केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

THIRUVANANTHAPURAM DISTRICT, KERALA

केरल क्षेत्र, तिरुवनंतपुरम

Kerala Region, Thiruvananthapuram

भारत सरकार

GOVERNMENT OF INDIA

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

MINISTRY OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION

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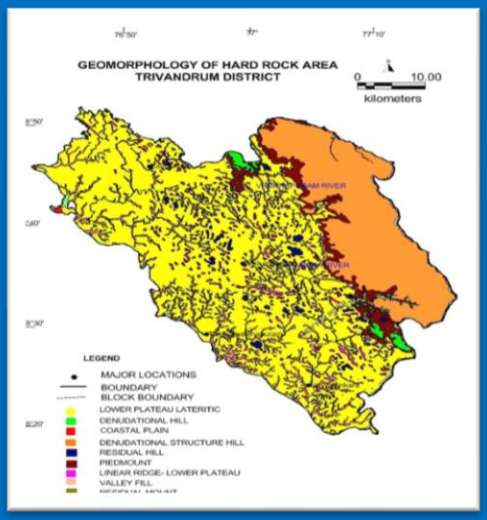
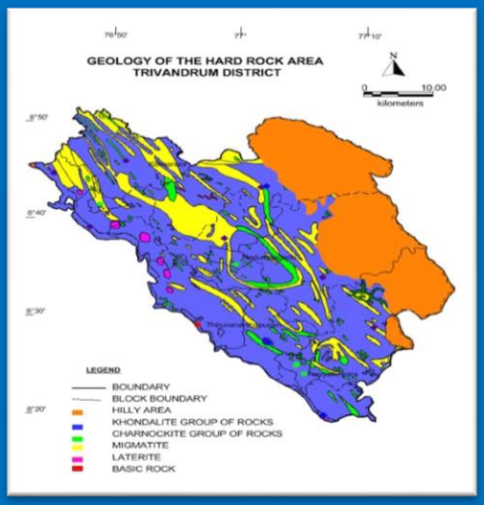
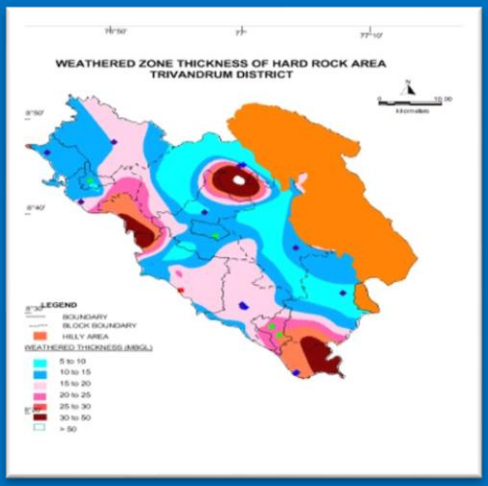
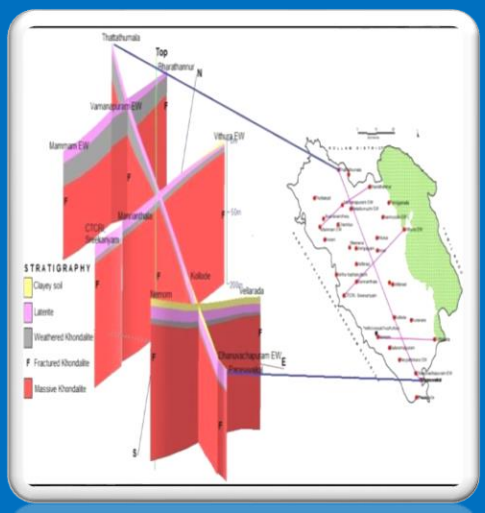
CENTRAL GROUND WATER BOARD

AQUIFER MAPPING AND MANAGEMENT PLAN OF THE HARD ROCK AREA OF THIRUVANANTHAPURAM DISTRICT, KERALA (AAP 2017-18)









KERALA REGION
Thiruvananthapuram
January 2019

TINKU BISWAL IAS
SECRETARY TO GOVERNMENT

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Foreword

Availability of fresh water has always been a prime consideration in fostering the socio economic growth of the people. Rapid urbanization coupled with irrigated agriculture and industrialization has resulted in increased demand of groundwater at an alarming rate. The advancements in drilling technology and easy availability of rigs gradually changed the role of groundwater from a supplementary source to a major source in irrigated agriculture. Unbridled exploitation of aquifer systems resulted in lowering of water levels which entailed management of these aquifer systems. In the last two decades there is a paradigm shift from development to management of groundwater for sustainability. To meet these challenges, it has become imperativeto formulate aquifer management plan to establish the priorities for groundwater use with community involvement at various levels of implementation. The National Aquifer Mapping Program of Central Ground Water Board is an endeavor in this direction.

Mapping of the hard rock aquifer systems of Thiruvananthapuram district is significant as more than80 percent of the total geographical area of the district is underlain by hard rocks.Though richly endowed with surface water sources such as rivers, tanks and ponds and having average annual rainfall exceeding 2000 mm, the topographic and geomorphic settings of the district allow utilization of only a small portion of the available resources. This report elucidates the aquifer geometry, the disposition, aquifer characteristics, resource utilization and quality aspects of the water-bearing formations which is essential for Judicious and planned development of ground water and its scientific management so as to ensure long-term sustainability of aquifer systems. I appreciate the efforts of Sri. V. Kunhambu, Regional Director and his team of officers in bringing out this report titled 'Aquifer mapping and management plan of the hard rock areas of Thiruvananthapuram district'.

I hope this report will be of help to the planners, administrators and stakeholders in the water sector inKerala and will serve as a useful guide for the optimal and sustainable management of the limited ground water resources in the hard rock areas of Thiruvananthapuram district

Tinku Biswal

TINKU BISWAL, IAS

Preface

The National Project on Aquifer Management (NAQUIM) is an initiative of the Ministry of Water Resources, Government of India, for mapping and managing the entire aquifer systems in the country.

The aquifer systems in Kerala are being mapped as part of this Programme and this report pertains to aquifer mapping of the hard rock terrains of Thiruvananthapuram district. The target scale of investigation is 1:50,000 and envisages detailed study of the aquifer systems up to 200 m depth, to ascertain their resource, water quality, sustainability, and finally evolve an aquifer management plan.

The report titled Aquifer Mapping and Management Plan of Hard Rock Area of Thiruvananthapuram district, Kerala gives a complete and detailed scientific account of the various aspects of the hard rock aquifers in the area including its vertical and horizontal dimensions, flow directions, quantum and quality of the resources, of both - the shallow and deeper zones of the hard rock aquifers. Voluminous data were generated consequent to hydrogeological studies, ground water regime monitoring studies, exploratory drilling, geophysical studies etc carried out in the district, and incorporated in the report. The information is further supplemented by various data collected from State departments. It portrays the various ground water issues pertaining to the area along with recommendation for suitable interventions and remedial measures. Thus, it provides a total and holistic solution to the water security problems in Thiruvananthapuram district.

This document has been prepared under the guidance of Dr. N. Vinayachandran, Scientist D & Nodal Officer, and Smt. Mini Chandran, Scientist D &Team leader. The painstaking efforts of field hydrogeologist Smt. Anisha K, Scientist B in carrying out the aquifer mapping are well appreciated. Dr. K.R. Sooryanarayana, Suptdg. Hydrogeologist and Dr. V.S. Joji, Scientist D deserves appreciation for their meticulous scrutiny of this report before printing. I am also thankful to the Chairman, Members and officers of CGWB, Faridabad for their valuable guidance in finalizing this document. Thanks, are also due to various organizations of Government of Kerala and Government of India for providing data required for the compilation of this document.

I hope this compilation will be of help to the planners, administrators and stakeholders in the water sector in Kerala and will serve as a useful guide for the optimal and sustainable management of ground water resources in Thiruvananthapuram district.

Thiruvananthapuram,
January 2019.

(V. Kunhambu)
Regional Director

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AQUIFER MAPPING AND MANAGEMENT PLAN IN THE HARD ROCK AREA OF THIRUVANANTHAPURAM DISTRICT, KERALA (2017-18)

1.Introduction

The aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water resources in aquifers. Aquifer mapping is not merely mapping, but management of ground water through community participation. Mapping of the hard rock areas of Thiruvananthapuram district covering 1800sq km was carried out as part of Annual Action Plan 2017-18.

1. 1 Approach and Methodology

The major activities envisaged under aquifer mapping to achieve the objectives are data gap analysis, data generation, data integration, preparation of thematic maps and development of aquifer models. The data gap analysis primarily involves compilation, analysis and interpretation of the existing data on the groundwater regime. The data inadequacy or data gaps identified from this study forms the base for additional data generation. The existing data and the new data generated under aquifer mapping activities have been integrated and various thematic maps depicting hydrogeology, hydrology, geomorphology, water quality etc. and cross-sections, fence diagrams, elevation models and aquifer geometry (2-D models and 3-D models) were prepared.

The information derived from various activities described above could be used to

i. Define the aquifer geometry and characterize the aquifer systems.

ii. Define groundwater regime behaviour.

iii. Identify the recharge characteristics and resource potential.

iv. Identify the hydro-chemical characteristics of weathered and fracture aquifer systems and the extent of contaminant/pollutant in groundwater, if any.

v. Arrive at an effective groundwater management plan.

1.2 About the Area

Mapping of the hard rock area of Thiruvananthapuram district was carried out as part of Annual Action Plan 2017-18. The Study area falls in the district of Thiruvananthapuram, formerly known as Thiruvananthapuram, the southern-most district of Kerala. Thiruvananthapuram city is the district headquarters as well as the State capital of Kerala.

The study area lies between North latitudes 8°19’ 13” and 8° 51’ 42”and East longitudes 76°43’05”and 77° 16’ 59”, covering an area of about 1800 sq.km of which 194Sq Km falls under hilly

and forest region and the balance area is considered for aquifer mapping. The mapping area includes whole of blocks like Kilimanoor, Vamanapuram, Vellanad, Nedumangadu, Perumkadavila, Thiruvananthapuram rural and part of bocks such as Parassala, Nemom, Pothencode, Chirayinkil, Varkala, and Attingal municipality and Parts of Thiruvananthapuram Corporation. The areas are covered by Survey of India Toposheets 58D/13, 14, 15 and 58H/1, 2, 3& 6. There are about 58panchayats in the study area and the total population of the study area is 2622474. The location map of the study area is given in **Fig.1.1.**

The district is blessed with both groundwater as well as surface water resources. Ground water is mainly used for drinking and industrial purposes. The ground water in the district is mostly developed through dug wells while the fractured crystalline aquifers are tapped through bore wells mainly for domestic, industrial and agricultural purposes. In the recent years due to fall in water level, the depth of dug wells as well as the number of bore wells have increased in many parts of the district. The lifting devices of water are centrifugal pump and jet pump for dug wells and submersible pumps and compressor for bore wells. Water is also being lifted by bucket and rope from dug wells for domestic purposes.

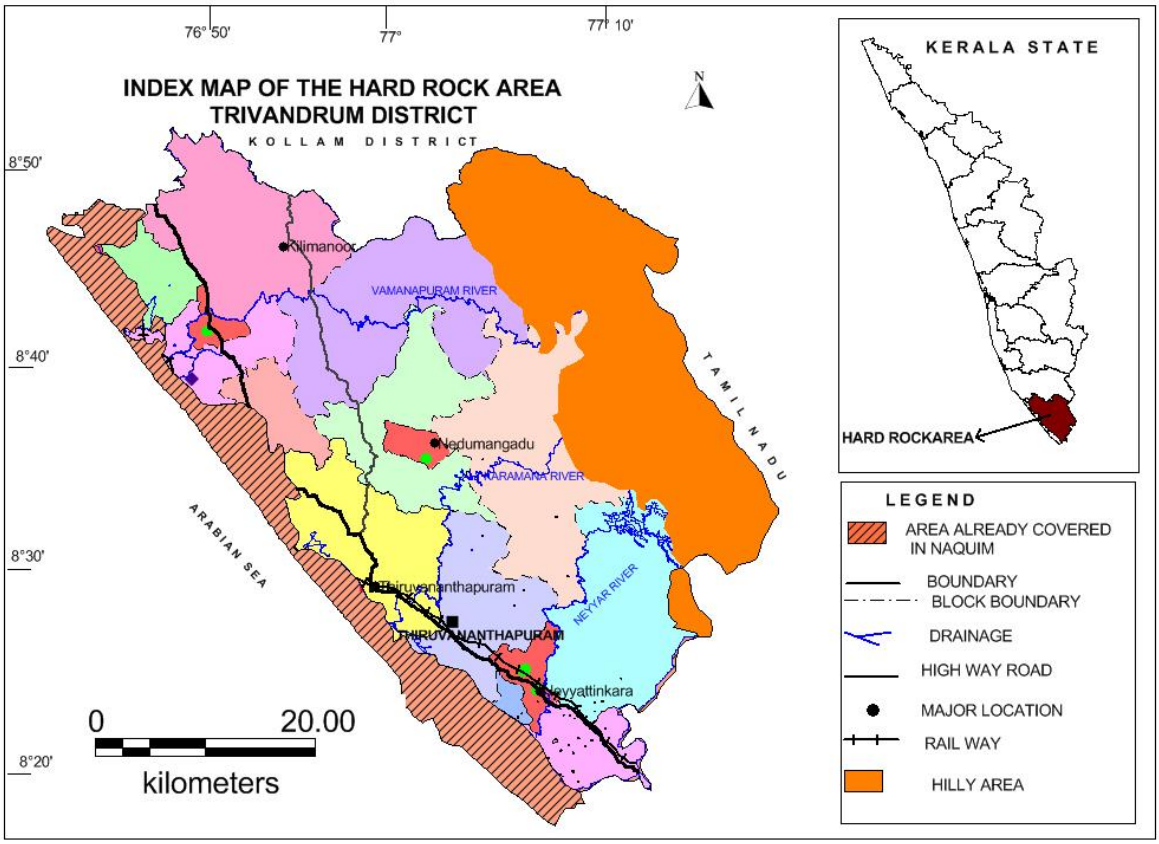


Fig.1.1: Location map of the study area

1.3 Climate

'Tropical monsoon' type of climatic condition prevails in Thiruvananthapuram district and experiences very moderate rainfall. India Meteorological Department maintains two observatories

(one in the Thiruvananthapuram city and another in the Thiruvananthapuram airport) and three other Rain gauge stations namely Nedumangadu, Neyyattinkara and Varkala. State Irrigation department is also maintaining 9 rain gauge stations in the study area.

1.4 Soil

The information on soil types of the area were collected from the published reports of CGWB. Soils found in the study area are red loams, riverine alluvium, lateritic soil, brown hydromorphic soil and forest loam. Most predominant soil is lateritic soil, mainly found along the midland, mostly reddish brown to yellowish red in colour. Brown hydromorphic soils are mostly confined to valley bottom in the midland which exhibits characters like grey horizon, mottling streaks, hard, organic matter deposition, iron and manganese concretions etc. Red loamy soils are highly porous, friable and low in organic matter, and are mainly seen in southern part of the district.

Based on textural characteristics of the soil five types of soil are encountered in the area; they are gravelly clay, loam soil, clayey soil, gravelly loam and sand. Gravelly clay is the most predominant soil type in the area and is seen all over the study area except the north-eastern part. Gravelly soil is light reddish brown in colour and well suited for agriculture. Loam soil is the mixture of soil seen along the hilly region and is ideal for plant growth. Clayey soil has high water retaining power. The soil map based on textural classification of the area modified after the soil map published by Kerala land Use board is shown in **Fig 1.2**

1.5 Geomorphology

Physiographically, the area has a very rugged topography with two major distinctive topographic units identified as midlands (of elevation ranging from 7.5 to 75 m amsl with low to moderate slope) and highlands (of elevation greater than 75 m amsl). Majority of the area comes under the midland. The highly rugged terrain in the eastern part of the district represents the highland where the elevation goes up to 1869 m amsl (Agasthya mala). The midland and highlands are carved out by denudational activities. Midland region is rugged and rolling. The high land region comprises the reserved and other forest land. The highly rugged terrain is characterized by NW-SE trending ridges, narrow valleys with steep slope, rocky cliff and escarpments. Various geomorphological features of the area are depicted in the modified geomorphological map sourced from the Land Use Board (**Fig. 1.3**).

1.6 Agriculture &Land use

Climate, type and characteristics of soils and irrigation facilities available are the major factors controlling the cropping pattern in the district. With a high density of population, the land availability for agriculture is highly limited. The cultivable land may be classified as wet, dry, garden and plantations. A wide variety of crops are being cultivated in the study area. Paddy is the important wet land crop. Coconut is one of the most important crops. Crops like rubber, tapioca, paddy, pepper, banana, vegetables, tea and coffee etc are the other crops. The midland area is occupied coconut, rubber and tapioca cultivation. **Table 1.1** shows the district wise area under major crops in Thiruvananthapuram district. The area under dry land paddy in the district is 0.51 Ha.

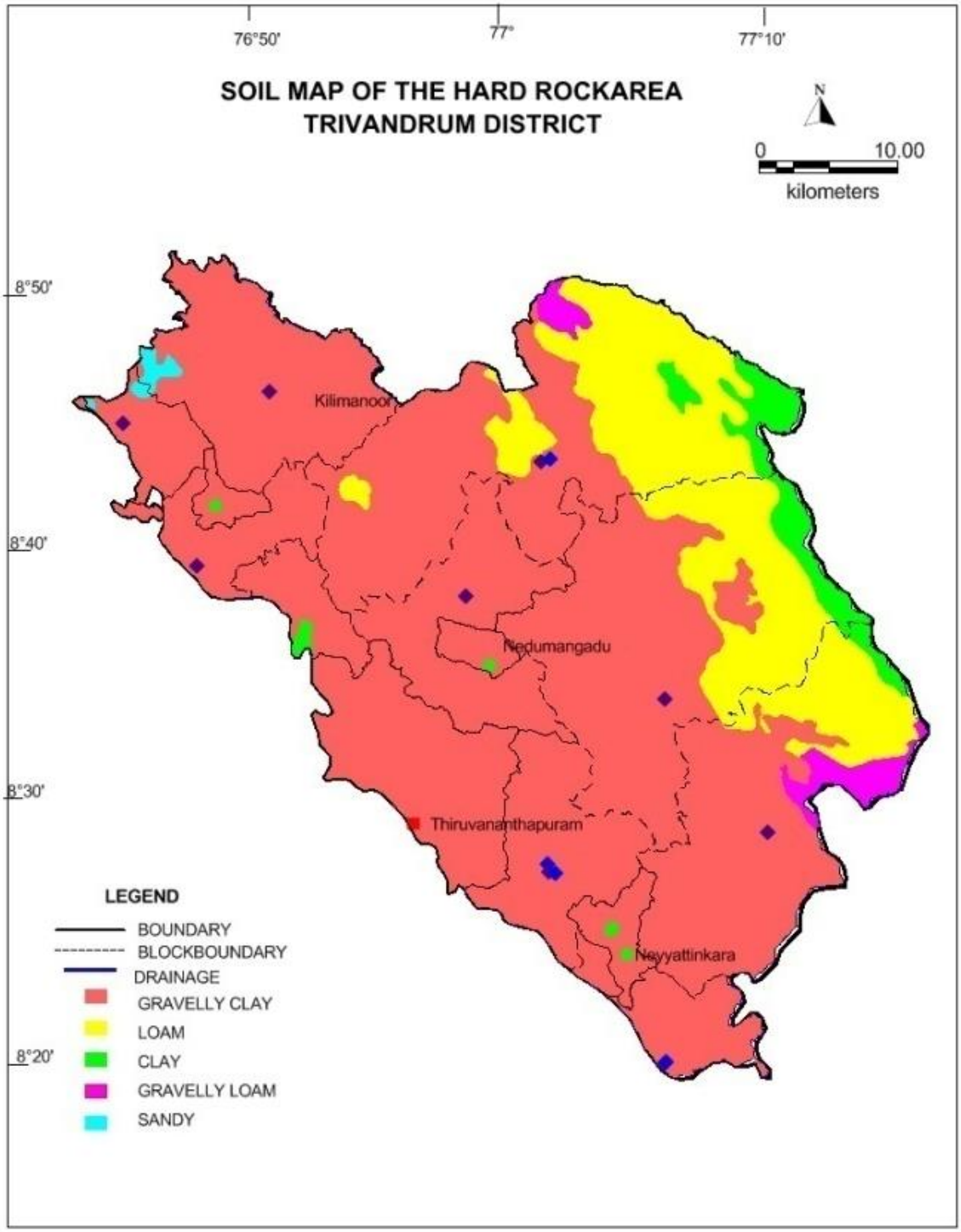


Fig.2.2: Soil Map

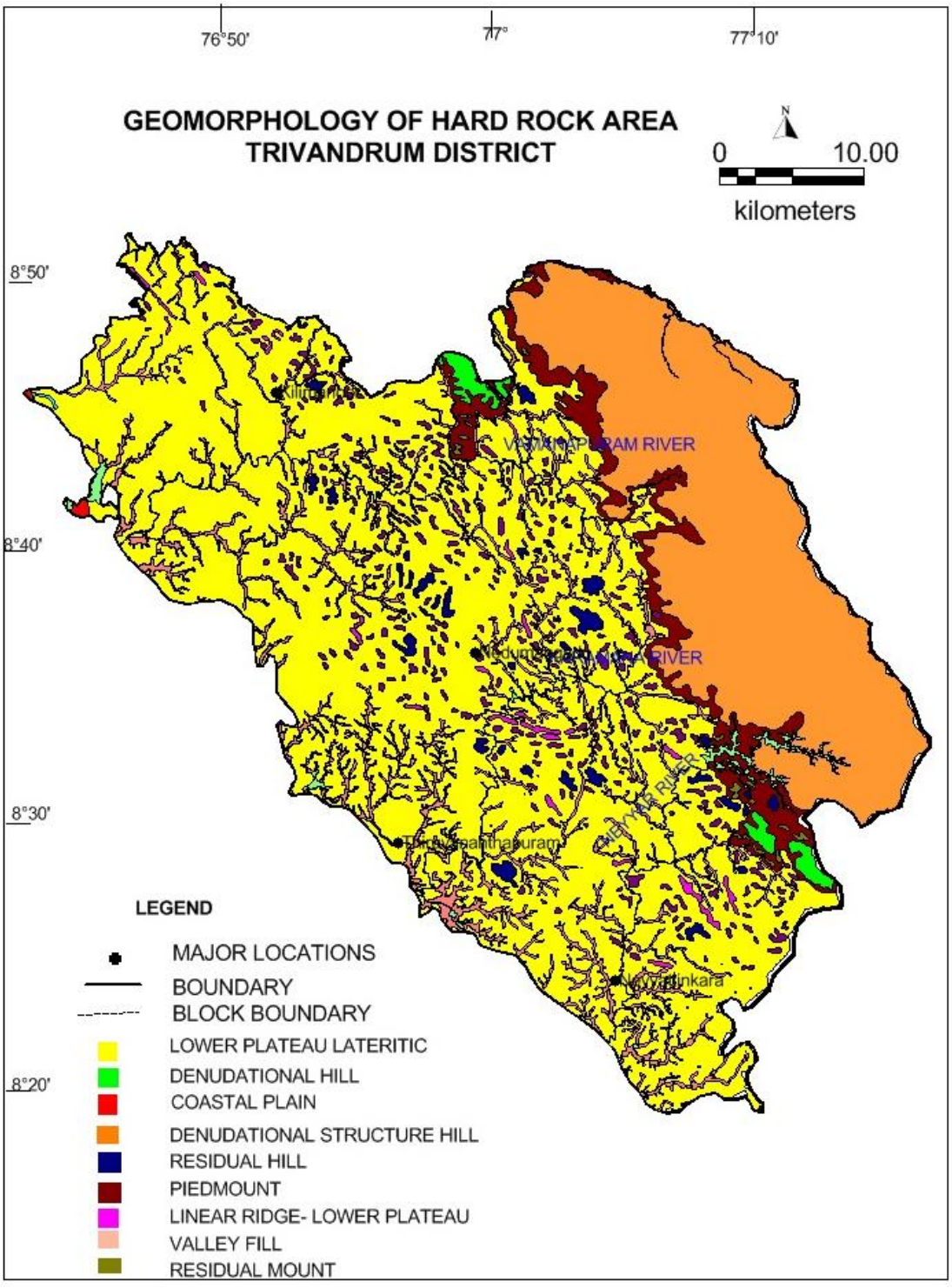


Fig.3.3: Geomorphology Map

Table 1.1: District wise area under major crops in Thiruvananthapuram district(Area in hectares)

