depends upon the geometry and resistivity of the elements constituting the given geologic medium. Thus

$$\rho_a = K(\Delta V/I)$$

where K is the geometrical factor having the dimension of length (m). Resistivity of rock formations varies over a wide range; depending on mineral constituents of rock, density, porosity, pore size and shape, water content, quality of water and temperature. There is no fixed limit for resistivity of various rocks; igneous and metamorphic rocks yield values in the range of 10^{2} to 10^{8} Ω-m; sedimentary and unconsolidated rocks vary between 1 to 10^{4} Ω-m.

5.3.2. Resistivity measurements

Generally for measuring the resistivities of the subsurface formations, four electrodes namely two current electrodes A and B and two potential electrodes M and N are required. There are different electrode arrangements for measuring the potential difference, which are uniquely used for different purposes in exploration techniques (Keller and Frishknecht, 1966). The most popular among them are Wenner (1915) and Schlumberger (1920).

5.3.3. Schlumberger array

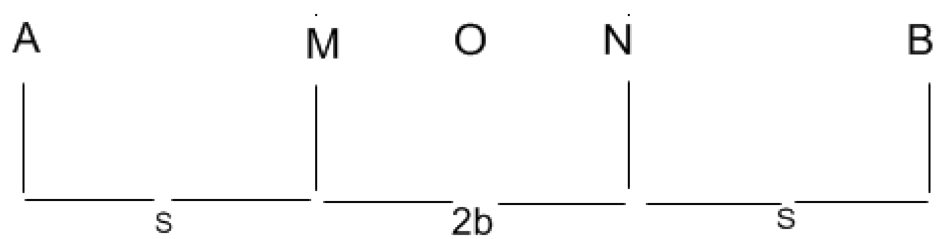
The Schlumberger array, consist of four co-linear point electrodes to measure the potential gradient at the midpoint. In this array the current electrodes and potential electrodes are spaced in the ratio of 1:5 and the geometrical factor K for this array is given by:

$$\mathbf{K = \pi \{(AB/2)^2-(MN/2)^2\}/MN}$$

$$\mathbf{(i.\,e.)\ K = \pi (S^2 - b^2)/2b}$$

Apparent resistivity ρa is calculated as $\rho_a = K\ (\Delta\ V/I)$

Where, s = half spacing of current electrodes and b = half spacing of potential electrodes.



Where s ≥ 5b

The above sketch is the schematic representation Of Schlumberger electrod configuration, when AM = MN = NB = s, results the Wenner configuration.

5.4 Vertical electrical sounding (VES)

Resistivity sounding is the study of resistivity variation with depth for a fixed center i.e. vertical investigations of subsurface geological layers. It is also called as vertical electrical sounding (VES). This method gives the information about depth and thickness of various subsurface layers and their potential for groundwater exploitation.

Since the fraction of total current flows at a depth varies with the current electrodes separations the field procedure is to use a fixed center with an expanding spread. The Wenner and Schlumberger arrays are particularly suited to this technique, wherein Schlumberger array has some specific advantages. There are always some naturally developing potential (self-potential, SP) in the ground, which have to be eliminated and nullified. Thus, in such electrode configuration, the potential difference for a selected value of AB/2 is measured and in turn the restivities are obtained. The resistivities are plotted against AB/2 on a double log graph.

A log-log plot of the apparent resistivity versus current electrode spacing (AB/2) is commonly referred to as the "sounding curve". Resistivity data is generally interpreted using the "modeling" process. A hypothetical model of the earth and its resistivity structure (geoelectric section) is generated. The theoretical electrical resistivity response over that model is then calculated. The theoretical response is then compared with the observed field response. The differences between the observed and the calculated are then adjusted to create a response which very closely fits the observed data. When this iterative process is automated it is referred to as "iterative inversion" or "optimization".

The end product from a D.C. resistivity surveyor VES is generally a "geoelectric" cross section showing thickness and resistivities of all the geoelectric units or layers. If borehole data or a conceptual geologic model is available, then a geologic identity can be assigned to the geoelectric units.

5.5 Field investigations

In general, electrical investigations particularly vertical electrical sounding., some of the significant applications are lateral differentiation of permeable formations from impermeable or less permeable formations and vertical distribution of various layers. Deciphering the silt, sand and clay zone thickness and the high conductive and water quality data.

A total of 30 vertical electrical soundings (VES) were carried out at selected locations (fig:5.1) within the Mathadivagu basin in order to decipher the subsurface conditions. The VES were carried out using a D.C Resistivity meter wherein the current and potential readings are displayed for calculating the resistance. Cast iron stakes as current electrodes and carbon filled porous pots as potential electrodes were used to improve the ground contact. The entire VESs were carried out with a maximum current electrode separation (AB/2) as 100 to 120 m covering the entire Mathadi vagu basin.

5.6 Interpretation procedures

5.6.1. Vertical electrical sounding (VES)

There are four basic type of sounding curves depending on the resistivity distribution with depth. If ρ_1, ρ_2 and ρ_3 are the resistivity of the subsurface layers With $\boldsymbol{\rho_1}$ at the top followed by ρ_2 and ρ_3 then,

i. **ρ1 < ρ2 < ρ3** is defined as A-type

ii. **ρ1 <ρ2 > ρ3** is defined as K-type

iii. **ρ1 > ρ2 < ρ3** is defined as H-type

iv. **ρ1 > ρ2 > ρ3** is defined as Q-type

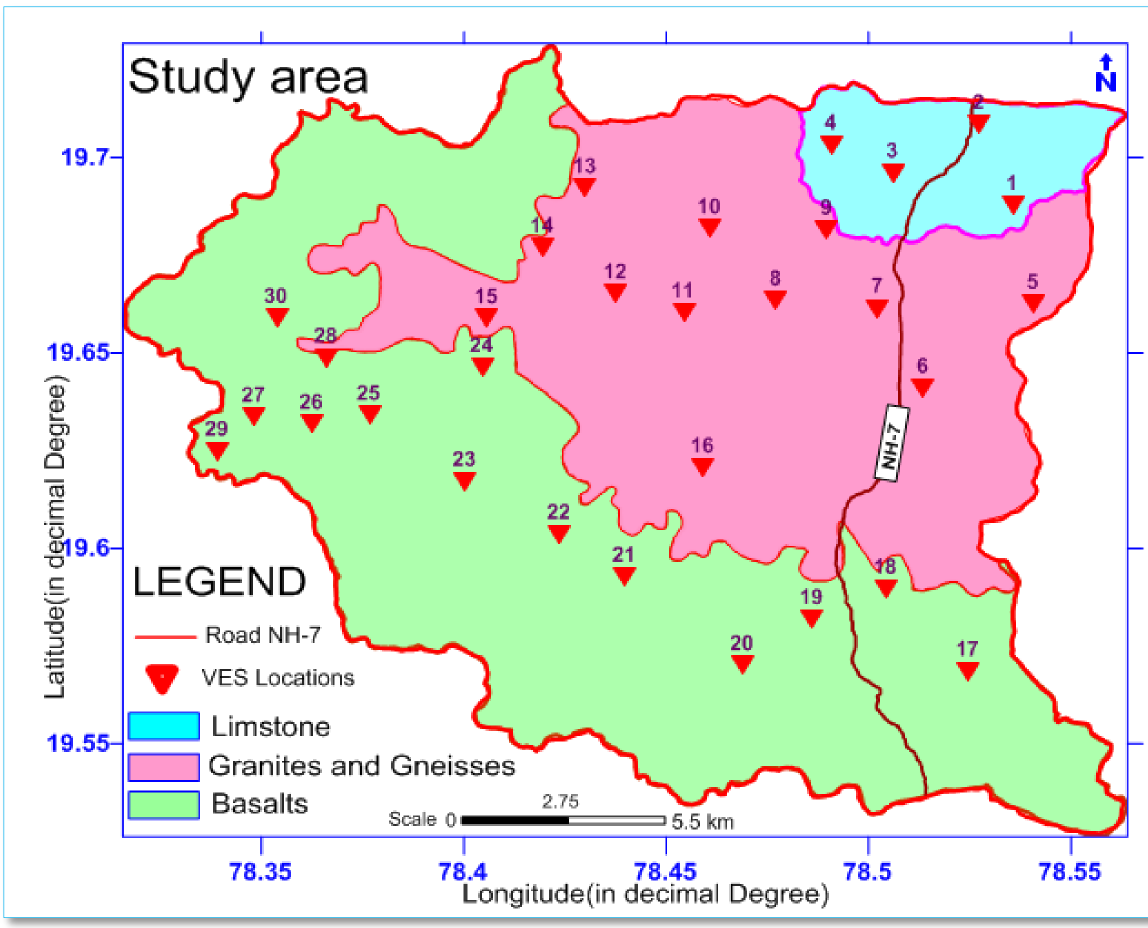


Fig: 5.1 Location of the VES conducted in Mathadi vagu basin

The VES data was analyzed initially with the curve matching using various master curve manuals (Stafenesco 1930' Cmpagnie Generale de Geophysique 1963' Orellena and

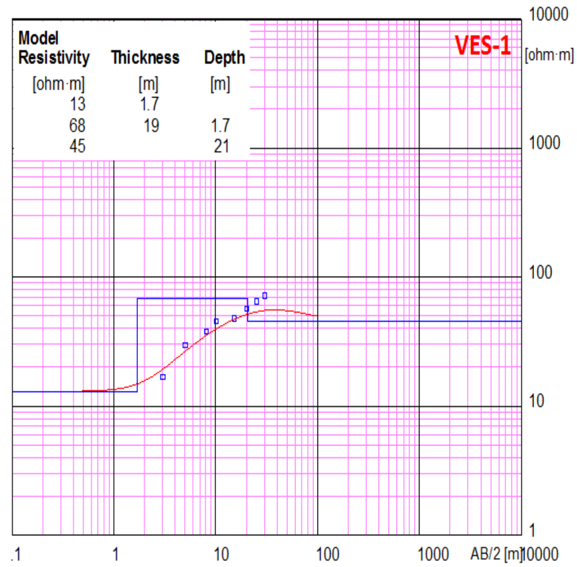
Mooney 1966; for obtaining the initial models. Iterative inversion algorithms developed by Gupta Sarma, (1982), Zohdy (1974) are available using different inversion codes. The sounding curves were interpreted using the softwares WINSEV-6.4 and RESIST-3.5 versions (Vander Velpan 1988) a program based on the steepest decent method. The interpreted results were compared with the groundwater quality of monitoring bore wells at maximum locations.

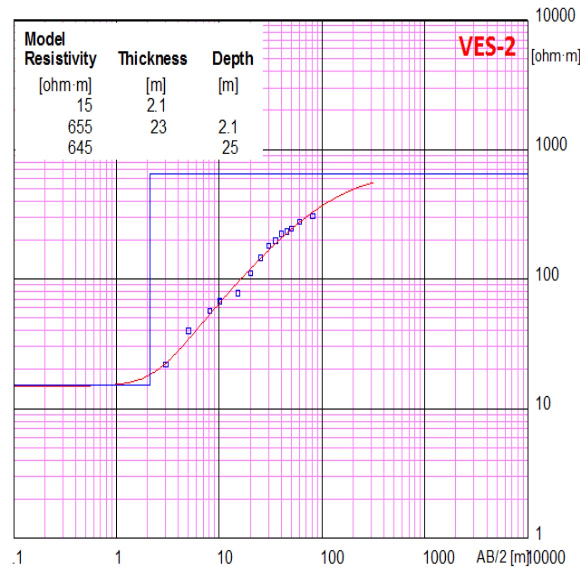
Table-5.1 gives the interpreted layer parameters (layer thickness and electrical resistivity) of 30 VES. Typical sounding curves obtained in the study area, are shown in Figures 5.2. The curves shows maximum of three layers, the maximum depth of information of 40 m. Based on resistivity values and geologic medium such as a dry silt, sand with clay coarse sand and clay at varying depth were inferred. Majority of the sounding curves are found as 'A' type (decreasing the electrical resistivity with depth) as it indicates the typical hard rock.

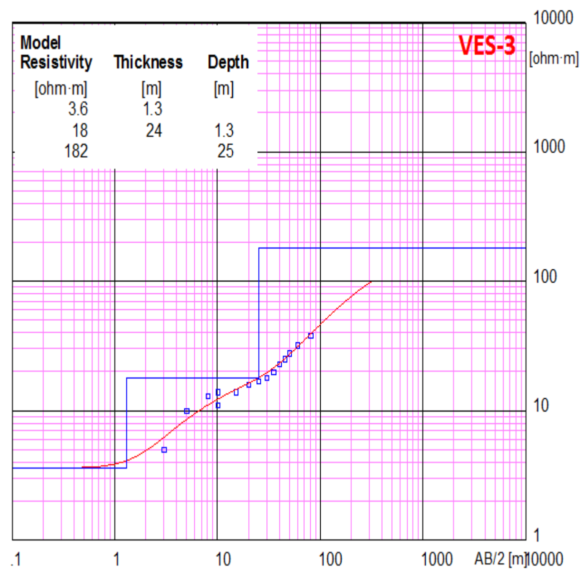
The resistivity values in Profile VES-I is interpreted as silty zone up to 5-10 m depth. Similar observations are also noted at VES nos, 30. The clay layer with sand holds a good aquifer system yielding an appreciable amount of groundwater. The deeper bore wells up to 45 m in this region are found with 3-5 inch of yield. This freshwater aquifer is vulnerable to pollution since it is overlain by silt which has high permeability. In these VES locations the source of pollution.

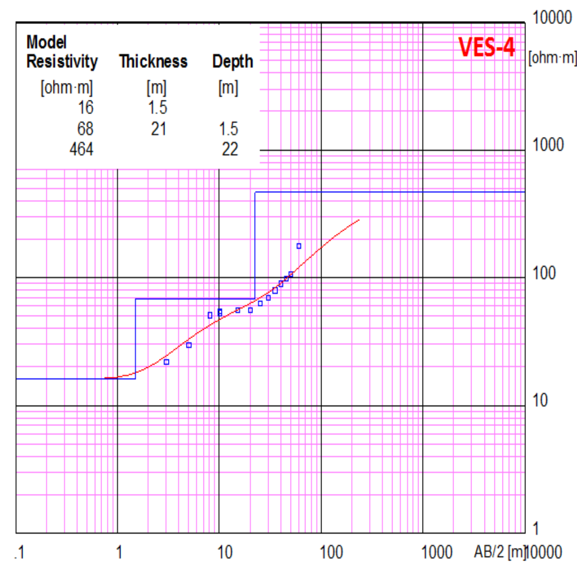
Table 5.1: VES data Interpreted layer from parameters from geological resistivity soundings of Mathadi vagu basin. ρ, h and H are electrical resistivity (Ohm- m), layer thickness (m) total thickness (m) respectively. Suffixes indicate the layer number.

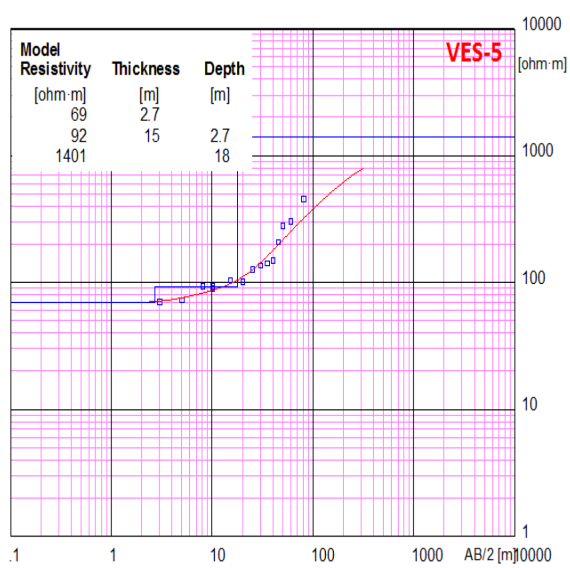
VES NO.	Location	Longitude	Lattitude	ρ1/h1	ρ2/h2	ρ3/h3	H(in m)
1	CCI Market yard	78.5357	19.6878	13/1.7	68/19	45	21
2	Chanda	78.5274	19.7084	15/2.1	655/23	645	25
3	Rampur	78.5060	19.6961	3.6/1.3	18/24	182	25
4	Pochera	78.4908	19.7033	16/1.5	68/21	464	22
5	Thantholi Road	78.5407	19.6625	69/2.7	92/15	1401	18
6	Near Mavala lake	78.5136	19.6409	9/4.5	47/3.3	892	7.8
7	Battisamargam	78.5023	19.6614	61/3.5	142/12	874	16
8	kodijam south	78.4772	19.6634	61/3.2	140/11	872	14
9	Ponnari	78.4897	19.6816	31/25	300/5.9	1617	8.4
10	Hasnapur	78.4608	19.6818	108/3.2	61/8	2992	11
11	Near Project Road	78.4543	19.6602	4.9/1.7	4.2/9.3	1453	11
12	Umdam	78.4376	19.6651	62/2.4	3.9/11	2823	13
13	Thamsi	78.4300	19.6922	4.1/0.7	100/7.3	401	8
14	Sunkidi	78.4195	19.6769	29/2.6	3.5/7.6	3021	10
15	Kothur	78.4057	19.6588	7.9/1.8	310/19	570	21
16	Devapur	78.4591	19.6206	43/4.4	158/5.8	3691	10
17	Garkampet	78.5246	19.5684	15/3.2	33/26	161	29
18	Sithagondi	78.5043	19.5896	8.8/1.8	75/3.5	1989	5.3
19	wijapur	78.4861	19.5818	7.9/4.6	30/7.5	579	12
20	waghapur	78.4689	19.5700	28/2.4	75/26	274	28
21	Pedapally-B	78.4398	19.5926	18/1.6	60/12	1095	14
22	Bharampur east	78.4236	19.6036	12/1.6	71/14	813	16
23	Bharampur north	78.4003	19.6171	35/2	92/20	400	22
24	Thalamadugu	78.4046	19.6463	40/1.4	551/3.9	9047	5.3
25	Dorli	78.3766	19.6340	3.7/4	70/10	589	14
26	Jhari	78.3624	19.6317	1.3/1.3	344/26	391	27
27	Indranagar	78.3482	19.6336	7.6/26	26/11	500	14
28	Kappardevi	78.3661	19.6488	4.4/1.8	118/4.5	1986	6.3
29	Umri	78.3391	19.6249	7.2/1.6	17/18	126	20
30	Dahegam	78.3538	19.6588	5.5/1.5	36/25	76	26

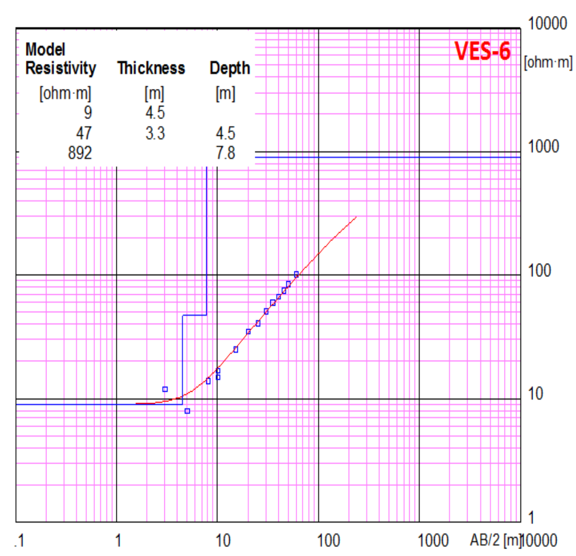

VES-1
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
13 | 1.7
68 | 19 | 1.7
45 | | 21
10000
1000
100
10
1
[ohm·m]
.1
1
10
100
1000
AB/2 [m]
10000

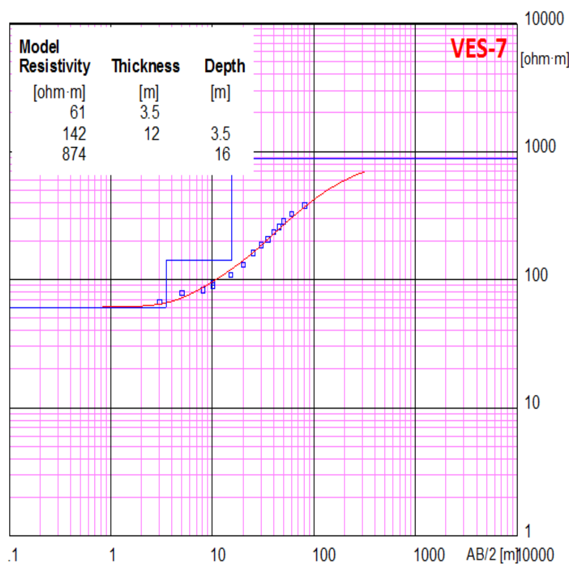

VES-2
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
15 | 2.1
655 | 23 | 2.1
645 | | 25
10000
1000
100
10
1
[ohm·m]
.1
1
10
100
1000
AB/2 [m]
10000

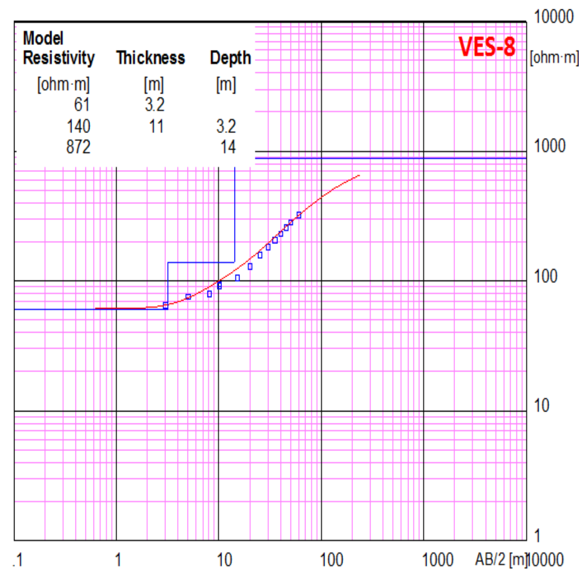

VES-3
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
3.6 | 1.3
18 | 24 | 1.3
182 | | 25
10000
1000
100
10
1
[ohm·m]
.1
1
10
100
1000
AB/2 [m]
10000

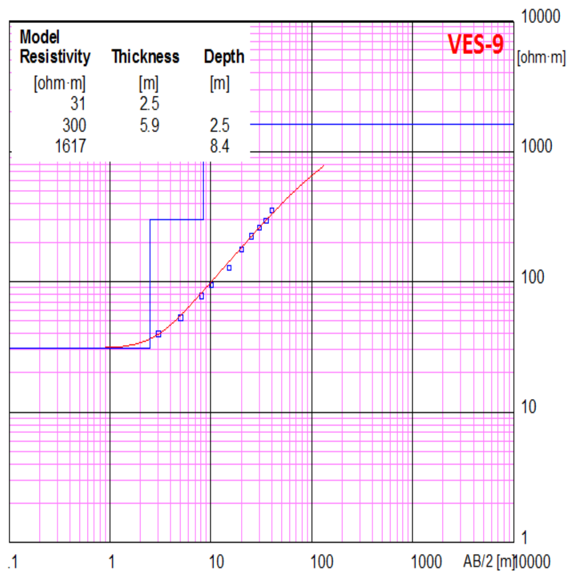

VES-4
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
16 | 1.5
68 | 21 | 1.5
464 | | 22
10000
1000
100
10
1
[ohm·m]
.1
1
10
100
1000
AB/2 [m]
10000

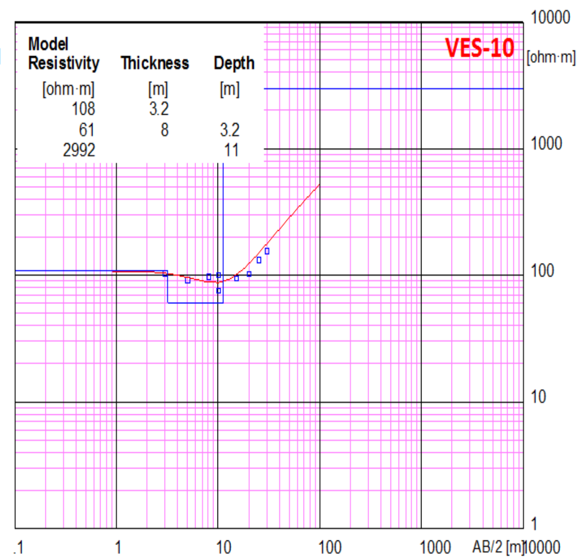

VES-5
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
69 | 2.7
92 | 15 | 2.7
1401 | | 18
10000
1000
100
10
1
[ohm·m]
.1
1
10
100
1000
AB/2 [m]
10000

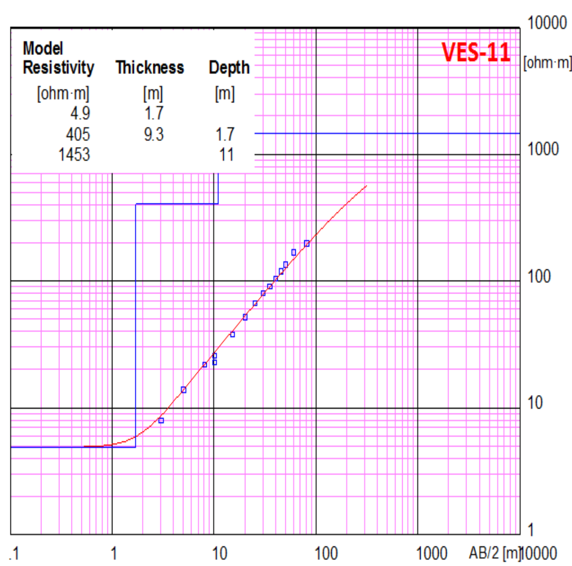

VES-6
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
9 | 4.5
47 | 3.3 | 4.5
892 | | 7.8
10000
1000
100
10
1
[ohm·m]
.1
1
10
100
1000
AB/2 [m]
10000

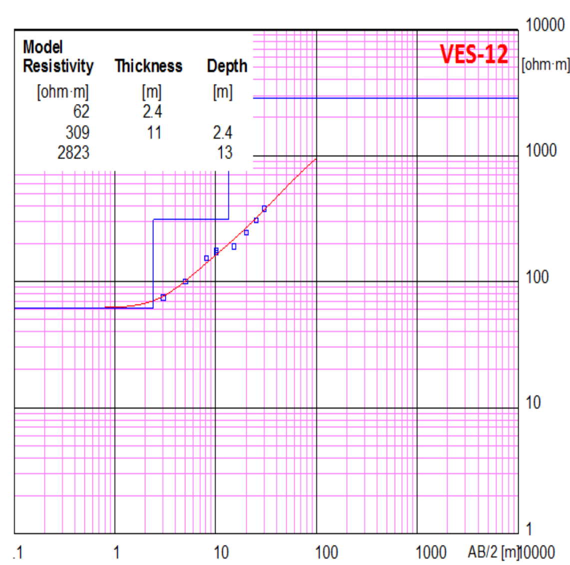

VES-7
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
61 | 3.5 |
142 | 12 | 3.5
874 | | 16
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

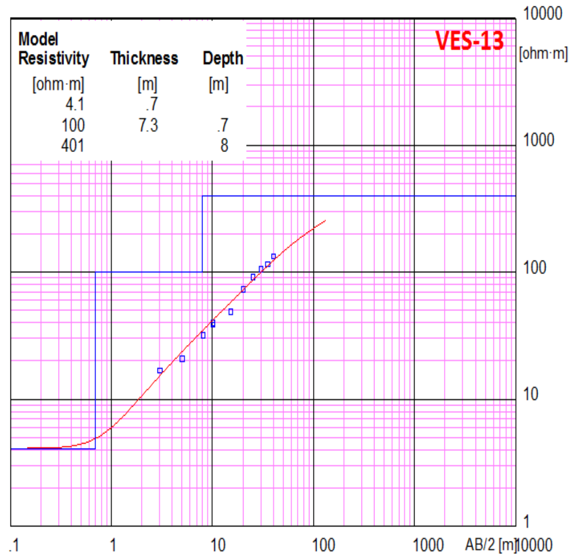

VES-8
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
61 | 3.2 |
140 | 11 | 3.2
872 | | 14
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

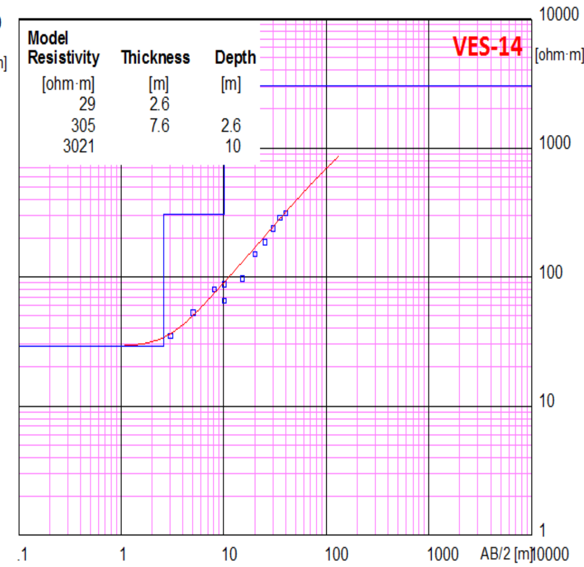

VES-9
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
31 | 2.5 |
300 | 5.9 | 2.5
1617 | | 8.4
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