Name of Blocks	Paddy	Pepper	Arecanaut	Banana	Plantain	Tapioca	Coconut
Athiyanoor	0.06	74.92	13.20	133.05	252	583.76	4190.59
Chirayinkil	212.64	97.25	86.30	60.21	471.37	1430.27	5006.89
Kilimanoor	764.01	444.38	157.76	98.28	703.10	3103.85	7431.13
Nedumaangadu	7.95	157.57	90.39	143.53	289.90	597.32	3521.85
Nemom	26.37	142.12	72.03	452.84	886.17	1138.45	6104.87
Parassala	329.3	109.42	28.92	475.01	431.94	866.16	5342.55
Perumkadavila	30.94	329.62	104.65	412.68	846.52	1400.46	5197.48
Pothencode	110.6	82.87	27.35	42.33	271.20	709.35	5598.65
Vamanapuram	68.11	250.51	146.19	187.21	666.78	1279.93	4077.89
Varkala	470.23	208.84	71.86	18.40	386.85	1858.17	6082.89
Vellanad	15.72	260.5	148.24	188.27	458.83	1020.05	4884.15
Municipalities	26.74	156.39	53.20	85.93	363.14	1210.35	4129.12
Corporation	30.26	86.43	33.36	31.43	450.45	555.52	11515.87

Source Agriculture statistics(2014-15)

An understanding of the land use pattern of an area is very important from groundwater point of view. As per the Agriculture statistics 2014-15 the land use pattern of the district is as shown in the **Table1.2**. The geographical area of the district has been classified into 14 different types of land uses. Net area sown (the area sown more than once will be counted only once.) accounts for about 59% of the total geographic area of the district, ie. 128290 Ha. Area sown more than once is 34458 Ha (16% of the total geographic area) and total cropped area of the district is 162748 Ha.

Table1.2: Land use pattern of the district

Land use pattern	Area in Hectares
Land put to non-agriculture use	31887
Forest	49861
Barren and cultivable use	206
Land under miscellaneous tree crops	16
Cultivable waste	412
Fallow other than current fallow	744
Current fallow	2869
Marshy land	6
Stillwater	4342
Water logged area	88
Social Forestry	60
Net area sown	128290
Area sown more than once	34458
Total Cropped area	162748

Source: Agriculture statistics (2014-15)

The undulating topography of the district makes minor irrigation schemes suited to the local requirements to irrigate the cultivated area. The details of source-wise net area irrigated is given in **Table1.3.** and gross area under irrigation is shown in **Table 1.4**

Table1.3: Source wise- Net area irrigated (Area in Hectare)

Source	Type	Area
Small Stream	Govt	3810
	Private	177
Pond	Govt	483
	Private	9
Well	Govt	-
	Private	2736
Borewell/Tube well		89
Lift / Minor Irrigation		-
From Rivers & Lake		3
Other Sources		382
Grand Total		7689

Table 1.4: Gross Area under Irrigation (Area in Hectare)

crops	Area under irrigation
Paddy	**2093**
Vegetables	**1312**
Coconut	**2198**
Arecanaut	**2**
Nutmeg	**9**
Banana	**2329**
Betel leaves	**15**
Other crops	**2039**

1.7 Drainage and Drainage Characteristics

The area is drained by three west flowing rivers, viz *Neyyar, Karamana and Vamanapuram*, originating in the western portion of the Western Ghat region. These rivers together with their tributaries exhibit dendritic pattern of drainage. Topo analysis of the area has brought to light the dendritic patterns of the major rivers. Dendritic pattern drainage is common in the flat lying rocks and in areas where the preferential zones of structural weakness are minimal. The tributaries joining the major rivers are showing trellies pattern in some area. The drainage pattern of the study area is shown in **Fig. 1.4.** The location of G&D site is given in **table 1.5.**

Table 1.5: The location of G&D site

#	G&D Site Location	Basin Name
1	Amaravilla	Neyyar
2	Ottasekeramangalam	Neyyar
3	Mankattukadavu	Karamana
4	Maruthankuzhi	Karamana
5	Valayinkil	Vamanapuram
6	Mylammoodu	Vamanapuram
7	Vamanapuram	Vamanapuram

The Neyyar River with catchments of 497 Sq.km originates from Agasthya mala at about 1860 m above msl and joins Arabian Sea near Poovar. The Neyyar Irrigation Project is one among the Major Irrigation Project construction across Neyyar River near Kattakkada in Thiruvananthapuram district. Neyyar river is a 6th order basin, incorporating 15 well marked drainage basin. The straight course of the river and its right-angled bends indicate that the structural features like fault or fracture systems have a direct control over the flow of the Neyyar river. The overall drainage pattern of the Neyyar river is dendritic to subdentritic superimposed with a rectangular pattern, The Neyyar river grades from a youth stage in the highlands to late mature stage in the lowlands. This might be the result of the upliftment of Agastya malai, exposing it to the second cycle of denudation. A significant decrease in the drainage density from highland to midland and then to low land is observed in the basin. The area with low drainage density indicates possibility of high recharge. Hence lowland and midland area is good for recharge. The Bifurcation ratio varies from 3.030 to 4.50. The stream length varies from 0.462 km to 0.568km in the highland, 0.631km to 0.873km in the midlands and 1.41km to 1.58km in the lowlands. The length of the river is only 60.50 km. The longitudinal profile in the basin gave a slope of 2° from coastline towards inland up to the piedmont of the Western Ghats.

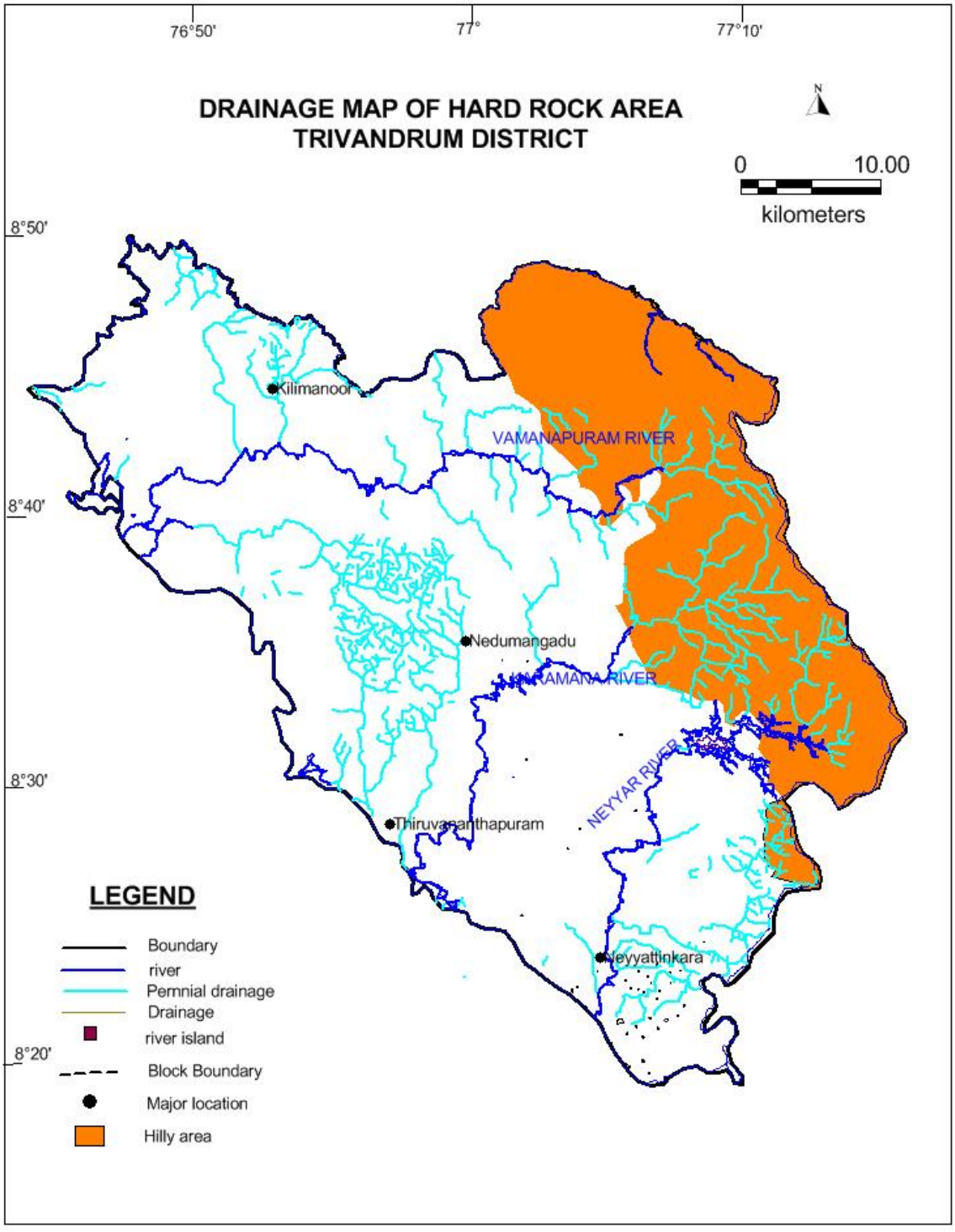


Fig.4.4: Drainage pattern in the study area

The Neyyar Irrigation Project was completed in 1973 and it envisages in irrigating an ayacut of 11740 Ha and catchment area of 140 km^2. The scheme has now become an integral part of the lives of the people of Neyyatinkara Taluk and its surroundings, since it is the main source of water for agricultural and drinking purpose. The project consists of a straight masonry dam across Neyyar river. This project consists of two canal systems viz; the Right Bank Main Canal and Left Bank Main Canal. Particulars of the branches of the Right Bank Canal and Left Bank Canal are given in **Table 1.6**

Table1.6: Particulars of the branches of Neyyar Project

#	**Left Bank Canal**	**Length (km)**
1.	Main Channel	33.82
2.	Perumkadavila Branch	5
3.	Chaikottukonam Branch	8
4.	Kollayil	12
5.	Notchiyoor	5
6.	Chenkal Minor	5
7.	Chenkal Major	8
8.	Karumanur Left Branch	2
9.	Karumanur Right Branch	8
10.	Kode	23
11.	Chulliyur Branch	1.50
12.	Veeyanoor Sub Channel	2
13.	Vadakara	150
14.	Kulathumel	0.50
15.	Chaikottukonam Sub Branch	5.00
16.	Palappally	1.50
17.	Vlathankara Field	-

#	**Right Bank Canal**	**Length (km)**
1.	Main Channel	33.40
2.	Vadakode Branch	8
3.	Perumbazhatoor Tributary	1
4.	Vizhijam	22
5.	Vellayani	10
6.	Marukil Branch	2
7.	Vellayani East	4
8.	Vellayani West	12
9.	Poovar East	18
10.	Poovar West	12

11.	Olathani	6
12.	Kodangavila	3
13.	Poovar	21
14.	Mavinkadavu filed	
15.	Chowara Branch	21

The other major river of the district is Karamana River, which is also perennial in nature, originates from Chemmunji Motta and Agastya malai at 1717 m above msl and joins the Arabian Sea near Pachallur with a total catchment area of 703 sq.km. Karamana river basin is a 6th order basin and exhibits dendritic pattern to sub dendritic pattern, the main tributaries of Karamana river such as killi Ar and Chittar exhibits trellis pattern. The two dams constructed across the river are Peppara dam and the Wellington water works (Aruvikkara Dam). The Peppara Dam is built on the upper reach of the river and is used for irrigation purposes. The Aruvikkara Dam provides water supply to Thiruvananthapuram for consumption. Thiruvananthapuram urban water supply scheme draws water from the Karamanariver from 3 places namely the reservoirs at Peppara, Aruvikkara and Kundaman kadavu near Thirumala.

The Vamanapuram River originates from the Chemunji motta hills of the Western Ghats. It is also called Attingal River. This river has a length of 88 km and a catchment area of 799 sq km. and it spreads along the districts of Thiruvananthapuram and Kollam. The river generally possesses dendritic pattern characterized by irregular branching of tributaries in many directions and indicates lack of structural control and is controlled by the lithology. Vamanapuram river is a seventh order stream. The drainage density varies from 1.6 to 4.48 and bifurcation ratio varies from 2.5 to 4.35 with an average of 3.5 which shows the dissected nature of Vamanapuram river basin and this variation is due to lithological and geological development. The drainage density is high to very high in eastern and north eastern portion of the basin and medium to low in the midland area. Based on drainage density the midland area is good for recharging. The elongation ratio of 6.1 proves the basin is oval in shape and the area is generally associated with strong relief and steep ground slopes. The Upper Chittar, Kallar and Manjaprayar are the tributaries of this river. The river meanders its way to the Anchuthengu back waters through Attingal town. The northern parts of district draw water from the Vamanapuram.

Mamam:- Mamam river originates in panthalacode hills Thiruvananthapuram district and flows 27 KM westward direction and ends up at Anchuthengu lake. Mamam river catchment areas are 114 Sq.Km out of which only 8 Sq.Km falls within the study.

A small portion of Kallada river and Ayiroor river also falls in the study area. Vellayanilake, the only freshwater lake present in the district with an area of 250 ha is the main source of drinking water of Nemom block and its surrounding areas. And the only other lake of the city is Aakkulam, the brackish water lake. The **table1.7** shows the area of drainage basin falling in the study area.

Table 1.7: Shows the area of drainage basin falling in the study area

#	Basin Name	Total Area in SqKM	Area falls within the study in SqKm	%
1	Neyyar	493	433	87
2	Karamana	694	615	88
3	Vamanapuram	770	685	88
4	Kallada	1616	103	06

1. 8 Geology of the Area

The study area is mostly underlain by the crystalline rocks of Archaean age. The major rock types areKhondalites and Charnockites followed by Migmatite and basic rocks. The sedimentary formations ranging in age from Miocene to Recent are seen along the western part of the area. The crystalline rocks exposed in the district exhibit evidences of intensive shearing and fracturing. The regional strike of foliation in Charnockites and Khondalites in the central part of the district is generally NW-SE and varies from WNW-ESE to NNW-SSE with south-westerly dip ranging from 25^0 to 80^0. The crystalline rocks have undergone several periods of tectonic deformation. The earliest phase appears to be folding and metamorphism of Amphibolite or Granulite facies, which has resulted in the formation of Charnockites, Pyroxene granites, Khondalites and Migmatite complex.

Most of the quartz and pegmatite veins have intruded along the fractures. Evidence of fracturing and faulting are observed at Vellanad, Perumkadavila, Vithura etc. The gneisses and Charnockites are traversed by two major sets of joints trending NW-SE, one of which is parallel to the regional foliation and the other perpendicular to it. Intensity of joints is found to be more in Khondalites. The general stratigraphic succession of rocks in Thiruvananthapuram district is given in Table **1.8** and its spatial distribution is depicted in Fig **1.5**

Table 1.8: The general stratigraphic succession of rocks in Thiruvananthapuram district

ERA	AGE	FORMATION	LITHOLOGY
QUARTERNARY	Recent	Alluvium	Sands and clays along the coast, flood plain deposits, river alluvium and valley fill deposits.
	Sub-recent	Laterites	Laterites and lateritic clays derived from Tertiary sediments and crystalline rocks.
TERTIARY	Lower Miocene	Warkali beds	Sandstone and clay with thin bands of lignite.
----------Unconformity----------			
-	Undated	Intrusives	Dolerite, gabbro, Pegmatites and Quartz veins.
PRE-CAMBRIAN	Archaean	Migmatite Group Charnockite Group Khondalite Group	Granite gneisses, charnockite, Biotite gneisses and Garnet Silliminite gneiss, graphite gneiss.

1.9 Previous Work

Central Ground Water Board has carried out Systematic Hydrogeological Survey in the district during 1974-75 and 1980-81. Later the same area was covered under Reappraisal Hydrogeological survey during 1997-98 and 2004-05. In 1983-88, the SIDA assisted Coastal Kerala Ground Water Project of CGWB has carried out detailed hydrogeological studies with exploration covering northern parts of the district mainly the Vamanapuram basin. Since 1969, Central Ground Water Board is monitoring the ground water levels and water quality in the district through a network of Ground Water Monitoring Wells. In addition to the routine work, CGWB has also taken up a number of short-term investigation studies, exploration and geophysical activities, sea water ingress studies, pollution studies, environmental impact studies in the district. Aquifer Mapping studies along the coastal tracts of Thiruvananthapuram district particularly the area underlain by sedimentary formation has been taken up during 2014-15.