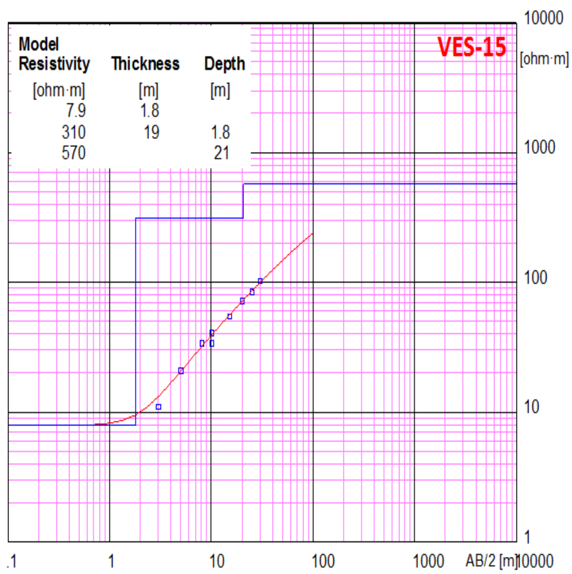

VES-10
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
108 | 3.2 |
61 | 8 | 3.2
2992 | | 11
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

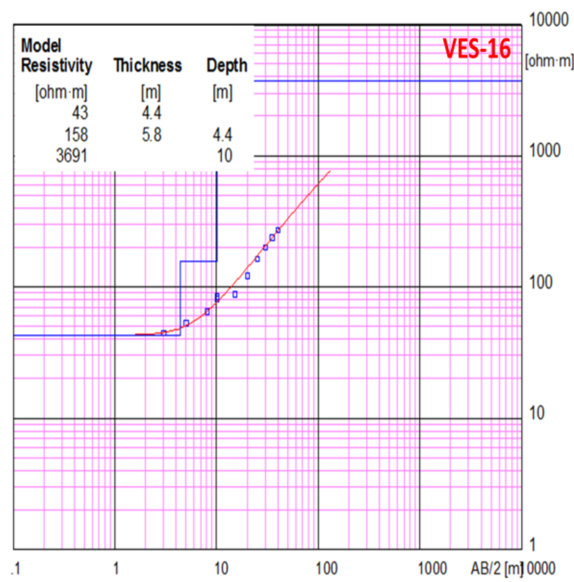

VES-11
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
4.9 | 1.7 |
405 | 9.3 | 1.7
1453 | | 11
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

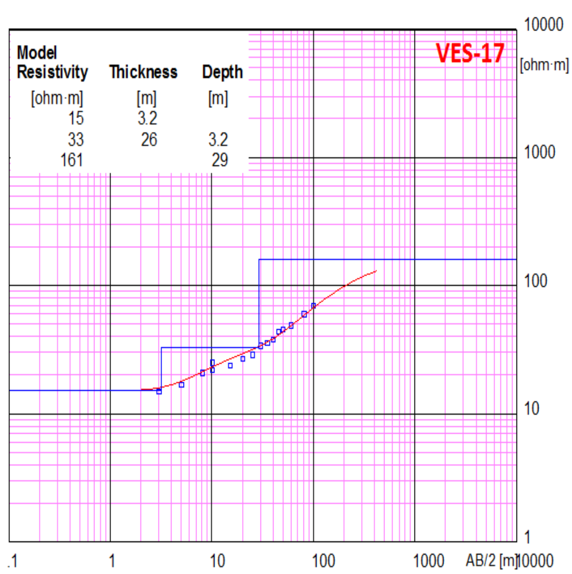

VES-12
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
62 | 2.4 |
309 | 11 | 2.4
2823 | | 13
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

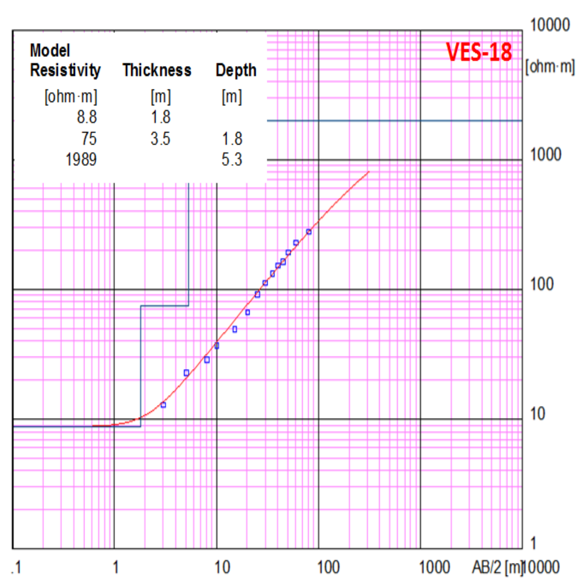

VES-13
Model
Resistivity Thickness Depth
[ohm·m] [m] [m]
4.1 .7
100 7.3 .7
401 8
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

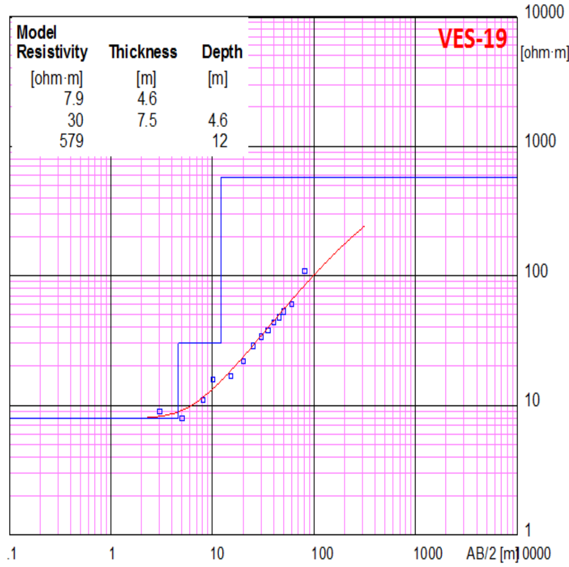

VES-14
Model
Resistivity Thickness Depth
[ohm·m] [m] [m]
29 2.6
305 7.6 2.6
3021 10
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

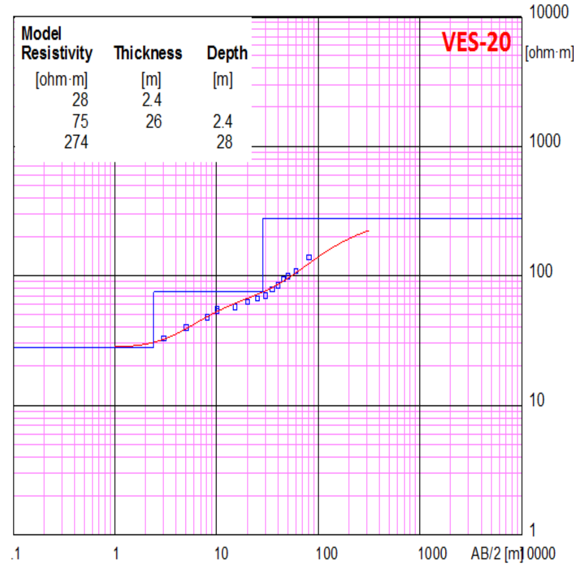

VES-15
Model
Resistivity Thickness Depth
[ohm·m] [m] [m]
7.9 1.8
310 19 1.8
570 21
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000


VES-16
Model
Resistivity Thickness Depth
[ohm·m] [m] [m]
43 4.4
158 5.8 4.4
3691 10
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

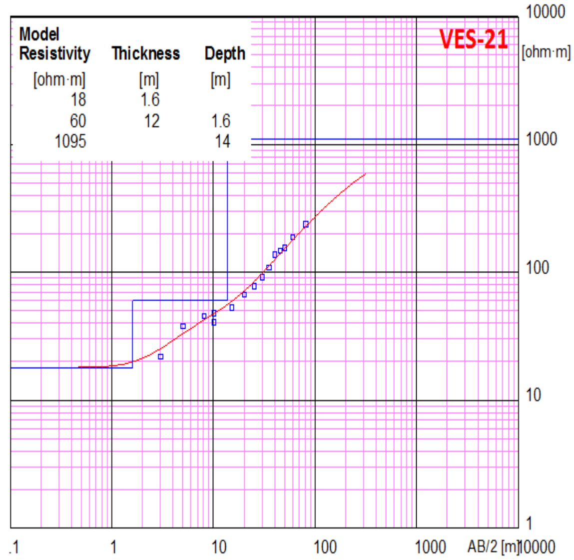

VES-17
Model
Resistivity Thickness Depth
[ohm·m] [m] [m]
15 3.2
33 26 3.2
161 29
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

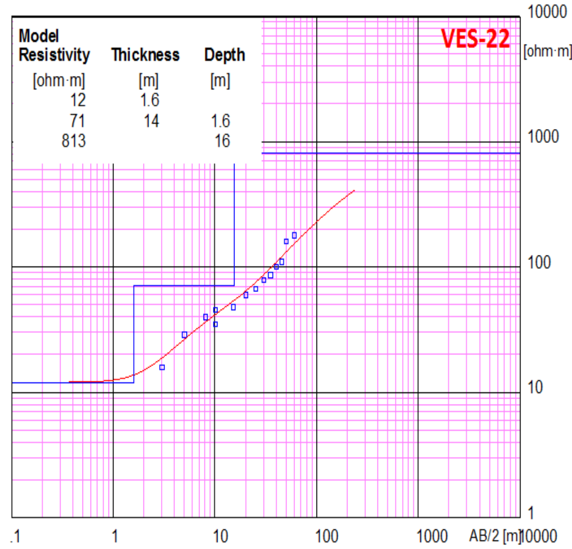

VES-18
Model
Resistivity Thickness Depth
[ohm·m] [m] [m]
8.8 1.8
75 3.5 1.8
1989 5.3
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

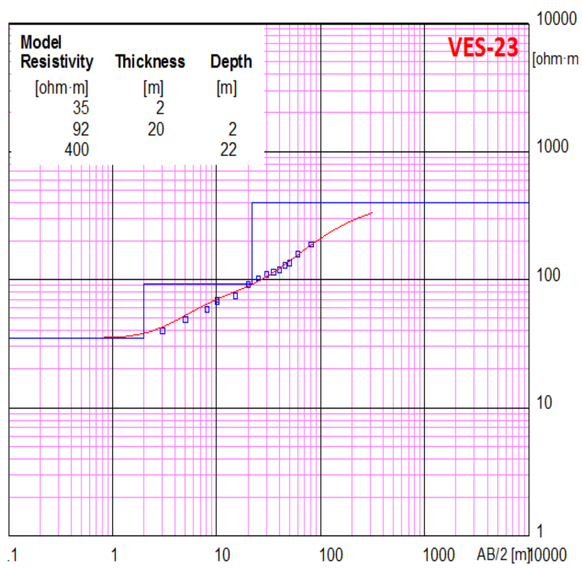

VES-19
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
7.9 | 4.6 |
30 | 7.5 | 4.6
579 | | 12
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
0000

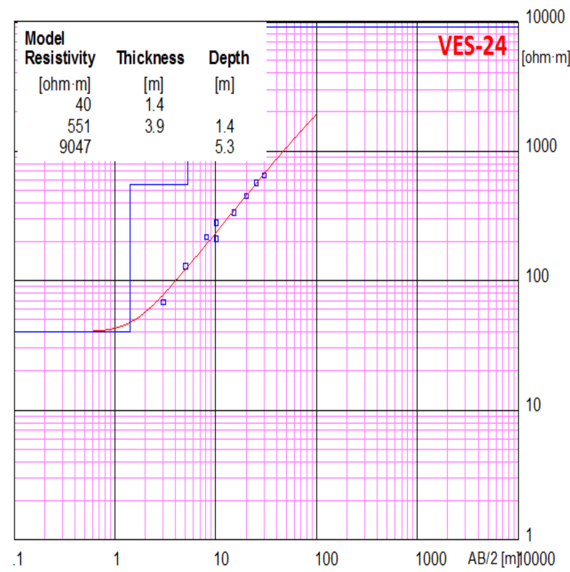

VES-20
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
28 | 2.4 |
75 | 26 | 2.4
274 | | 28
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
0000

3


VES-21
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
18 | 1.6 |
60 | 12 | 1.6
1095 | | 14
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
0000


VES-22
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
12 | 1.6 |
71 | 14 | 1.6
813 | | 16
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000


VES-23
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
35 | 2 |
92 | 20 | 2
400 | | 22
10000
[ohm·m
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000


VES-24
Model
Resistivity [ohm·m] | Thickness [m] | Depth [m]
40 | 1.4 |
551 | 3.9 | 1.4
9047 | | 5.3
10000
[ohm·m]
1000
100
10
1
.1
1
10
100
1000
AB/2 [m]
10000

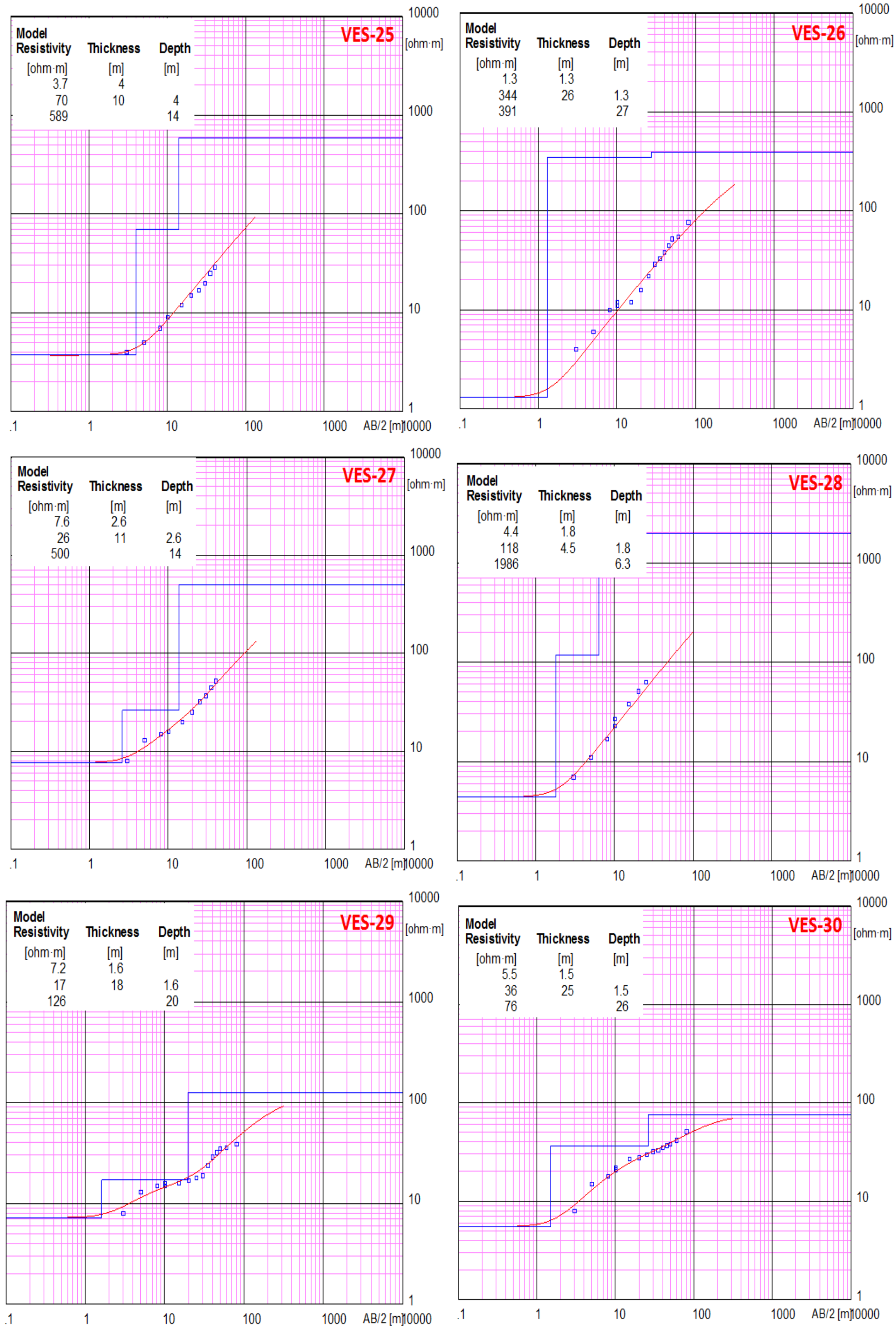


Fig- 5.2: VES Curves from 1 to 30 of Mathadi vagu basin.

5.7 Summary

Based on geophysical investigations the analysis data, the following significant inferences are made in conceptualizing the aquifer system. Geophysical investigations VES revealed the general lithology of the study area. The top soil is silt followed by sand (fine to medium) and underlain by sandy clay. Among total 30 VES, 30 VES curves are 'A' type which indicates Granitic environment where geological succession is Granites and Gneisses up to 100 m depth, the geological succession is sand underlain by clay lenses. 30 VES curve are 'A' type indicating clay at depths 30-40 m where the geological succession is clay followed by Granites.

The low resistivity range 3-8 Q-m is deciphered up to 30-50 m depth at Mathdivagu basin. The low resistivity range in this area is verified by groundwater TDS value which ranges from 1000-1370 mg/I.

Some important conclusion on the nature, occurrence, and prospecting for ground water in the study area could be drown based on the large amount of geophysical investigation carried out, supported by the studies of hydrological and hydrogeological appects. In view of the availability of large amount of data on the resistivity values some generalisations , in respect of granite aquifer system could be made. The weathered and fractured nature of formation which is found to be potential aquifers, is characterised by the resistivity values of the order of 30-100 ohm.m., where is high resistivity values (above 100 ohm.m.) are found to represent moderate to poor yielding formation.

The potential zones in Deccan traps formation are vesicular portions that are encountered at deeper depths and the fractured portions of basalt occurring intermittently at different depths, the resistivity values of the order of 100-250 ohm.m. are indicative of the presence of fractured to semi fractured basalt which are moderately yielding while the second layer resistivity values of the order of 7 -55 ohm.m have yielded good excellent water in Thmsi, Umdam, Thalamadugu, waghapur, Pippal koti. Sunkidi, Hasnapur and kodad villages of the studyb area, which can attribute to the presence of weathered and fractured basalt devoid of clay. Where as places, formation with similar, low resistivity values often result in poor yield of ground water owing to the presence of thick clay bed. Hence it is very difficult to generalise by assigning resistivity values for a specific nature of formation.

It is observed that the potential water bearing zones in Limestone area is charecterised by 13 to 45 ohm.m.

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PHOTO 5.1: Vertical electrical Sounding at Dahegam village

PHOTO 5.2: Vertical electrical Sounding at Somarpet village.

CHAPTER - 6
GROUNDWATER QUALITY

6.1. Introduction

Water is the essence of life and safe drinking water is the basic human need to all. Although water is necessary for the survival of human being, many are not able to get sufficient potable drinking water supply to maintain basic hygiene. In developing countries infant mortality is mostly due to drinking of contaminated water (WHO 1993, 2000, 2002 and 2003) and poor hygiene causing respiratory diseases are widely reported. Globally 1.1 billion people are forced to rely on unsafe drinking water sources from lakes, rivers and open wells (WHO/UNICEF 2000; WHO/UNICEF-JMP 2004).

The increasing exploitation of ground water has lead to changes in aquifer characteristics including water quality regime. Some perceived changes in ground water quality are due to a change in the aquifer being tapped; i.e. a deeper and hitherto untapped aquifer being tapped now or well in aquifer in topographic lows that were never used to supply domestic water now being put to such use under so called protected water supply scheme for the villages etc.

In the study area, weathered in Deccan traps or in the limestones or in the granitic terrain ground water quality from shallow weathered zones almost always had all the major ionic constuents within the permissible limits. This can be largely attributed to good absorbing capacity of clay minerals in the weathered zone. However, the contact decreases with depth and the rock is largely unaltered. Hence fractured and fissured zone, released chemical constituents hardly get absorbed and the chemistry is fully controlled by reactions rates in the solution at any given temperature, Eh or pH range and the host rock chemical constituents that can go in and out of the solution.

Water is universal solvent and its ability to dissolve minerals during its flow in the saturated zone determines the total dissolved solids. The quality of groundwater in any area is controlled by the geology vegetation and its location with respect to other surface water bodies like streams, canals and tanks nearby industrial establishment (Back and Hanshaw, 1965 and Todd. 1980). To evolve a scientific basis for development and management of groundwater resources in different situations in relation to water quality, it is essential to identify the polluted zones in regard to their lateral and vertical extent and the composition of the water (Back and Hanshaw 1965). The quantity of available water for any purpose, without assessing its quality would lead to hazards for plant, animal and human beings. In India groundwater resources are getting increasingly polluted due to unplanned disposal of untreated wastes of industry and excessive use of fertilizers in agriculture sector. Chemistry of water can indicate instant water quality. When we sample water, we have an immediate understanding of the chemical "signature" of a particular sample from wells or a section of the stream at the time of sampling.

In view of alarming rate of land-use changes in urban areas, it is important to understand the linkages between land use change and groundwater dynamics, as the land use affects the quality of groundwater being recharged. Surface water infiltration is a major source of recharge in lakes dominated watersheds. Consequently understanding the interaction of groundwater and surface water is important to decipher groundwater dynamics. In many hydrological systems, the surface water and groundwater are intricately linked, especially in low lands and shallow aquifers as in the case of the study area. The drinking water sources in the villages of Thamsi, Thalamadugy, Umdam, and Bharampur villages have been deteriorated due to agricultural activities using more pesticides and overexploitation of groundwater sources. Mathadivagu flows towards north east. The total dissolved solids (TDS) of the water varied from 1200 to 1800 mg/l with an average of 1500 mg/l (Sankaran et al. 2011). Apart from this, there are several cotton industries operating at Adilabad town. Which were the prime sources of subsurface pollution in the northern part? The present status of groundwater quality is briefed hereunder.

6.2. Groundwater quality parameters

Groundwater being a solvent that is in contact with various earth materials contains dissolved cations and anions as well as some non- ionic inorganic materials such as Silica ($Si0_2$). In general, groundwater contains dissolved solids that range in concentration from less than 100 mg/I to more than 500000 mg/I (Hem 1985). A large number of parameters signifying the quality of water for various utility have been reported by Freeze and Cherry (1979). They are broadly classified into 3 categories. i.e. physical, bacteriological and chemical. The Physical analysis includes temperature, color, turbidity, odor and taste. Bacteriological analysis includes test to detect the presence of coliform bacteria, which indicate the sanitary quality of water for the consumption of human beings. The chemical analysis includes major cations, anions and trace elements. Further, in chemical analysis, total hardness is an important property, which is mainly caused by the cations of calcium and magnesium. It is defined as the sum of concentration of calcium and magnesium ions and is expressed in mg/I as $CaC0_3$. The physical parameters of groundwater are found to be satisfactory in the study area and hence the chemical analysis was carried out and reported here.

6.3. Chemical analysis of major ions for shallow bore wells

The groundwater quality analyses of total 37 groundwater samples collected from the study area of 525 km^2 (Figure 4.1) were made for pH, EC, major ions concentrations during December 2011 (post monsoon) and June 2012 (pre monsoon). All these samples were analyzed in the laboratory as per the standard procedures of American Public Health Association (Brown et al. 1974 and APHA 1985,1998). The detailed chemical analysis for major ions concentration for the above two seasons are presented in Tables 6.1 & 6.2 include WHO limits of the various elements, their minimum, maximum and average values as well as the standard deviations of the Samples.

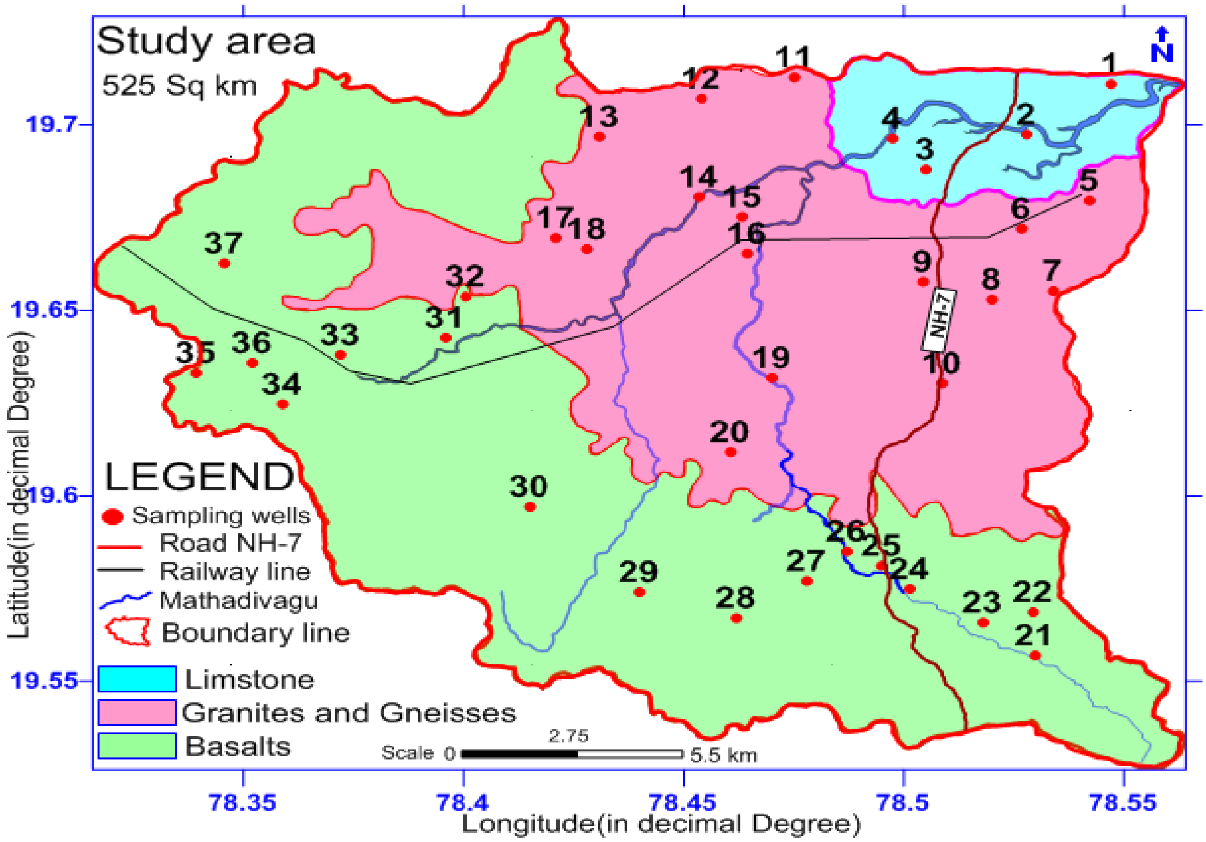


Fig: 6.1. Location map of water samples in the study area.

Water sample location map (Figure 4.1) is divided in to three parts (i.e. .limestone area, granitic terrain and Deccan traps) (Figures 4.la b & c) to visualize clearly the water sample location along with well ID.

The objective of the water quality analysis is mainly to understand the influence of industrial effluent and Agricultural activities and surface water to the groundwater. Most of the groundwater samples located Mathadi vagu basin show medium concentration of TDS.