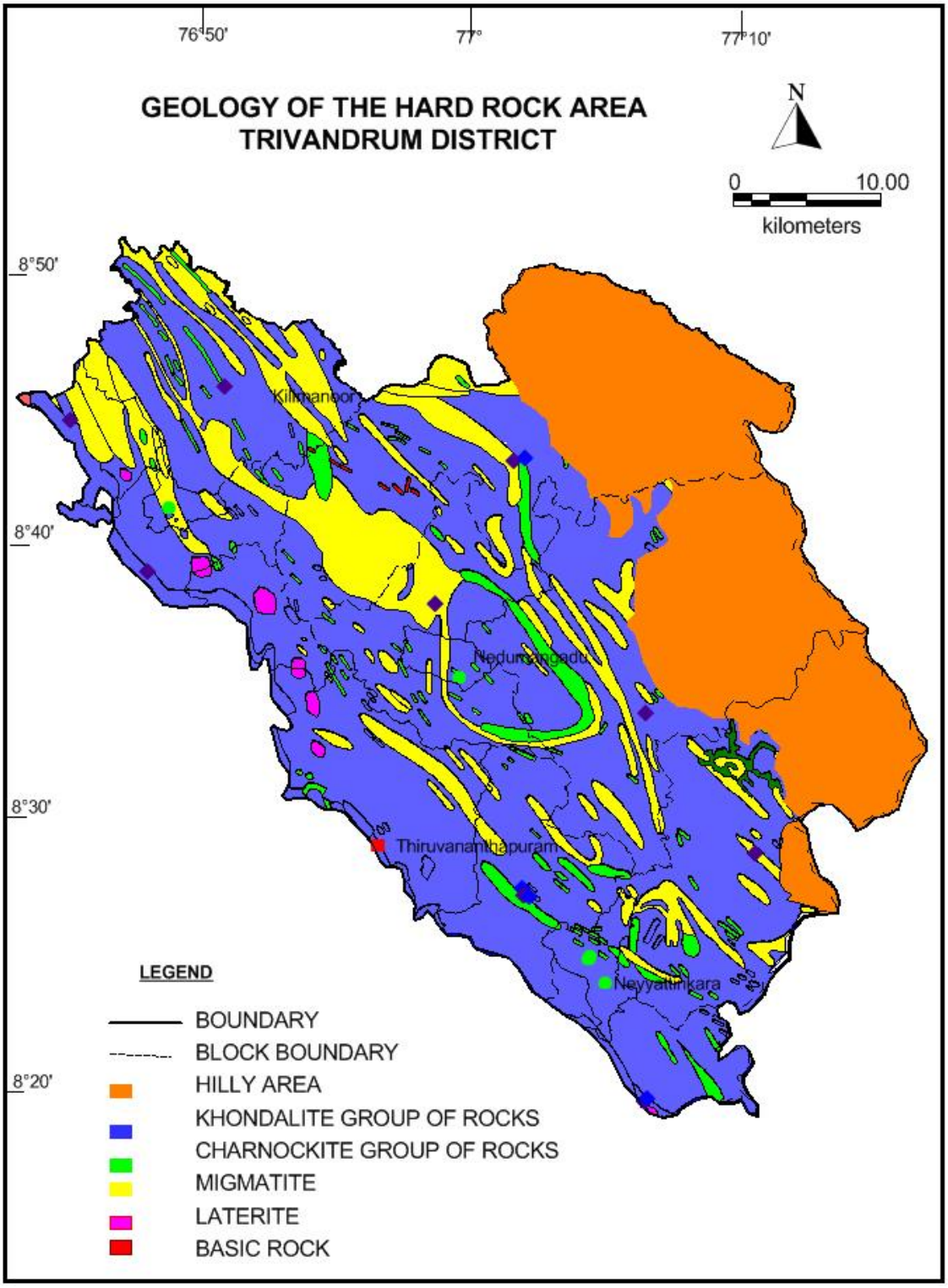


Fig.5.5: Geology of the area

2 DATA COLLECTION, GENERATION AND INTERPRETATION

2.1 Data collection and Data Gap Analysis

The historical or available data of the study area on Geology, Geophysics, Hydrogeology and Hydrochemistry generated under various studies by the CGWB such as Systematic Hydrogeologial studies, Reappraisal Hydrogeological studies, Groundwater Management studies, Exploratory drilling and special studies have been utilized for data gap analysis in conjunction with the data collected from various State and Central government departments. The thematic layers on drainage, geomorphology, land use and land cover were reproduced from the data obtained from concerned State departments. The existing data on various themes are analyzed for finding the data gaps is given in **Table 2.1** and the results of the data gap analysis are described in detail in subsequent sections.

Table 2.1: The data availability for data gap analysis

#	**Themes**	**Data Availability**
1	Groundwater level data	74 no
2	Piezometers	15 no.
3	Groundwater quality Data	Dug wells-18nos. Bore wells/pz -30/12.
4	Borehole Lithology Data	32 no
5	Geophysical Data	22 no
6	Pumping Test	23 no
7	Land use and Land Cover	Available
8	Drainage	Available
9	Geology	Available
10	Soil	Available
11	Climate Data	Available

2.1.1 Water Level Monitoring

Water level monitoring wells maintained by CGWB and SGWD in the area have been made part of the monitoring network for the present study. 74 dug wells are presently monitored by CGWB and 49 dug wells by SGWD for water levels in the phreatic aquifer system. CGWB wells are being monitored

four times (January, April, August and November) in a year whereas; the monitoring wells of State Ground Water Department (SGWD) are being monitored every month. The status of water level monitoring wells of CGWB in the area is listed in **Table2.2.** The historical data from these stations have been used for data gap analysis and identified 26 new sites to fill up the data gaps. Measurements of water levels in wells are necessary for the evaluation of the quantity of ground water and its interaction with surface water and rainfall. Water level is the fundamental indicator of the status of groundwater resource.

2.1.2 Exploration

Information on aquifer geometry, Groundwater potential of fracture systems and their characterization are primarily inferred from exploratory drilling data. The basic data from 32 exploratory drillings in the area is used for data gap analysis and based on this study data gaps were identified for 14 more exploratory wells. Information on weathered thickness and depth of occurrence of fractures are also inferred from geophysical data such as Vertical Electrical Sounding (VES) and profiling.

2.1.3 VES and Profiling

Geophysical data on VES and profiling are used to extract information on the weathered thickness, fracture depth, thickness of fracture etc. The aquifer geometry could be refined from the interpretation of geophysical data in conjunction with the available groundwater exploration data. Geophysical methods are normally employed as a reconnaissance study before exploratory drilling as the cost of geophysical investigation is much less when compared to exploratory drilling and it is effectively used to extract subsurface information. VES data for 22 locations are used for data gap analysis .Based on the study data gap of 32 VES data gap sites were identified.

2.1.4 Water Quality Monitoring

The historical data on water quality in the area is available from the water level monitoring stations maintained by CGWB. Water sampling is being done every year from these wells during pre-monsoon period (April). The data gap analysis has been carried out to find out the adequacy of information on water quality and identified 8 new locations for additional sampling.

Table 2.2: The status of water level monitoring wells of CGWB

Administrative block	**CGWB**	
	Dug well	**Piezometer**
Attingal municipality	2	1
Chirayinkeezhu	3	1
Kilimanoor	6	2
Nemom	6	2
Parassala	3	2
Perumkadavila	10	1
Thiruvananthapuram corporation	7	2
Vamanapuram	14	1
Varkala	1	1
Vellanad	24	1
Athiyanoor	3	
Pothencode	4	1
Nedumangadu	11	-
Neyyattinkara municipality	3	-
Nedumangadu municipality	3	-

2.1.5 Rainfall

The study area is the part of Thiruvananthapuram district which is the southernmost district of Kerala. Rainfall pattern of the district is in such a way that it receives rainfall in almost all months of the year. The study area receives both South West and North East monsoon. The region receives rainfall in other remaining months also. The annual average rainfall of the study area varies from 646 to 2564 mm and mean annual average rainfall is 1687(IMD data, 2001-16). The Southwest monsoon contributes 47% of rainfall from June to September and the northeast monsoon contributes about 27%, remaining 26% is received in the remaining months. The graph showing average annual rainfall for the last 16 years is shown in the **Fig 2.1.**

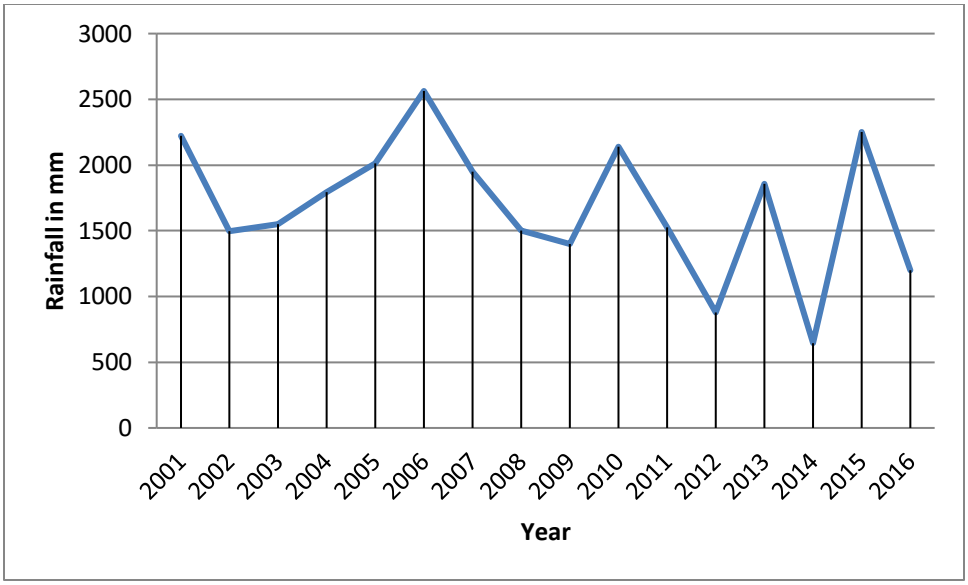


Fig.6.1: Graph showing Annual Average rainfall

The spatial variation in rainfall over the area is best represented by isohyetal map in **Fig. 2.2** which shows a gradual increase in rainfall from South West to North East direction. The mean monthly rainfall of Thiruvananthapuram district for the last five years is shown in **Table 2.3 and Fig 2.3** and the normal monthly rainfall variations for 4 IMD stations of Thiruvananthapuram district is depicted in **Fig 2.4**

Table 2.3: Mean Monthly rainfall of Thiruvananthapuram district

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
2012	14.4	35.1	26.1	164.7	88.7	99.1	146.2	169.7	77.7	159.3	140.7	32.7
2013	10.5	63.1	46.8	31.7	120.9	525.3	247.9	115.8	219.7	155.9	273.9	33.6
2014	45.8	13.1	35.1	136.4	272.6	142.4	118.7	458.6	189.4	288.3	128.6	83
2015	9.6	0.4	50.6	257.3	336.8	358.7	60.6	71.4	307.1	367	275.8	156.8
2016	3.2	3.7	19	58.1	429.1	395	119.4	42.2	15.7	43.4	47.2	21.8

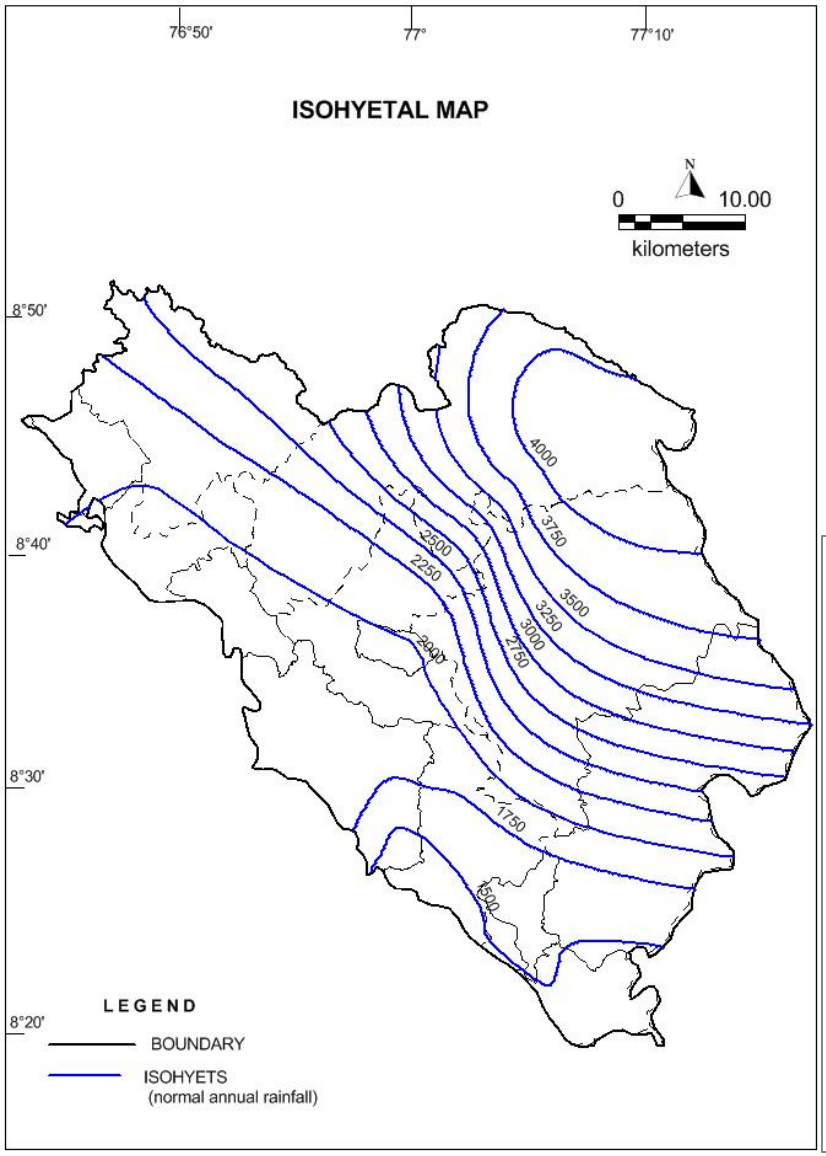


Fig.7.2: Isohyetal Map of rainfall in the area

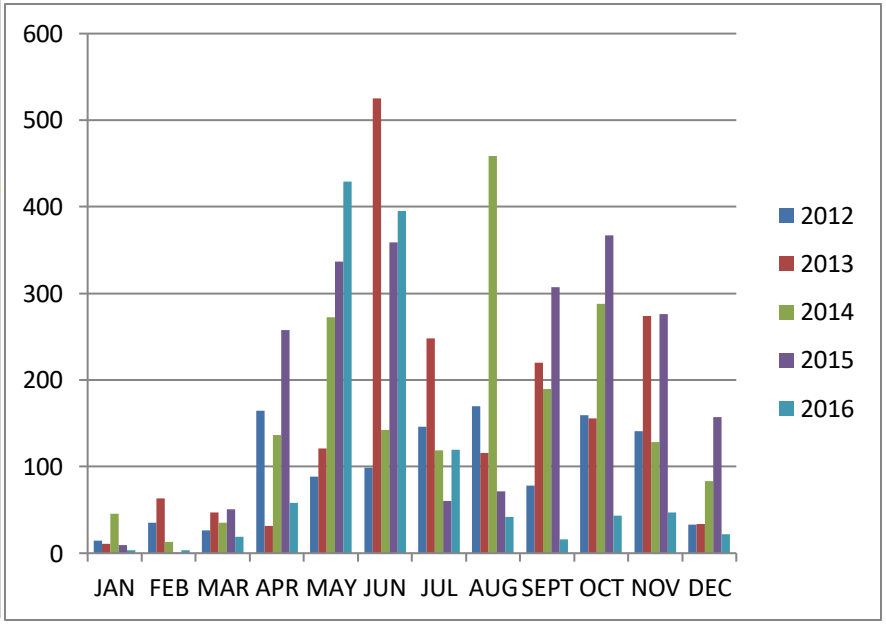


Fig.8.3: Graphical Representation of Mean Monthly Rainfall

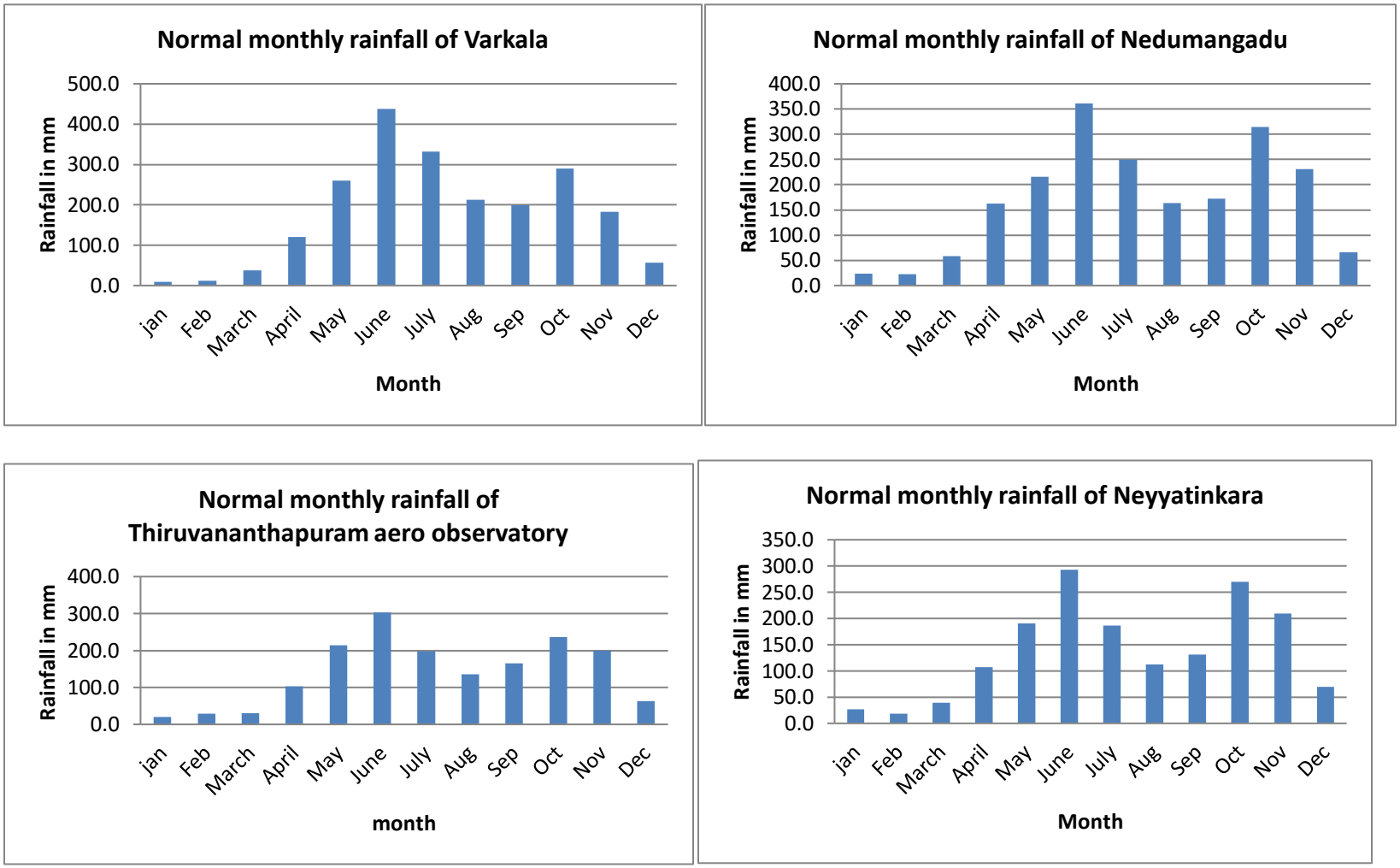


Fig.9.4: Normal Monthly rainfall of IMD stations in the study area

2.2 Data Generation and Integration

The data gaps were identified from detailed analysis of existing data and based on the finding of the studies new data generated for the data gaps. The activities include establishment of Key wells, water quality monitoring wells, geophysical survey and aquifer evaluation. The data gap identified and the new addition of data under various themes is given in **Table**.**2.3.** The value addition made after data generation and integration of various components of the groundwater regime are described in the following sections.

Table2.3: Data requirement and data generated under aquifer mapping

Themes	**Existing data**	**Data Gap**	**Total**	**Data generated**
Dug wells	74	26	100	26
Exploratory wells	32	5	37	5
Piezometers	15	8	23	8
VES	21	34	55	34
Water quality	18	8	26	8
Pumping tests	24	Nil	24	Nil

Based on the findings of data gap analysis 5 new exploratory wells were constructed in the area and drilling is still carrying out in the study area to decipher the aquifer geometry. The basic data reports of the exploratory wells already drilled is being prepared and will be incorporated subsequently. The location map of exploratory wells drilled is shown in the Fig **2.5**

20 VES were conducted in the data gap areas and 23 VES investigations were carried out for locating the sites for exploratory drillings. Thus, 64 VES investigation were made in the area and the locations of VES are shown in **Fig 2.6.** The VES were carried out by employing Schlumberger and half schlumberger electrode configuration up to a maximum spread length (AB) of 300m.

For ground water level monitoring 26 additional monitoring stations were established apart from the existing NHS wells and monitored four times in a year. The integrated data on water level could refine water level maps and resource computations. The data from 15 piezometers is also used for interpretations. The integrated data on water level monitoring stations (dug wells) are given in **Table 2.4** and an integrated location map of water quality stations is shown in **Fig 2.7.**

The existing water level monitoring wells are maintained as water quality monitoring wells by CGWB. The historic data of the existing water quality monitoring dug wells as well as the data of the piezometers, exploratory and observation wells analysed during drilling is used for interpretation.