Table 6.1 Major ion chemistry of ground water samples, post monsoon (December, 2011) of the study area (all the parameters are in mg/l except pH)

S. No	pH	TDS	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	CO_3^-	HCO_3^-	NO_3	F	TH
1	7.44	680	22.2	139.2	127.0	34.1	76.2	29.4	0	488.0	133.5	0.0	457
2	7.51	960	118.4	40.5	191.3	50.7	217.8	96.0	0	469.7	212.8	1.2	686
3	7.36	780	56.0	1.1	151.3	77.5	128.4	64.1	0	408.7	258.9	0.5	696
4	7.48	590	30.2	1.3	107.8	69.1	68.7	36.8	0	515.5	66.6	0.6	553
5	7.57	620	130.7	18.0	93.6	28.6	160.0	24.3	0	424.0	9.6	0.0	351
6	7.22	620	122.9	1.5	130.9	17.8	125.6	74.3	0	363.0	73.6	0.5	400
7	7.41	269	58.1	1.7	59.3	7.8	18.6	6.6	0	317.2	0.0	1.1	180
8	7.45	660	81.9	1.1	121.3	62.2	54.2	40.3	0	683.2	48.0	1.2	558
9	6.28	300	43.7	1.4	65.7	11.0	39.6	27.1	0	143.4	98.8	0.4	210
10	6.86	167	36.7	1.5	21.4	9.5	22.9	16.9	0	137.3	1.4	0.5	92
11	7.27	513	41.1	2.1	134.1	33.9	73.4	27.6	0	344.7	139.9	1.5	474
12	7.5	700	109.6	6.8	118.1	52.3	94.2	59.0	0	542.9	123.5	1.4	510
13	7.56	720	86.2	62.1	96.2	56.3	91.0	51.3	0	478.9	157.4	1.4	471
14	7.68	214	20.4	2.1	38.3	22.8	16.5	11.7	0	201.3	1.4	0.5	189
15	7.48	740	79.4	4.1	131.9	65.0	98.4	52.0	0	485.0	198.0	0.9	597
16	7.35	960	122.1	5.1	199.8	75.4	185.7	84.3	0	546.0	230.4	1.1	809
17	7.38	1110	169.8	50.9	238.8	64.0	242.4	111.0	0	561.2	263.7	1.1	859
18	7.72	1370	160.2	159.9	242.9	78.2	333.7	124.9	0	564.3	407.4	0.0	928
19	7.52	247	29.5	2.2	36.7	27.8	18.0	9.7	0	247.5	2.0	0.1	206
20	7.78	1150	134.3	239.0	136.4	56.5	202.2	106.7	0	576.5	298.1	0.0	572
21	7.41	530	22.1	0.5	162.0	33.1	39.0	26.5	0	445.3	136.7	0.5	541
22	7.35	513	27.8	0.9	164.4	27.6	65.7	36.0	0	393.5	128.8	0.4	524
23	7.25	520	25.5	0.8	136.1	43.6	40.3	15.2	0	478.9	105.4	0.6	519
24	7.31	275	32.5	2.2	41.8	32.1	13.5	10.2	0	329.4	2.8	0.8	236
25	7.36	520	76.7	0.9	64.1	55.8	44.1	45.5	0	445.3	83.0	4.5	389
26	7.37	810	61.7	2.4	193.8	63.1	140.8	74.5	0	500.2	193.5	1.9	743
27	7.45	415	37.9	0.8	89.0	44.0	26.7	29.0	0	475.8	29.9	0.6	403
28	7.17	1030	49.5	6.3	311.5	66.0	218.2	91.7	0	503.3	315.2	0.0	1049
29	7.53	690	61.4	0.9	125.5	70.1	92.3	61.6	0	427.0	188.1	0.7	601
30	7.22	670	38.3	0.5	189.3	41.9	112.8	64.1	0	381.3	166.9	0.4	645
31	7.55	890	112.8	25.0	196.6	60.1	147.9	86.0	0	552.1	176.1	0.4	738
32	7.36	770	34.3	7.9	169.7	80.3	123.2	59.0	0	460.6	194.4	0.6	754
33	7.54	580	37.2	1.5	87.7	76.3	57.8	34.9	0	417.9	135.0	0.9	532
34	7.6	860	57.9	141.2	131.0	58.3	119.3	56.5	0	442.3	257.7	0.0	567
35	7.55	401	36.5	0.7	83.7	42.7	23.0	10.1	0	405.7	84.2	1.0	384
36	7.46	860	35.5	2.0	223.3	82.9	124.9	69.0	0	481.9	274.4	0.9	898
37	7.71	469	32.9	13.3	125.6	37.9	29.7	23.1	0	460.6	93.8	0.5	469
MIN	6.28	167.00	20.44	0.47	21.40	7.80	13.51	6.58	0	137.25	0.00	0.00	92
MAX	7.78	1370.00	169.83	238.99	311.48	82.87	333.68	124.90	0	683.20	407.40	4.54	1049
AVG	7.41	653.32	65.78	25.66	133.45	49.09	99.64	49.91	0	435.09	142.99	0.78	535

Table 6.2 Major ion chemistry of ground water samples, pre monsoon (June, 2012) of the study area (all the parameters are in mg/l except pH)

S. No	pH	TDS	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	CO_3^-	HCO_3^-	NO_3	F	TH
1	7.4	830	54.8	173.3	140.0	39.4	99.9	48.0	0.0	589.0	158.1	0.0	512
2	7.5	840	122.5	8.4	165.9	48.1	195.8	68.7	0.0	442.0	116.2	1.1	612
3	8.1	650	61.0	1.2	74.9	78.7	140.1	41.1	12.0	177.0	265.1	0.8	510
4	8.0	333	38.2	1.9	56.8	26.9	54.1	19.2	6.0	162.0	106.6	1.4	252
5	7.1	910	262.3	30.6	65.0	39.5	342.9	46.3	0.0	390.0	24.0	0.4	325
6	8.0	474	128.3	1.8	55.5	17.7	134.7	73.4	9.0	134.0	83.5	0.4	212
7	7.5	271	57.9	1.5	64.4	7.7	16.8	7.3	0.0	305.0	0.8	1.0	193
8	7.4	560	83.6	1.1	77.2	60.6	61.6	38.5	0.0	515.0	49.3	0.9	441
9	7.5	339	44.9	1.4	91.1	17.0	12.5	10.8	0.0	339.0	55.5	1.1	298
10	6.9	750	239.4	24.3	41.7	24.0	274.5	33.2	0.0	275.0	20.6	1.4	202
11	7.3	690	24.6	0.9	213.2	12.9	131.8	25.0	0.0	387.0	190.5	0.5	586
12	7.9	1100	141.2	12.0	99.1	118.7	319.1	73.2	9.0	259.0	359.7	0.9	734
13	7.7	580	69.6	48.4	83.1	49.2	61.0	35.6	0.0	458.0	94.3	1.4	409
14	7.8	219	27.7	1.9	29.6	23.2	24.4	11.4	0.0	207.0	1.1	0.5	169
15	7.6	560	61.8	4.1	92.2	50.3	49.2	36.1	0.0	409.0	171.3	0.9	437
16	7.5	680	82.6	4.0	126.9	48.8	128.1	52.7	0.0	467.0	81.0	1.1	518
17	7.6	1110	145.6	67.7	180.5	64.6	228.5	115.5	0.0	528.0	272.6	1.1	716
18	7.1	1130	136.7	128.9	166.1	57.7	281.7	67.0	0.0	561.0	142.8	1.1	652
19	7.6	186	44.9	1.8	14.0	13.9	29.4	9.2	0.0	146.0	2.1	0.8	92
20	8.0	980	117.5	197.3	110.4	45.3	161.6	76.3	9.0	555.0	181.4	0.0	462
21	7.4	320	20.5	0.6	82.2	25.9	14.5	12.5	0.0	378.0	6.6	0.5	312
22	7.5	292	17.3	0.8	71.6	22.6	13.1	12.4	0.0	271.0	58.8	0.6	272
23	7.5	520	25.2	1.3	135.1	43.7	34.1	13.7	0.0	528.0	87.8	0.7	517
24	7.4	339	57.6	4.2	32.0	41.3	24.1	8.2	0.0	387.0	9.0	1.0	249
25	7.7	490	80.3	0.9	61.6	52.5	25.9	27.1	0.0	485.0	59.2	4.3	369
26	8.4	620	39.4	8.8	127.3	64.3	97.6	49.7	45.0	400.0	82.5	2.3	582
27	7.8	499	33.8	1.1	91.8	55.6	44.5	33.3	0.0	503.0	59.5	0.5	458
28	7.2	1060	47.1	4.0	257.8	79.5	228.5	94.5	0.0	406.0	376.5	0.5	970
29	8.2	491	50.1	0.3	60.7	63.2	69.3	59.9	15.0	217.0	190.6	0.7	411
30	7.8	590	72.3	0.9	110.9	48.7	70.2	47.8	0.0	357.0	125.9	2.5	477
31	7.4	1180	111.6	27.7	235.4	86.5	315.2	106.3	0.0	543.0	248.8	0.7	943
32	7.6	610	30.5	6.5	119.7	63.2	72.3	49.5	0.0	406.0	150.0	0.7	559
33	7.7	488	29.0	1.2	88.6	66.4	38.8	22.2	0.0	418.0	134.9	0.8	494
34	8.1	910	60.4	200.2	138.1	57.8	131.9	73.6	15.0	397.0	317.7	0.0	582
35	7.9	395	36.3	0.2	74.1	42.8	20.1	9.4	6.0	381.0	89.3	1.1	361
36	7.6	530	27.6	0.9	123.4	44.4	44.5	33.2	0.0	451.0	105.4	0.4	490
37	7.8	397	24.0	7.8	85.7	33.8	15.7	13.3	0.0	427.0	59.3	0.6	353
MIN	6.9	186	17.3	0.2	14.0	7.7	12.5	7.3	0.0	134.2	0.8	0.0	92
MAX	8.4	1180	262.3	200.2	257.8	118.7	342.9	115.5	45.0	588.7	376.5	4.3	970
AVG	7.6	619.5	73.2	26.5	103.9	46.9	108.3	42.0	3.4	385.4	122.7	0.9	452

A detailed chemical analysis for major ions including pH, TDS and Total Hardness of groundwater samples from shallow bore wells is summarized in Table 4.1 for post monsoon (December 2011) and in Table 4.2 for pre monsoon (January 2012). The major cations include sodium, potassium, calcium and magnesium, and major anions include sulfate, chloride and bicarbonate nitrate and fluorite.

Table 6.3 Statistics of chemical parameters for groundwater samples post monsoon (December 2011) of the study area

Parameters in mg/l, except pH	**Min**	**Max**	**Mean**	**St Dev**	**WHO Guideline value(1984)**	**% of the samples crossed the WHO limits**
pH	6.28	7.78	7.41	0.25	6.5-8.5	3(acidic)
TDS	167	1370	653.32	277.7	500	76
Na	20.44	169.83	65.78	42.2	200	0
K	0.47	238.99	25.66	54.5	100	11
Ca	21.4	311.48	133.45	64.5	75	81
Mg	7.8	82.87	49.09	21.4	30	78
Cl	13.51	333.68	99.64	75.0	200	14
SO4	6.58	124.9	49.91	31.6	200	0
HCO3	137.25	683.2	435.09	116.8	200	95
NO3	0	407.4	142.99	101.4	45	82
F	0	4.54	0.78	0.789	1.5	5
Total Hardness	85.46915	1118.4957	534.91809	224.4	100	97

Table 6.4 Statistics of chemical parameters for groundwater samples pre monsoon (June2012) of the study area

Parameters in mg/l, except pH	**MIN**	**MAX**	**AVG**	**St Dev**	**WHO Guideline value(1984)**	**% of the samples crossed the WHO limits**
pH	6.91	8.37	7.63	0.32	6.5-8.5	0
TDS	186	1180	619.54	277.8	500	59
Na	17.32	262.31	73.19	56.9	200	5
K	0.22	200.2	26.48	55.1	100	11
Ca	13.97	257.77	103.88	55.5	75	65
Mg	7.69	118.69	46.94	23.1	30	73
Cl	12.45	342.85	108.32	99.3	200	19
SO4	7.3	115.54	42.03	28.8	200	0
HCO3	134.2	588.65	385.37	124.2	200	89
NO3	0.79	376.52	122.65	100	45	81
F	0	4.2921	0.94	0.771	1.5	8
Total Hardness	92.01	970.2	452.16	197.6	100	97

Statistical summary of chemical parameters of groundwater samples from shallow bore wells is shown in Table 6.3 for post monsoon season (December 2011) and in Table 6.4 for pre monsoon (January 2012) seasons. The post monsoon chemical data base is compared with drinking water standards of WHO 1984, shows 6 %, 100%, 75%, 26%, 83%, 78%, 90%, 92%, 60% and 100% of groundwater samples from shallow bore wells crossed the permissible limits of pH, TDS, Na^+, K^+, Ca^{2+}, Mg^{2+} SO4 $^{2+}$ Cl^-, $HC0_3^-$ and Total Hardness. Similarly the pre monsoon chemical data base is also compared with the WHO 1984 drinking standards, shows 0%, 99%, 67%,17%,78%,94%,82%,81%,68% and 100% of groundwater samples from shallow bore wells crossed permissible limits of pH, TDS, Na^+, K^+, Ca^{2+}, Mg^2+, SO_4 $^{2+}$, Cl^- , $HC0_3^-$ and Total Hardness. The high range of standard deviation (see Table 4.3 & 4.4) in both the seasons for parameters like TDS, Na^+,Ca^{2+}, Mg^{2+}, SO_4 $^{2+}$ $Cl^{-,}$ $HC0_3^-$ and Total Hardness indicate the multiple sources of dissolved in groundwater.

PEARSON CORRELATION OF MAJOR ION ANALYSIS IN POSTMONSOON DECEMBER, 2011

Table 6.5 Correlation Coefficient of chemical parameters for groundwater samples post monsoon (December 2011).

	pH	EC	TDS	Na	K	Ca	Mg	Cl	SO_4	HCO_3	NO_3	F	TH
pH	1.000												
EC	0.344	1.000											
TDS	0.344	1.000	1. 000										
NA	0.238	0.682	0.681	1.000									
K	0.380	0.567	0.568	0.417	1.000								
Ca	0.112	0.828	0.828	0.373	0.189	1.000							
Mg	0.393	0.722	0.723	0.270	0.167	0.587	1.000						
Cl	0.219	0.930	0.930	0.764	0.506	0.785	0.539	1.000					
SO_4	0.190	0.932	0.933	0.733	0.465	0.786	0.620	0.923	1.000				
HCO_3	0.532	0.742	0.743	0.478	0.334	0.607	0.707	0.528	0.582	1.000			
NO_3	0.188	0.906	0.906	0.433	0.514	0.824	0.705	0.822	0.851	0.525	1.000		
F	-0.037	-0.099	-0.100	0.077	-0.308	-0.153	0.135	-0.174	-0.027	0.108	-0.135	1.000	
TH	0.234	0.877	0.878	0.373	0.201	0.948	0.813	0.775	0.807	0.713	0.868	-0.057	1.000

PEARSON CORRELATION OF MAJOR IAN ANALYSIS IN PRE MONSOON JUNE, 2011

Table 6.6 Correlation Coefficient of chemical parameters for groundwater samples pre monsoon (June 2012).

	pH	EC	TDS	Na	K	Ca	Mg	Cl	SO_4	HCO_3	CO_3	NO_3	F	TH
pH	1.000													
EC	-0.204	1.000												
TDS	-0.204	1.000	1..000											
Na	-0.354	0.578	0.577	1.000										
K	0.024	0.533	0.530	0.234	1.000									
Ca	-0.241	0.714	0.716	-0.001	0.253	1.000								
Mg	0.234	0.642	0.641	0.148	0.097	0.409	1.000							
Cl	-0.316	0.876	0.877	0.803	0.304	0.472	0.478	1.000						
SO_4	0.055	0.866	0. 866	0.462	0.418	0.650	0.617	0.740	1.000					
HCO_3	-0.310	0.492	0.490	0.059	0.434	0.563	0.279	0.154	0.299	1.000				
CO_3	0.686	0.072	0. 072	-0.066	0.120	-0.019	0.258	0.048	0.186	-0.199	1.000			
NO_3	0.202	0.722	0.723	0.063	0.342	0.656	0.723	0.512	0.734	0.129	0.195	1.000		
F	0.135	-0.132	-0.132	0.058	-0.317	-0.153	0.077	-0.132	-0.120	0.015	0.139	-0.199	1.000	
TH	-0.057	0.810	0.811	0.070	0.225	0.899	0.768	0.561	0.752	0.530	0.111	0.808	-0.070	1.000

Correlation coefficient of chemical parameters for groundwater samples from shallow bore wells is summarized in Table 6.5 for post monsoon (December 2011) seasons and in Table 6.6 for pre monsoon (June2012). In post monsoon water samples a positive correlation coefficient> 0.9 is observed between TDS and Na^+, $SO_4{}^{2+}$ Cl^- & total hardness, indicating the significant contribution of the ions in increasing TDS value. The contribution of K^+ and Ca^{2+} is also there in TDS where a positive correlation is found from 0.7-0.8. Similar trend is observed in post monsoon samples of the same bore wells. A negative correlation between pH and other parameters indicates lower the pH greater the concentration of dissolved ions in other words the acidic nature of water encourages to dissolve ions.

6.3.1 Potential hydrogenise (pH)

The symbol pH is used to express the acidity or alkalinity in water. It influences the chemical and biological process within the water body (Hem 1985). It is expressed as the negative logarithm of the hydrogen-ion concentration in water. The measure of pH is on a scale of 0-14 wherein pH less than 7 is acidic and greater than 7 is alkaline (basic) and exact 7 is neutral. The permissible range for pH is 6.5-8.5 (WHO 1984).

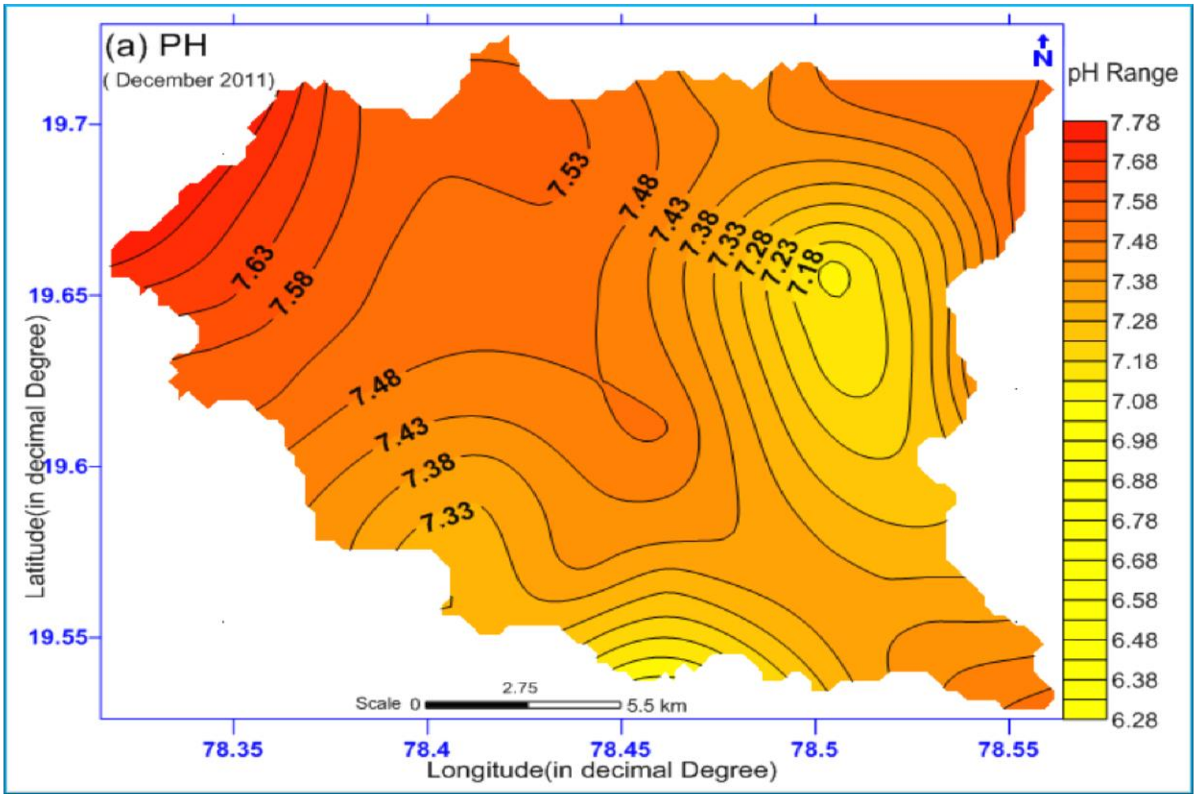


Fig: 6.2 pH contour map of post monsoon of the study area

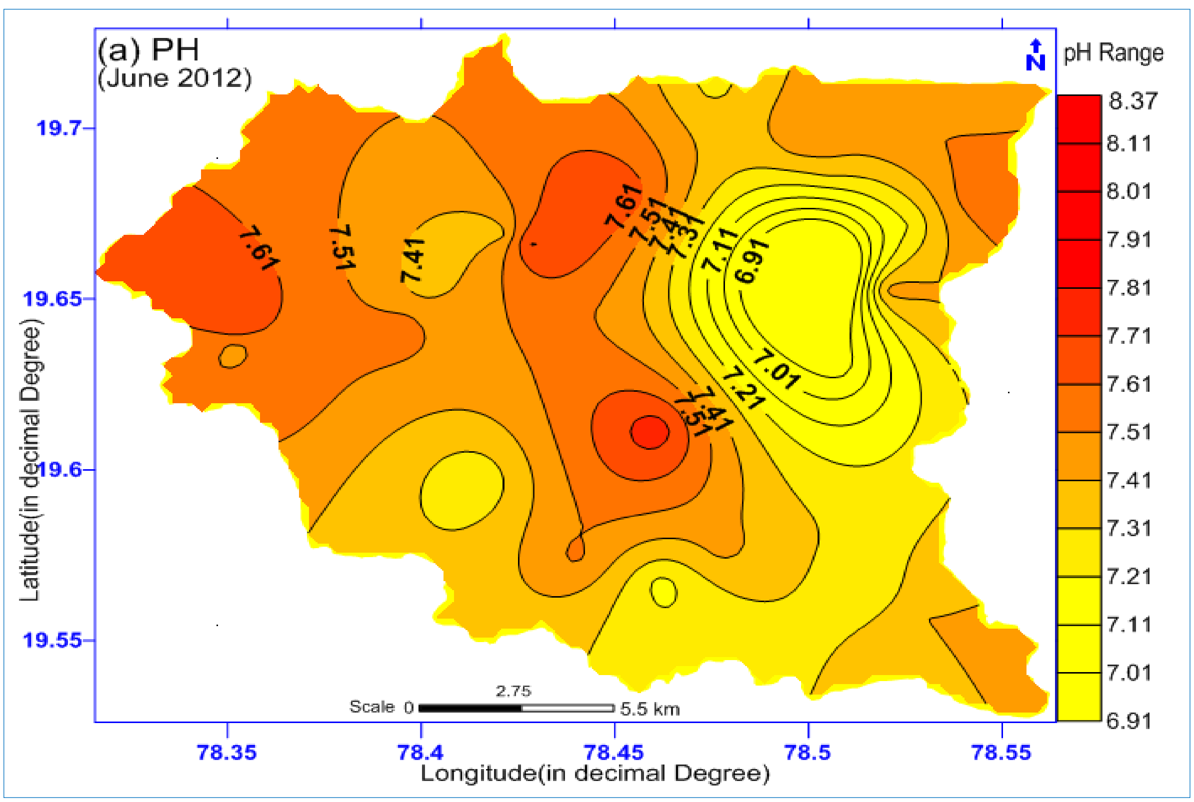


Fig: 6.3 pH contour map of pre monsoon of the study area

In the study area the pH of the post monsoon samples varies from 6.28 to 7.78. Only 4 samples are found below permissible limit (acidic nature) 6.28 at Battisamargam village and water treatment plant (Figure 6.2) the increased acidic nature of groundwater samples in this zone could be due to pesticides and other raw materials by closed industries. The pH of pre monsoon samples varied within the permissible limit from 6.9 to 8.4 (Figure 6.2). Alkaline pH above 8 was noted in the middle to southern part of the study area could be due to surface water interaction with groundwater and agriculture run off.

6.3.2 Total dissolved solids (TDS)

It is the amount of various dissolved material in the water. The bulk of total dissolved solids include bicarbonate, carbonate, sulfate, chloride, nitrate, calcium, magnesium, sodium, potassium and some heavy metals and trace constituents are common. Major ions occur naturally in water as a result of geochemical weathering of rocks, surface run off, atmospheric deposition and anthropogenic contamination. The TDS content of groundwater may range from 20 mg/l in area of high rainfall to over 100000 mg/l in some desert brines (Hem 1985). Several processes may cause an increase in TDS content of groundwater. Some of these include movement through rocks containing soluble mineral matter, concentration by evaporation and contamination due to influx industrial and municipal wastewater disposal, agreculturure etc. The WHO (1984) limit of TDS for drinking water is 500 mg/l for highest desirable and 1000 mg/l is for maximum permissible. High concentration of TDS may cause the water to be corrosive, salty or brackish taste.

Total dissolved solids (TDS) concentration gives a general nature of groundwater quality. TDS concentration monitored for two different seasons namely December 2011 (post monsoon), June2012 (pre monsoon) in the study area is found to vary from 168 - 1370 mg/l, 186 - 1180 mg/l (Figure 6.3) respectively. The spatio -temporal variations of TDS concentration in groundwater.

Table: 6.7. Classification of groundwater based on TDS (Carroll 1962)

Water class	**TDS (mg/l)**
Fresh water	0 to 1,000
Brakish water	1,000 to 10,000
Saline water	10,000 to 1,00,000
Brine	>1,00,000

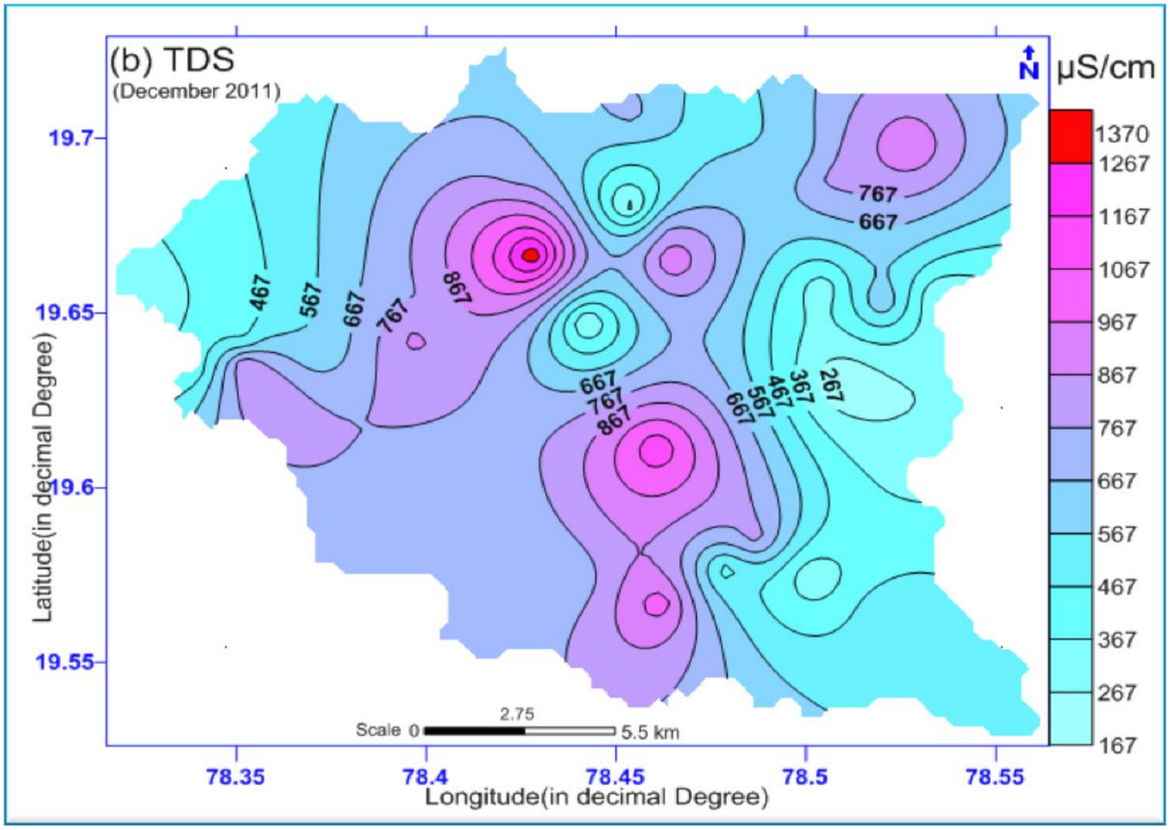


Fig: 6.4 Variation of TDS concentration during post monsoon.

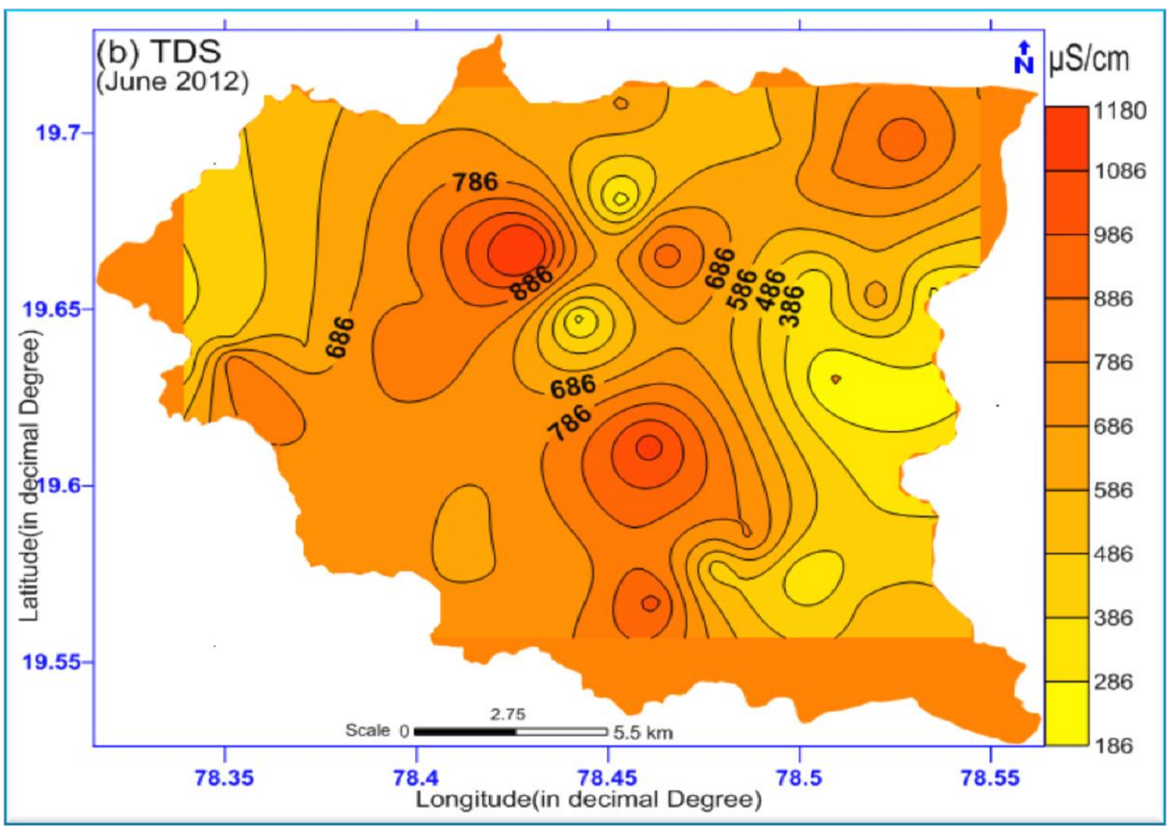


Fig: 6.5 Variation of TDS concentration, pre monsoon.