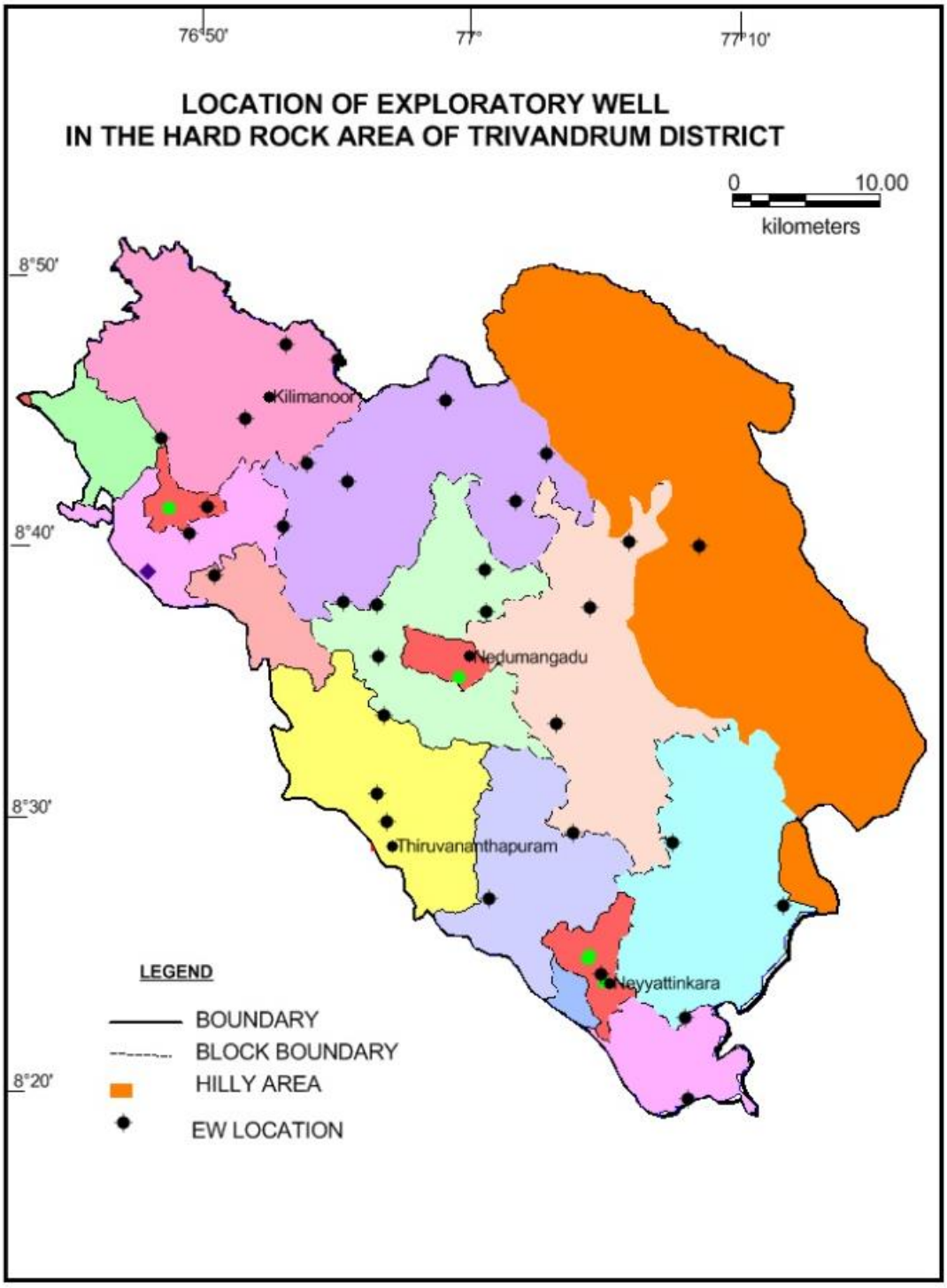


Fig.10.5: Location of Exploratory wells

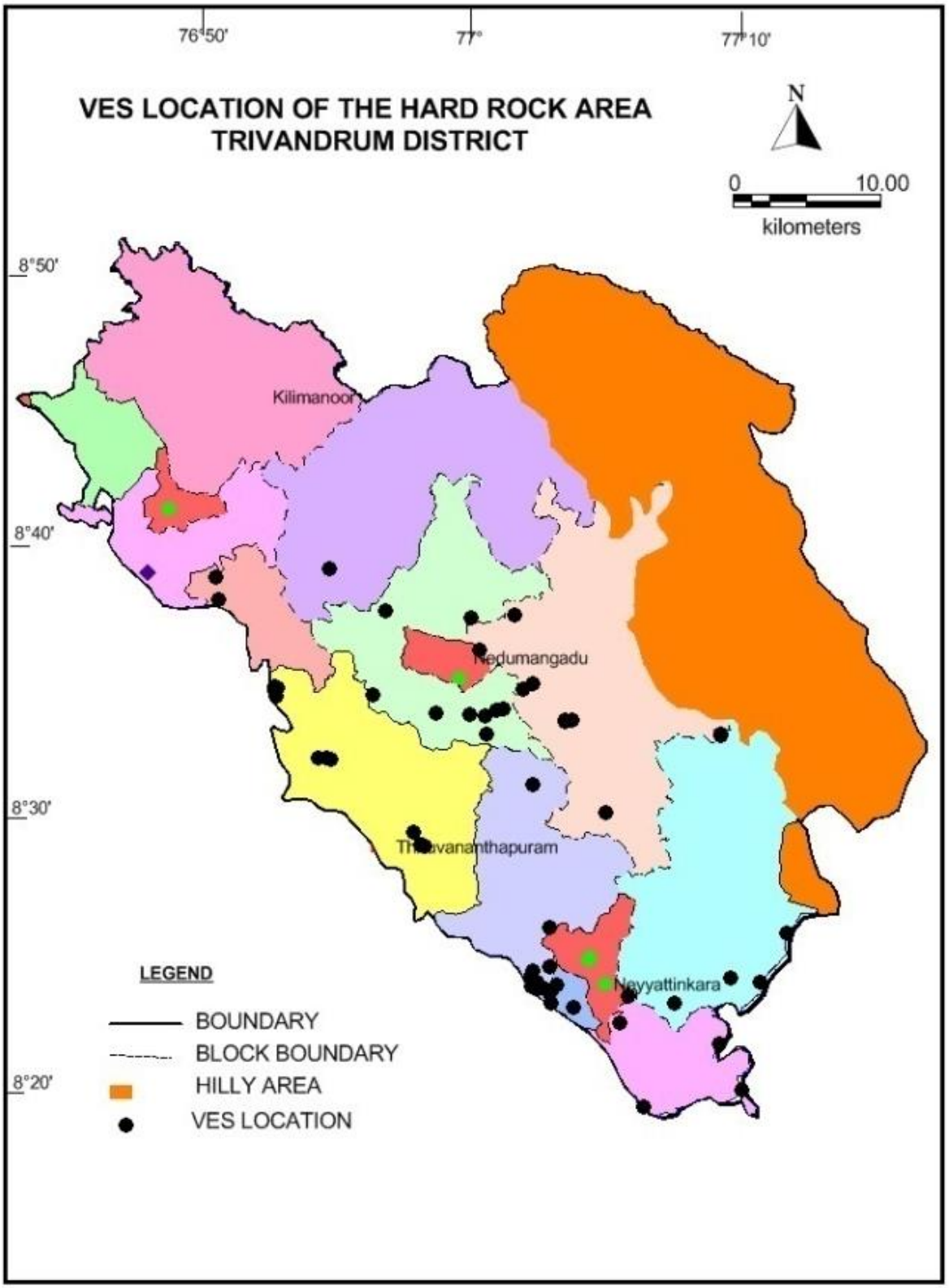


Fig.11.6: Location of VES

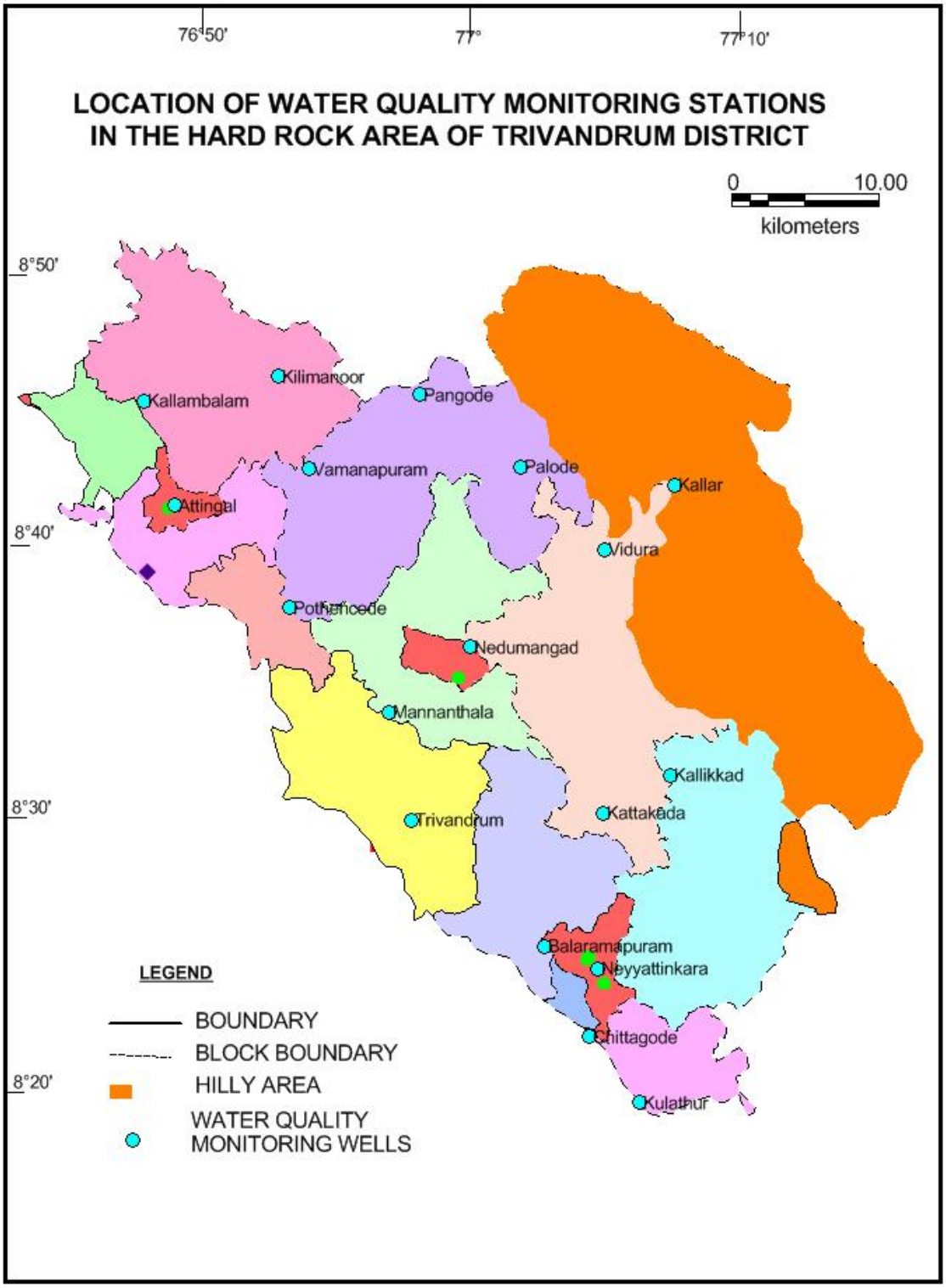


Fig.12.7: Location Water Quality monitoring stations

Table 2.4: Integrated data on water level monitoring stations (dug wells)

#	Location	Latitude	longitude	depth	MP	Elevation	Type	Aquifer
1	Amboori	8.5033	77.19	11.9	0.7	172	NHS	Laterite
2	Anappara	8.69639	77.11	10.61	0.55	120	NHS	Gneiss
3	Aralumoodu	8.41472	77.06	19.89	0.75	61	NHS	Charnockite
4	Ariyanadu	8.57992	77.09	8.1	0.7	68.9	NHS	Gneiss
5	Arukannukuzhi	8.70875	77.07	6.5	0.77	108	NHS	Charnockite
6	Aruvikara	8.56859	77.01	9.7	0.75	53	NHS	Laterite
7	Athazhamangalam	8.38479	77.07	21.95	0.7	49.4	NHS	Khondalite
8	Attingal	8.69833	76.82	15	0.85	39.6	NHS	Laterite
9	Attukal	8.65694	77.01	8.35	0.8	94.8	KOW	Laterite
10	Ayyankode	8.475	77.16	10.09	0.66		NHS	Charnockite
11	Balaramapuram	8.425	77.05	15	0.9	79.6	NHS	Laterite
12	Bharathanoor	8.76556	76.99	10.18	0.8	102	NHS	Khondalite
13	Bounder mukku	8.61667	77.1	9.7	0.74	109	KOW	Khondalite
14	Changa	8.57846	77.07	12.55	0.7	87.5	NHS	Charnockite
15	Chaykottukonam	8.40222	77.11	12.5	0.6	39.6	NHS	Gneiss
16	Cheeranikara	8.64877	76.96	10	0.8	180	NHS	Gneiss
17	Chembur	8.6825	76.88	13.8	0.75	53.3	NHS	Gneiss
18	Chennampara	8.65917	77.08	13.15	0.65	128	NHS	Charnockite
19	Cheriyakonni	8.54472	77.02	12.96	0.66	65.8	KOW	Gneiss
20	Cherunniyur	8.72361	76.76	17	0.8	43	NHS	Charnockite
21	Chettachal	8.68875	77.06	4	0.8	97.8	KOW	Laterite

22	Chullimanoor	8.64286	77.02	9.63	0.65	121	NHS	Charnockite
23	Ithye	8.60936	77.09	10	0.7	123	NHS	Charnockite
24	Kallar	8.70944	77.13	9.47	0.84	148	NHS	Khondalite
25	Kallikkad	8.53056	77.13	7.3	1	62.5	NHS	Laterite
26	Kandala	8.48345	77.07	15	0.7	86.6	NHS	Charnockite
27	Kannanoor	8.48444	77.19	30	0.88	119	KOW	Gneiss
28	Karakulam	8.56417	76.99	9	0.7	45.1	NHS	Laterite
29	Kariavattom	8.56417	76.9	8.5	0.7	31.7	NHS	Laterite
30	Karinga	8.62776	77.04	3.86	0.65	101	NHS	Charnockite
31	Karipur	8.62306	77.02	11.1	0.7	90.2	KOW	Laterite
32	Kattakkada	8.5075	77.08	8.9	0.95	85.6	NHS	Laterite
33	Kaypadi	8.57833	76.98	11.6	0.78	57	KOW	Laterite
34	Kilimannor	8.77639	76.88	10.4	0.81	30.5	NHS	Gneiss
35	Kollankonam	8.52083	77.03	14	0.7	44.8	KOW	Laterite
36	Korani	8.65833	76.84	10.4	0.8	40.8	NHS	Laterite
37	Kowdiar	8.52194	76.96	11	1	46	KOW	Laterite
38	Kulathur	8.32694	77.1	17.05	0.74	27.4	NHS	Laterite
39	Madavoor	8.82217	76.82	14.9	1	56.1	NHS	Laterite
40	Malayadi	8.30056	77.17	8.35	0.85	116	NHS	Charnockite
41	Mangalapuram	8.62278	76.86	24.22	0.68	56.7	NHS	Khondalite
42	Mannanthala	8.55791	76.94	11.5	0.7	52.7	NHS	Laterite
43	Mannaram	8.63534	77.09	9	0.77	130	KOW	Gneiss
44	Maruthamala	8.675	77.13	11	0.74	130	NHS	Khondalite
45	Meenangal	8.63722	77.1	11	0.7	92	NHS	Charnockite

46	Melvettoor	8.72472	76.74	40.45	0.75	64.6	NHS	Gneiss
47	Muduvila	8.71111	76.97	12.8	0.72	74.1	KOW	Khondalite
48	Mundela	8.58137	77.03	13.27	0.8	70.4	KOW	Laterite
49	Muzhi	8.63917	77	6.7	0.72	69.8	NHS	Laterite
50	Nanniyode	8.69944	77.03	9	0.95	98.8	NHS	Khondalite
51	Naruvamoodu	8.44736	77.04	12	0.8	64.3	KOW	Laterite
52	Navaikulam	8.79556	76.8	19.56	0.9	101	NHS	Laterite
53	Nedumangad	8.60944	77	13.3	0.65	67.4	NHS	Laterite
54	Neyyar dam	8.53306	77.14	5.5	0.65	77.4	KOW	Gneiss
55	Neyyattinkara	8.40722	77.08	16.47	0.8	33.8	NHS	Khondalite
56	Ookod	8.44694	76.99	13	0.7	25.6	NHS	Charnockite
57	Ottashekharamangalam	8.61083	77	7.47	0.65		NHS	Charnockite
58	Palode	8.7225	77.03	10.04	1.1	80.8	NHS	Laterite
59	Pangode	8.76528	76.97	8.31	0.65	128	NHS	Laterite
60	Parandakuzhi	8.81629	76.9	17.76	0.65	106	NHS	Charnockite
61	Parandode	8.62028	77.09	7.5			NHS	
62	Parassala	8.34389	77.15	5	0.75	46.6	NHS	Laterite
63	Paruthipalli	8.55694	77.11	6.8	0.72	79.9	KOW	Gneiss
64	Pazhya chantha	8.74806	76.93	8.7	0.8	125	KOW	Laterite
65	Peringamala	8.74944	77.05	10	0.75	129	NHS	Khondalite
66	Perumgulam	8.72444	76.81	8.9	0.75	48.5	NHS	Laterite
67	Perumgur(R1)	8.61944	76.94	8.5	0.92	54.6	NHS	Laterite
68	Perunkadavila	8.44194	77.11	16.88	0.85	58.8	NHS	Laterite
69	Pirappankod	8.65556	76.92	10	0.8	68	NHS	Laterite

70	Ponganadu	8.78222	76.84	12	0.7	53	NHS	Khondalite
71	Ponmudi(R1)	8.74704	77.13	5.4	0.8	685	NHS	Khondalites
72	Poojapura	8.4971	76.98	15	0.7	36	KOW	Khondalite
73	Poovachal	8.53528	77.09	16	0.7	95.4	NHS	Charnockite
74	Pothencod	8.62111	76.89	13.39	0.82	71.9	NHS	Laterite
75	Pudukulangara	8.59613	77.03	8.05	0.55	94.5	KOW	Laterite
76	sasthanthala	8.38611	77.08	9.25	0.86		NHS	
77	Sasthavattom	8.64417	76.81	12.1	0.85	23.5	NHS	Laterite
78	Shankaramugham	8.57111	77.02	8.3	0.7	74.4	NHS	Charnockite
79	Statue	8.4975	76.95	15	0.82	37.5	KOW	Laterite
80	Tekkada	8.63056	76.96	6.15	0.65	73.5	NHS	Gneiss
81	Tennoor	8.70704	77.07	9.2	0.8	106	KOW	Laterite
82	Thalikuzhy	8.74278	76.91	16.32	0.65	130	KOW	Laterite
83	Tholicode	8.65472	77.05	10.1	0.8	150	NHS	Charnockite
84	Thiruvananthapuram	8.50431	76.96	17.36	0.63	45.7	NHS	Laterite
85	Udyankulangara	8.37972	77.12	16.9	0.7	59.4	NHS	Laterite
86	Uriyakode	8.54917	77.06	9.63	0.6	103	KOW	Gneiss
87	Uzhamalakkal	8.59056	77.06	8.5	0.7	73.2	NHS	Charnockite
88	Valakkad	8.68694	76.87	14	0.69	69.5	NHS	Laterite
89	Vamanapuram	8.71944	76.9	8.62	0.8	30.8	NHS	Laterite
90	Vattapara	8.59167	76.95	12.15	0.85	103	NHS	Laterite
91	Vattavila	8.37528	77.11	13	0.7	48.8	NHS	Laterite
92	Vattiyoorkavu	8.52916	76.99	10	1	51.8	KOW	Laterite
93	Vazhichal	8.50361	77.16	10	0.7	80.8	NHS	Charnockite

94	Veeranakavu	8.52333	77.12	6.27	0.45	63.1	NHS	Charnockite
95	Vellaikadavu	8.53361	77.01	12	0.7	31.4	KOW	Laterite
96	Vellanad	8.5615	77.07	9.18	1	89	NHS	Laterite
97	Vellarada(R1)	8.44417	77.2	8.89	0.8	122	NHS	Laterite
98	Vengod	8.65611	76.87	10.36	0.7	63.7	NHS	Gneiss
99	Venjaramoodu	8.67925	76.91	13.9	0.71	60.4	NHS	Charnockite
100	Vilapilshala	8.52556	77.04	12	0.6	63.1	NHS	Laterite

3. AQUIFER MAPPING

The weathered zone and fracture system in crystalline rocks form the repositories of groundwater in the area. Groundwater exists under phreatic condition in shallow fractures and weathered zone and under semi confined conditions in fracture systems. The weathered zone and the zone of fractures are interconnected and groundwater draft from the fracture system affects the groundwater levels in the weathered zone. Hence, the area is considered to have two aquifer systems which are inter connected but have different hydraulic properties. Thus, the aquifer systems are mapped as;

1. Weathered zone with associated shallow fractures and

2. The Deeper Fracture system

*3.*1Weathered zone with associated shallow fractures

The Laterite and weathered Khondalite/gneiss associated with shallow fractures form the phreatic aquifer system in the study area. The Laterites of sub Recent age occur as a residual deposit due to weathering of crystalline rocks. The typical Laterite profile seen in crystalline terrain consists of lateritic soil at the top followed by soft Laterite, Lithomargic clay and weathered zone. The occurrence and movement of groundwater in the weathered zone is mainly influenced by the depth of weathering and topography and groundwater follows the topography. Groundwater abstraction structures in this zone include dug wells and shallow bore wells. The depth of dug wells ranges from 3.86 to 22 mbgl and that of bore well up to the depth of 30-40m bgl. The water level ranges from 1.48 to 16.88 mbgl during the pre-monsoon period. During post monsoon period the water level ranges from1.02 to 18.12 mbgl. The yielding capacity of phreatic aquifers varies spatially and is related to the aquifer characteristics, rainfall received, surface water availability and thickness of weathered residuum.