For two periods are shown in figure 6.4. At Mavala lake (center of the study area) there is a patch of high TDS range 167-1370 mg/I in December 2011 (post monsoon), 186-1180 mg/l in June 2012 (pre monsoon),. The decreasing trend of TDS concentration with time is due to dilution by rain water. The high TDS in this zone reflects the industrial influence and Agriculture activities and municipal waste. Apart from above a patch of high TDS range 167-1370 mg/l, 186 -1180mg/l is also identified in post monsoon, pre monsoon at Thalamadugu village in the Mathadi vagu basin area. This could be combined effect of industrial and agriculture activity, towards the western part of the study area. With time, groundwater was recharged by rain from non monsoon to monsoon period (Figure 6.3). The phenomenon of increase and decrease in TDS concentration indicate the hydrochemical dynamic nature of the aquifer system in the study area. And over exploitation of groundwater in the south caused groundwater level drop thereby generating reversal of hydraulic gradient towards west.

6.3.3. Sodium

Sodium is one of the important constituents in the determination of suitability of water for irrigation purpose. The primary source of sodium in natural water is from the release of the soluble products during the weathering of plagioclase feldspars. Repeated e of irrigated water can, also increase sodium concentrations in soils thereby affecting the soil permeability and texture and thus rendering it unsuitable for cultivation (Triwedi and Goel 1984). The WHO limit for Sodium is 200 mg/I for domestic use and when in excess can cause cardiovascular diseases. In women it causes toxemia, a disease associated with pregnancy (NAS 1977). Many industrial wastes and domestic sewage are rich in sodium and increase its concentration in waters after disposal. Sodium salts are highly soluble in water and unlike calcium and magnesium there are no precipitating reaction to reduce its concentration. Sodium has tendency to get absorbed on the clay particles but may effectively be exchanged by Ca^{2+} and Mg^{2+} thus gets increased in concentration in some waters. The higher concentration of sodium can be related to cardiovascular diseases. Besides, high concentration of sodium associated with chlorides and sulfates make the water salty render it unpalatable.

The sodium concentration vary from 20-170 mg/I (mean: 66 mg/l) and 17-262mg/l (mean: 73.2 mg/I) during post and pre monsoon study respectively (Figure6.6 & Tables 6.3 & 6.4). A patch of high concentration of sodium value 150-262 mg/I was observed during post and pre monsoon period low value is observed at Mathadi vagu project and high value observed at Sunkidi village.

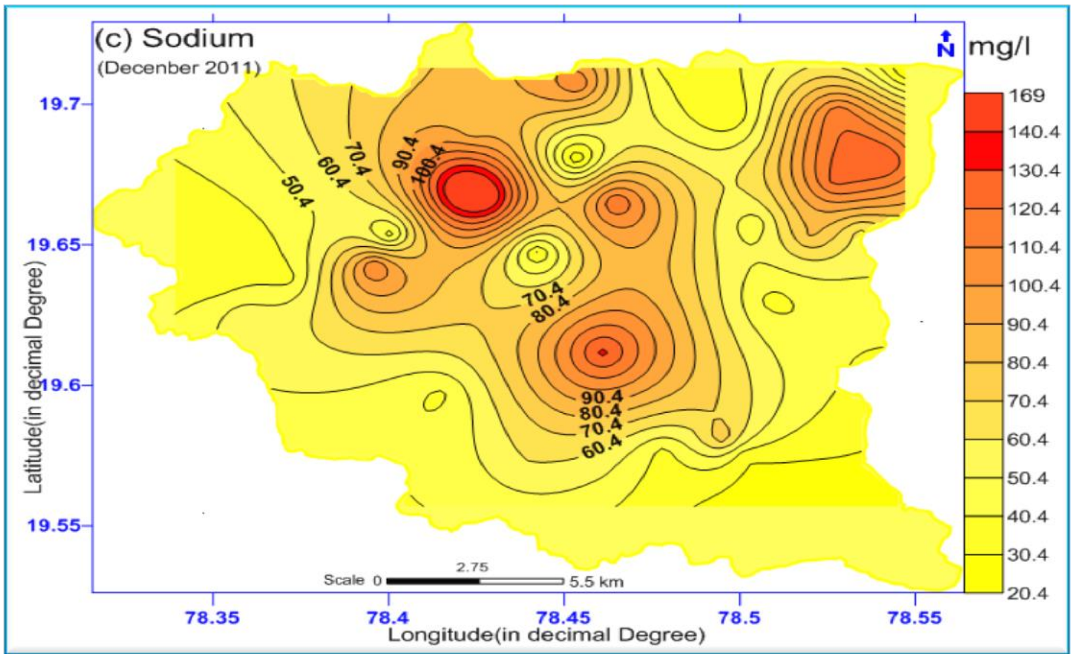


Fig: 6.6 Variation of sodium concentration during post monsoon .

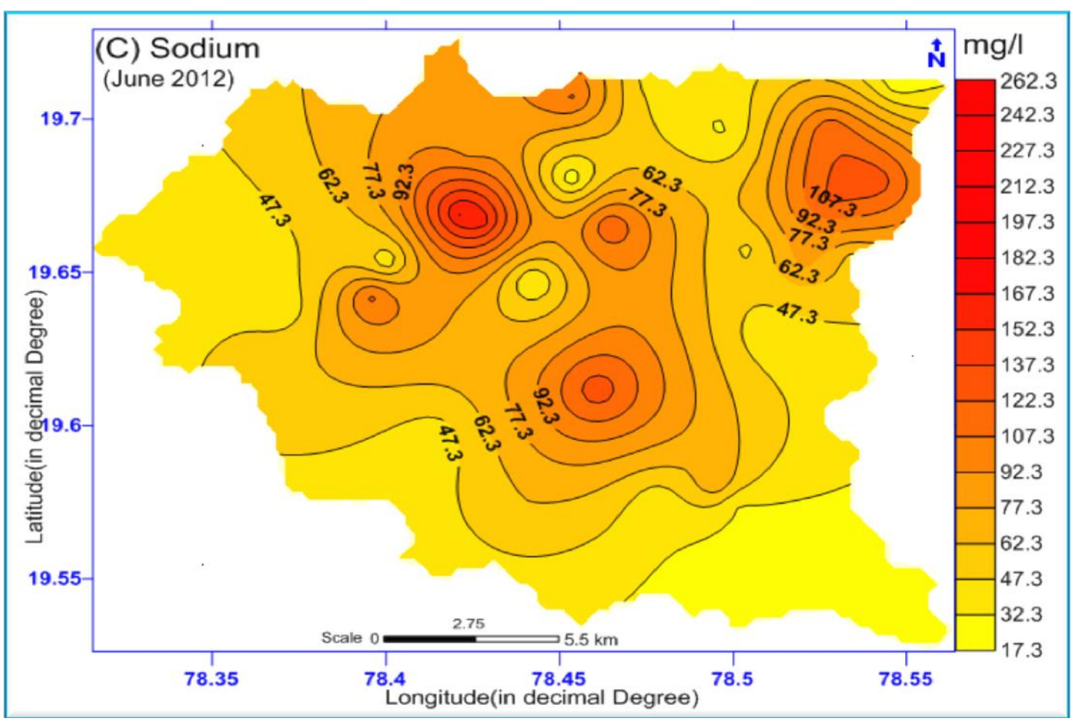


Fig: 6.7 Variation of sodium concentration during pre monsoon

6.3.4. Potassium

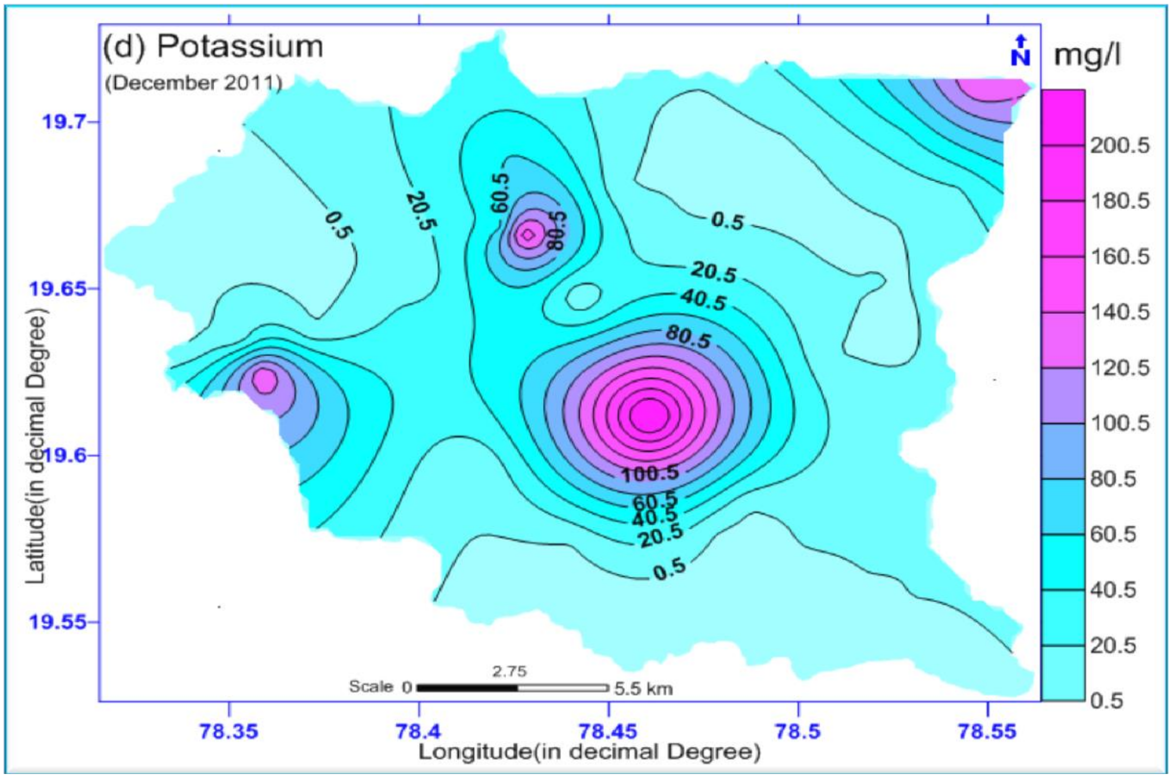


Fig: 6.8 Variation of potassium concentration during post monsoon

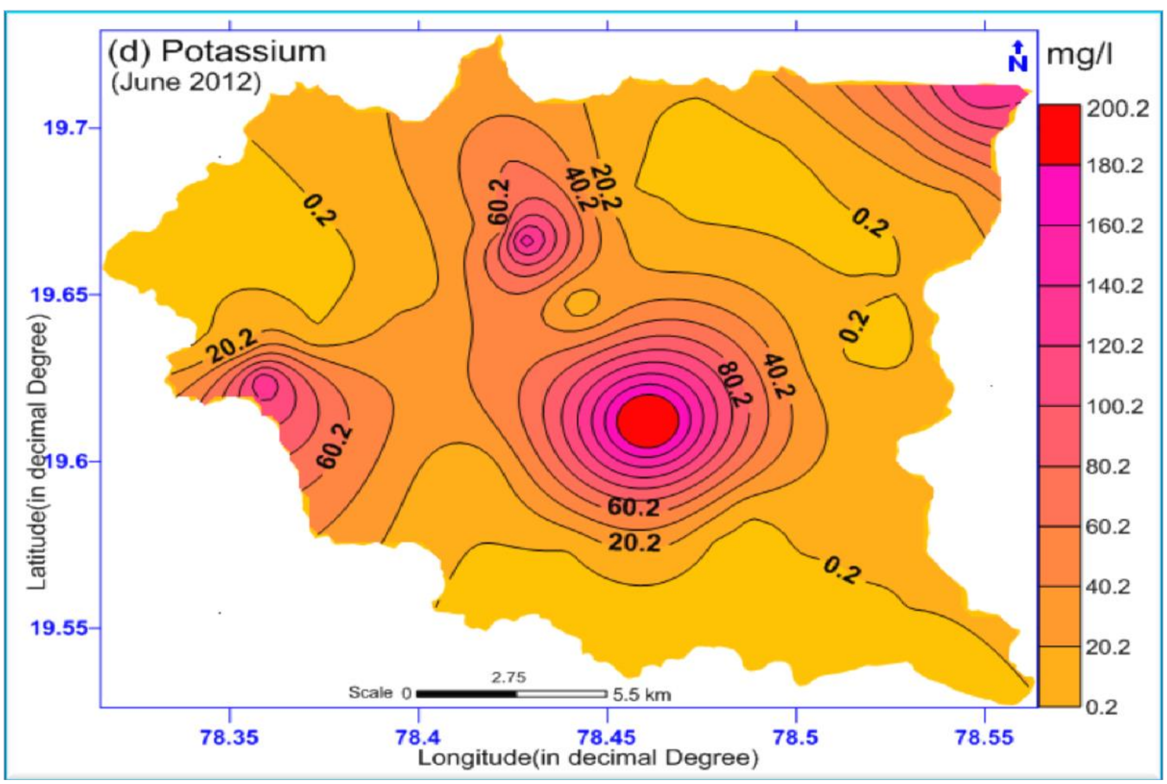


Fig: 6.9 Variation of potassium concentration during pre monsoon

Potassium occurs at fairly low concentrations in groundwater. However, excessive fertilizer usage can increase the potassium concentration in surface as well as groundwater. The major source in natural fresh waters is weathering of rocks but the concentration increases in the polluted waters due to disposal of wastewaters. Potassium salt being more soluble than sodium salt, are the last to crystallize during evaporation.

The potassium concentration in groundwater is found to vary from0.5-239mg/l (mean: 26 mg/I) and 0.2-200 mg/1 (mean: 27 mg/I) in post and pre monsoon seasons respectively (Tables 6.3 & 6.4). Very high concentration of potassium 159-239mg/l .the low value is present in the Somarpet village and highest value is present at Devapur village.

6.3.5. Magnesium

Magnesium is also one of the abundant elements in rocks. It causes hardness in water. The common sources of magnesium in hydrosphere are Dolomite, Olivine, Biotite and Hornblende minerals in rocks. The magnesium concentration in sea water is high compare to groundwater quality. Sewage and industrial waters are also important contributors of magnesium. High concentration combined sulfates acts as laxative to human beings. Magnesium adds to the hardness of the water and with calcium poses the problem of scale formation in boilers. In general, the magnesium concentration higher than calcium concentration at coastal area indicates sea water contamination.

The magnesium concentration in groundwater is found to vary from 7.8-83 mg/I (mean: 49 mg/l) and 7.7-118 mg/I in pre and post monsoon seasons respectively (Tables 6.3 & 6.4). The very high concentration of magnesium value observed at Umri-T village, and low value observed at Thantholi Road.

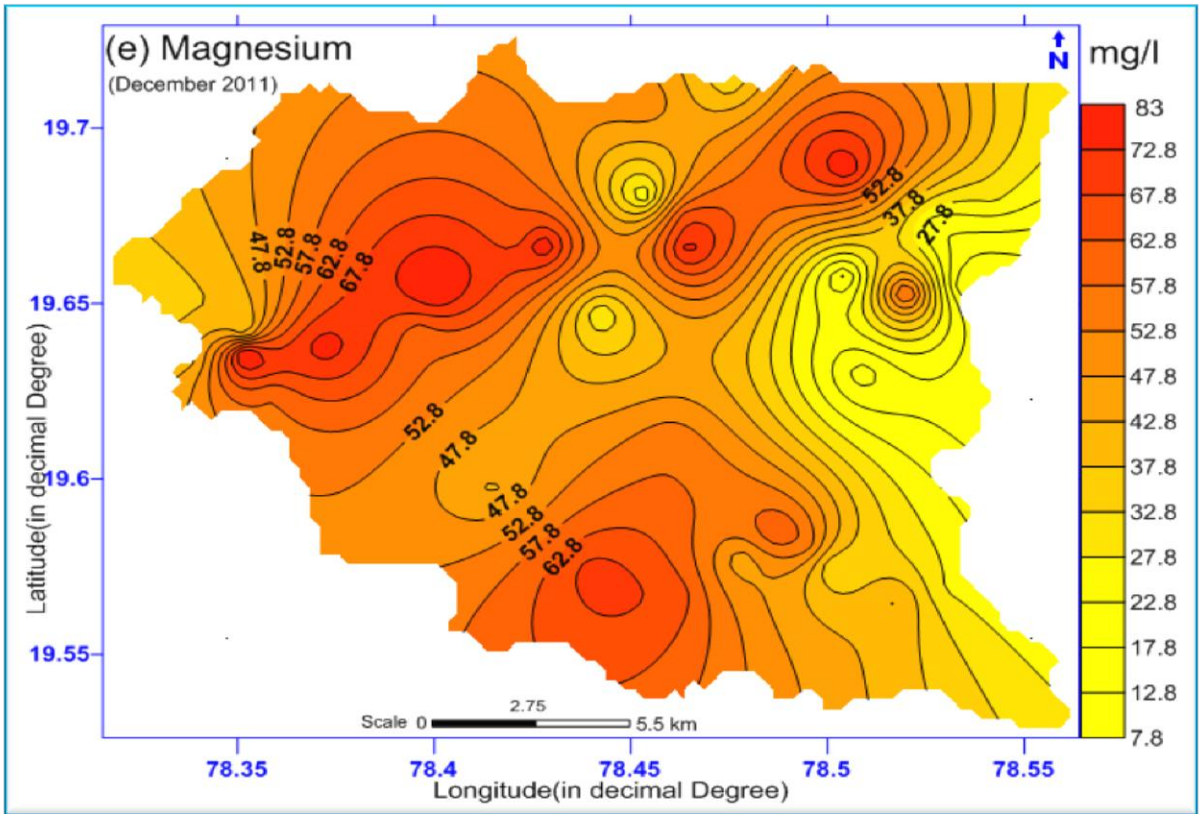


Fig: 6.10 Variation of magnesium concentration during post monsoon

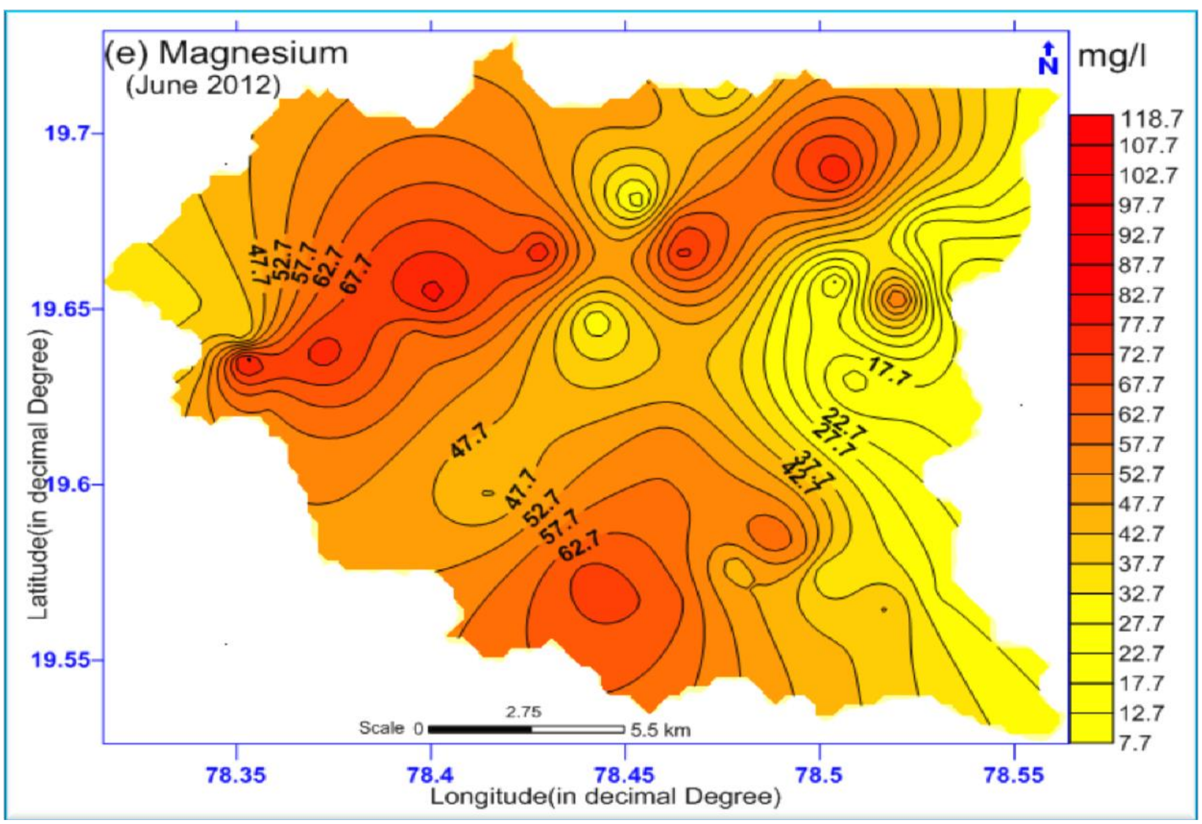


Fig: 6.11 Variation of magnesium concentration during pre monsoon

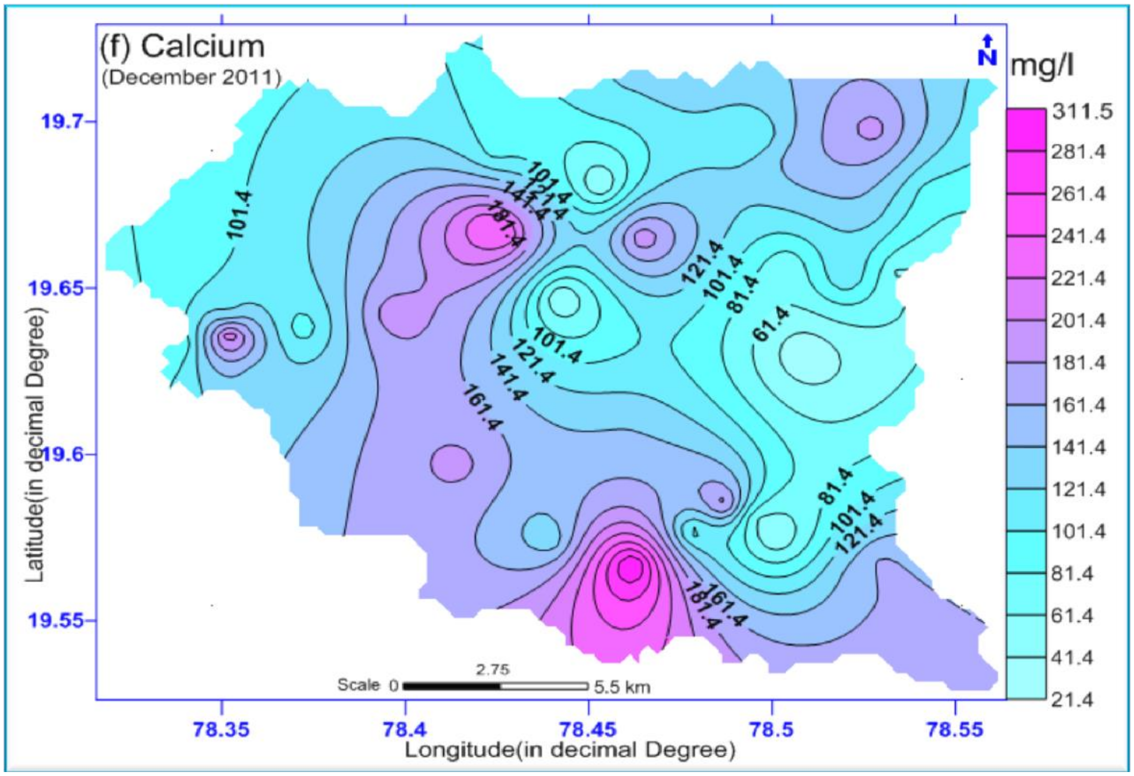


Fig: 6.12 Variation of calcium concentration during post monsoon

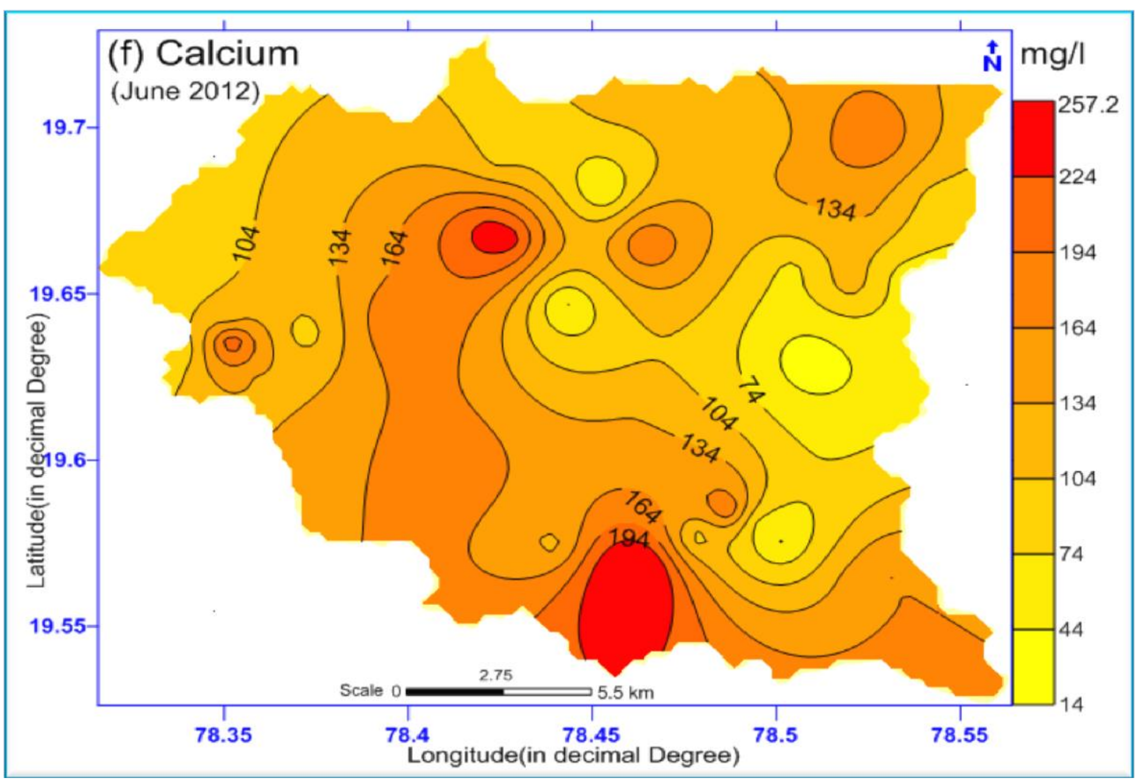


Fig: 6.13 Variation of calcium concentration during pre monsoon

6.3.6. Calcium

Calcium is a principal cation and it is widely distributed in earth's crust and is important elements in all waters. It is mainly derived from weathering of Silicate mineral groups of Plagioclase, Pyroxene and Amphiboles which are present in rocks. The Calcium concentration in normal groundwater generally range between 10 and 100 mg/1. Calcium concentrations at this level has no adverse effect on the health of human beings and animals. High concentration of calcium is not desirable for washing and other domestic uses. The most commonly noticed effect of calcium in water is its tendency to react with soap to form a precipitate called "Soap curd" (Davis and Dewiest 1966).

The Calcium concentration in groundwater was found varying from 21.4-312 mg/I (mean: 133 mg/l) and 14-119 mg/I (mean: 104 mg/I) in post and pre monsoon period respectively (Tables 6.3 & 6.4). Very high concentration of calcium value is observed at Waghapur village low value observed at Mavala lake. the closed units and open dumping of municipal solid waste which increased the Ca^{2+} concentration in this area. (Figure 6.12& 6.13) indicated suitability of water for drinking as per WHO standards.