3.1.1 Thickness of weathered zone

From the exploratory drilling data two aquifer zones were identified viz; the weathered zone (aquifer Zone- 1) and the fracture zone below it. Weathered zone includes the weathered formation and the shallow fractures and its thickness varies in the range of 5.5-52 m. The weathered thickness in the area vary highly as observed from exploratory drillings and the data have been used to elucidate the lateral and vertical changes in weathered zone. The information from 38 bore wells has been analyzed for understanding the spatial variations in the thickness of weathered zone. The thickness of the weathered zone is high in the southern, north eastern (Nanniyode area) and in the western central area. The Spatial variations of weathered zone thickness in the area are given in **Fig 3.1.**

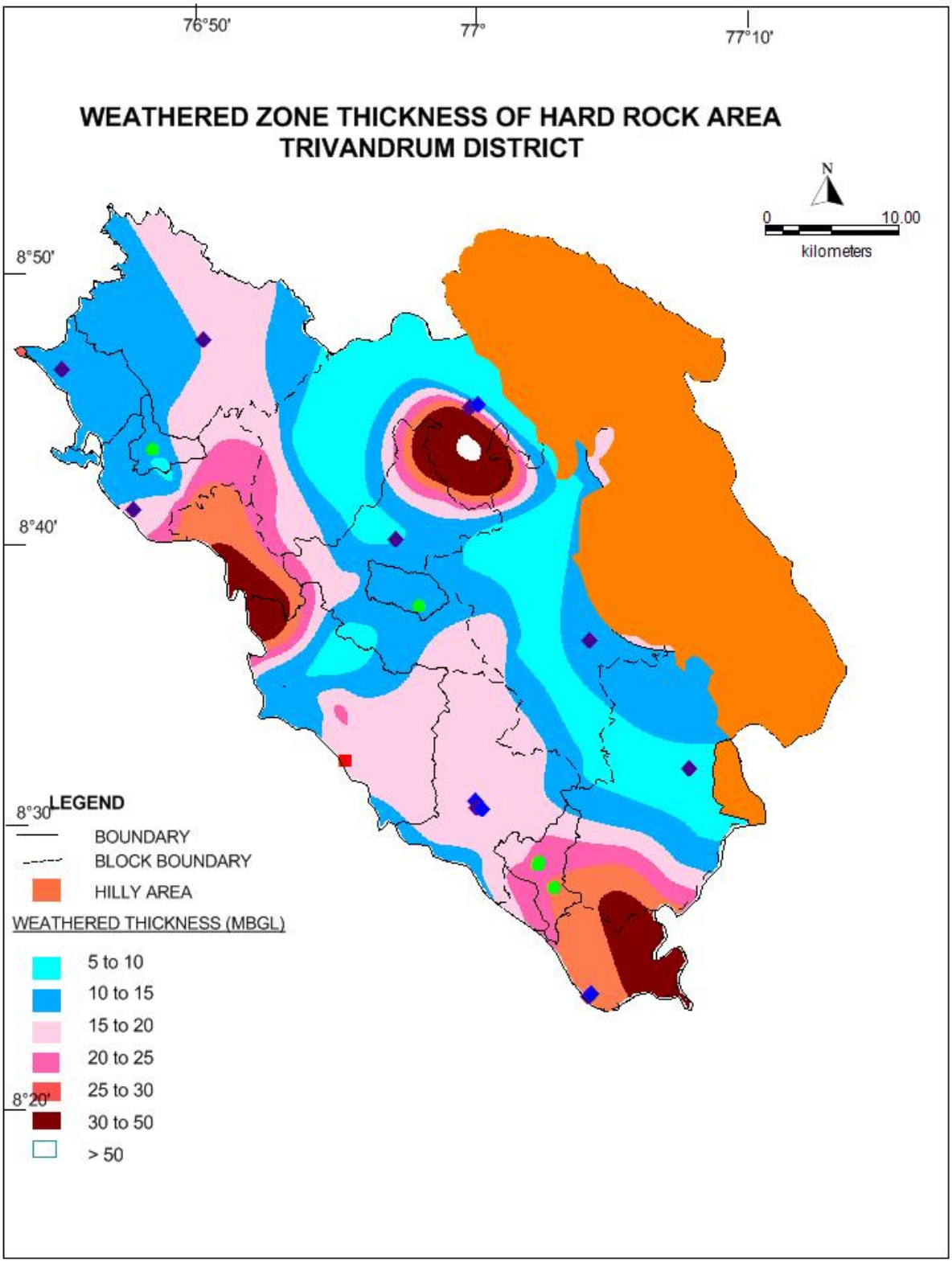


Fig3.1: Spatial variation of weathered zone thickness in the area

3.1.2. Water levels

Measurements of water levels in wells are necessary for the evaluation of the quantity of ground water and its interaction with surface water and rainfall. Water level is the fundamental indicator of the status of groundwater resource. The water levels were monitored four times (April, August, November and January) during the field season from 100 dug wells which include 26 newly established dug wells for this purpose and the remaining are regular monitoring wells (NHS) of CGWB. The water level data given in **Table 3.1.** April water level is considered as pre-monsoon and that of November is taken as post-monsoon for detailed analysis.

The water levels in the phreatic aquifer were analyzed for pre and post monsoon water levels and depth to water level maps were prepared (**Fig. 3.2 and 3.3**). Analysis of the pre- and post-monsoon water level map shows that major part of the Thiruvananthapuram districts shows water levels in the range of 5 to 10 m bgl. Deeper water levels (> 10 m bgl) are found as patches. But the area having deeper water level (> 10 m bgl) has slightly increased in the post monsoon particularly in the southern part of the study area during 2016. The deepening of the water level during post monsoon period mainly indicate the deficiency of rainfall in Thiruvananthapuram district in the analysed year especially in the southern part.

Water level fluctuations in the wells in an area between two periods is indicative of the net changes in the ground water storage during the period in response to the recharge and discharge components and is an important parameter for planning sustainable ground water development. About 54% of the wells analysed in the area shows fall in water level and in majority of the area water level fall is in within 2 m. The study area shows a fall in water level from 4 to 0.01 m bgl and rise in water level from 0.08 to 4.41 m bgl, the fluctuation map is given in **Fig.3.4.** The water table elevation contour map (Fig **3.5**) shows that the general flow of ground water is towards the west. Map showing saturated thickness of phreatic aquifer during pre and post monsoon period is also given in **fig 3.6 and 3.7** respectively.

Table3.1: Water level data from the Phreatic aquifers

#	Location	Depth to Water level in mbgl			
		16-Apr	16-Nov	17-Apr	17-Nov
1	Amboori	9.41	9.08	10.51	5.6
2	Anappara	8.91	5.36	10.84	4.98
3	Aralumoodu	11.17	11.05	13.01	16.58
4	Ariyanadu	5.1	5.49	5.39	-
5	Arukannukuzhi	-	4.02	5.33	5.83
6	Aruvikara	3.64	3.92	4.96	1.73
7	Athazhamangalam	16.88		21.1	20.35
8	Attingal	11.59	11.57	12.58	8.25
9	Attukal	6.63	6.93	dry	4.83
10	Ayyankode	8.24	9.6	9.34	8.11
11	Balaramapuram	9.87	9.96	13.42	7.83
12	Bharathanoor	9.22	8.6	9.73	5.72
13	Bounder mukku	7.66	7.2	9.6	5.11
14	Changa	10.46	10.32	11.76	6.68
15	Chaykottukonam	7.16	7.98	9.04	6.35
16	Cheeranikara	8.53	9.44	10.54	6.63
17	Chembur	11.68	10.99	13.62	6.74
18	Chennampara	9.87	8.37	dry	6.85
19	Cheriyakonni	8	8.67	11.11	6.82
20	Cherunniyur	15.3	15	16.2	14
21	Chettachal	2.5	2.42	3.94	1.98
22	Chullimanoor	6.75	6.26	7.48	4.8
23	Ithye	8.53	7.72	10.55	6.64
24	Kallar	5	3.88	4.87	-
25	Kallikkad	-	1.25	1.99	0.1
26	Kandala	-	13.95	12.4	7.35
27	Kannanoor	14.46	18.12	17.1	-

28	Karakulam	3.53	2.9	4.89	2.07
29	Kariavattom	3.58	2.69	2.72	1.3
30	Karinga	2.33	2.63	2.81	2.15
31	Karipur	8.44	9.05	11.53	5.7
32	Kattakkada	5.55	4.02	3.92	2.61
33	Kaypadi	6.7	7.9	8.68	6.1
34	Kilimannor	6.4	7.46	-	5.23
35	Kollankonam	10.51	11.02	12.3	9.62
36	Korani	7.69	8.52	-	7.12
37	Kowdiar	9.95	9.82	11.02	6.7
38	Kulathur	10.14		12.28	7.22
39	Madavoor	13.57	11.45	14.59	8.91
40	Malayadi	-		8.48	3.99
41	Mangalapuram	20.72	22.15	-	18.32
42	Mannanthala	8.67	8.03	8.14	4.6
43	Mannaram	6.98	5.65	8.34	3.97
44	Maruthamala	7.95	7.18	8.35	5.95
45	Meenangal	10.55	9.28	Dry	6.45
46	Melvettoor	34.68	-	38	35.05
47	Muduvila	6.73	9.73	9.24	5.99
48	Mundela	10	10.31	13.41	6.1
49	Muzhi	3.29	3.3	dry	2.91
50	Nanniyode	5.33	5.47	6	6.12
51	Naruvamoodu	9.75	10.78	12.13	9.5
52	Navaikulam	13.16	12.6	16.34	9.01
53	Nedumangad	9.33	8.91	11.23	7.25
54	Neyyar dam	2.25	2.59	4.27	2.37
55	Neyyattinkara	13.45	14.22	14.22	12.56
56	Ookod	9.9	11.44	11.9	10.3
57	Ottashekharamangalam	4.18	3.28	4.79	3.8
58	Palode	7.92	3.78	7.61	3.22

59	Pangode	7.39	5.89	8.07	4.3
60	Parandakuzhi	11.35	16.08	17.67	1.9
61	Parandode	5.83		6.5	3.8
62	Parassala	1.48	1.02	2.47	0.34
63	Paruthipalli	2.43	2.51	4.28	1.9
64	Pazhya chantha	5	5.06	5.61	3.28
65	Peringamala	-	7.9	-	7.31
66	Perumgulam	7.37	7.7	8.04	6.62
67	Perumgur(R1)	4.32	4.81	5.13	1.53
68	Perunkadavila	8.49	9.4	14.77	12.47
69	Pirappankod	7.8	8.41	8.53	5.27
70	Ponganadu	5.9	6.56	7.3	3.53
71	Ponmudi(R1)	-	3.85	4.51	-
72	Poojapura	8.11	13.79	13.7	4.25
73	Poovachal	12.86	13.09	14.57	11.35
74	Pothencod	10.49	11.24	12.66	8.92
75	Pudukulangara	6	6	8.56	4.64
76	sasthanthala	5.27	6.87	6.74	2.57
77	Sasthavattom	5.1	4.55	6.99	1.92
78	Shankaramugham	5.78	5.92	7.5	5.18
79	Statue	9.25	9.88	10.03	7.45
80	Tekkada	3.96	3.71	3.88	2.91
81	Tennoor	6.63	5.74	8.9	4.91
82	Thalikuzhy	13.05	13.9	16.71	12.28
83	Tholicode	8.76	7.79	dry	5.52
84	Thiruvananthapuram	13.27	12.55	11.4	11.97
85	Udyankulangara	9.9	10.53	12.76	10.37
86	Uriyakode	6.48	6.54	8.65	4.31
87	Uzhamalakkal	5.74	6.24	7.76	2.52
88	Valakkad	12.18	12.61	15.38	11.36
89	Vamanapuram	7.6	3.68	6.62	1.56

90	Vattapara	8.96	9.89	10.85	8.65
91	Vattavila	8.48	4.77	10.9	7.72
92	Vattiyoorkavu	8.29	9.22	9.97	7.78
93	Vazhichal	6.15	6.46	8.75	4.98
94	Veeranakavu	4.34	4.2	4.95	3.93
95	Vellaikadavu	8.15	12.32	8.53	4.53
96	Vellanad	6.19	6.06	7.7	4.98
97	Vellarada(R1)	4.74	4.86	6.07	4.3
98	Vengod	7.47	7.2	8.96	7.23
99	Venjaramoodu	10.27	8	11.08	7.67
100	Vilapilshala	8.7	9.17	10.97	7.03
101	Vithura	10.55	11.13	14.01	10.58