6.3.7. Chloride

Chloride is a minor constituent in the earth's crust, but a major dissolved constituent in natural water. Chloride is important in terms of metabolic processes and influence osmotic salinity balance and ion exchange. The most important source of chlorides in the water is discharge of domestic sewage and industrial effluent. Man and other animal excrete contain very high quantities of chlorides together with nitrogenous compounds. About 8-15 gm of NaCI is excreted by a person per day. Therefore, the chloride concentration serves as an indicator of pollution by sewage. Although the chloride content of ocean water and important entity in the hydrological cycle is of the order of 13000 mg/l, the chloride content in rain water may be high in coastal areas and in desert tracts. Chloride is highly soluble with most of the naturally occurring cations and does not precipitate sediment and cannot be removed biologically in treatment of wastes. It is harmless up to 1500 mg/l concentration. It can also corrode concrete by extracting calcium the form of calcite. $MgCl_2$ water generates hydrochloric acid after heating, which is highly corrosive and create problems in boilers. Higher Chloride concentration can reduce the toxicity of nitrate to aquatic life. The spatial variation of chloride concentration during December2011 and June2012 period in groundwater are shown respectively in (Figure 6.14 &6.15). The chloride concentrations in groundwater were found varying from 13.5-333mg/l, and 12.5-342.2 mg/l in December 2011 and June 2012 period respectively (Tables 6.3 & 6.4). A patch of high concentration of respectively was found at Umdam village.

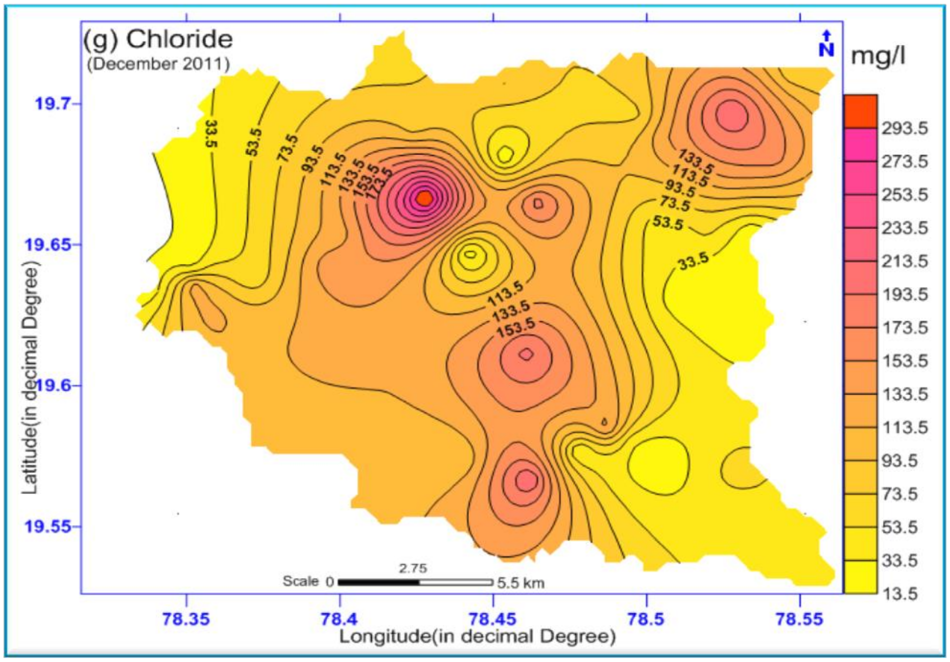


Fig: 6.14 Variation of chloride concentration during post monsoon

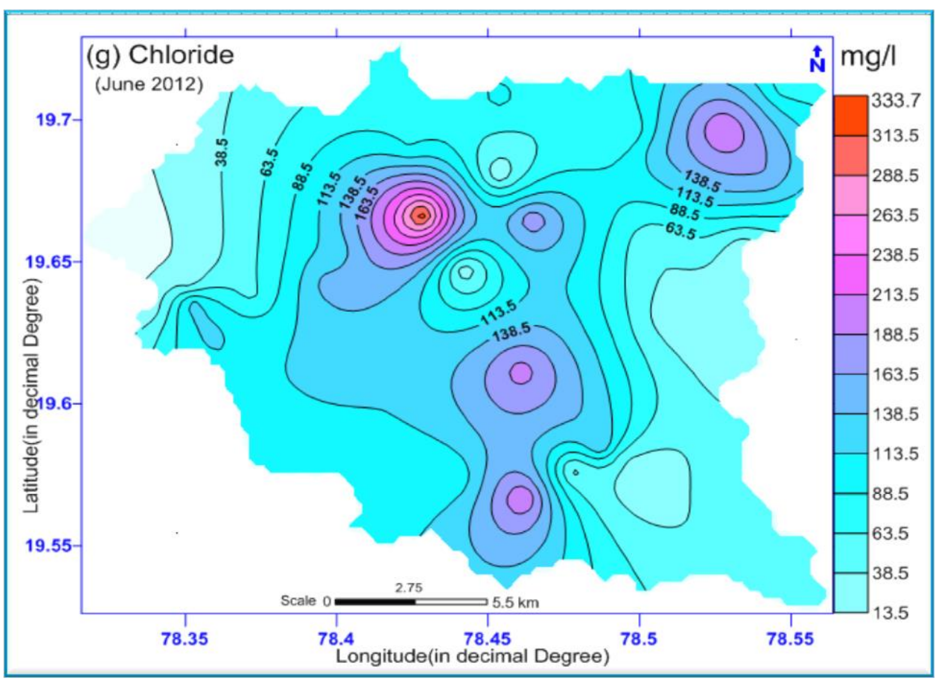


Fig: 6.15 Variation of chloride concentration during pre monsoon

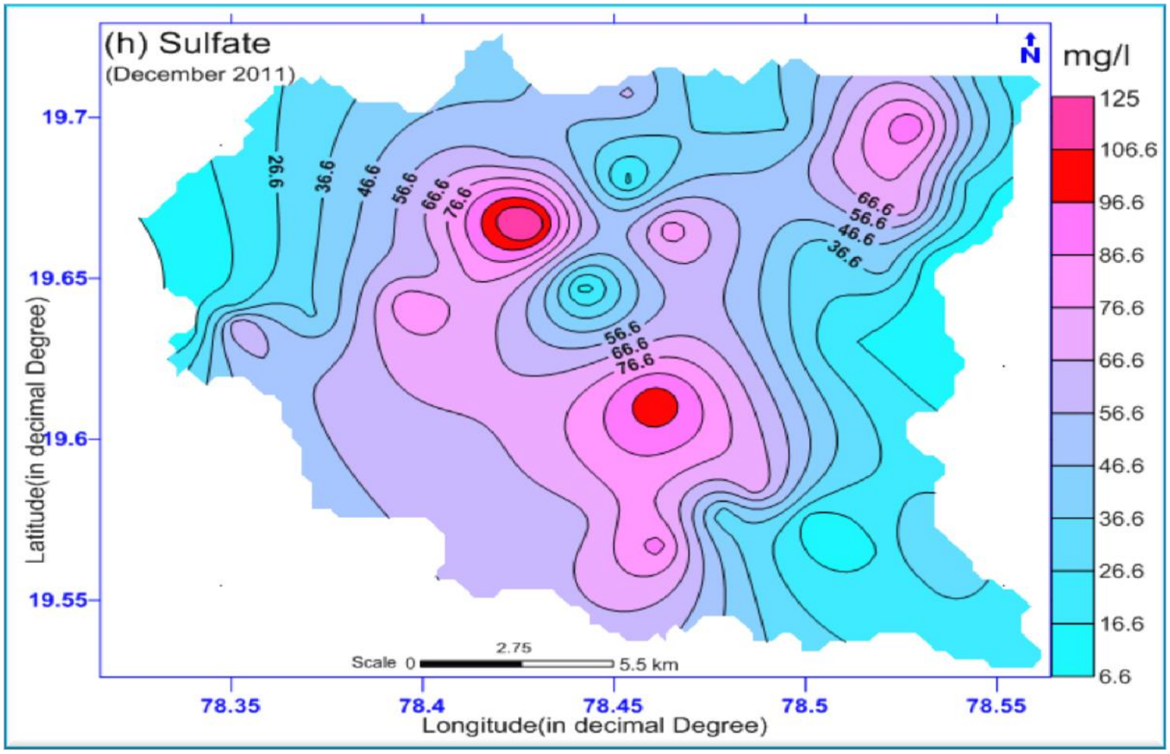


Fig: 6.16 Variation of Sulfate concentration during post monsoon

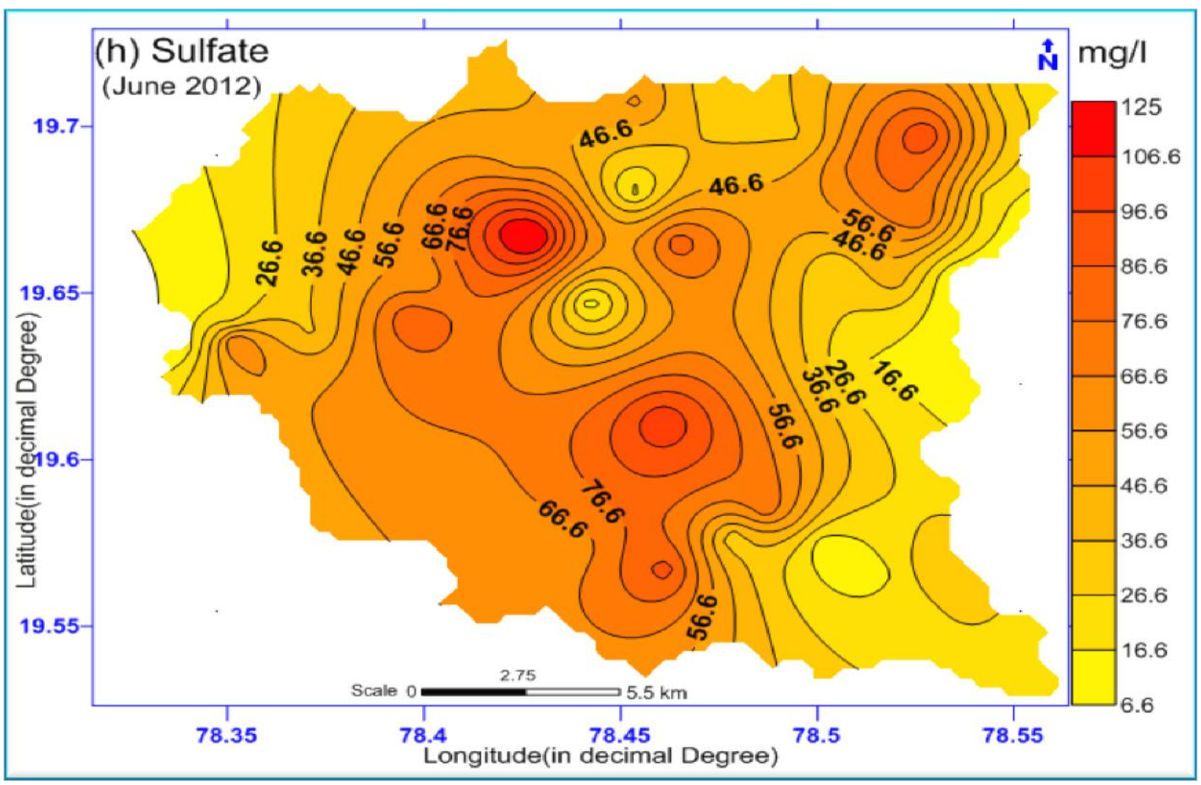


Fig: 6.17 Variation of Sulfate concentration during pre monsoon

6.3.8. Sulfates

Sulfates occur naturally in water as a result of leaching from surrounding rock. Industries that burn coal release sulfur compound into the atmosphere to become a part of the acid rain problem. Dissolved sulfate is derived from the dissolution of gypsum or the oxidation of sulfide minerals such as pyrite. Dissolved sulfate is stable under oxidizing condition; however, under reducing conditions, it can be converted to hydrogen sulfide (H_2S). Dissolved sulfate can combine with Calcium to form scales in water heaters and boiler. At concentrations exceeding 500-600 mg/I it imparts a bitter taste and may cause laxative effects in some individuals (Ragunath 1987).

The sulfate concentration in groundwater is found to vary from 6.6-125 mg/I and 7.3-116 mg/I in post and pre monsoon seasons (Table 6.3 & 6.4) concentration of minimum is at Thantholi Road and maximum at Umdam village.

The sulfur value below 200 mg/I is identified in the west side of study area (Figure 6.5) which is below permissible limit of WHO standard.

6.3.9. Bicarbonate

The-carbonate and bicarbonates contribute to all the alkalinity or acid neutralizing power of water. The primary source of carbonates and bicarbonates in groundwater is the dissolved carbon dioxide in rain (snow). The surface water bodies are rich in bicarbonates compared to groundwater. Bicarbonate rich groundwater shows the aquifer is directly recharged by the surface water. The carbonates are absent in waters with the pH values less than 8.3.

The Bicarbonate in groundwater is found to vary from 137-683 mg/I (mean: 435 mg/I) and 134-588 mg/I (mean: 385) in post and pre monsoons respectively (Tables 6.3 & 6.4). The decreased mean value in pre monsoons a significant recharge from surface run off during monsoon. Low CONCENTRATION OF Calcium is at Mavala lake and high value present at Ramnagar village in Mathadivagu basin.

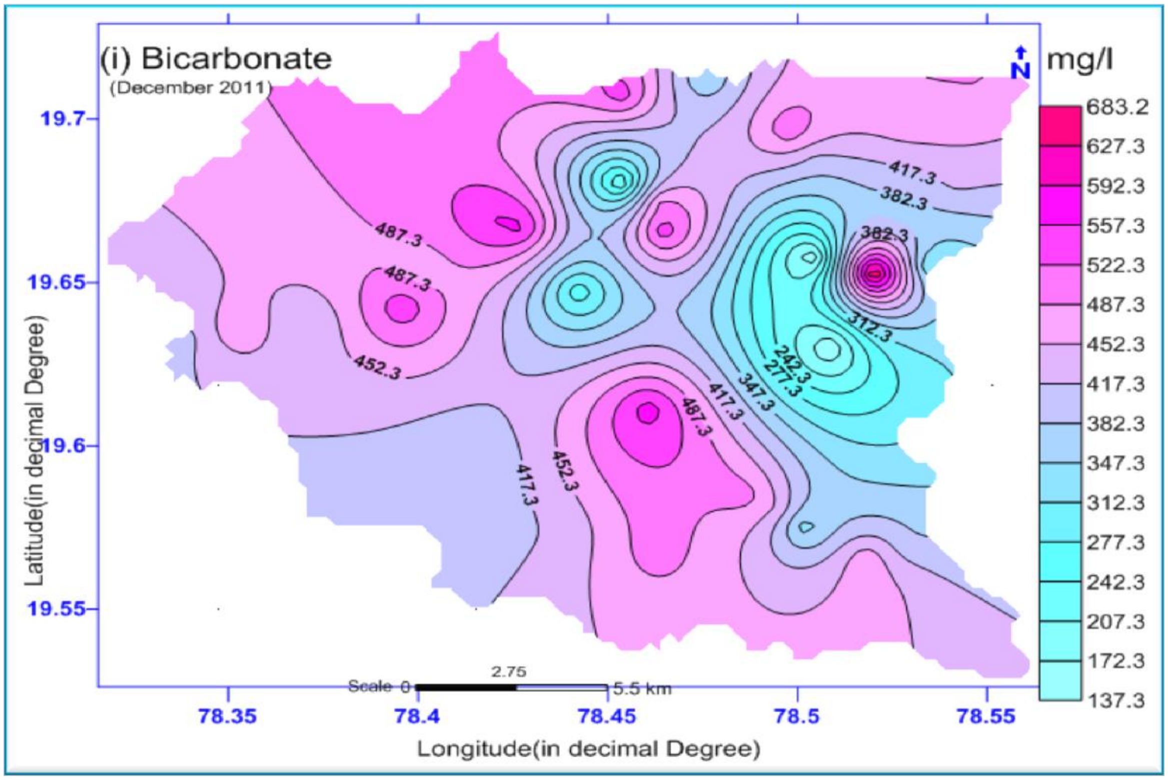


Fig: 6.18 Variation of bicarbonate concentration during post monsoon

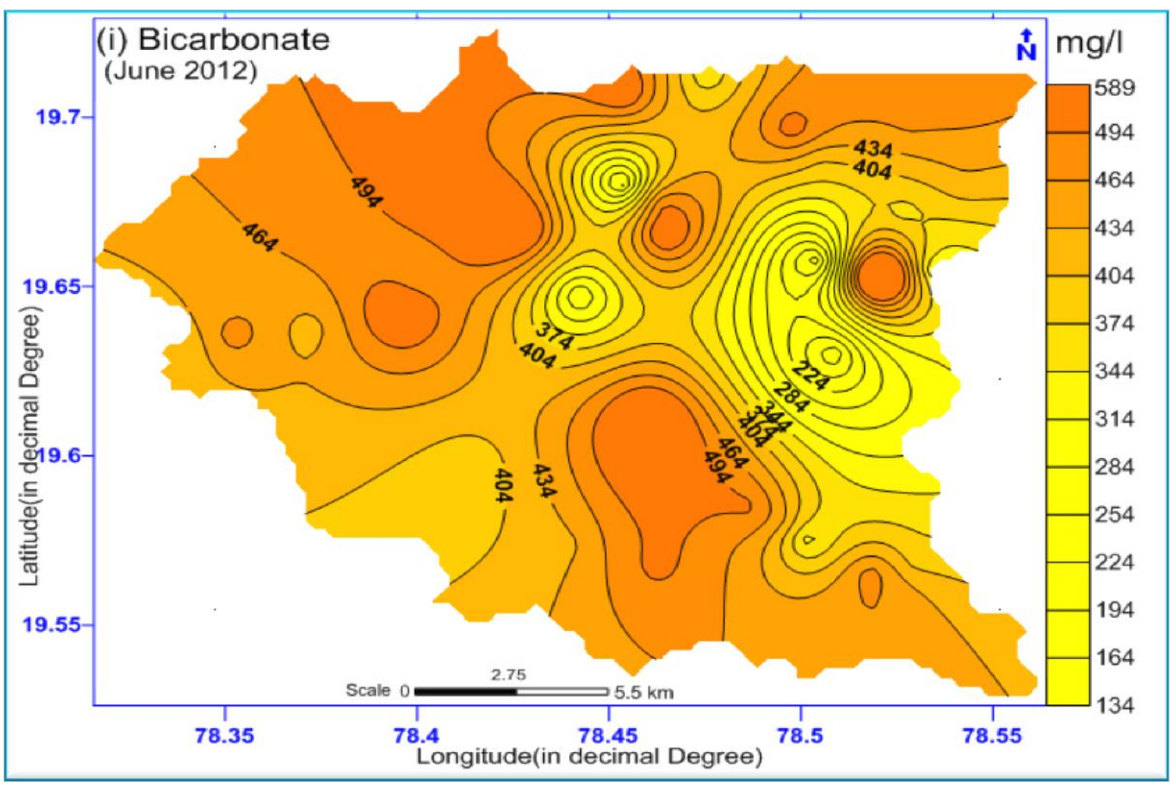


Fig: 6.19 Variation of bicarbonate concentration during pre monsoon

6.4. Nitrates

Nitrates in ground water originate from various natural resources (such as atmospheric deposition and dissolution of geological materials). Nitrates reach ground water as non point contaminants from agriculture activities, human excreta etc. The permissible limits of the nitrate as N in ground water is 45mg/l. higher concentration of nitrate may cause Methaemoglobinemia (blue baby syndrome) in infants. Nitrate can oxidise haemoglobin of blood to Methaemoglobin a pigment that is incapable of acting as carrier of oxygen. As a result the whole body becomes blue leading to Methaemoglobinemia disease.

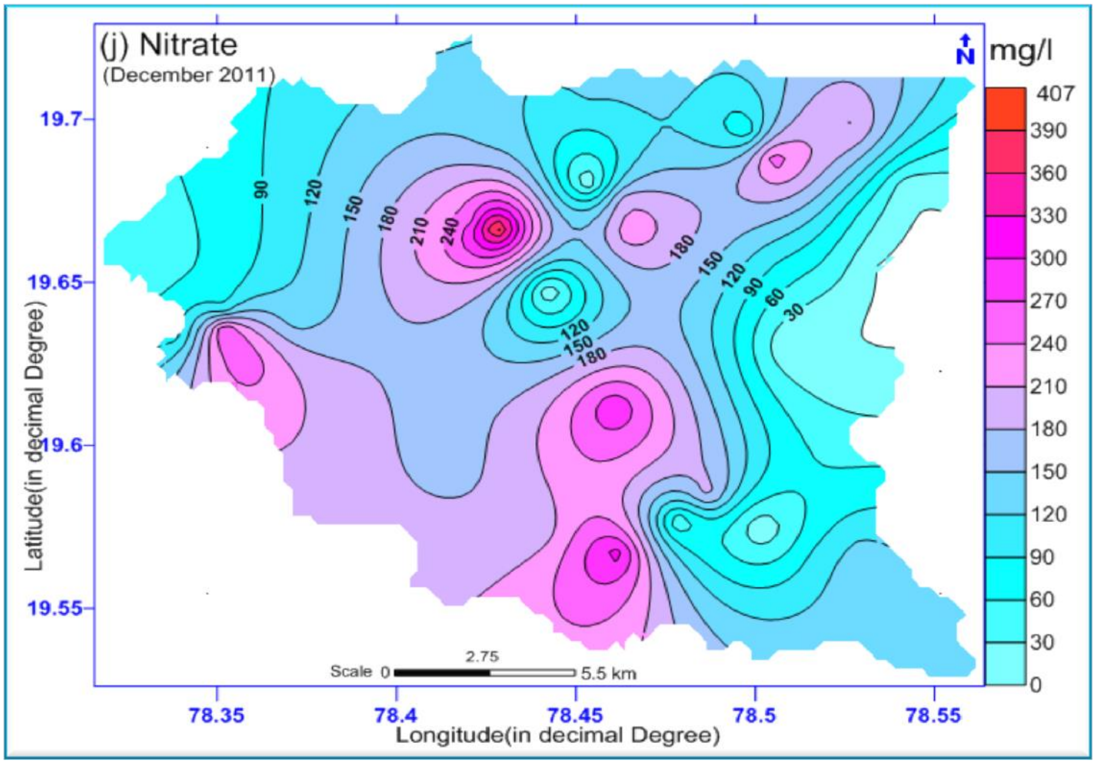
Higher value of nitrate are observed in certain villages namely Umdam and Devapur which may be due to local and anthropological pollution.

6.4.1. Sources of Nitrate in the area

The analytical results reveal that 6 wells have nitrate below 45mg/l, the safe limit for human consumption, 7 wells have nitrate in the range of 46 to 100 mg/1 and 22 wells show nitrate in the range of 101 to 407 mg/1. One well has nitrate 'more than 400 mg/1. The origin of nitrate in the area is ascribed to industrial activity, sewage and animal wastes and agricultural sources.

Cotton mills are one of the established industries in the area for more than 50 years. More than 60 tannery units situated in the area have been discharging untreated effluent in the nearby streams, ponds and open land before the inception of treatment plants. These solid wastes are usually dumped in the vacant lands. High Agriculture activities are going in the area.

Most of the monitoring wells located near the town show high nitrate values. The extensive use of organic and chemical fertilizers in the area is also responsible for the incidence of high concentration of nitrate. All the nitrate salts, which are in anionic form are highly soluble in water and are repelled by most of the clay minerals invariably found in all soils. Its high mobility favors the transport of this anion to very long distances in the shallow zone. As the shallow formation water is saturated with dissolved oxygen, anaerobic conditions does not exist which favors high nitrate ground waters. The high levels of potassium with nitrate show the relation between fertilizer use and occurrence of nitrate. Most of the wells in the cultivated area have high nitrate levels, which confirm the contribution of nitrate from fertilizer use. Because fertilizers are used continuously, infiltrating water downward to the water table where they can migrate in the ground water flow regime carries a considerable part of them.



Fig; 6.20Variation of Nitrate concentration during post monsoon

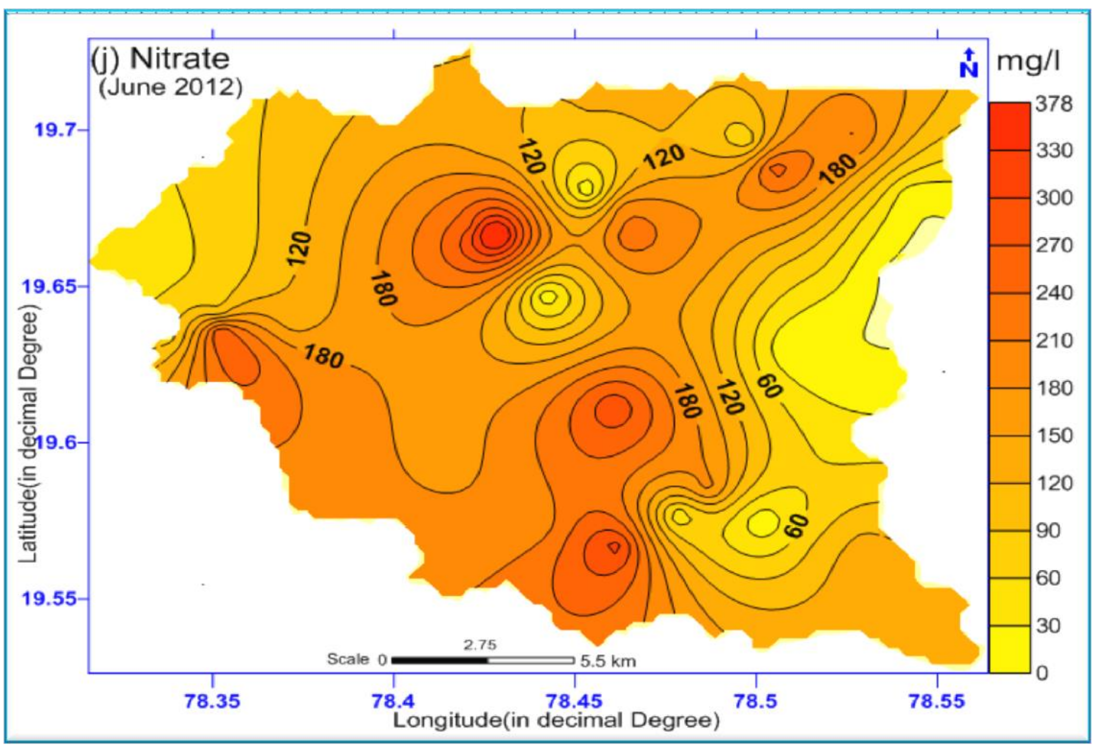


Fig: 6.21Variation of Nitrate concentration during pre monsoon

6.5. Fluoride

Fluorides are low in solubility and amounts present in ordinary water are limited (Hem 1959). Fluoride frequently occurs in igneous and metamorphic rocks as a component of amphiboles e.g, Hornblende and of the micas (Hem 1959,1970) containing alkali rocks and obsidian are high in fluoride compared to other igneous rocks (Rankama and Sharma 1950). The fluoride concentration in natural water which as a total dissolved solids content of less than 1000 mg/l is usually less than 1 mg/l. High fluoride concentration may be expected in ground water from calcium poor aquifers and in areas where fluoride bearing minerals are common. The fluoride concentration in the study area is shown in (Fig: 6.22 &6.23). High fluoride concentration exceeding the drinking water standard limit for fluoride i.e 1.5 mg/l set by WHO/BIS is observed in Sithagondi (4.5 mg/l), Kamlapur (1.9 mg/l), and Pippalkoti (1.5 mg/l), villages. By practicing rain water harvesting method in these areas, the portability of water can be improved there is a scope of identifying the portable pockets in the above villages by detailed water quality inventory.

Fluoride ions have certain potentially beneficial effects up to 1 mg/l but excessive fluoride in drinking water supplies produces objectionable, dental “fluorosis “ that increases continuum with increasing Fluoride concentration . The fluoride concentration for a given community depends on climate conditions and proportional to the volume of water intake. This is in turn primarily influenced by air temperature.