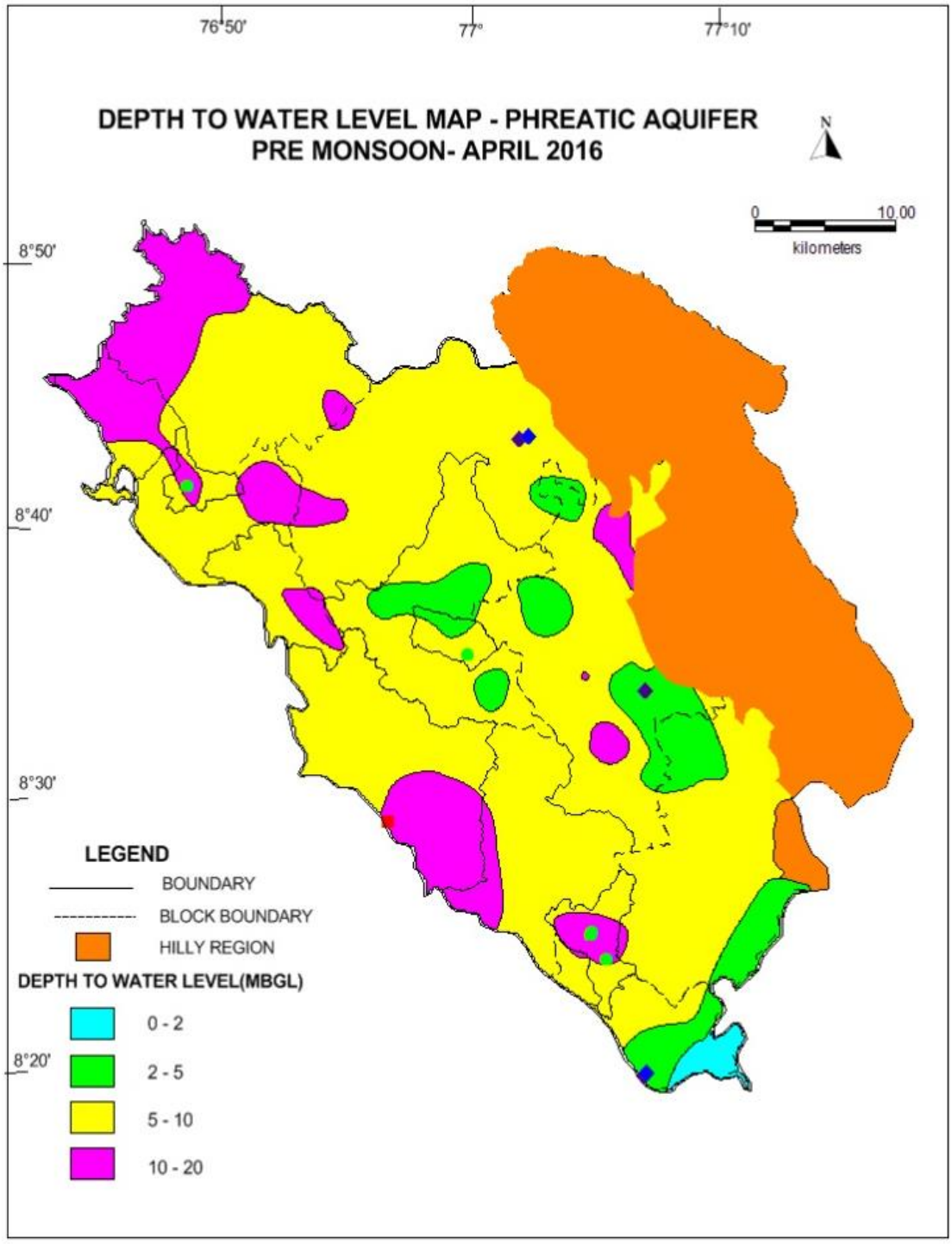


Fig.3.2:Pre-monsoon Water level map of Phreatic aquifer

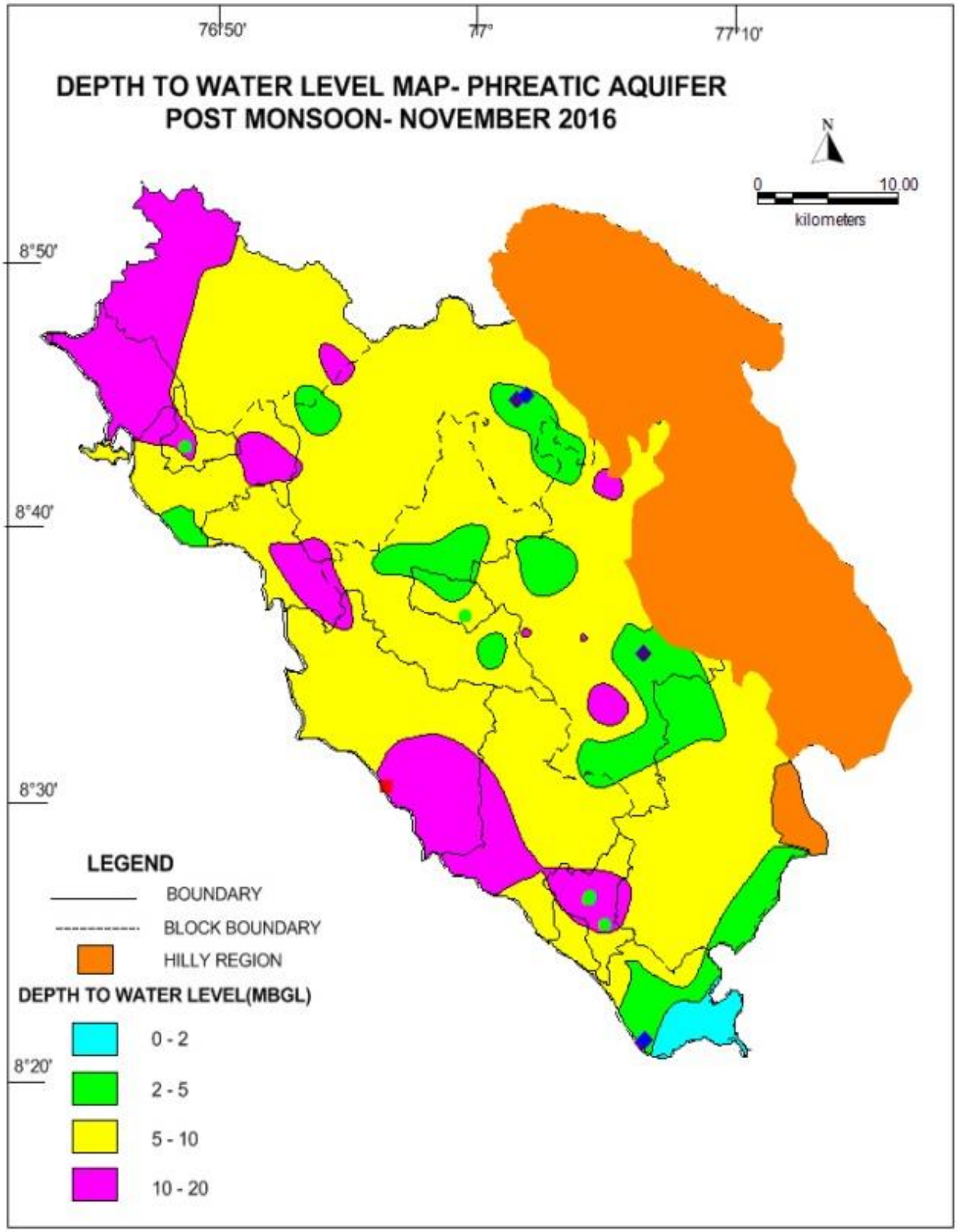


Fig.3.3: Post Monsoon Water level map of Phreatic aquifer

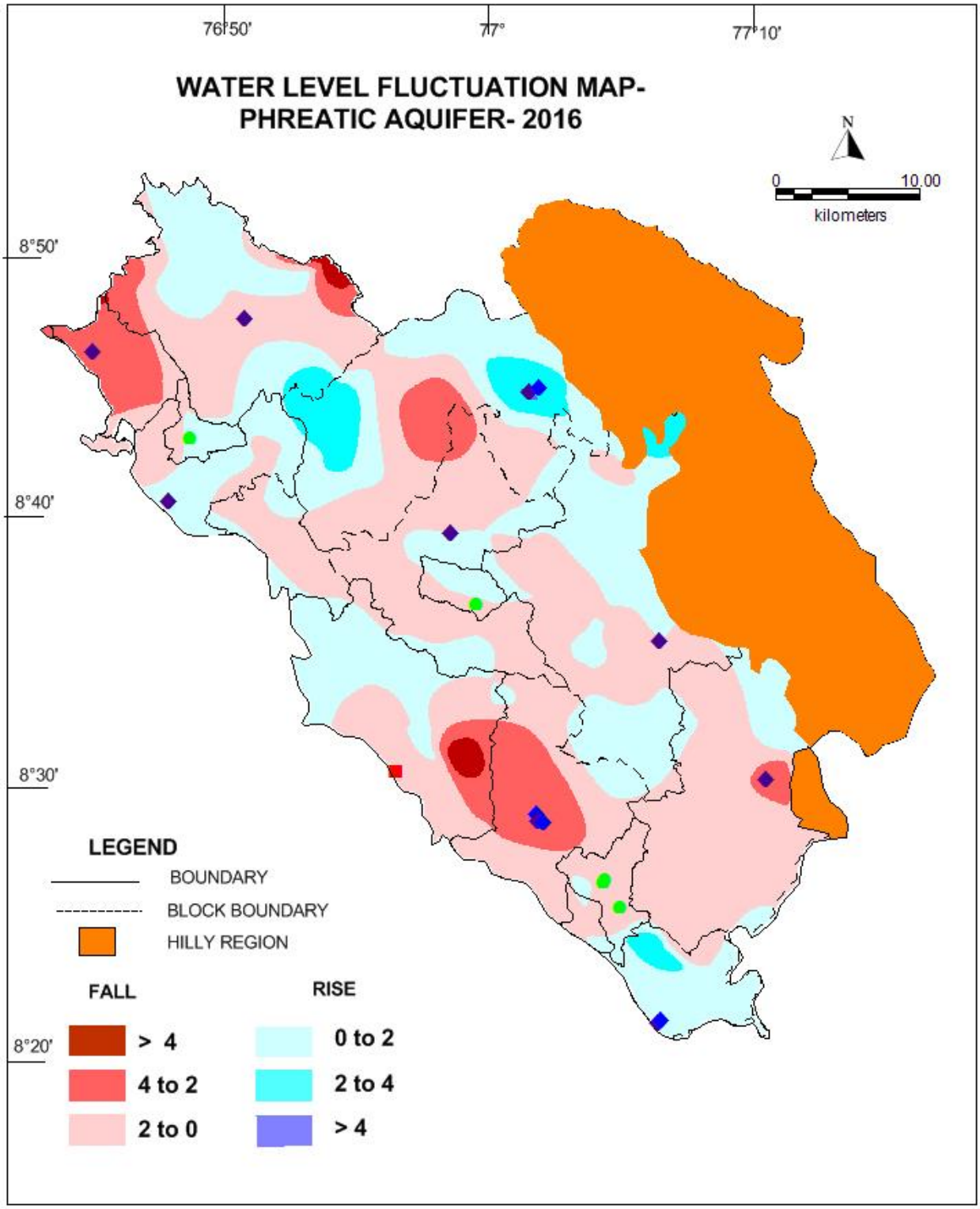


Fig.3.4: Water level Fluctuation map of Phreatic aquifer

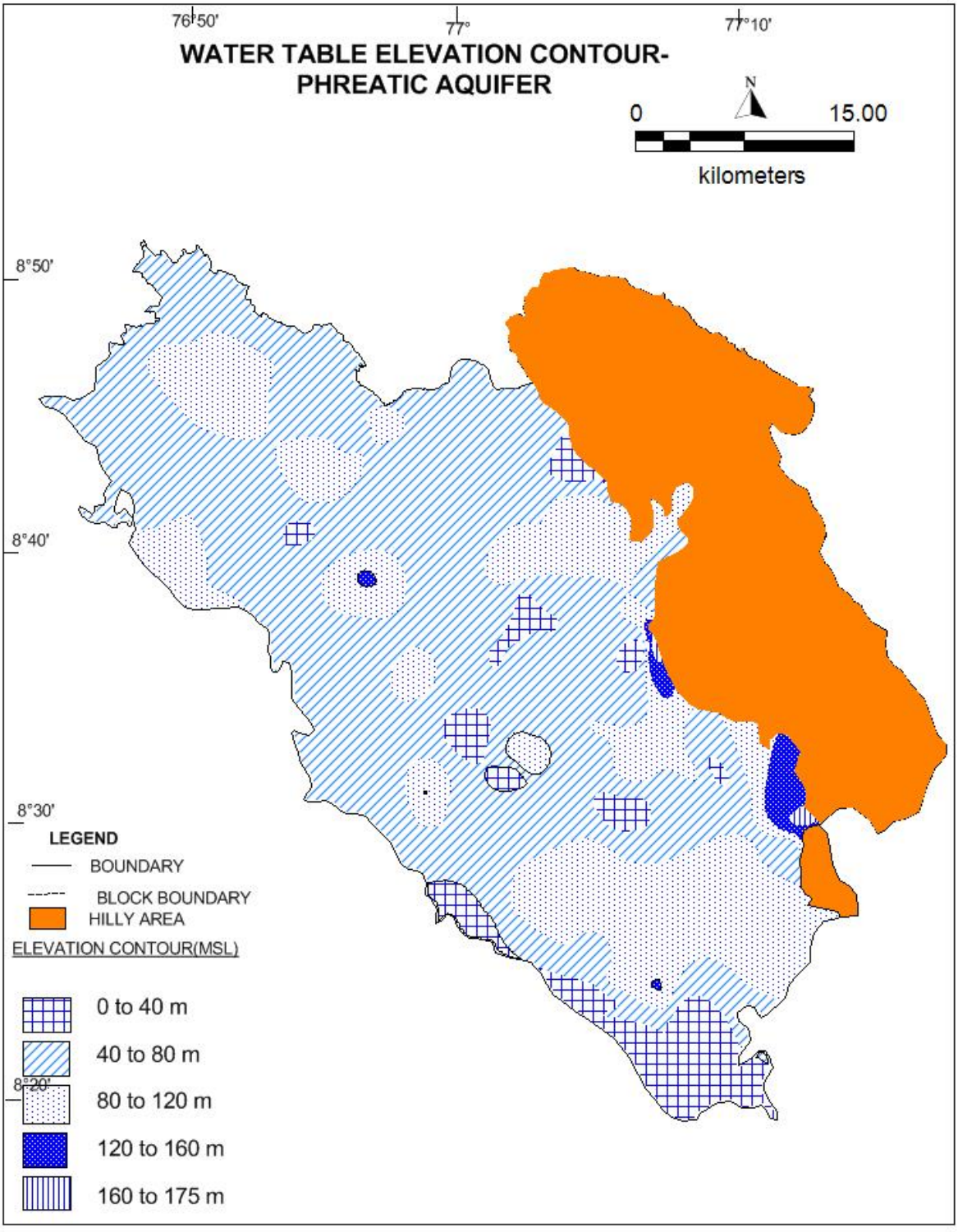


Fig.3.5 Water table elevation contour map of Phreatic aquifer.

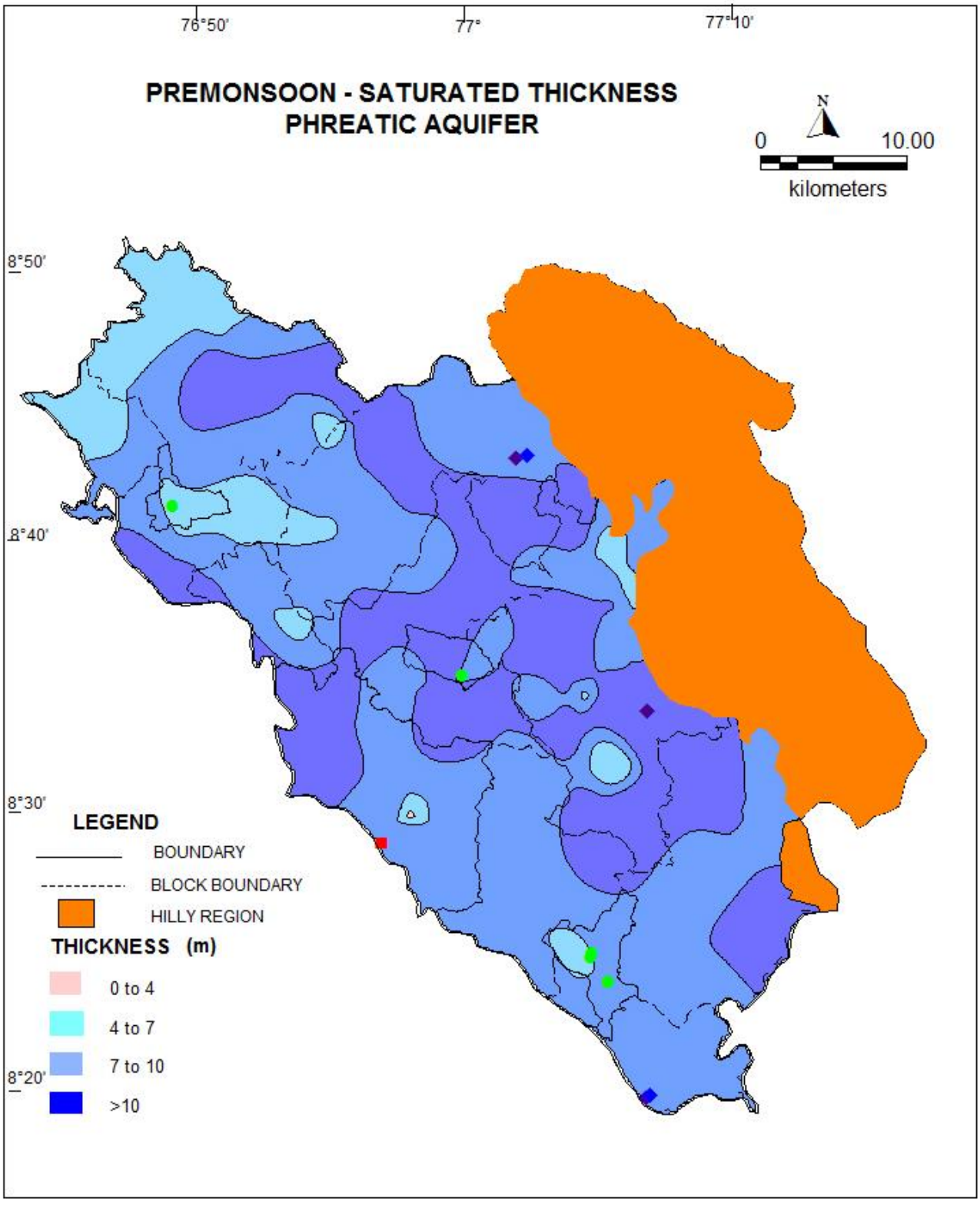


Fig.3.6 Pre- Monsoon Saturated thickness of Phreatic aquifer

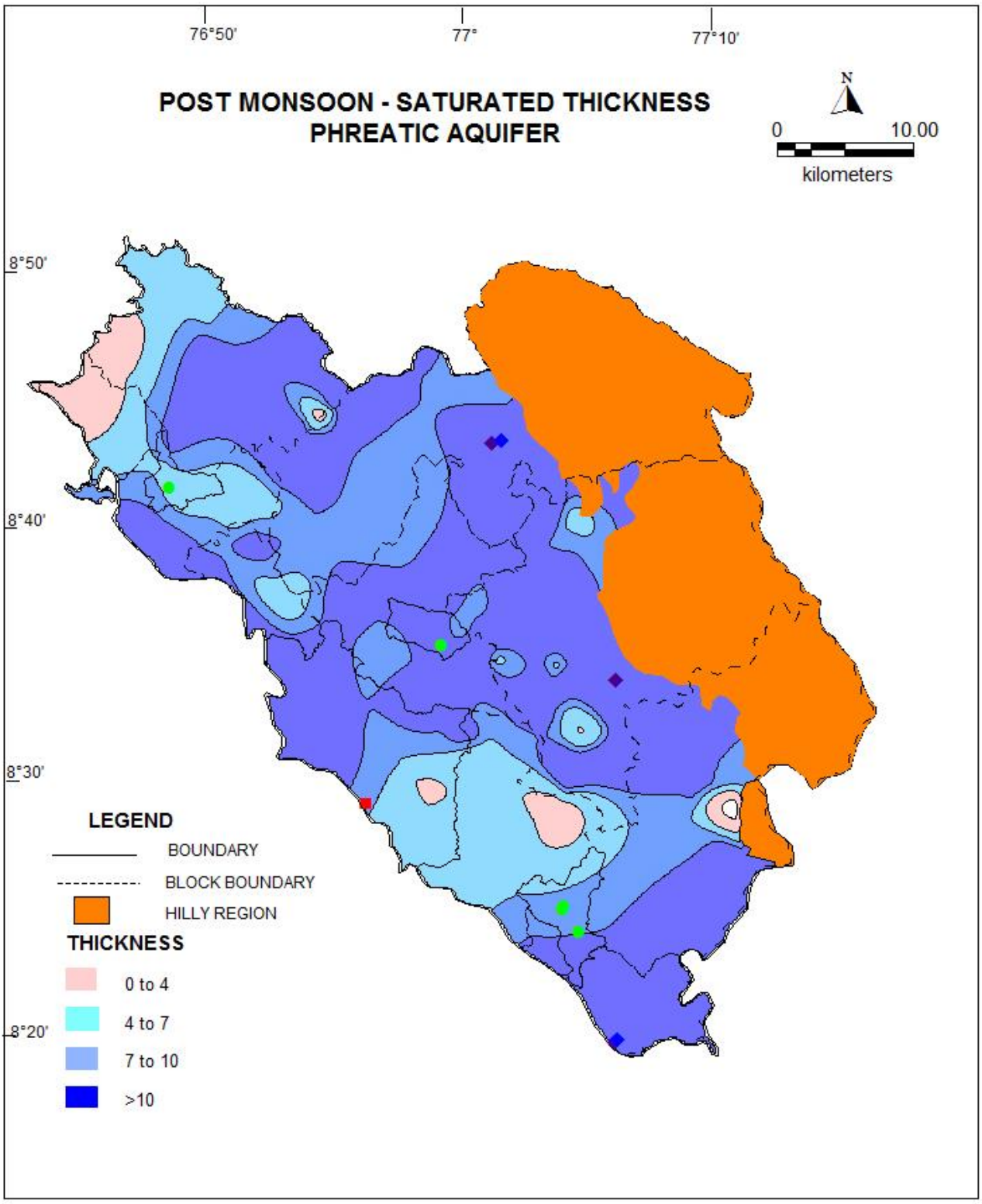


Fig.3.7: Post- Monsoon Saturated thickness of Phreatic aquifer

3.1.3. Water level trend

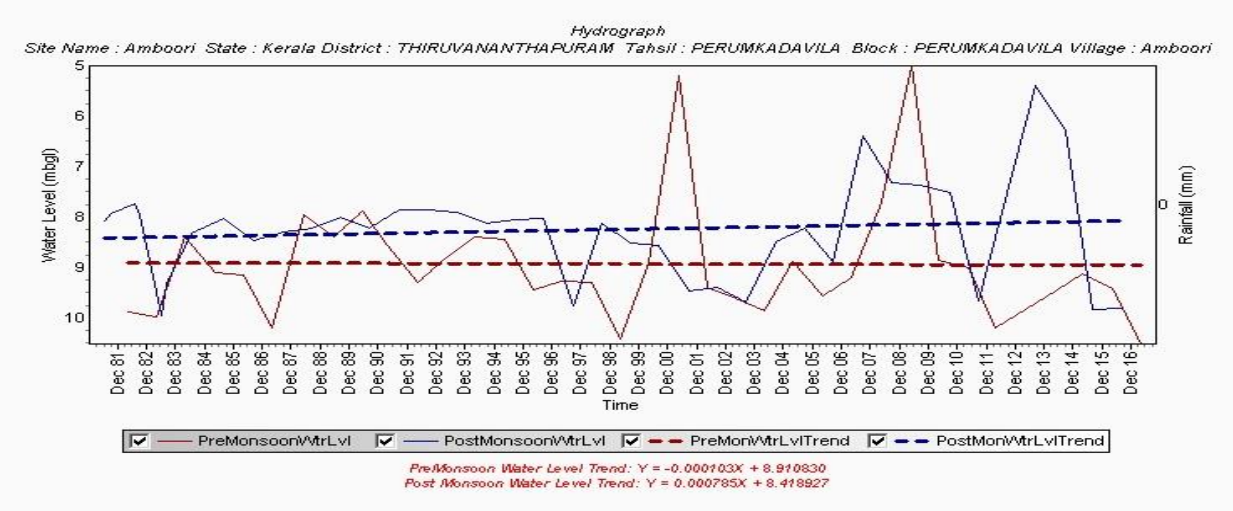
The variation in water level with reference to time and space is the net result of groundwater development and recharge. The long-term change in water level is discernible from the trend of water levels over a period of time and is best reflected in a hydrograph.

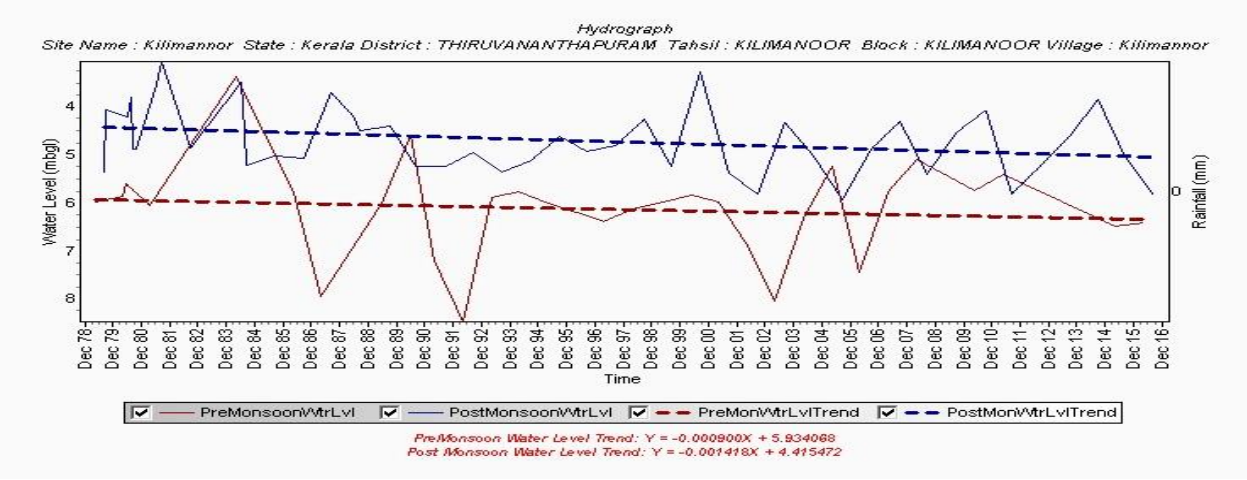
The Decadal trend (2007-2016)of ground water levels, for pre- monsoon and post monsoon periods is given below in table **3.2**. Analysis of decadal trend shows that during premonsoon 31% of the analysed wells shows rise and 68 % of the wells shows fall and during post monsoon period 43% of the wells shows rise and 56% shows fall. The hydrographs of some wells are given in Fig. 3.8

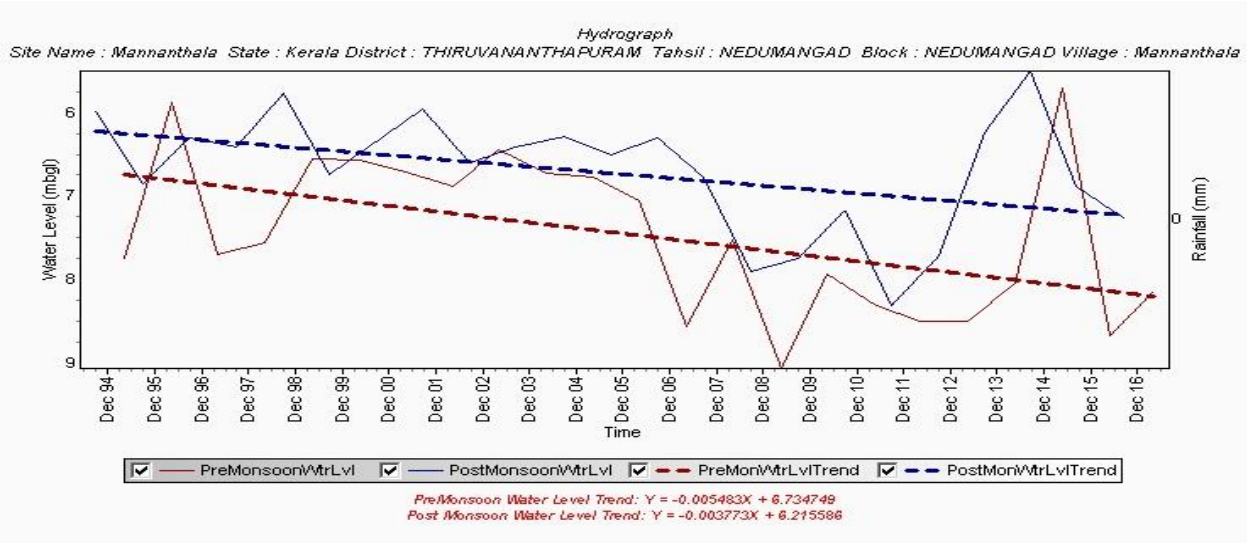
Table 3.2 Table Showing trend of the water level

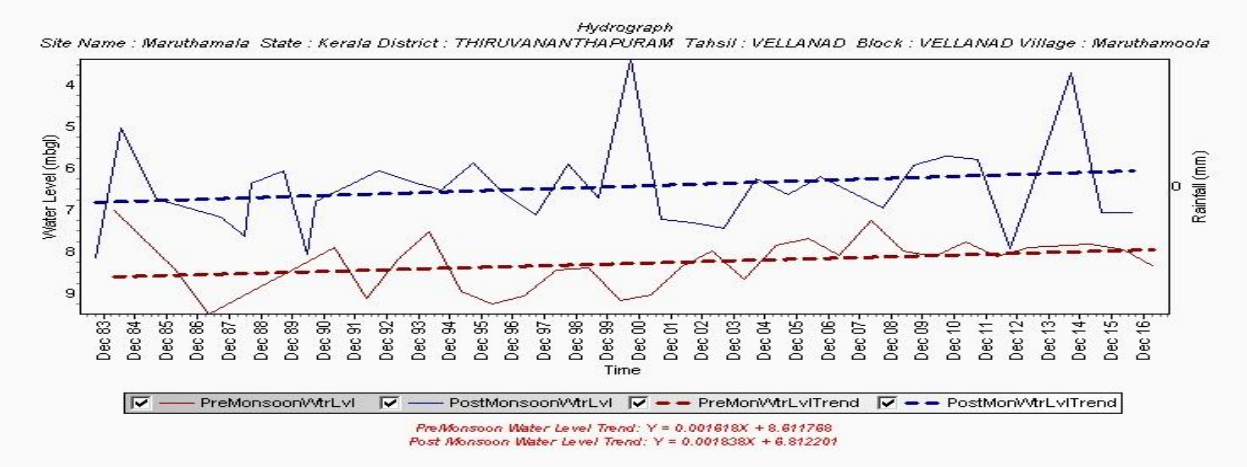
#	Location	Pre _monsoon Trend(m/year)	Post monsoon Trend (m/year)
1	Ariyanadu Pz	0.005	0.117
2	Aruvikara	-0.339	0.032
3	Attingal	-0.452	-0.230
4	Attingal Pz	-0.135	-0.080
5	Chengal Pz	-0.685	-0.540
6	Kallambalam(R1)	-0.098	0.130
7	Kallar	-0.080	-0.020
8	Kallikkad	0.029	-0.150
9	Kattakkada	-0.136	-0.012
10	Kilimannor	-0.118	-0.060
11	Korani	-0.067	-0.050
12	Kulathoor pz	-0.126	-0.010
13	Madavur	-0.052	0.016
14	Mannanthala	0.090	0.102
15	Mannanthala Pz	0.161	0.189
16	Maruthamala	-0.122	-0.011
17	Nedumangad	-0.081	0.065
18	Nemom	-0.421	-0.470