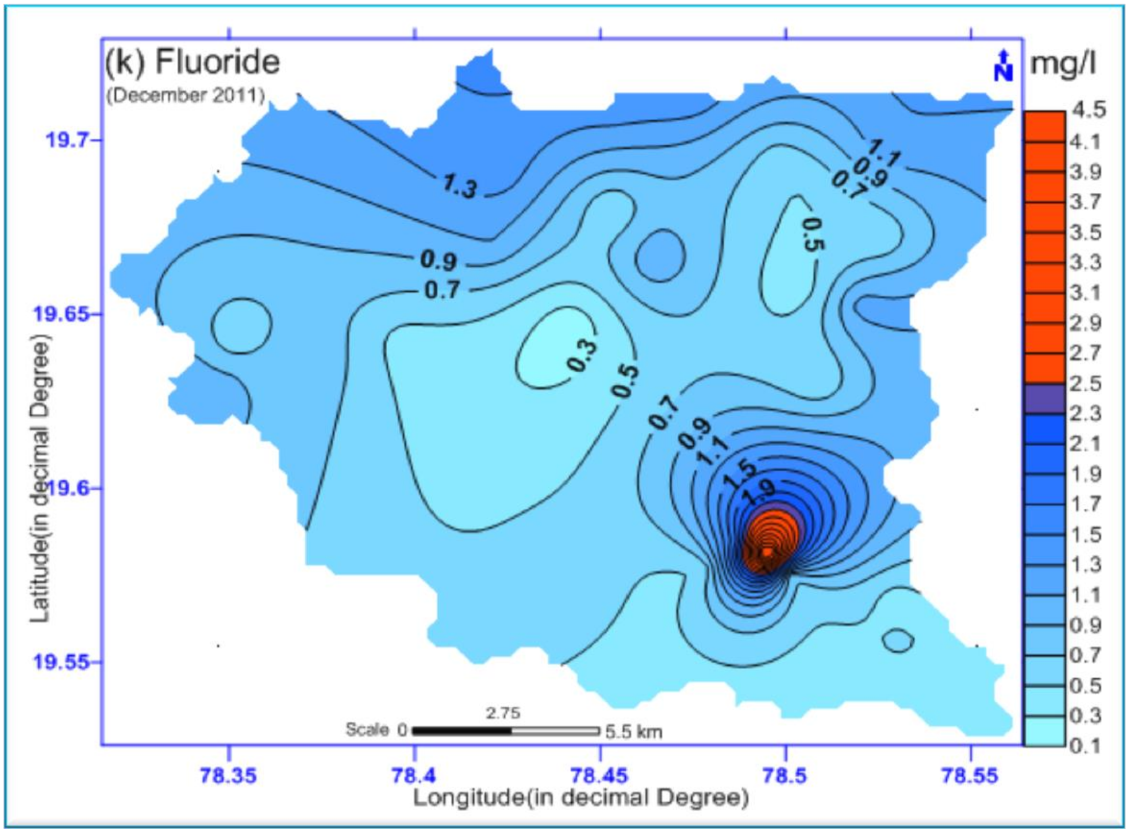


Fig: 6.22 Variation of Fluoride concentrations during post monsoon

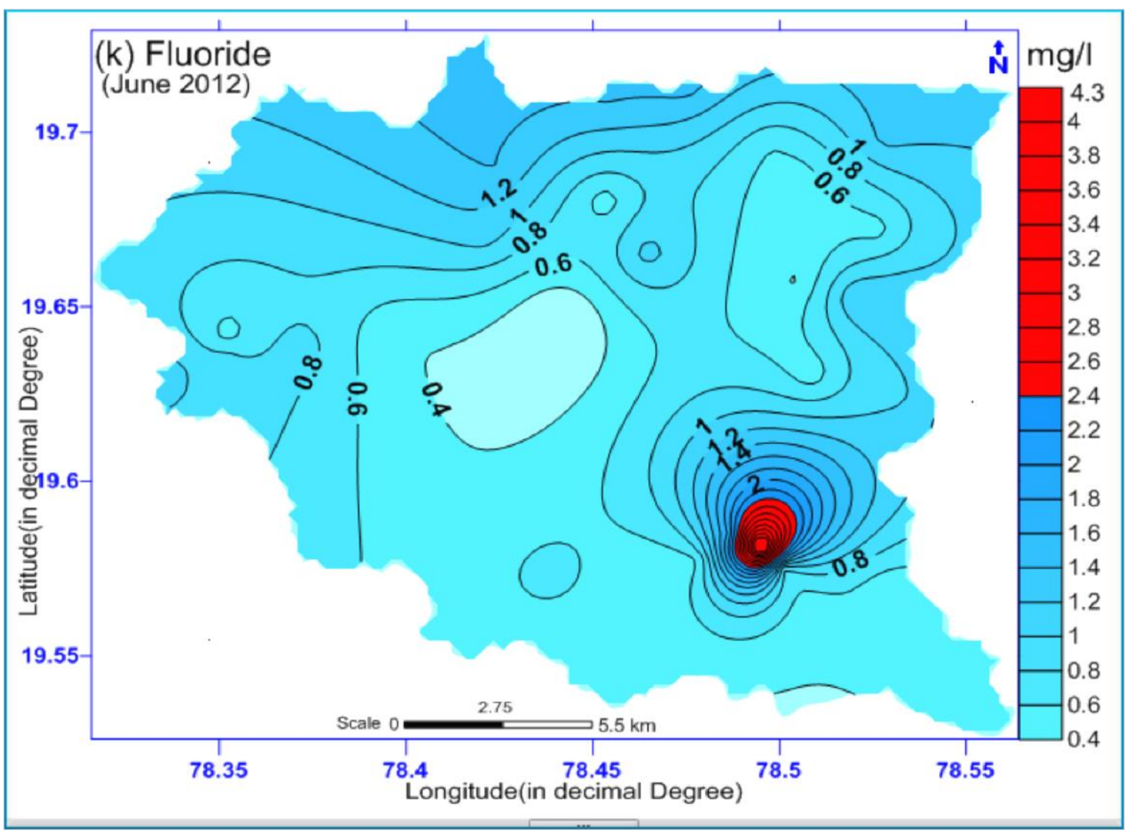


Fig: 6.23 Variation of Fluoride concentrations during pre monsoon

6.5.1. Sources of fluoride in the area

The occurrence of fluoride in ground water in the area is basically a natural phenomenon influenced by local and regional geological setting and hydrogeological conditions. Fluoride enrichment in ground water takes place mainly through leaching and weathering of the fluoride bearing minerals present in rocks and sediments. Geologically the area is underlain by crystalline rocks of Achaean age with varied composition. These are potential sources of fluoride bearing mineral. The major fluoride bearing mineral found in igneous & metamorphic rocks are Fluorapatite, Fluorite, Cryolite, Biotite, Muscovite, Lepidolite, Tourmaline, Hornblend series minerals, Asbetos etc. The most plausible process responsible for the evolution of fluoride rich natural water is the effective chemical weathering of fluoride-rich mineral. On vegetated ground and soils water acquires biologically produced carbon dioxide several times greater than the atmospheric levels, thereby enhancing the chemical decomposition of rock minerals. The arid to semi arid climate of the area is conducive to weathering. There is effective chemical weathering in wet season and evapotranspiration in dry season. Therefore the total salinity together with fluoride of surface waters and shallow ground waters increase conspicuously. Enrichment process must have been repeated for a long time to achieve present levels of concentration. High fluoride groundwaters in the area are concentrated mostly in the discharge area. the ground water moves along its flow paths from recharge to discharge area, evapotranspiration increases. The dry climate with low rainfall favors salinisation of ground water along the flow direction. As result, precipitation of calcite occurs in the form of kankar, which is noticed in some places in the area. Soils become more alkaline with very high pH, which limits the solubility of calcite. The conditions allow fluoride to accumulate in ground water environment.

6.6. Total Hardness

Total hardness is an important property of water, which prevents the lether formation with soap and increases in boiling point of water. Principal cations imparting hardness are calcium and magnesium. However, other reactions such as strontium, iron and manganese also contribute to the hardness. The anions responsible for hardness are mainly bicarbonate, carbonate sulfate, chloride nitrate and silicate. Hardness is called as temporary hardness if carbonates and carbonates salts of the cations cause it, since it can be removed by boiling the water. Mainly sulfates and chloride of the metals cause permanent hardness. The hardness denotes the concentration of calcium and magnesium in water, and is usually expressed as the equivalent of $CaC0_3$. Hardness is an important criterion for determining the usability of water for domestic, drinking and many industrial supplies. Hardness has no known adverse effect on human health. It is undesirable due to the formation of heat retarding insulating scales in the boilers and other heat exchange equipments. The hard water is also not suitable for domestic use in washing, cleaning and laundering.

Table: 6.8. Classification of water based on Hardness (Sawyer and McCarty, 1967)

Hardness mg/L as $CaCO_3$	**Water class**
0-75	Soft
75-150	Moderately hard
150-300	Hard
Over 300	Very hard

Total hardness was recorded in post and pre monsoon seasons as 85-1118.4 mg/l (mean: 535 mg/l) and 92-970 mg/l (mean :452 mg/I) respectively in the study area (Figure 6.11& Tables 6.3 & 6.4). The very high concentrations of hardness 1000-3278 mg/I (post monsoon) and 2000-4962mg/l (post monsoon) respectively, is noted in the north of the study area at Thamsi mandal.

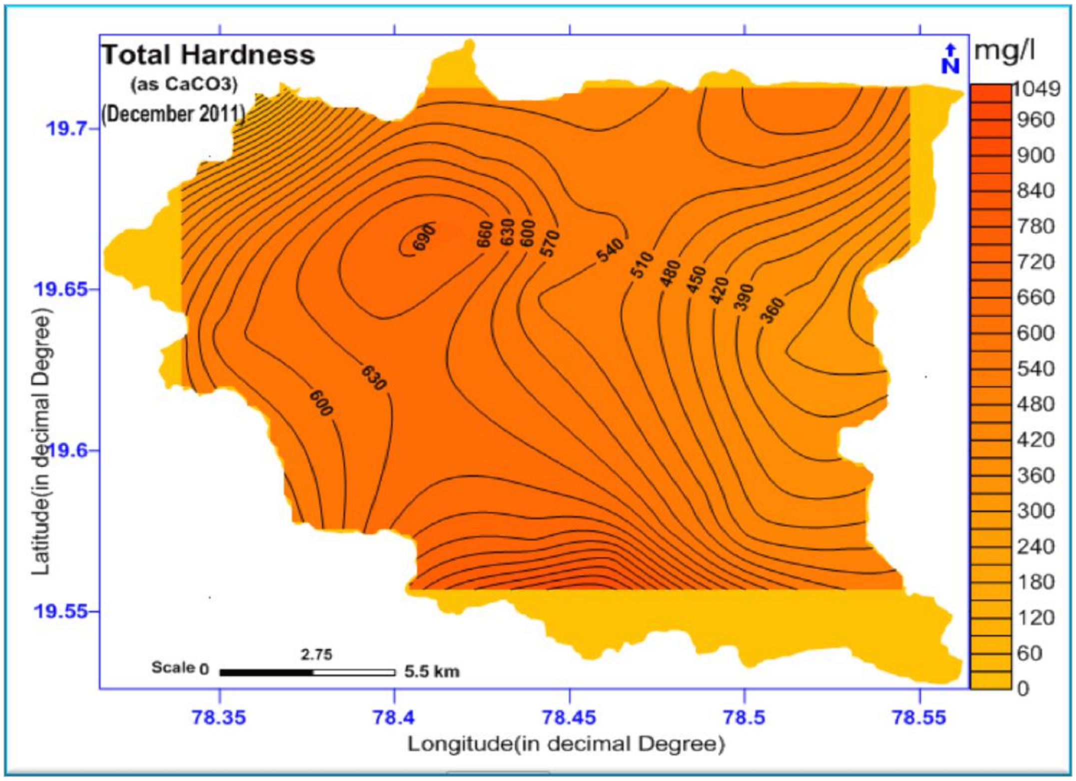


Fig: 6.24 Variation of total hardness concentration during post monsoon season

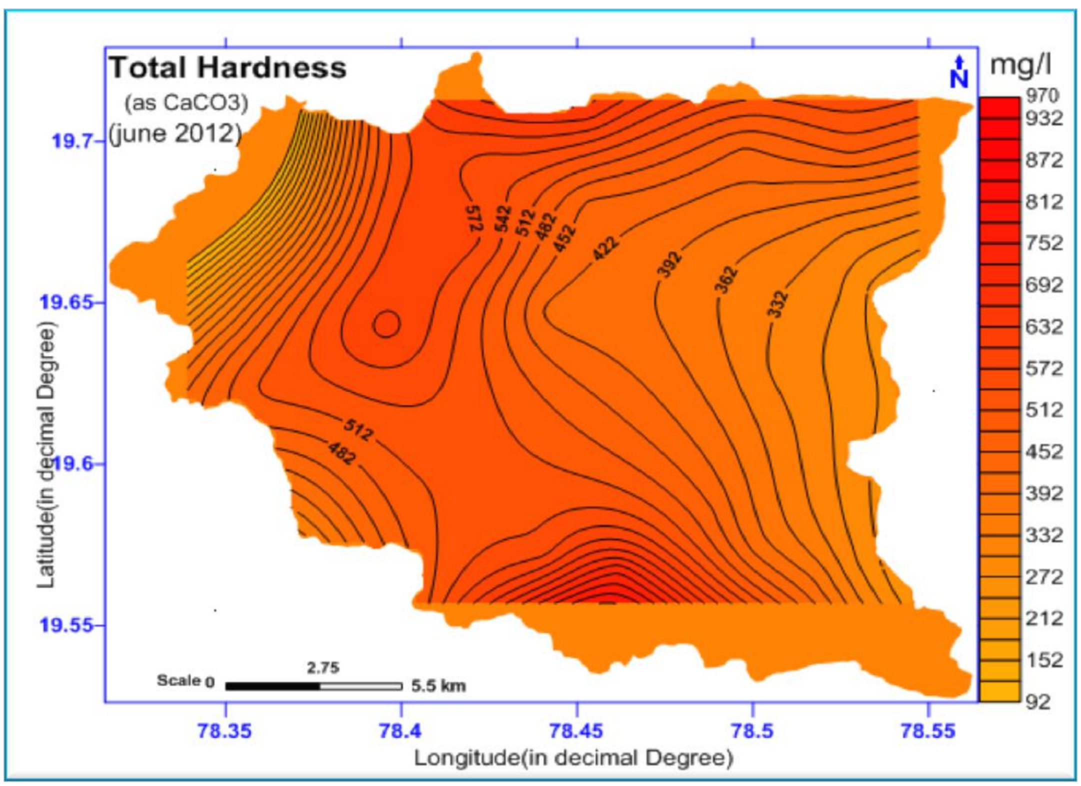


Fig: 6.25 Variation of total hardness concentration during pre monsoon season

6.7. Irrigation suitability of shallow wells

Water quality, soil types and cropping practices play an important role for a Suitability of irrigation practice (Kumar et al. 2007).

6.7.1. Piper plot

The geochemical evolution of groundwater can be understood by plotting the concentrations of major cations and anions in the Piper tri-linear diagram. The tri-linear plotting method proposed by Piper (1944) is the most extensively used technique for analyzing the geochemical facies of groundwater. The Piper diagram plots the major ions as percentages of mille-equivalents in two base triangles. The total cations and the total anions are set equal to 100% and the data points in the two triangles are projected onto an adjacent grid. This plot reveals useful properties and relationships for large sample groups. The main purpose of the Piper diagram is to show clustering of data points to indicate samples that have similar compositions.

Piper plot of post monsoon seasons showed clusters of samples tend close to calcium & magnesium and sulfate and chloride in diamond facies (Figure 6.13) showing water rich in chloride and sulfates of calcium and magnesium. Whereas in post monsoon seasons, the cluster is spreading towards bicarbonates and sodium & potassium ions (Figure 6.26) of the diamond shape. The spread of cluster towards bicarbonates facies in pre monsoon period indicates an appreciable recharge of surface water to groundwater.

In general the groundwater quality in the study area was found changing from S04-CI-Ca-Mg in post monsoon to S04-CI-HC03-Na-K in the pre monsoon. The broad classification of groundwater inferred from the Piper plots was Ca-Mg- S04-Cl -HC03 type (Figure 6.26).

Piper plot - Mathadivagu basin.

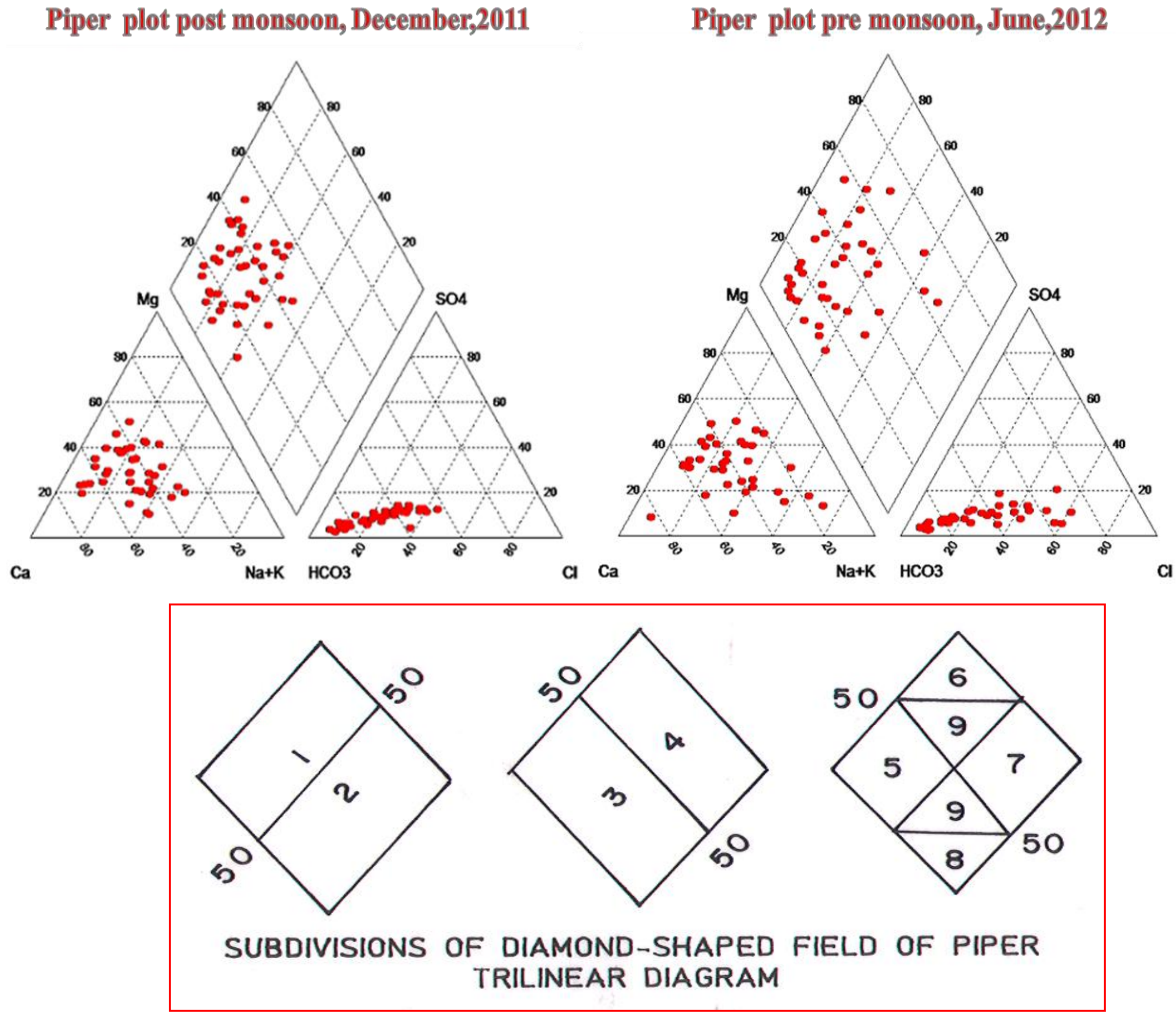


Fig: 6.26 Piper plots for groundwater samples during post and pre monsoons

6.7.2. US Salinity diagram

Similarly, to classify groundwater suitability for irrigation Wilcox (1955) gave a diagram using sodium content as percentage sodium and Electrical Conductivity. A Wilcox plot can be used to quickly determine the viability of water for irrigation purposes.

The Wilcox plot is also known as the U.S. Department of Agriculture diagram. The Wilcox plot is a simple scatter plot of Sodium Hazard (SAR) on the Y-axis vs. Salinity Hazard (Conductivity) on the X-axis. The Conductivity is plotted by default in a log scale.

US salinity diagram (Richards 1954) was used to plot the chemical data base describes that 25%, 24%, II % and 11 % of the groundwater samples of pre monsoon fall in the field C4S2, C3 1, C4S 1 and C4S2 respectively and few samples in C4S4, indicating salinity hazard 'High to Very High' category and sodium hazard 'Low to Very High' category (Figure 4.27).

Wilcox diagram –Mathadi vagu basin

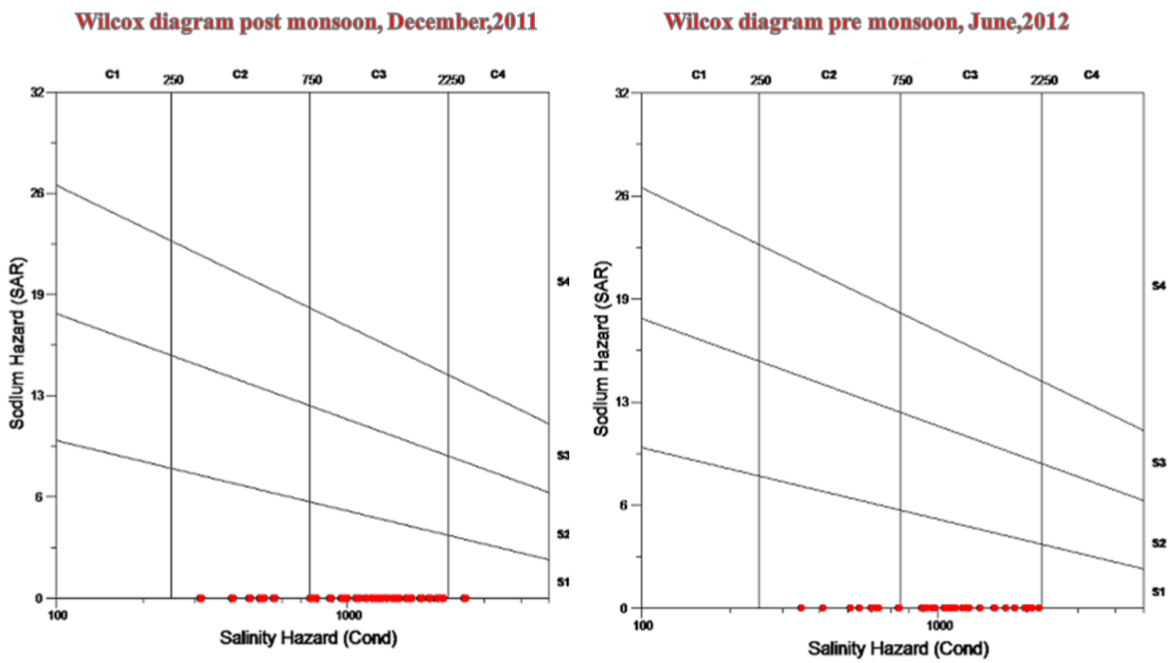


Fig: 6.27 Wilcox plot for groundwater samples during post and pre monsoon periods of the study period

Ground water	
Sodium (Alkali) hazard	**Salinity hazard**
S1: Low	C1: Low
S2: Medium	C2: Medium
S3: High	C3: High
S4:Very high	C4:Very high

In post monsoon period, 2.7%, 81%, 16%, and zero percentage of the samples fall in C4S1, C3S1, C2S1 and C1S1 respectively category showing salinity hazard 'Medium to low' and sodium hazard 'Low to Medium' category. In both the monsoon periods the majority of the samples show salinity hazard low to medium indicating the influence of industrial activities. High salinity hazard showing the suitability for salt tolerance plants but restricts its suitability for irrigation, particularly in soils with restricted drainage (Karanth 1989; Mohan et al. 2000).

6.7.3. Durov diagram

Durov Diagram proposed by S.A Durov (1948). The basis, once again, is percentage plotting of cations and anions in separate triangles (Fig6.28). The intersection of lines extended from the points to the central rectangular field gives a point representing a type of water. From that points, lines drawn to adjacent rectangles give points showing total concentration (scale in meq/l) and any other optional characteristic constituent of the problems studied are usually located at the vertices of triangles farther from the central field.
Durov further improved his diagram to permit analysis of chemical composition and total dissolved solids. His double tetrahedral diagram utilizes a system of rectangular projections of spatial dimensions in the plan. The spatial expression removes the restriction of a geometrical expression. Although not convenient for common use in reports of investigation, it can be used in special generic studies of the origin of chemical composition of water.
According to this diagram the following Hydrochemical type prevail in the groundwater of the study area: Ca-HCO_3, Mg- HCO_3, Na- HCO_3, Na-Cl, Mg-Cl and Ca-Cl. In the first and second groups belong the most samples from bore wells located in the central and eastern part of the study area. They are considered as fresh waters of natural replenishment through Granites and basalts.

Durov diagram –Mathadi vagu basin

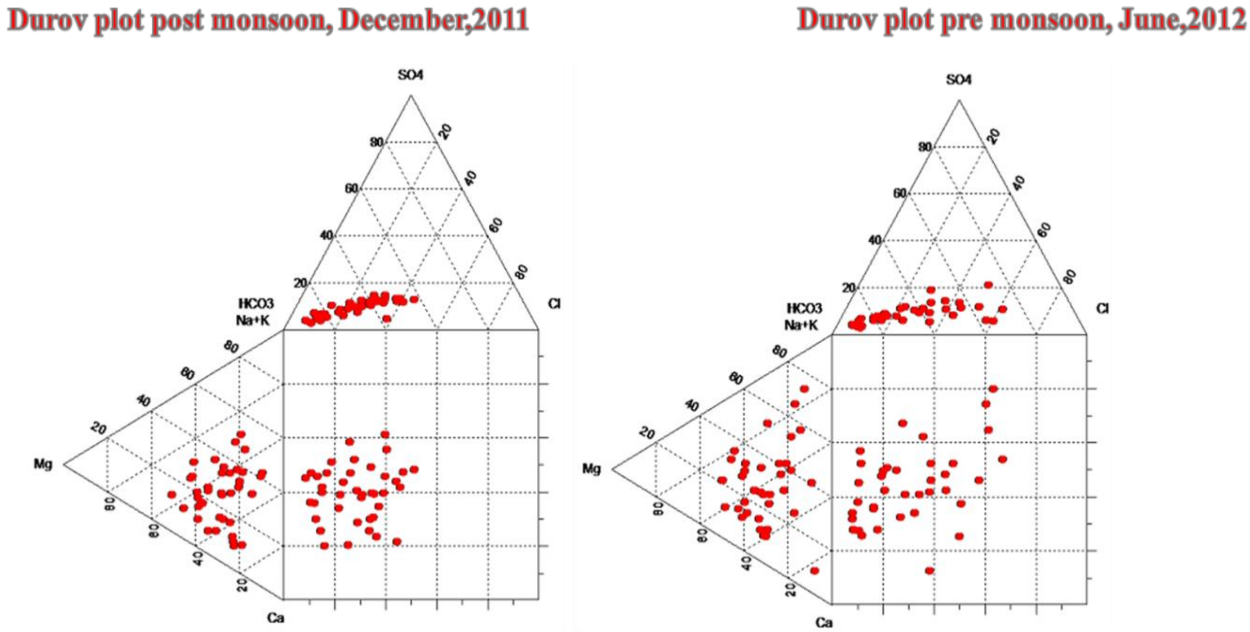


Fig 6.28 Durov plot for groundwater samples during post and pre monsoon periods of the study period

Table 6.9 Classification of groundwater based irrigation suitability and % of samples falling in various categories

Category	**Ranges**	**Percent of the samples**	
		December 2011 (Post monsoon)	**June 2012 (Pre monsoon)**
Based on EC (µS/cm)			
Excellent	<250	0	0
Good	250-750	16	27
Permissible	750-2,000	76	62
Doubtful	2,000-3,000	8	11
Unsuitable	>3,000	0	0
Based on Alkalinity Hazard (SAR)(Richards 1954)			
Excellent	0-10	100	100
Good	10-18	0	0
Doubtful	18-26	0	0
Unsuitable	> 26	0	0
Based on Soluble Sodium Percentage(SSP) after Wilcox (1955)			
Excellent	<20	46	38
Good	20-40	41	49
Permissible	40-60	14	14
Doubtful	60-80	0	0
Unsafe	>80	0	0
Residual Sodium Carbonates(RSC)(Richards 1954)			
Good	<1.25	51	38
Medium	1.25-2.5	16	22
Bad	>2.5	32	41
Kelley's Ratio (Kelley 1951)			
Good	s1	100	14
Not good	>1	0	32

Table 6.10 Classification of water for irrigation suitability is post monsoon.

Post monsoon, December-2011								
Well ID	**EC**	**SAR**	**MAR**	**SSP**	**RSC**	**KR**	**TH**	**PI**
1	1270	0.45	30.63	33.09	1.01	0.11	457.36	27.73
2	1800	1.97	30.42	31.11	2.58	0.38	685.8	39.82
3	1470	0.92	45.8	15.06	3.05	0.18	696.05	30.66
4	1100	0.56	51.4	10.8	1.55	0.12	552.87	33.98
5	1170	3.04	33.48	46.7	0.08	0.81	351.08	63.22
6	1170	2.67	18.27	40.24	0.85	0.67	400.08	58.18
7	505	1.89	17.78	41.65	1.6	0.7	180.15	77.96
8	1230	1.51	45.79	24.34	0.81	0.32	558.01	46.82
9	562	1.31	21.72	31.65	0.25	0.45	209.58	56
10	314	1.66	42.16	46.99	0.42	0.86	92.48	88.83
11	963	0.82	29.43	16.25	1.57	0.19	474.37	36.81
12	1320	2.11	42.2	32.65	0.7	0.47	509.7	51.24
13	1370	1.73	49.1	36.15	0.96	0.4	471.48	44.36
14	403	0.65	49.6	19.87	0.47	0.23	189.25	57.22
15	1370	1.41	44.84	22.93	0.79	0.29	596.53	40.5
16	1810	1.87	38.34	25.17	3.5	0.33	808.57	38.42
17	2070	2.52	30.62	33.59	3.73	0.43	859.49	40.29
18	2560	2.29	34.66	37.35	2.73	0.38	927.81	33.81
19	463	0.89	55.58	24.54	0.03	0.31	205.91	60.35
20	2150	2.44	40.56	51.09	2.82	0.51	572.41	38.11
21	1000	0.41	25.19	8.24	1.3	0.09	540.65	31.11
22	962	0.53	21.68	10.51	1.94	0.12	524.36	32.05
23	980	0.49	34.59	9.82	0.83	0.11	519.04	33.99
24	516	0.92	55.93	23.75	0.73	0.3	235.82	60.32
25	980	1.69	58.92	30.13	0.85	0.43	389.18	54.19
26	1510	0.98	34.93	15.57	3.54	0.18	743.35	31.5
27	780	0.82	44.91	17.16	0.22	0.2	403.04	45.66
28	1930	0.66	25.89	9.92	7.64	0.1	1049.3	21.57
29	1280	1.09	47.96	18.27	2	0.22	601.33	36.11
30	1260	0.66	26.74	11.52	3.96	0.13	645.11	28.6
31	1670	1.81	33.54	27.33	2.87	0.33	738	38.99
32	1450	0.54	43.83	10.08	4.39	0.1	753.69	25.27
33	1080	0.7	58.91	13.47	1.63	0.15	532.21	34.39
34	1620	1.06	42.33	35.09	0.07	0.22	566.67	29.84
35	753	0.81	45.7	17.33	0.33	0.21	384.12	44.87
36	1610	0.51	37.97	8.13	5.63	0.09	897.93	22.25
37	880	0.66	33.16	15.87	0.32	0.15	469.21	37.47

Table 6.11 Classification of water for irrigation suitability in pre monsoon.

Pre monsoon, June-2012								
Well ID	**EC**	**SAR**	**MAR**	**SSP**	**RSC**	**KR**	**TH**	**PI**
1	1560	0.9	85	34	1.3	0.2	512	27
2	1570	1.9	85	26	6.9	0.3	612	37
3	1220	1.2	61	21	2.9	0.3	510	34
4	625	1	78	22	1.6	0.3	252	43
5	1710	6	73	62	0.5	1.6	325	71
6	890	3.4	84	51	1.9	1	212	64
7	510	1.5	93	31	0.7	0.4	193	58
8	1080	1.7	68	28	0.1	0.4	441	50
9	637	1	90	19	1.9	0.2	298	42
10	1400	6.9	74	70	0.2	2.3	203	80
11	1290	0.4	96	5.7	8.8	0.1	586	19
12	2050	2.3	58	31	4	0.4	734	40
13	1080	1.4	74	31	0.3	0.3	409	43
14	412	0.9	68	26	0.2	0.3	169	63
15	1060	1.2	75	22	0.6	0.3	437	41
16	1270	1.4	81	22	3.9	0.3	518	38
17	2070	2.1	82	31	5	0.4	716	35
18	2110	2.1	83	36	5.1	0.4	652	35
19	349	2	63	52	0.6	1.1	92	91
20	1840	2.2	80	47	0.7	0.5	462	38
21	601	0.4	84	10	1.8	0.1	312	38
22	549	0.4	84	9.9	1.6	0.1	272	37
23	970	0.4	84	7.8	3.2	0.1	517	28
24	637	1.6	56	36	1.8	0.5	249	69
25	930	1.8	66	31	1.2	0.5	369	56
26	1160	0.7	77	12	5.8	0.1	582	27
27	928	0.7	73	13	1.1	0.1	458	37
28	1980	0.6	84	7.9	12	0.1	970	17
29	926	1.1	61	21	1.5	0.3	411	39
30	1100	1.3	79	22	3.7	0.3	477	38
31	2210	1.4	82	19	11	0.2	943	27
32	1140	0.5	76	10	3.9	0.1	559	27
33	916	0.6	69	11	1.6	0.1	494	33
34	1710	1	80	35	2.6	0.2	582	24
35	742	0.8	74	16	0.6	0.2	361	42
36	990	0.5	82	9	3.3	0.1	490	29
37	747	0.5	81	12	0.8	0.1	353	37

6.7.4. Electrical Conductivity (EC)

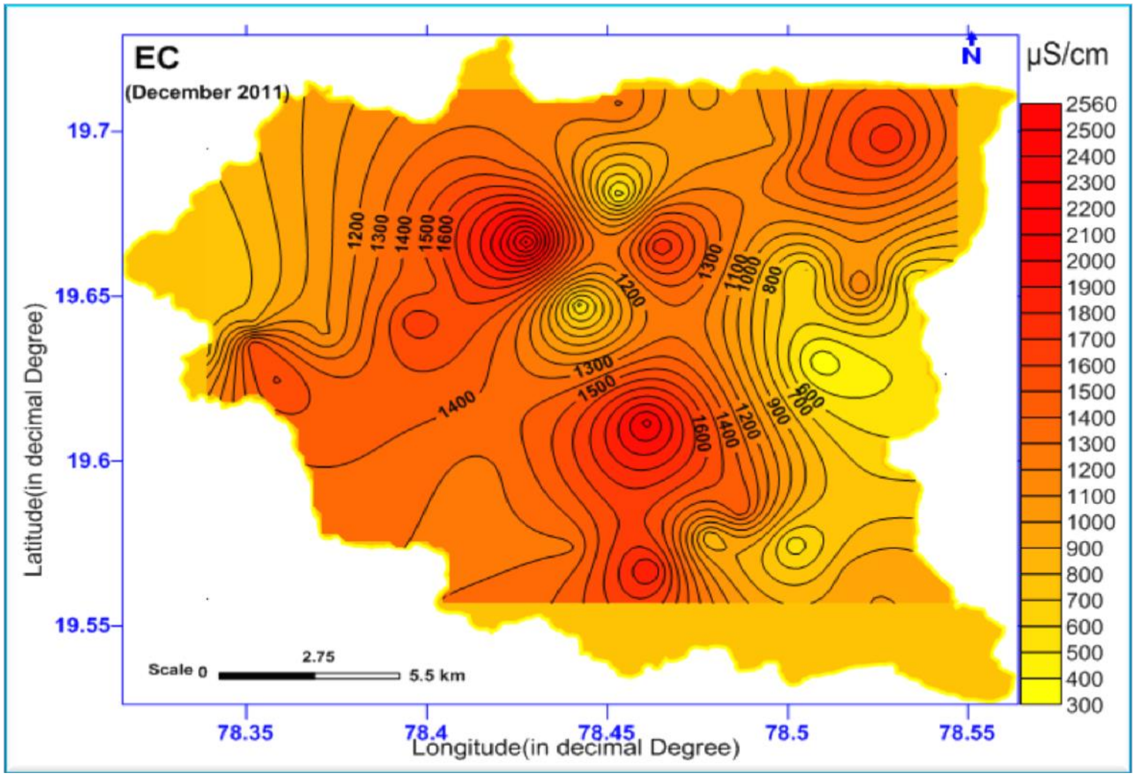


Fig: 6.29 Variation of Electrical conductivity (EC)' of post monsoon

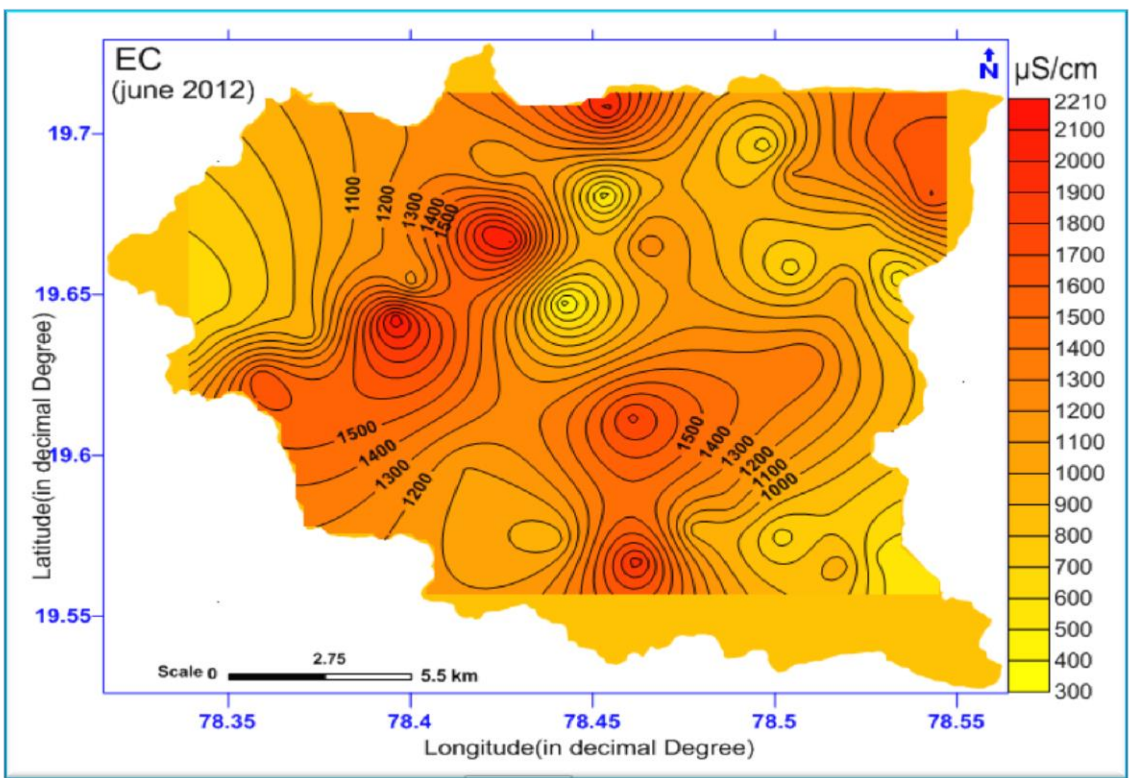


Fig: 6.30 Variation of Electrical Conductivity (EC) of pre monsoon

Electrical conductivity (EC) varies from 314 to 2560 µS/cm (mean: 1225 µS/cm) in post monsoon and 349-2210 µS/cm (mean: 1161µS/cm) in pre monsoon seasons (Table 6.9). In post monsoon 8%, 76%, and 16% of samples fall in 'Doubtful', 'Permissible' and and 'Good' category respectively of US salinity plot. category respectively but in pre monsoon 11 %, 62%, and 27% of samples fall in 'Doubtful and 'Permissible" Good' category respectively of US salinity plot. Figure 6.29 and 6.30 show the area of Thalamadugu and Devapur villages are high concentration of EC. It indicates an appreciable amount of groundwater recharge during monsoon reducing the electrical conductivity of groundwater.

6.7.5. Sodium adsorption ratio (SAR)

Excessive sodium content in water renders its unsuitability for soils containing exchangeable Ca^{2+} and Mg^{2+} ions. If the percentage of Na^{+} to (Ca^{2+} + Mg^{2+} +Na^{+}) is considerably >50 in irrigation waters soil containing exchangeable calcium and magnesium take up sodium in exchange for Ca^{2+} and Mg^{2+} causing flocculation and impairment of the tilt and permeability of soils. The SAR is an important parameter for determining the suitability of water for irrigation. The sodium hazard in irrigated waters is expressed by determining the sodium absorption ratio (SAR) by the relation (Todd 1980). All the concentration in this equation are expressed mg/l.

$$\boldsymbol{SAR} = \frac{\mathbf{Na}}{\sqrt{(\mathbf{Ca} + \mathbf{Mg})/2}}$$

As per SAR classification (Table 6.9 & Figure 6.31 and 6.32) the total study area fall under 'Excellent' category in post and pre monsoon agriculture purpose.

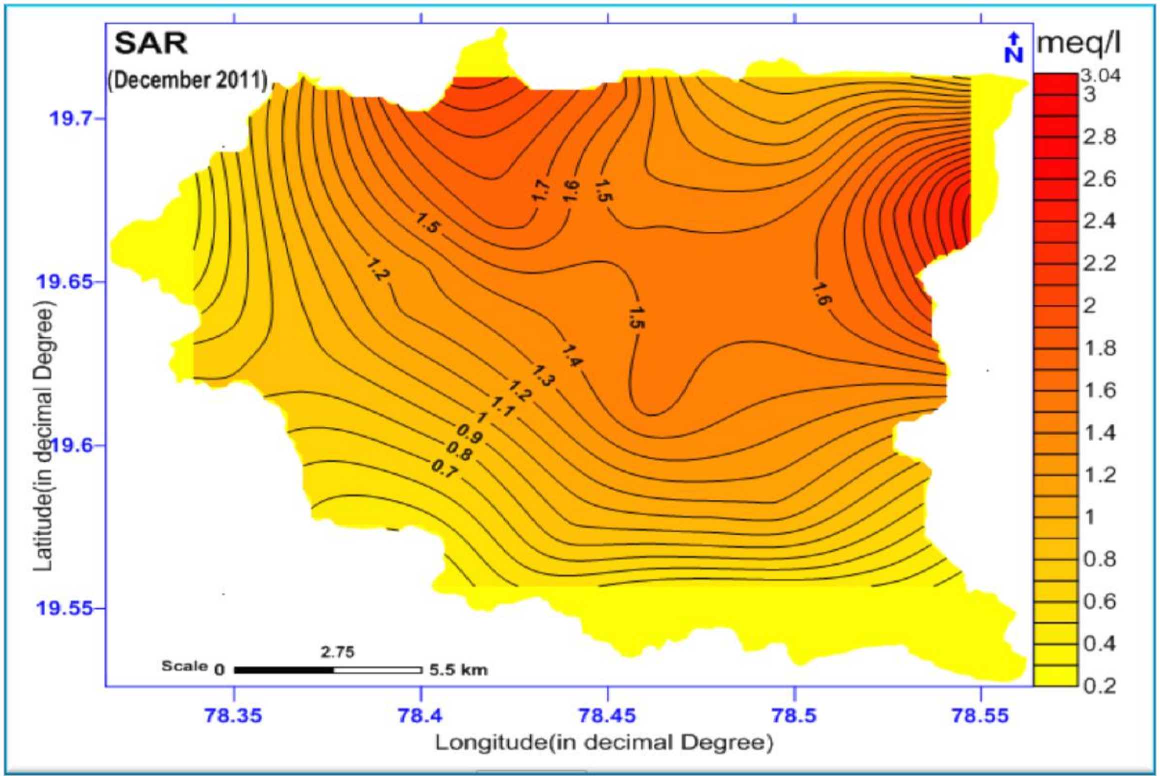


Fig: 6.31 Variation of Sodium Adsorption Ratio (SAR)' post monsoon

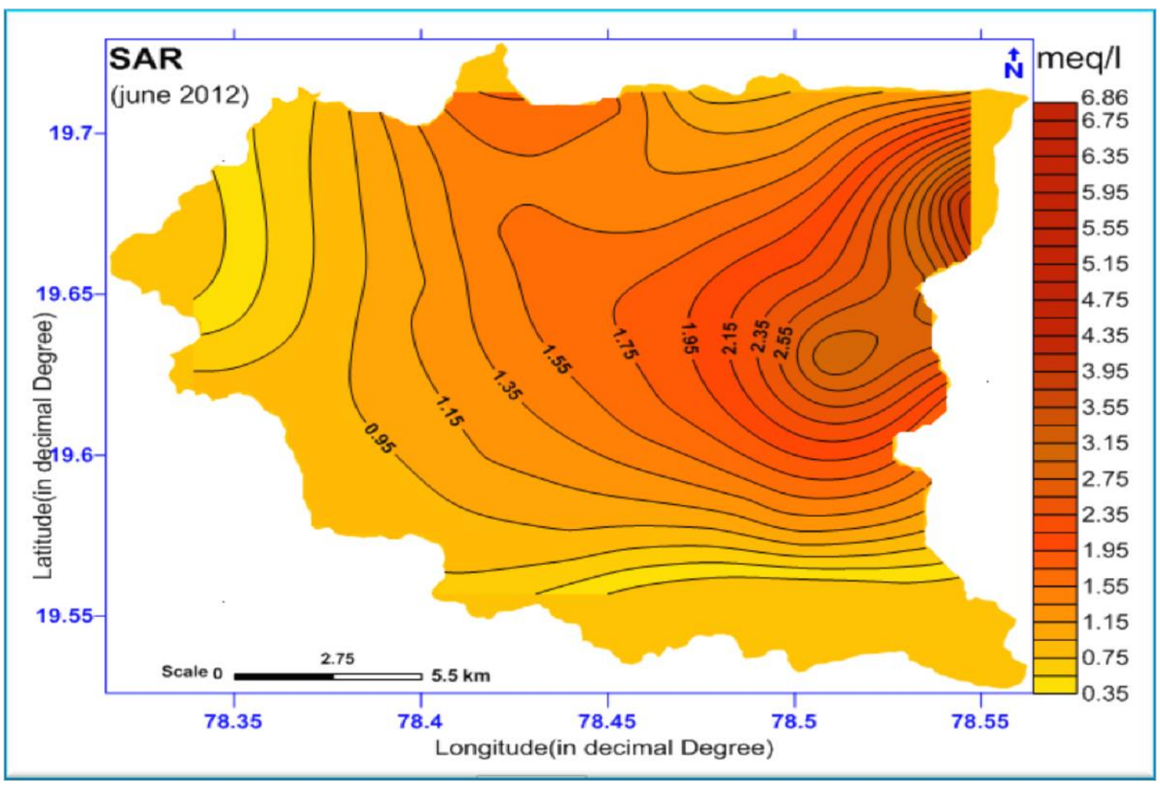


Fig: 6.32 Variation of Sodium Adsorption Ratio (SAR)' of pre monsoon season

6.7.6. Magnesium adsorption ratio (MAR):

In the study area, the MAR values less than the permissible limits in table 6.10 and 6.11. In the study area, these values are found within a range of 16 to 59.2 in post monsoon and 56 to 96 pre monsoon seasons they ranges between 39 and 77.

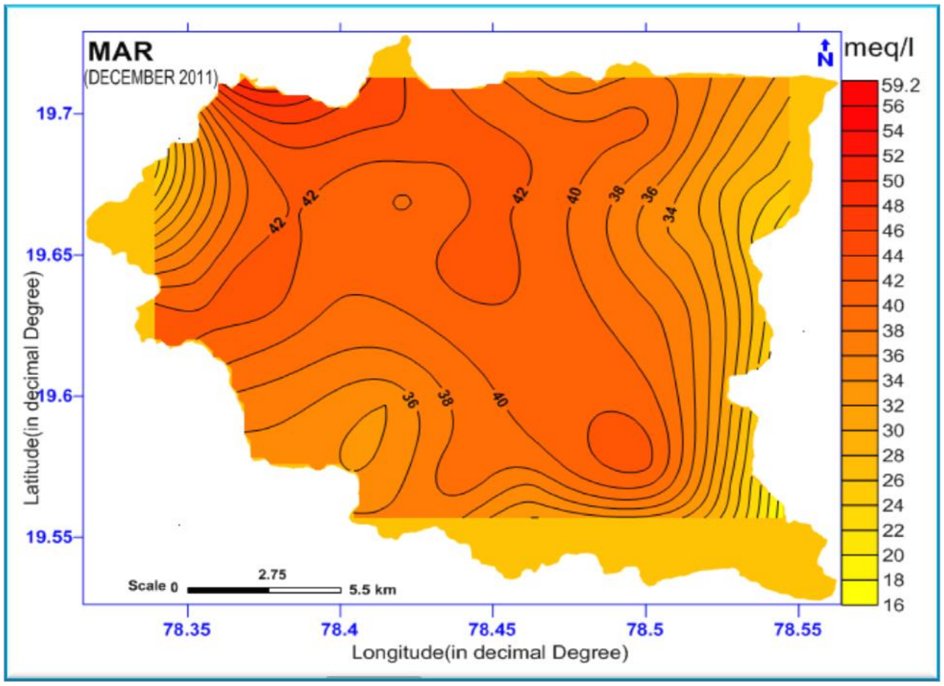


Fig: 6.33 Variation of Magnesium Adsorption Ratio (MAR)' in post monsoon

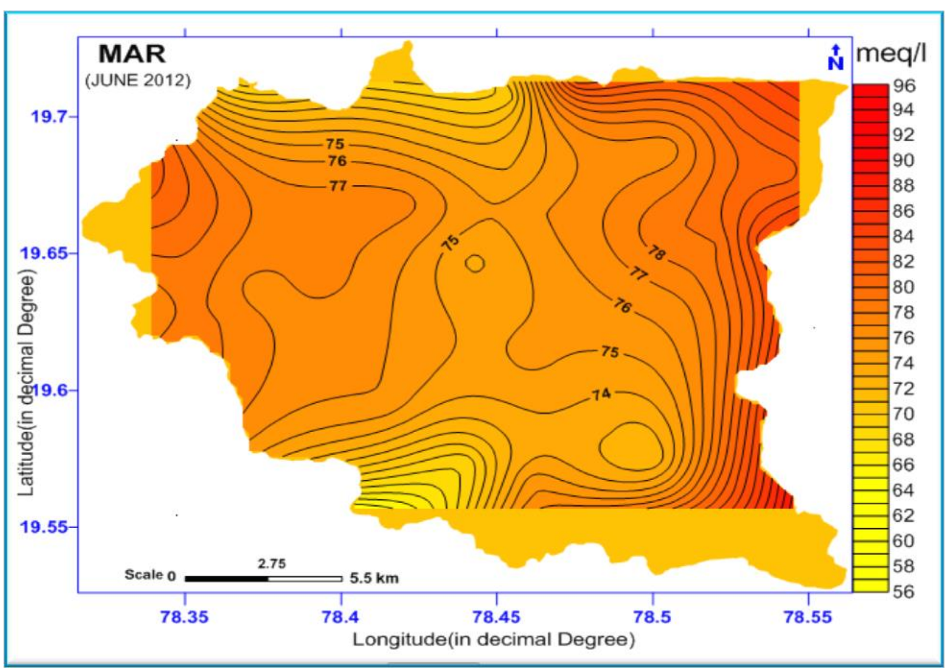


Fig: 6.34 Variation of Magnesium Adsorption Ratio (MAR)' in pre monsoon

$$MAR = \frac{\text{Mg x 100}}{\text{Ca +Mg}}$$

6.7.7. Soluble Sodium Percentage (SSP):

Sodium content expressed in terms of sodium percentage or soluble sodium percentage defined as. Where, all ionic concentration is expressed in mg/l.

$$Na\ \% = \frac{\text{Na x K x 100}}{\text{Ca +Mg+Na+K}}$$

Where all ionic concentration is expressed in mg/l.

The SSP of the groundwater sample in post monsoon show 46%, 41%, 14%, and 0% of the samples (Table 6.10 and 6.11 and Figure 6.35 and 6.36) falling in Good, Permissible, Doubtful and Unsafe categories, respectively. Similarly pre monsoon period 38%, 49%, 14% and 0% of samples fallen in Good. Permissible, Doubtful and Unsafe categories, respectively (Wilcox 1955). The western part of the study area falls in Good to Permissible in both the seasons. Patches of Doubtful category were identified at Thantholi Road and Pochera village in both the seasons, which need proper treatment before exploitation for irrigation purpose.

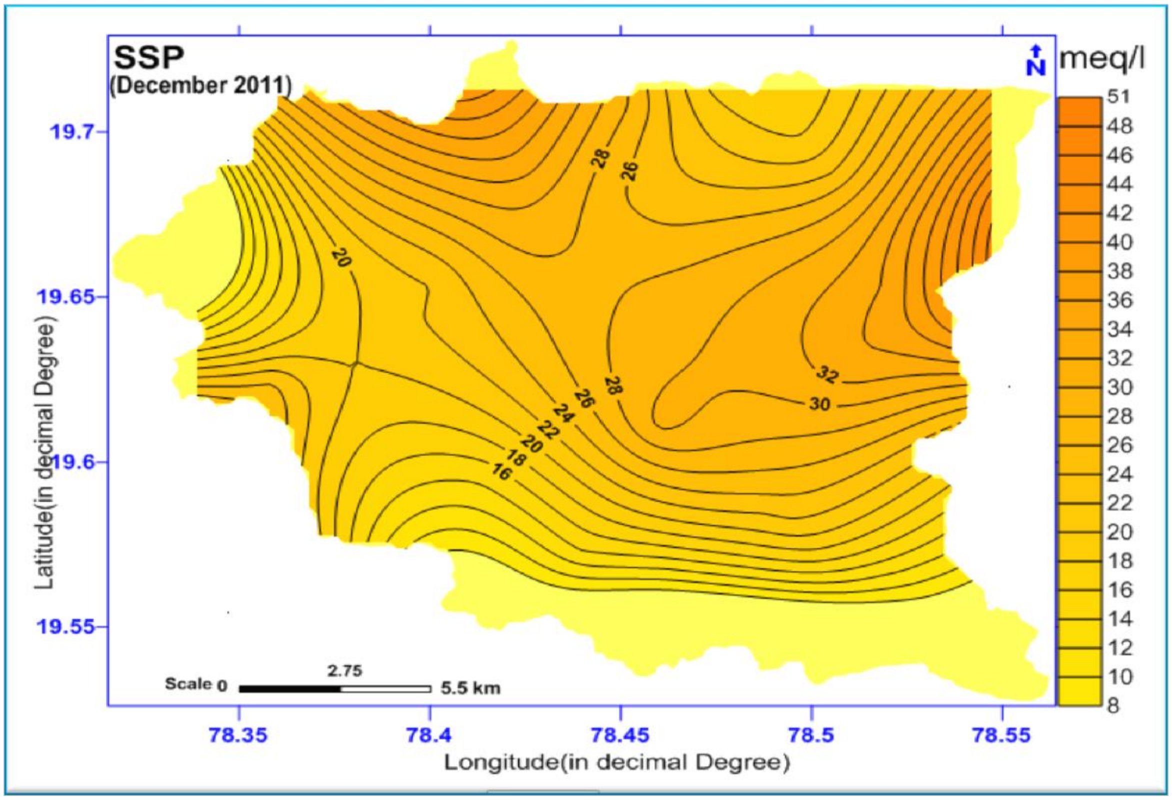


Fig: 6.35 Variation of Soluble Sodium Percentage (SSP)' of post monsoon

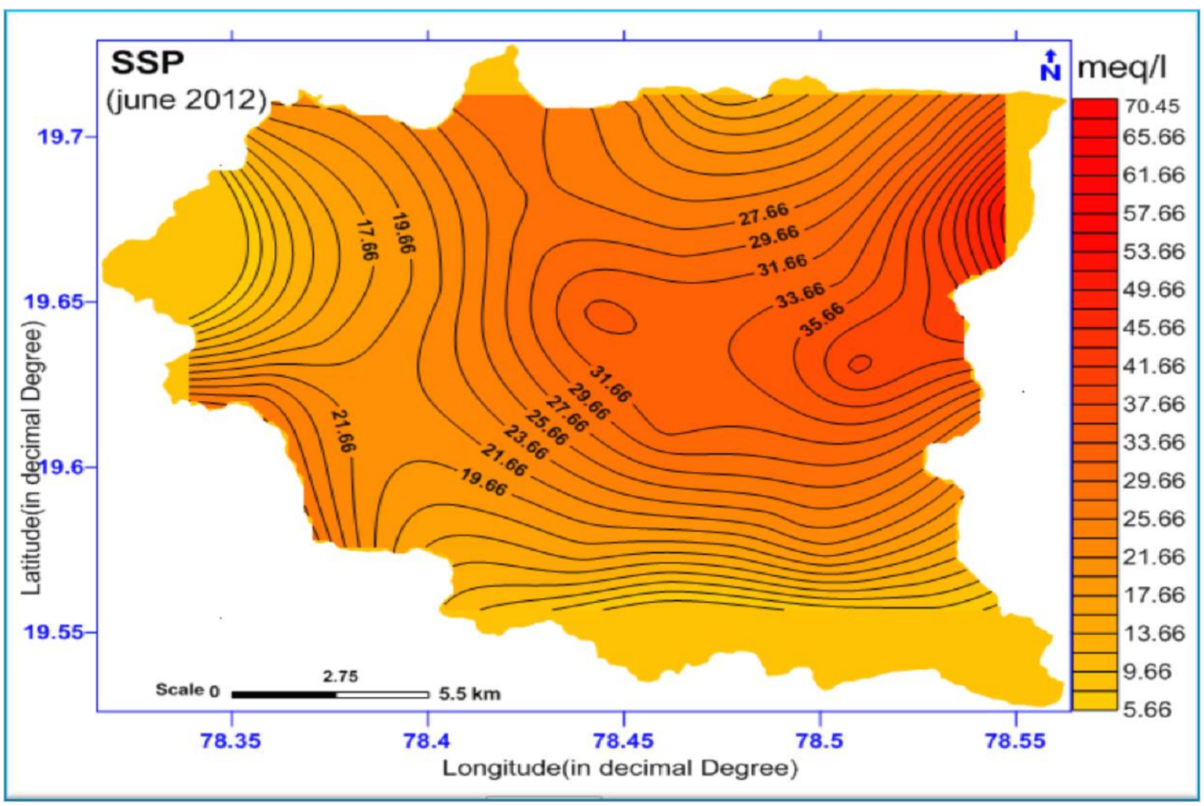


Fig: 6.36 Variations of Soluble Sodium Percentage (SSP)' of pre monsoon

6.7.8 Residual Sodium Carbonates (RSC)

If water contains carbonate and bicarbonate in excess of calcium and magnesium, then it is likely to perceptible calcium displayed by exchange reactions. The result is an increase in sodium hazard of water (USDA 1954). The excess quantity of carbonate and bicarbonate is denoted by residual sodium carbonate and is determined by the formula as below (Ragunath 1987)

$$RSC = (CO^{2-}_3 + HCO^{-}_3) - (Ca^{2+} + Mg^{2+}$$

Where all ionic concentrations are expressed in meq/l. The RSC values were calculated for the groundwater samples show post monsoon season 51%,16% ,32% and pre monsoon season 38%,22% and 41% of samples fall in 'Good',’Medium’and ‘Bad’ category indicating suitability of groundwater for irrigation and drinking purposes.