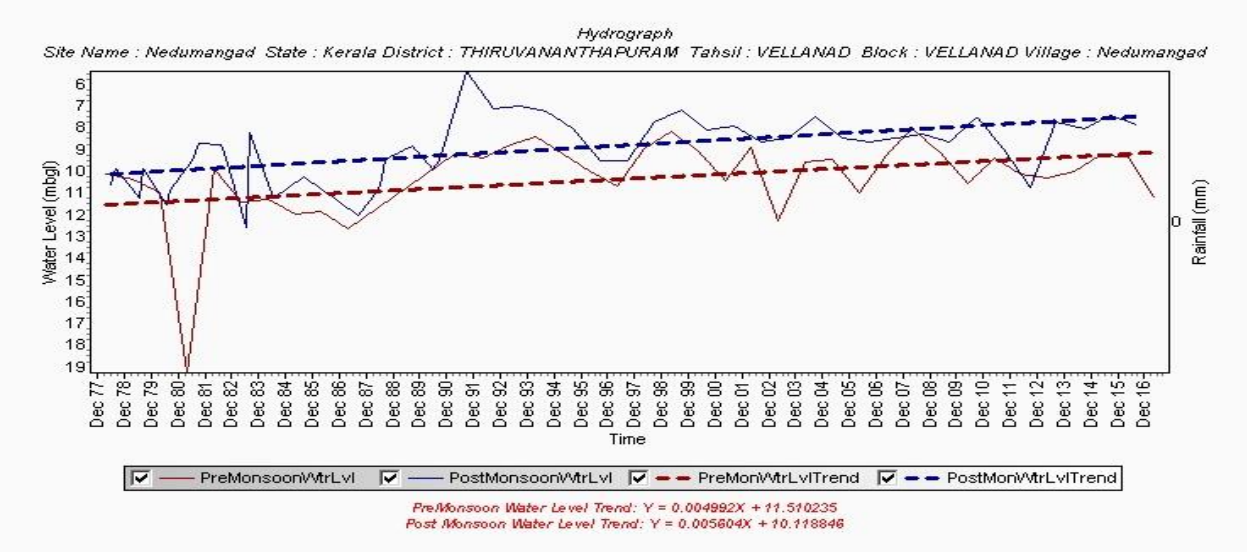
19	Neyyattinkara	0.115	0.040
20	Palode	-0.064	-0.004
21	Panavoor	0.018	0.059
22	Pangode	-0.111	-0.026
23	Parassala	0.052	-0.005
24	Parassala pz	-0.171	0.083
25	Pattom Pz	0.312	0.289
26	Peringamala Pz	-0.095	-0.204
27	Perumgur(R1)	0.310	0.232
28	Perunkadavila	0.164	0.359
29	Pirappankod	-0.013	0.057
30	Ponganadu Pz	-0.046	-0.124
31	Ponmudi(R1)	-0.054	-0.080
32	Pothencod	-0.186	-0.012
33	Thiruvananthapuram	-0.223	-0.273
34	Udayankulangara Pz	-0.295	0.133
35	Vamanapuram	-0.368	-0.026
36	Vazhakkad Pz	0.034	-0.043
37	Vellanad	-0.053	-0.069
38	Vellarada(R1)	0.007	-0.036
39	Vengod Pz	0.145	0.059
40	Vilappilsala Pz	-0.096	0.152
41	Vithura	-0.155	0.046


Hydrograph
Site Name : Amboori State : Kerala District : THIRUVANANTHAPURAM Tahsil : PERUMKADAVILA Block : PERUMKADAVILA Village : Amboori
Water Level (mbgl)
Raintall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.000103X + 8.910830
Post Monsoon Water Level Trend: Y = 0.000785X + 8.418927


Hydrograph
Site Name : Kilimannor State : Kerala District : THIRUVANANTHAPURAM Tahsil : KILIMANOOR Block : KILIMANOOR Village : Kilimannor
Water Level (mbgl)
Raintall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.000900X + 5.934068
Post Monsoon Water Level Trend: Y = -0.001418X + 4.415472


Hydrograph
Site Name : Mannanthala State : Kerala District : THIRUVANANTHAPURAM Tahsil : NEDUMANGAD Block : NEDUMANGAD Village : Mannanthala
Water Level (mbgl)
Raintall (mm)
Time
PreMonsoonWtrLvl
PostMonsoonWtrLvl
PreMonWtrLvlTrend
PostMonWtrLvlTrend
PreMonsoon Water Level Trend: Y = -0.005483X + 6.734749
Post Monsoon Water Level Trend: Y = -0.003773X + 6.215586





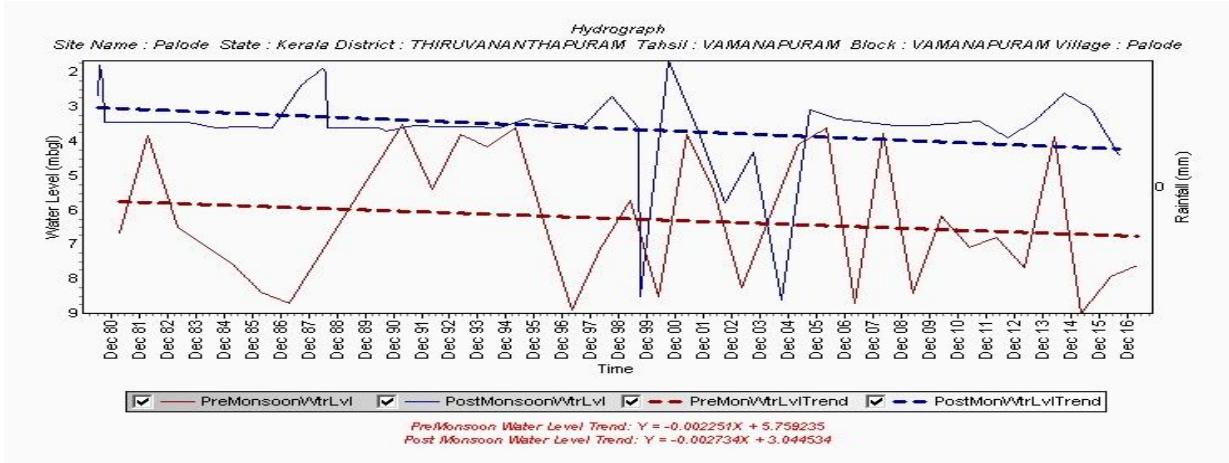


Fig.3.8: Hydrographs of some wells

3.1.4. Quality of water in the weathered zone

In a groundwater flow regime water chemistry constantly undergoes modification due to various processes such as dissolution of minerals, precipitation of dissolved ions under unstable conditions, cation exchange etc. The chemical composition of subsurface water is controlled by various factors such as the amount of dissolved CO_2 in rain water and soil, the composition of the rocks through which the water percolates and the duration of contact between the water and the soil/rock. Further there is a direct relationship between hydraulic conductivity of aquifers and TDS of groundwater. Thus, with the decrease in hydraulic conductivity there is general increase in chemical concentration of various ions in groundwater.

The hydrochemical evolution along the flow paths are significantly altered under anthropogenic interferences and consequent pollution of aquifer systems (Drever, 1982; Langmuir, 1997; Abu-Jabeer, 2001; Singh et al, 2007). The effects of pollution in the flow system can easily be identified from a comparison of dissolved ions and ion ratio studies in simple terms (Hem, 1985).

The existing water quality data from 17 dug wells for the month of April (Table 3.4) have been analyzed for extracting information on regional distribution of water quality and their suitability for various uses. The groundwater quality in the area is generally good for all purposes. In all the locations PH is within the acceptable limit and shows slightly acidic trend. The electrical conductivity (in µS/cm at 25^{o} C) of ground water in phreatic zone is in the range of 74 to 410 and Chloride in the range of 11-82 mg/l. Fluoride content in the observation wells monitored is in the range of 0 to 0.38 mg/l in the study area. Nitrate above the permissible is noted in three locations. Ground Water department has found that about 70% of the wells of Thiruvananthapuram are contaminated with coliform bacteria.

The CGWB has conducted micro level pollution study in and around the Vilappilshala waste disposal plant site (Now abandoned), Vilappilshala grama panchayath during 2001-2002. Ground water quality of both ground water and surface water was analysed during the study. All the chemical parameters (inorganic as well as heavy metal ions) are within the permissible limit as per Bureau of Indian drinking water standards whereas microbiologically both the surface and ground water samples are observed to be contaminated relative to Bureau of Indian drinking water standards.

The epm values of the samples were plotted in Hill- Piper diagram (**Fig. 3.9**). Majority of the samples falls in the field where chemical properties are dominated by alkalies and strong acids i.e. Na- Cl type water.

Gibbs (1970) found that the three mechanism - atmospheric precipitation, rock dominance and evaporation-crystallization process are the major factors controlling, the composition of **t**he dissolved salts of the world's water. Other second order factors, such as relief, vegetation and composition of material in the basin cause only minor deviations within the zones dominated by the three above prime factors. The diagram of Gibbs (1970) forms an excellent tool in understanding the chemical evolution of the surface water and groundwater hence the chemical analysis data of ground

water samples collected from phreatic aquifers has been plotted on the Gibbs diagram - TDS *vs* (Na^++ K^+)/ (Na^++ K^+) +Ca^{2+} and TDS *vs* $Cl^-/Cl^-+HCO_3^-$ and is shown in Fig. **3.10**. The samples fall in the rock dominance zone.

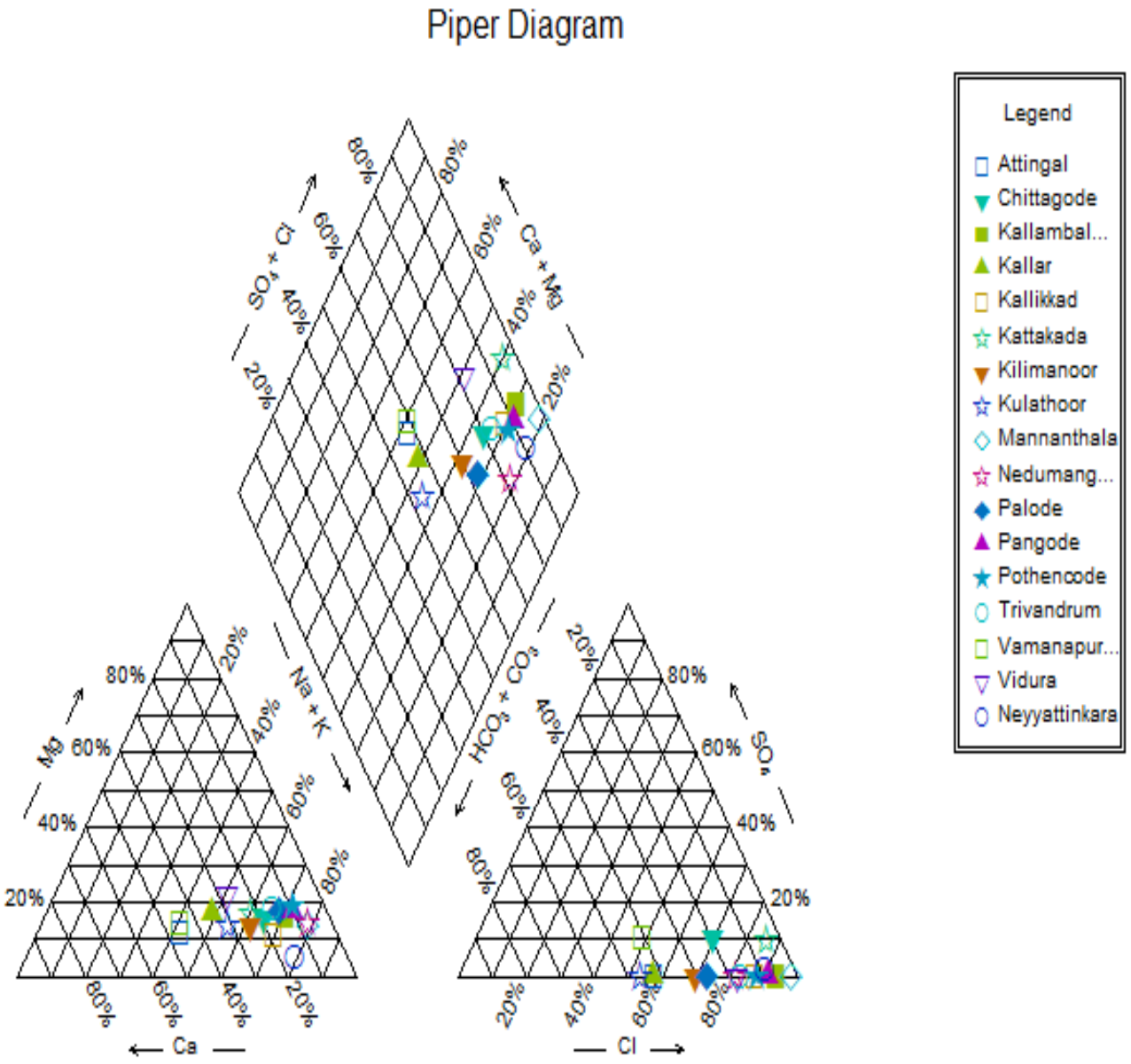
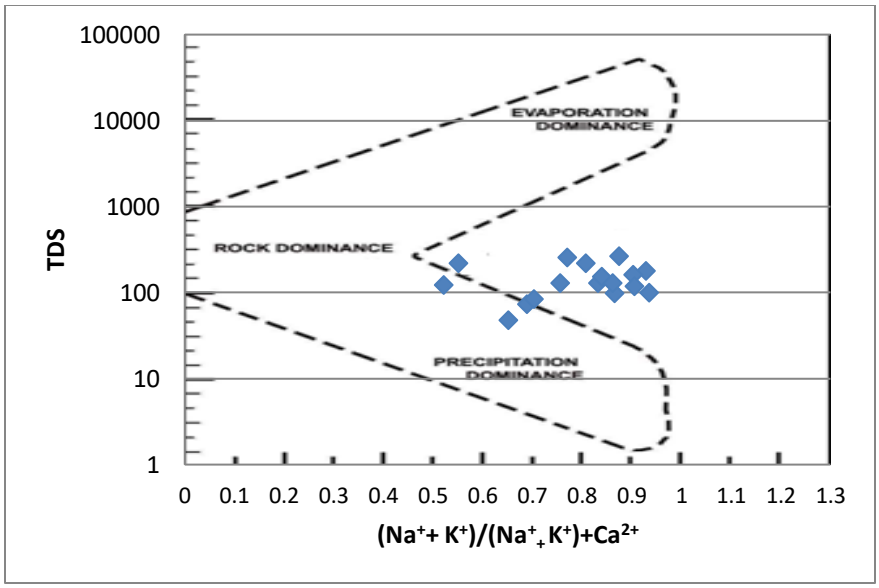


Fig.3.9: Piper Diagram of phreatic Aquifer



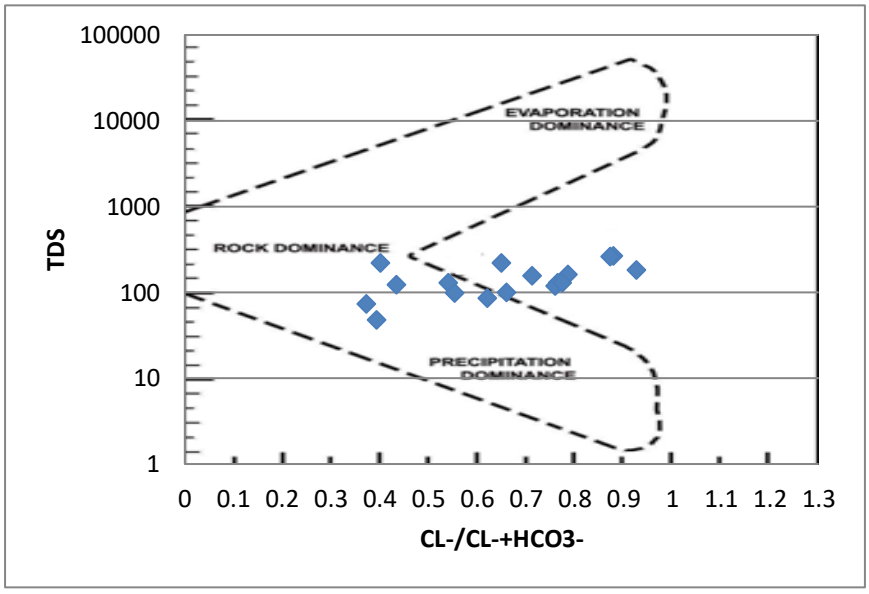


Fig.3.10: Gibbs Diagram of phreatic aquifer

Table 3.4: Chemical Quality of Samples from Phreatic Aqui

Location	pH	EC in	TH as $CaCO_3$	Ca	Mg	Na		K	CO_3	HCO_3	SO_4	Cl	F	NO_3
Attingal	7.69	190	40	13	2	13		1.2	0	34	0	26	0.07	19
Chittagode	7.24	340	45	10	4.9	34		7.9	0	34	12	63	0.09	21
Kallambalam	7	410	45	8	6.1	42		14	0	9.8	0	71	0.24	78
Kallar	7	74	12	3.2	0.97	4.6		1.4	0	17	0	11	0.09	0.96
Kallikkad	6.89	200	22	5.6	2	18		9.9	0	12	0	39	0.02	18
Kattakada	6.45	400	60	14	6.1	36		11	0	12	12	82	0.23	78
Kilimanoor	7.17	200	28	7.2	2.4	20		2.3	0	29	0	34	0.14	18
Kulathur	7.21	114	20	5.6	1.5	10		2.4	0	27	0	16	0.2	2.7
Mannanthala	6.07	280	22	3.2	3.4	34		7.6	0	4.9	0	61	0.26	40
Nedumangad	6.83	154	12	1.6	2	18		5.2	0	17	0	33	0.15	6.8
Palode	6.89	152	18	3.2	2.4	15		5.7	0	17	traces	21	0.1	20
Pangode	6.53	250	28	4	4.4	30		7.2	0	12	0	44	0.16	55
Pothencode	6.78	183	18	2.4	2.9	19		3.9	0	9.8	0	31	0.38	36
Thiruvananthapuram	7.13	240	30	5.6	3.9	24		5.3	0	15	traces	37	0.3	37
Vamanapuram	7.57	340	85	26	4.9	21		11	0	85	16	57	0.17	11
Vidura	6.55	131	22	4.8	2.4	9.6		1.8	0	9.8	traces	16	0.06	30
Neyyattinkara	6.52	200	16	4.8	0.97	26		4	0	12	1	41	0	37

3.2 The fracture aquifer system

The subsurface geology was studied from the logs of borewells drilled by Central Ground Water Board. In hard rocks the lithology and lineament play an important role. The availability of water in these zones depend on presence of secondary porosity (interconnected fracture zones or lineaments). The information on weathered thickness and fracture zones from exploratory wells have been used for the preparation of various diagrams A total of 38 borewells have been drilled in the hard rock area of Thiruvananthapuram district, majority of them tapping fractured Khondalites and Garnetiferous gneisses except one well at Melattumuzhy which was drilled in Gabbro rock. The depth of the wells ranged from 48 to 200 mbgl. The borewells were located in NW, NNW and NE lineaments. The depth to fracture zones ranges from 9 m to 196 m bgl and the drill time discharge ranges from 0.2 to 20 lps. The water in the bore well occurs in confined or semi-confined system. The depth to fracture zones ranges from 9 m to 196 m bgl and the drill time discharge ranges from 0.2 to 17.5 lps. Khondalites have a smaller number of fractures and open joints and is more susceptible for weathering and produce clay minerals. Hence along shear zones and weathered surface more of clayey minerals are observed. However due to high zone of weathering Khondalites area forms better phreatic aquifer of limited potential. The fracture zones of Khondalite are not so good aquifers as they are filled with clay formed by the weathering of Khondalites. A lineament map of the area is given in Fig. 3.11

The weathered zone thicknesses of the area vary widely with high degree of weathering in some parts of the district like area around Nanniyode in Vamanapuram block, in Pothencode and Parassala blocks. The upper clayey layer which is prominent in the eastern part of the study area disappears towards west and is replaced by Laterite. The bore wells drilled in the Khondalite group of rocks in Thiruvananthapuram district are mostly low yielding. The Panel diagram prepared from the logs of bore wells drilled by CGWB showing the lateral and vertical variation of different stratigraphic units are depicted in fig. 3.12 and cross sections in fig. 3.13

A high yielding exploratory well (discharge 10 lps) drilled at Melattumuzhy in Thiruvananthapuram district is in the contact of gabbro dyke on NW-SE lineament. A borewell drilled at Nanniyode in Thiruvananthapuram district in a shear zone has an overburden (clayey formation) of 46 metres with exposed hard rocks on both side of the shear zone. The borewell drilled in Khondalite rock at Bharathannur in Thiruvananthapuram district encountered fractures at shallow depth (less than 15m) and deeper levels but yielded poor due to the presence of clay in the fracture. A 3D view of the area is shown in fig. 3.14.