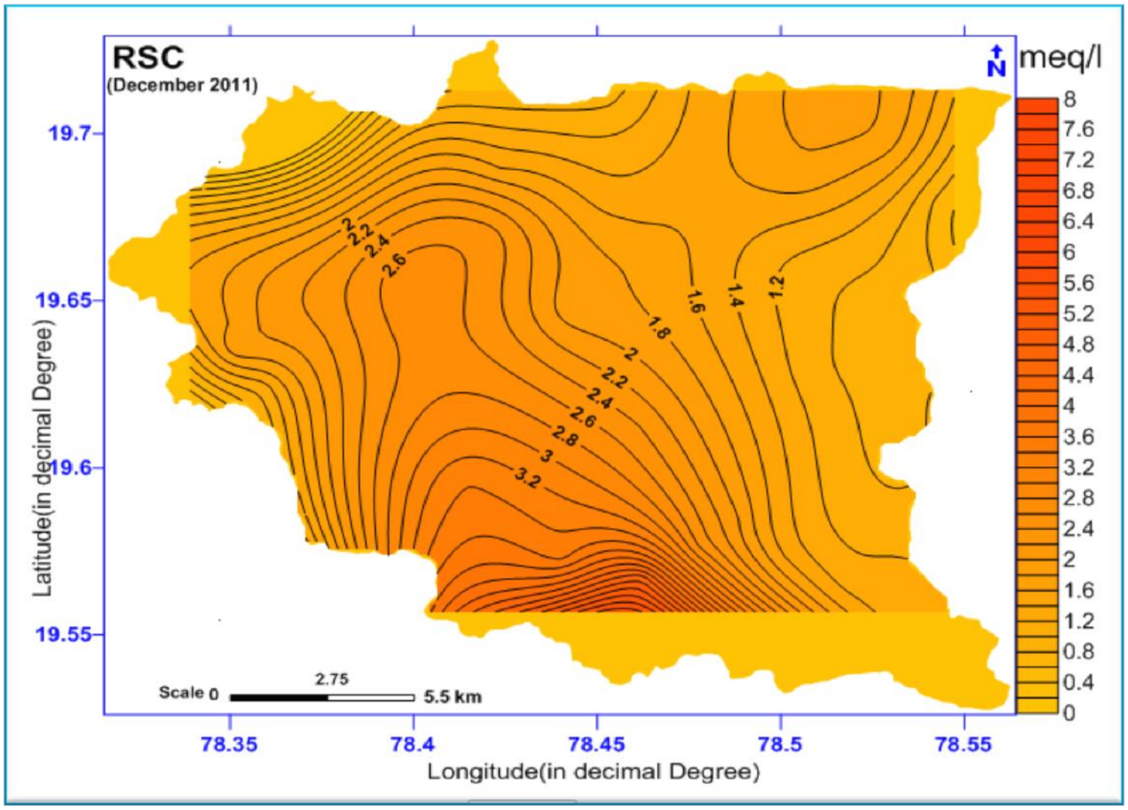


Fig: 6.37 Variations of Residual Sodium Carbonate (RSC)' of post monsoon

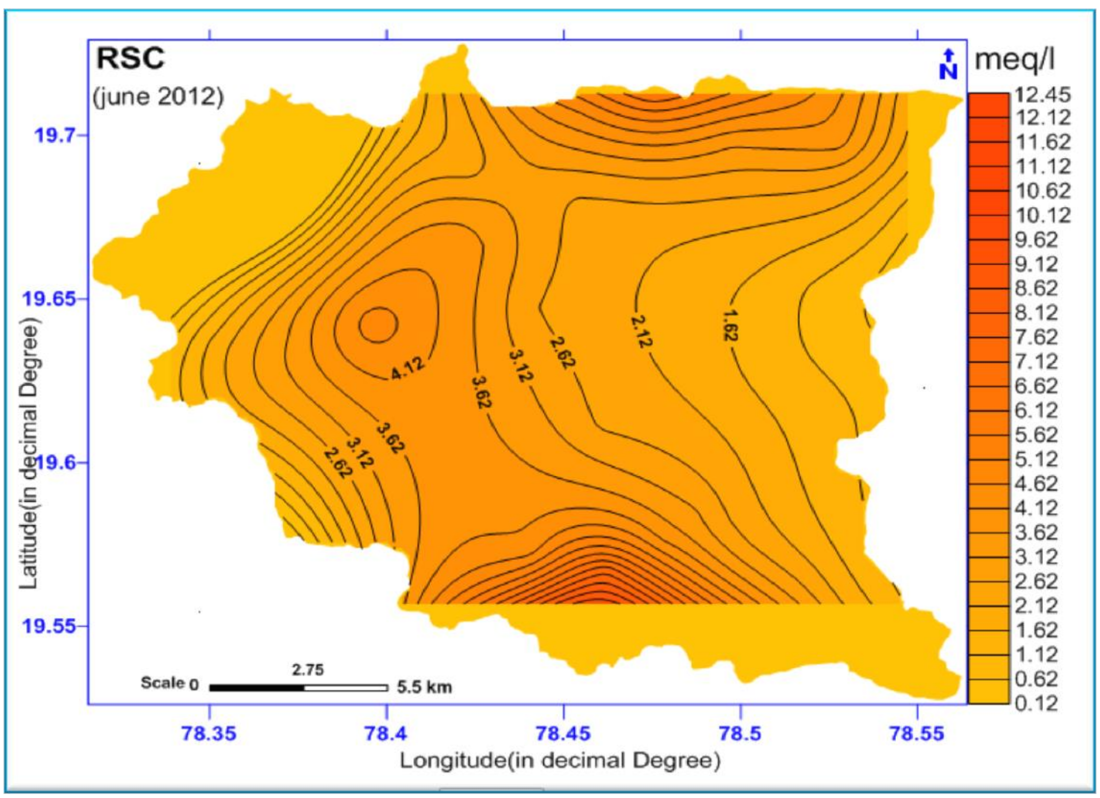


Fig: 6.38 Variations of Residual Sodium Carbonate (RSC)' of pre monsoon

6.7.9. Kelley's Ratio

. The Kelley's Ratio (KR) reflects the alkali hazard of the water. KR ≤ 1 indicates the water is good for irrigation. As against this, the KR values> 1 are considered indicative of causing alkali hazard to the soils.

From Table 6.10 and 6.11 it was observed that 100% and 14% of samples are in 'Good' category for irrigation in post monsoon and pre monsoon respectively. But 0% (post monsoon) and 86% (pre monsoon) of samples fall in not good category of KR. There from Pachera, Thantholi Road, Ramnagar villages and Kajjarla lake. This indicate groundwater from granitic area is rich in alkali hazard and need further treatment before application for irrigation (Figure 6.39 and 6.40).

$$KR = \frac{Na}{Ca + Mg}$$

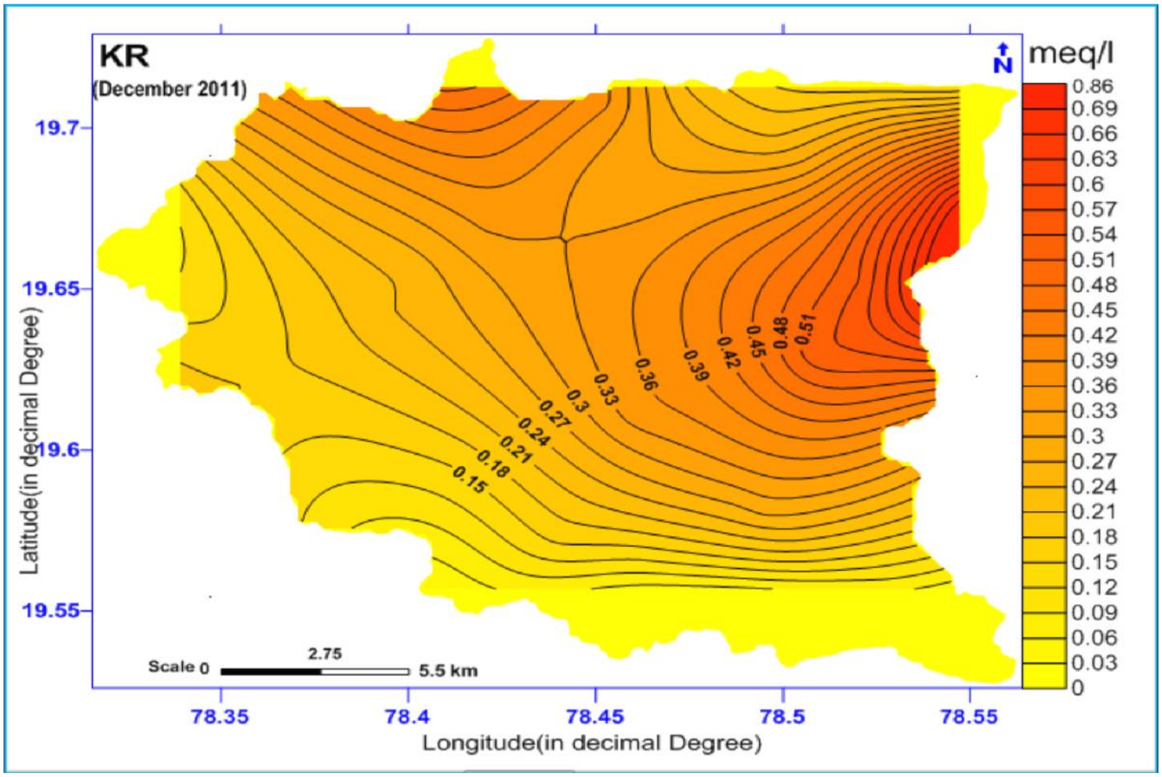


Fig: 6.39 Variation of Kelley's ratio (Kelley 1951) in post monsoon.

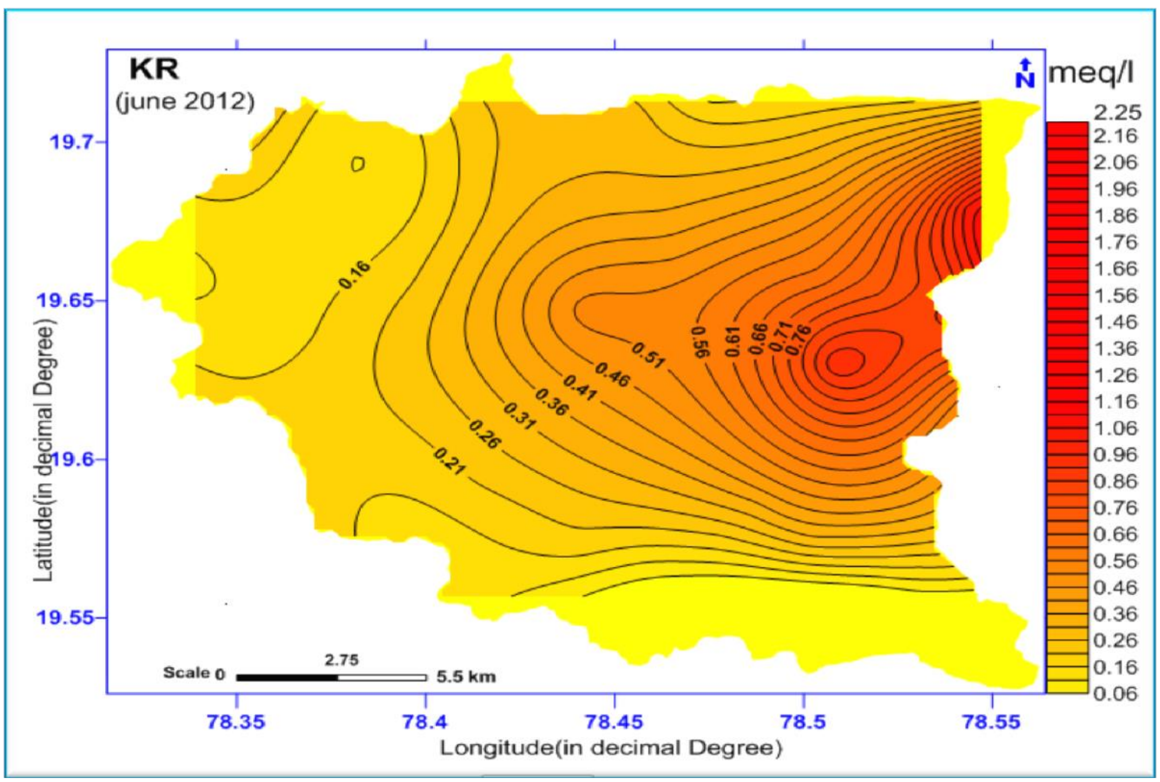


Fig: 6.40 Variation of Kelley's ratio (Kelley 1951) in pre monsoon.

6.8. Summary

The chemical analysis of water samples (post and pre monsoons) of shallow borewells, deeper bore wells, Mathadi vagu basin samples at various locations are carried out for major ions. The results of the chemical analysis are compared with WHO drinking water standard and interpreted using various techniques such as statistical tools, water types, agriculture classification and ionic concentration plots to understand the hydrodynamic nature of dissolved ions and sources of pollution. Based on the interpretation of the chemical data base the major points were drawn and summarized as following.

- The chemical analysis of the groundwater samples indicated higher concentrations of TDS (>1800 mg/l). And other major ions in well located in industrial are and have influence of industrial effluents.
- 100% and 99% of samples in post and pre monsoon respectively are found within - WHO drinking water standards of TDS.
- In general the TDS and major ion concentration are found to be higher in the Umdam village due to Agriculture waste. but in the south of Umdam village are because .The Piper and Wilcox plot indicate that the groundwater in the study area has low and high salinity hazard and broad classification of groundwater inferred from the Piper plot was Ca-Mg- S04-CI -HC03 type.
- Agriculture classification of groundwater based on Electrical conductivity (EC), Sodium Absorption Ratio (SAR) Soluble Sodium Percentage (SSP) and Kelley's Ratio (KR) show the groundwater from at Pochera, Thantholi Road and Ramnagar village is not suitable for irrigation purposes.
- The water samples from deeper bore wells tapping aquifer from Mathadi vagu basin in Granites and Basalts is suitable for drinking purposes as per WHO drinking water standards.
- The concentrations of Nitrate and Fluoride in groundwater are found to be in excess of permissible limits, the WHO standard of drinking water is a few wells.

Recommendations

The following measures are suggested to mitigate the problems related to excess nitrate, and fluoride.

1. Alternate water supply sources may be identified for supply of safe drinking water in areas having fluoride and nitrate in excess of permissible limits.

2. Treatment techniques to remove excess fluoride and nitrate may be adopted on domestic and village basis.

3. Higher intake of calcium with vitamin C in the endemic area by people for combating fluorosis.

4. In the study area it is found that uncontaminated fresh water occurs in the recharge areas that is southeastern parts. Hence drinking water wells could be located in that area,

5. Detailed study of hydrogeological and hydrochemical aspects of occurrence of fluoride should be carried out to study the factors controlling their occurrence.

6. Proper solid waste and effluent treatment .techniques should be adopted for all industries.

7. Detailed study on fluorosis and methaemoglobinemia among the people should be conducted and the public should be told about water quality and heath.

8. Artificial recharge techniques may be adopted at suitable locations to minimize the concentration of pollutants.

9. Excessive use of nitrogenous fertilizers should be avoided and the nitrate-rich water may be used for agricultural purposes only.

10. Feasibility of insitu treatment techniques like bio-remediation may be studied for minimizing excess nitrate.

CHAPTER-7

SUMMARY AND CONCLUSIONS

7.1. SUMMARY

Mathadi vagu basin study is spread over 525 sq.k.ms falling in between geographical co-ordinates of latitude 19°18'45" and 19°37'15" N and longitude 78°28'45" and 79°05'00" E. The area forming a plateau with many ridges and slopes comprising forming rugged and undulatory topography, is a part of Adilabad district. The hills slope moderately due southwest and steeply due east, the altitudes range between 260 and 600m. above m.s.l. About 47 percent of total geographical area is covered under reserve forest, mostly with teak species, with wild and other animals inhabiting it. Major area is covered by black cotton soil with small isolated patches of red soil. Eastern part of the area *is* connected to Hyderabad-Nagpur high way NH7 at Gudihatnoor to Adilabad. Poor irrigation facilities compelled the tribes to cultivate only rainfed crops.

The area is hilly with steep slopes all around and 60 percent of the area from west to east is underlain by Deccan traps. Traps in the area are characterized by flat topped hills and step like structures, "Mesa" and "Butte". They range from vesicular, massive, spheroidal, and columnar jointed to weathered for mountains. The Deccan traps are seen to occupy at 363m. Contour lying unconformably above granite at near Sithagondi in the Northwest and at Umdam at 341m. Contour above shales to reach highest spot height of 623m. in the Northeast near Somarpet village.

Granites and Gneisses cover part of central and eastern area. The rock units have been subjected to tectonic activity resulting in fault and shear zones which multiple joints with systematic alignment have extended to greater depths. Penganga limestones occupy the extreme northeastern part of the area. A small tongue is mapped at the Rampur village, and the limestone are faulted and folded as seen in from Rampur to Adilabad which have undergone elephant skin weathering, horizontally bedded or with gentle slope dipping 10° to 12° due east. Intertrappean and infra-trappean beds are significant features for groundwater occurrence in this area. Granitic and limestone terrains are characterized by prominent structural features and also secondary porosity, whereas the Deccan traps have such features in limited extent. Based on the mapping, 4 major lineaments are identified.

The area exhibits dendritic to sub-dendritic drainage pattern in general with sub parallel drainage pattern at places. The area has in to three formations namely Limestone, Granites and Gneisses and Deccan traps. Morphometric studies are made in combination of different geological formations. Analysis indicates stream orders are 1st to 6th in Mathadi vagu basin with total stream lengths of all the orders in the basins as 588.5 Kms and total number of stream segments of all orders is 1469. Mean bifurcation ratio 4.44. Average drainage density is 1.22 Km. *I* Sq.km. and it indicates coarse drainage texture caused by resistant geological formation and dense, forest. The drainage pattern study and morphometric analysis help to deduce that the area is of high intensity of precipitation with high run-off resulting in more number of surface drainage channels due to steep slopes.

Well inventory reveals that dug well depths vary between 5 and 15m. Below ground level (bgl) and depth to water level between 1.6 and 14 m. bgl. Circular shaped irrigation well diameter ranges between 6 and 8m. The average yield of the wells ranges between 20 and 40m^3/day. Crops grown are cotton, turmeric, paddy, maize and vegetables. Each well fitted with 3 H.P centrifugal, electric motor irrigates an area of 0.5 to 1.5 ha. Bore wells are not common in the area. The average depth of bore wells ranges between 60 to 120m. and average depth to water level in bore wells range between 3 and 15m. bgl. Average yield ranges between 4000 and 8000 liters per hour irrigating 1.0 to 2.0 hectares dry crops in 46 percent of bore wells. During the well inventory it was observed that 60 percent of the dug wells taken up were feasible for irrigation purpose and these dug wells and bore wells are taken up by farmers at their own choice locations, without any scientific approach. In granites and Deccan traps groundwater occurs under water table conditions in weathered zone in the topographic lows and in fractured zones along lineaments due to structural control. In limestone, groundwater occurs in cavernous under semi weathered conditions. Normally fracture zones are encountered between 20 and 40m. depth. Extensive areas of traps are not suitable for dug wells because of massive and shallow basement. Areas with weathered to semi weathered treys and vesicular traps at moderate slopes give moderate to good yielding dug wells. Due to layered formation of vesicular and massive traps at structurally controlled spots 60 to 90m. bore wells give good yield. From the groundwater monitoring in observation wells it is observed that water level is ranges between 1.6 and 14m. below ground level (bgl) during December and between 3.5 to 19m. b.gl. during June, with water table drown from post to pre monsoon ranging from 1.9m to 11.50m. Detailed monitoring in 37 Observation bore wells during 2001 and 2012 years has shown that water level was ranging between 1.60 to 14.00m b.g.l. during December and 3.40 to 19.60m b.g.1. during June.

Geophysical investigations at 30 sites along sections A - B and X - Y with interpreted VES data, suggests three layered geoelectrical medium at all places with top soil ranging from 1.3 to 3m. thick, weathered to semi weathered granite with a thickness ranging from 12.5 to 33m. having resistivity values ranging between 35 ohm.m. and 220 ohm.m. which is followed by basement at depth. In limestone the geo-electric section suggest 3 to 4 layers with top soil 1 to 4.80m. thickness, second layer 8 to 28.8m. with resistivity values of 8 ohm.m. to 525 ohm.m., 8 to 45 ohm.m. range indicate presence of cavernous nature, generally proved to be potential zone for groundwater. Second and Third layer are mostly hard and compact limestones with 1700 ohm.m. and higher with 45m. thickness.

Deccan traps cover about 50 percent of the study area. The VES data analysis reveals top soil to be 1 to 4.2m. Thickness followed by weathered to semi weathered basalt from 6 to 35m. Thick ranging in resistivity from 3 ohm.m. to 290 ohm.m. The potential zones in Deccan traps are vesicular portions that are encountered at greater depths and although fractured zones intermittently occur at shallow depths.

Pumping tests were conducted at 9, Wells in all the 3 geological formations. The specific capacity of the wells studied range in general from 0.00586 to 0.53 m3/min/m. The Yield factor of the wells studied range in general from 0.038 to 9.38.

The transmittivity value in 4 tests conducted in granitic rocks is $3.06x10^{-5}$ m^3 /sec, $3.10x10^{-5}$ m^3 /sec, $4.06x10^{-3}$ m^3/sec and $4.09x10^{-4}$ m^3/sec during pumping phase and recovery phase determined by using Theis Method.

The transmittivity value in 4 test in basaltic is $2.19x10^{-3}$ m^3 /sec, $1.50x10^{-3}$ m^3 /sec, $1.97x10^{-5}$ m^3 /sec and$1.01x10^{-2}$ m^3/sec during pumping phase and recovery phase determined by using Theis Method .In one test limestone area the transmissivity is $3.29x10^{-3}$ m^3 /sec by using during pumping phase and recovery phase determined by using Theis method.

Storage Co-efficient Storage Co-efficient value in 4 tests conducted in granitic rocks is ranges $1.81x10^{-4}$, $1.55x10^{-6}$, $3.47x10^{-7}$ and $2.91x10^{-3}$ during pumping phase and recovery phase determined by using Theis Method.

The Storage Co-efficient value in 4 test in basaltic is ranges $3.91x10^{-2}$, $9.50x10^{-3}$, $1.51x10^{-4}$ and $1.01x10^{-2}$ during pumping phase and recovery phase determined by using Theis Method .In one test limestone area the Storage Co-efficient is $2.34x10^{-6}$ by using during pumping phase and recovery phase determined by using Theis method through Aquifer software.

Hydrochemistry of groundwater is studied in post and pre monsoon periods from 37 water samples. pH ranges from 6.28 to 7.78 during post monsoon period. Small pocket indicates alkaline conditions. TDS concentration ranges from 167 mg/lt. to 1370 m.g/l. 80 percent of the area is characterized by low TDS falling in desirable category. Alkalinity ranges from 40 to 360 mg/l. As per BIS, limit of alkalinity for drinking water is 200 mg/lt. High Nitrates concentration 407mg/l is observed in Umdam village, whereas the analytical results reveal that 6 wells have nitrate below 45mg/l, the safe limit for human consumption. 7 wells have nitrate in the range of 46 to 100 mg/1 and 22 wells show nitrate in the range of 101 to 400 mg/1. One well haves nitrate 'more than 400 mg/1. The origin of nitrate in the area is ascribed to industrial activity, sewage and animal wastes and agricultural sources.

The desirable limit for total hardness for drinking water is 970 mg/l. The value TH is the area fall within it. As per classification of piper diagram, out of 37 samples, 36 fall in sub area 1 where alkaline earth exceeds alkalies. Water quality is also suitable for irrigation as per USS diagram. As per Wilcox classification, 5 samples fall in permissible to doubtful for irrigation use, all others are excellent to good and good to permissible. As per Residual Sodium Carbonate (RSC) classification, 37 samples as per SAR classification the total study area fall under 'Excellent' category in pre and post monsoon periods.

7.2. CONCLUSIONS AND SUGGESTIONS

Scientific and systematic integrated groundwater investigations followed by development over the past two decades delivered excellent results. The development works here have proved to be a model project in other areas. This protocol may be followed in other areas in our state and the country.

Tracking of lineaments and structural controls gave good results in all the three formations Viz. Granite, limestone and Deccan traps. It may be continued and extended to other areas in the district.

Low well density and only 16.23% stage of groundwater development give much scope for future developmental programmes. However, a cautious approach by maintaining a minimum spacing of 250m between adjacent wells has to be adopted as per AP Water Land and Tree Act 2002 (WALTA). This would help avoid interference and indiscriminate exploitation of groundwater and also to retain water table level at shallow depth.

Taking up schemes to improve groundwater quality in respect of fluoride and nitrate concentration in some areas. Dispose of animal waste away from village to prevent groundwater contamination from nitrates to help reduce health hazard.

Paddy crop during rabi season is not be advisable, instead, it is better to encourage wheat, groundnut, soya bean, sunflower and other commercial crops. Propagate sericulture, instead of paddy, underground for better returns.

Encourage horticulture under moderate groundwater potential wells, by adopting micro irrigation system with sprinkler and drip irrigation.

Suitable scientific steps are needed for arresting part of the huge run-off by taking up rainwater harvesting structures in areas of poor groundwater potential particularly in massive trap plateaus

Take up construction of Minor Irrigation tanks in the area .Construction of surface water storage tanks with more than two meters depth to minimise water spread in massive Deccan trap areas by raising huge bunds, to harvest rainwater on higher contours, minimising evaporation losses particularly in summer months.

Due to good rainfall and steep slope and accelerated, run-off, low cost artificial recharge structures do not withstand. Hence, take up wide earthen structures at specific locations, and need based masonry structures.

Proper implementation of water-shed programmes by creating site specific recharge structures and allowing the water stored from check dams and percolation tanks, to recharge to groundwater with peoples' active participation.

Each village should follow the given simple water budgeting procedure to assess surface and groundwater for the water year, allocate drinking water requirement for summer months and then plan the usage for agriculture and other purposes.

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STATEMENT OF CORRECTIONS

Specific Comments of the Examiner - Explanation by the Author

CHAPTER-1

Comment 1. Aim and Objective of the research work is not clearly mentioned.

Explanation: Aim and objectives of the research work have been already mentioned clearly. However they are given point - wise after suggestion.

Comment 2. NW-SE trends usually refer for strike of the formation and not for the basin.

Explanation: Trend is not only used for strike but it is also generally used while describing a basin. It is found in many research publications.

CHAPTER-2

Comment 1. Large area is designated as residual hills in the geomorphology figure.

Explanation: In the geomorphology map, it is a 'grouping error' in the SURFER-9 Software which is corrected and incorporated accordingly, description is also given.

Comment 2. The word 'Identification of Lineaments' should be referred as 'interpretation of lineaments.

Explanation: The word 'Identification of Lineaments' is changed as 'interpretation of lineaments' according to the suggestion.

Comment 3. Candidate represented good photographs however, proper labeling has not done.

Explanation: Proper labelling has been given to all the photographs.

CHAPTER-3

Comment 1. The candidate allotted chapter-3 for hydrogeology, drainage aspects and morphometry. The drainage aspect itself is a part of morphometry, why he separately mentioned in the title.

Explanation: Drainage aspect is included within the morphometry.

Comment 2. The title 3.1 i.e. 'hydrogeology' again mentioned as 3.1.1 'General introduction' which has no meaning, all this could have described under one heading.

Explanation: Correction incorporated.

Comment 3. The candidate made an attempt to do ‘morphometric analyses’ for the basin. The chapter could have been titled as ‘morphometry analyses.

Explanation: Morphometric analysis is widely used in many research publications. The same is used in the present studies.

CHAPTER-4

Comment 1. The well inventory (water level) data should be incorporated under the chapter-4 instead of chapter-3.

Explanation: Well inventory is carried out to understand the ground water conditions in the area – it is retained in chapter 3.

Comment 2. The candidate utilised capital letters for all tables (eg: 4.1).

Explanation: All the tables are in appropriate font except 4.1 which is corrected.

CHAPTER-5

Comment 1. How the curves are plotted? What types of Softwares are used in plotting curves are not mentioned in the thesis.

Explanation: Curves are plotted by using RESIST- 3.5 and WINSEV-6.4 Softwares which is already mentioned in the thesis on page no. 107.

CHAPTER-6

Comment 1.The comparison of results in between tables 6.3, 6.4 and 6.5 are not matching. The percentage of values is wrongly mentioned in the tables.

Explanation: The comparison of results in between tables 6.3, 6.4 and 6.5 are checked once again carefully. The percentages of values mentioned in the tables are corrected.