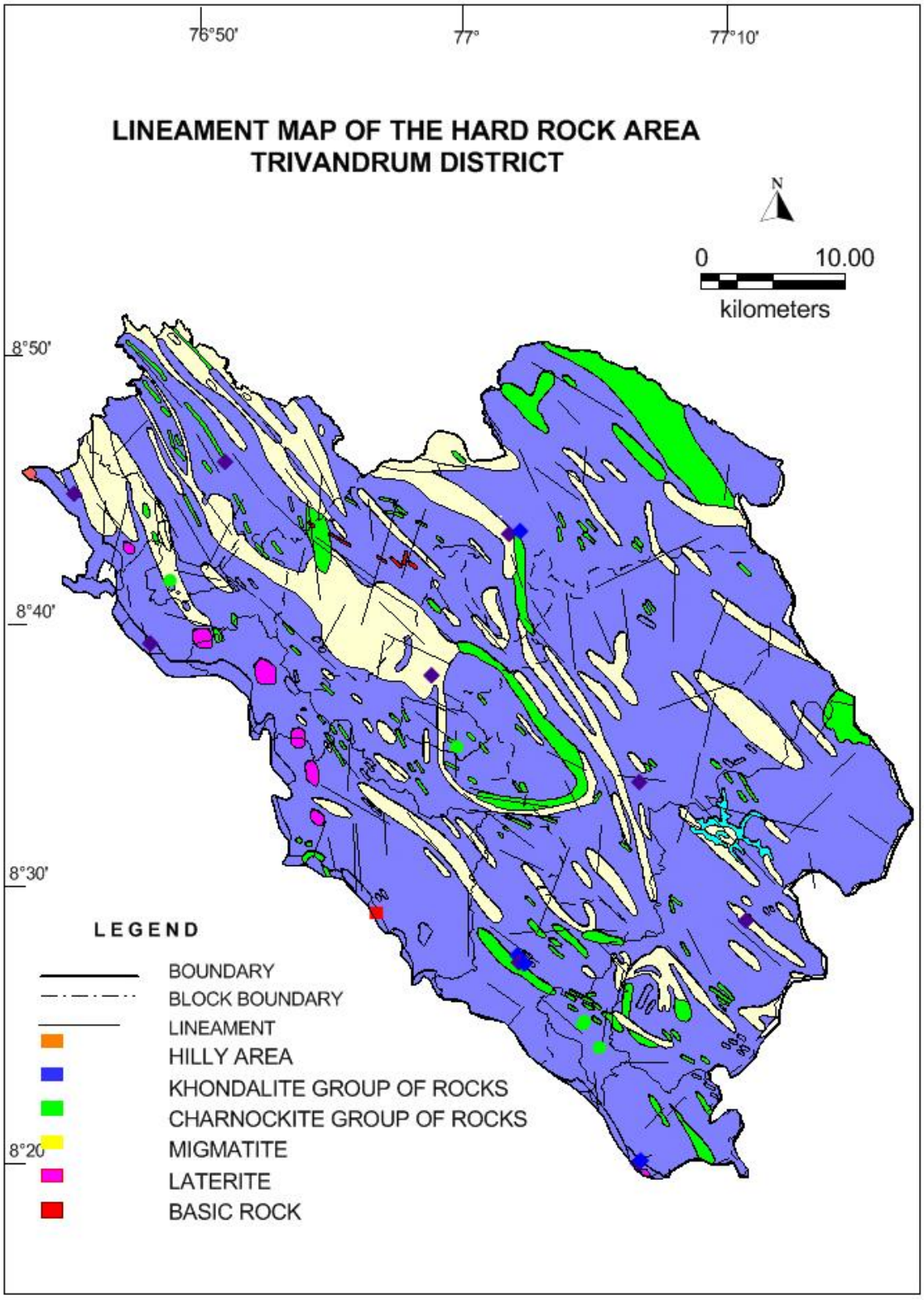


Fig.3.11: Lineament map of the area

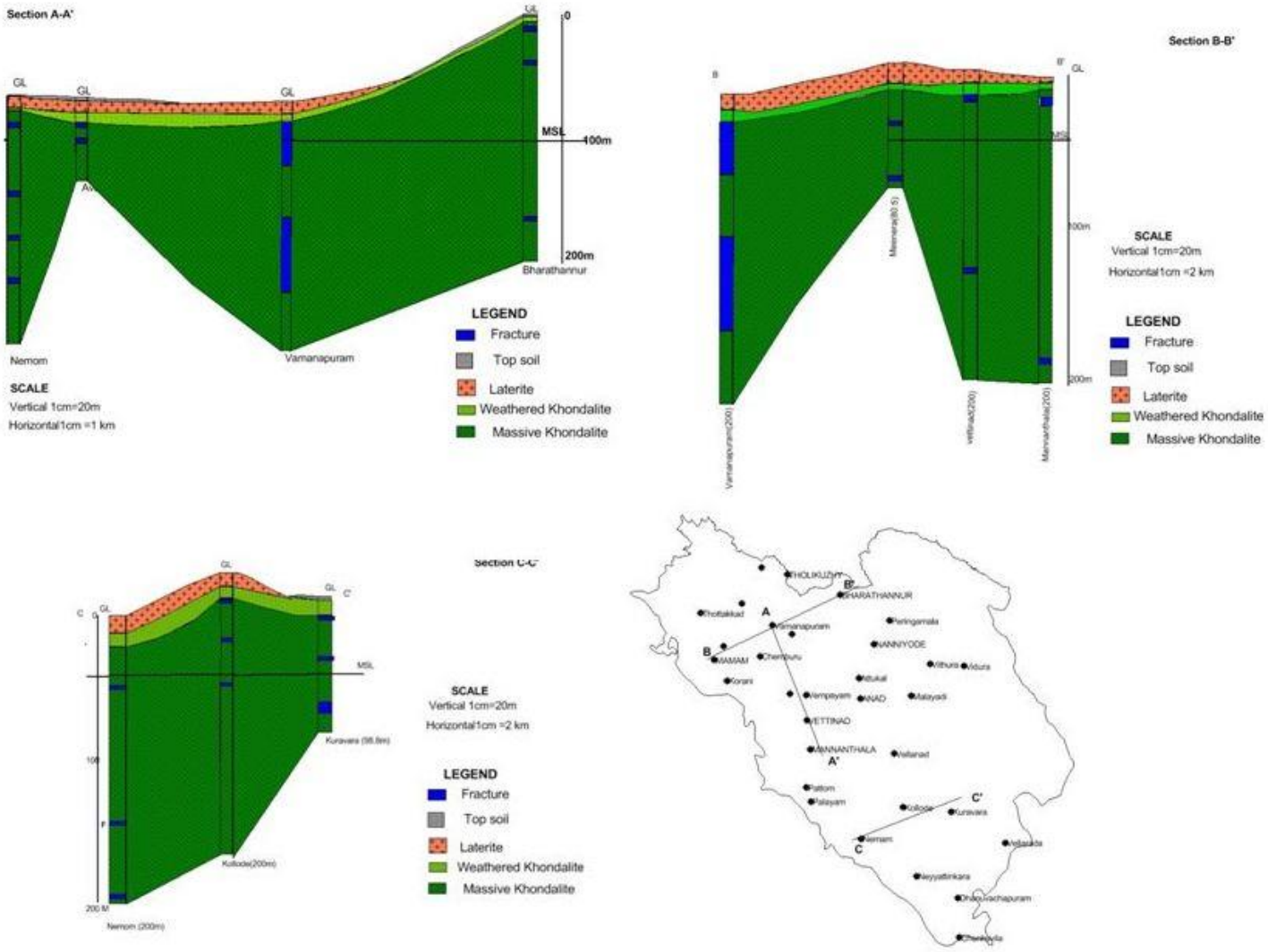


Fig.3.12: Cross section along AA', B-B' and C-C'

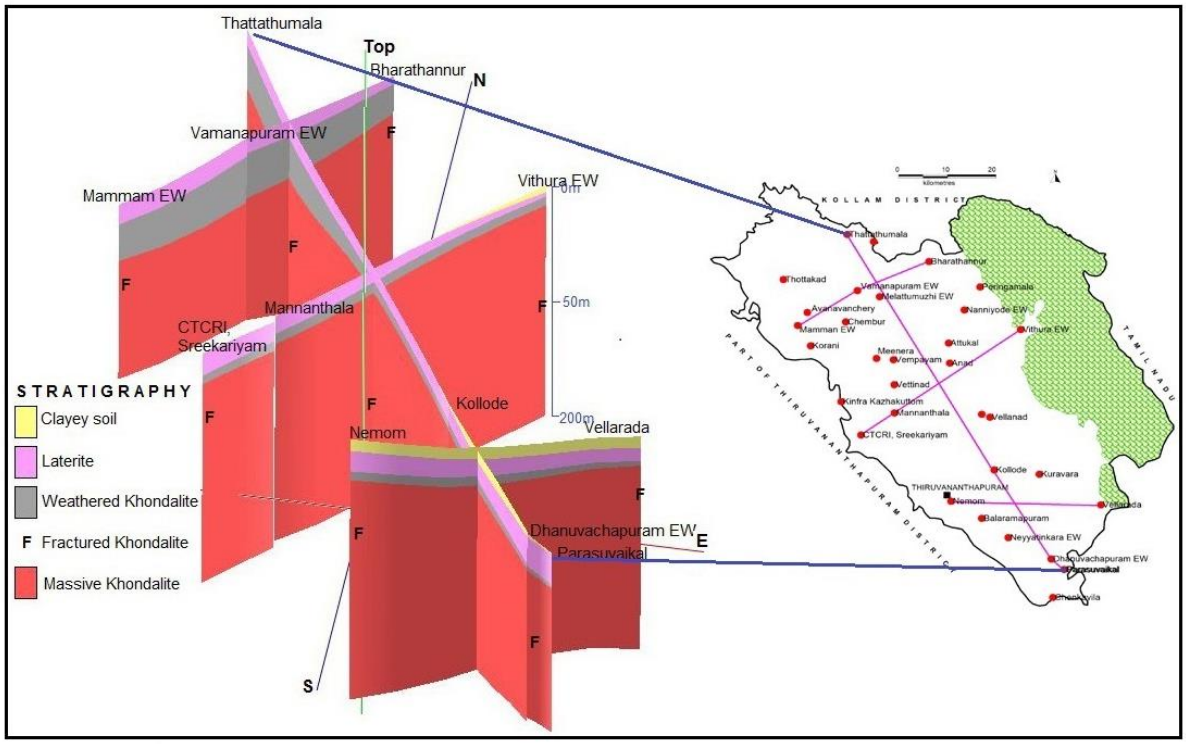


Fig.3.13: Panel Diagram

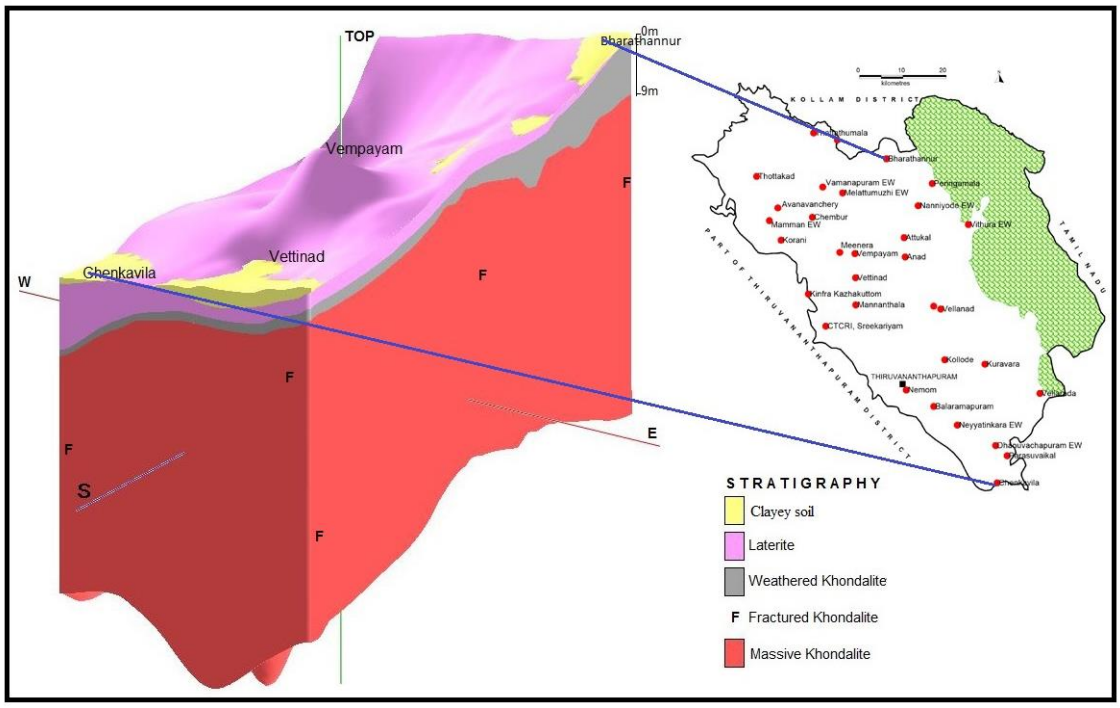


Fig.3.14: 3D view of the area

3.2.1 Geophysical investigations

The interpreted results of the VES indicated that the first layer resistivity varying in the range of 49-5227ohm.m. At about 59 VES the resistivity is in the range of 49-3194 ohm.m represents the top soil. Lower order of resistivity indicates clayey nature of soil. In the remaining four VES resistivity was varying in the range of 3743-5227 ohm. m indicating the Lateritic nature. The thickness of first layer is varying in the range of 0.26-5.54 m.

The second layer resistivity was varying in the range of 9-1686 ohm.m except at four VES where it was varying in the range of 2810-4160 ohm.m. The thickness of this layer was varying in the range of 0.92-24.4 m except at one VES where it was 36.6 m (at VES- 45). In this resistivity range the formation with resistivity upto 50 ohm.m was considered as Clay in nature and was recorded at 6 no. of VES. The resistivity of the second layer at these 6 VES was varying in the range of 9-46 ohm.m with thickness in the range of 0.71-4.7m. At 21 VES the resistivity was recorded as the range of 58-163 ohm.m with thickness of 1.6-10.35 m (except at three VES No's: 29, 36 & 45 where it was varying 18, 21.4 & 36 m respectively) may be of weathered nature. At the remaining 36 VES the resistivity of the second layer is varying in the range of 256-4165 ohm.m. The higher order of this resistivity indicates compactness of lateritic material. The thickness of this formation is varying in the range of 1-24 m.

The third layer resistivity was varying in the range of 4-1812 ohm.m except at two VES the resistivity was around 2450 ohm.m (at VES - 14) and 3520 ohm.m (at VES -18) respectively. The thickness of this layer was varying in the range of 1.47-41 m except at two VES the thickness was recorded as around 58m (at VES - 35) and 55 m (at VES – 51) respectively. In this resistivity range the formation with resistivity up to 40 ohm.m was considered as Clay in nature and was recorded at 14 no. of VES. The resistivity of the third layer at these 14 VES was varying in the range of 4-43 ohm.m with thickness in the range of 4.59-14.56m. Except at four VES the thickness was varying in the range of 22-41 m. At 22 VES the resistivity was recorded as the range of 50-190 ohm.m with thickness of 1.5-36 m (except at two VES No's: 35 & 51 where it was varying 58 & 55 m respectively) was considered as weathered in nature. At the remaining 27 VES the resistivity of the third layer is varying in the range of 200-3520 ohm.m. The higher order of this resistivity indicates compactness of lateritic material. The thickness of this formation is varying in the range of 4-37 m. The third layer was extending in nature at three VES (VES- 1, 41 and 45).

The interpreted results have given rise to fourth layer at about 60 VES only. Out of this 60 VES at about 5 VES the fourth layer was recorded as massive formation (resistivity was recorded as VH). At about 28 VES the fourth layer was extending in nature with resistivity range of 53 ohm.m to very high (VH). At the remaining 27 VES the resistivity of the fourth layer was varying in the range of 12-2961 ohm.m with thickness in the range of 2.3-106.6 m.

The interpreted results have given rise to fifth layer at about 32 VES only. Out of this 32 VES at about 19 VES the fifth layer was extending in nature. At the remaining 13 VES the resistivity was varying in the range of 17-837 ohm.m with thickness in the range of 8.4-43.7 m. The Interpreted Geophysical (VES) data is given in **Table3. 5**

Table 3.5: Interpreted Geophysical (VES) data

#	VES Location	Interpreted Results												Total Spread Length (AB) (m.)
		Resistivity (Ohm.m.)						Thickness (m.)					Depth to Massive	
		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	h_1	h_2	h_3	h_4	h5		
1	Palamoodu	1183	412	179	-	-	-	3.9	5.4	Ext.	-	-	-	120
2	Palamoodu	618	3522	363	48	VH	-	0.6	1.0	14.2	16.4	Ext.	32	240
3	Puthenpalem 1	550	63	1625	92	3482	-	1.8	3.0	6.7	16.6	Ext.	28	180
4	Puthenpalem 2	934	65	521	76	-	-	1.8	1.7	25.1	Ext.	-	-	300
5	Kallingal 1	165	68	183	378	-	-	0.8	3.5	30.8	Ext.	-	35	140
6	Kallingal 2	81	12	396	984	-	-	1.3	1.1	30	Ext.			200
7	Karippur 1	2385	155	18	95	20	198	0.6	2.5	5.7	8.5	17.3	34.5	140
8	Karippur 2	487	96	5	2990	-	-	2.0	8.4	30	Ext.	-	-	240
9	Mundela 1	260	103	426	78	502	-	0.8	3.5	4.4	7.8	Ext.	16.5	200
10	Mundela 2	957	74	777	99	2800	-	1.3	1.6	3.9	8.5	Ext.		300
11	Pudukulangara 1	113	271	189	283	168	500	0.5	2.4	3.3	9.2	16.4	32	160
12	Pudukulangara 2	230	82	192	64	130	-	2.2	4.4	10.4	19.2	Ext.		240
13	Mullassery 1	560	1596	330	2961	113	1426	0.6	2.0	3.2	5.2	15.2		120
14	Mullassery 2	819	617	2454	318	41	1531	0.9	2.4	2.4	2.3	8.4	16.4	100
15	Karakulam	147	20	4	52	118	-	1.6	4.7	6.3	18.6	Ext.		180
16	Maruthamkodu	142	9	17	89	300	-	1.2	3.1	5.3	8.7		18.4	240
17	Vilapilsala 1	1855	680	518	701	138	898	0.5	1.1	5.3	8.1	9.7	25	100
18	Vilapilsala 2	3194	427	3528	VH	-	-	1.6	17.3	10	-	-		160
19	Kattakada 1	2226	675	306	883	-	-	1.1	4.2	30	Ext.	-	35.3	160
20	Kattakada 2	3137	635	117	1678	82	-	0.5	8.9	6.4	22.1	-		240
21	Rameswaram	336	126	38	139			0.93	3.05	14.56			18	
22	Nadurkolla	73	35	114	40	343		0.53	0.71	1.47	9.46		13	
23	Vandicher	1086	366	34	115	48		1.62	2.19	4.59	24.72		33	
24	Parassala 2	49	163	28	303			2.32	2.25	6.90			11.5	
25	Nilimamoodu	504	160	73	316	175		0.77	4.53	6.35	14.92		26.5	
26	Kalinganada	272	46	171	422			1.71	1.05	19.50		-	22	
27	Avanakuzhi	146	108	70	245			1.12	5.40	27.02			33.5	
28	Palachakonam 1	69	879	54	2529	158		1.83	1.60	6.67	26.53		37	
29	Palachakonam 2	424	58	150	106			0.91	17.84	23.85			43	

30	Mangalathukonam	1529	4165	581	69			0.65	2.24	13.70			16.5	
31	Palachalkonam	220	10	187	29	166		0.75	0.86	2.12	29.90		34	
32	Tanomoodu 2	406	1560	566	182	1552		0.39	1.00	9.41	21.55		32	
33	Tanomoodu 3	3766	316	93	1580			2.00	8.34	34.96		-	45	
34	Paniyurkunnur	267	1413	210	268			0.26	2.81	11.18		-	14	
35	Kappukadu 1	1772	380	65	144	-	-	0.4	11.5	58.3	Ext.	-	-	300
36	Kappukadu 2	1304	98	40	157	-	-	3.5	21.4	30.8	Ext.	-	-	400
37	Kappukadu 3	3743	825	368	169	1294	-	1.34	9.43	31.8	28.53	Ext.	-	300
38	Karode1	493	105	22	53	-	-	4.4	3.4	13.5	Ext.	-	21	100
39	Karode 2	776	383	18	84	17	263	1.0	2.9	5.3	7.5	12.5	29	180
40	Parassala	319	1686	286	32	3288	-	1.5	2.1	18.9	13.1	Ext.	35	240
41	Kinfra 1	442	119	12	-	-	-	3.0	9.7	Ext.	-	-	-	70
42	Kinfra	2584	693	43	212	58	-	1.2	5.1	6.8	11.2	Ext.	-	120
43	Kinfra	1534	334	1812	VH	-	-	1.0	20.0	9.0	Ext.	-	-	200
44	Kinfra	1601	757	13	155	-	-	4.2	8.8	21.9	Ext.	-	-	140
45	Kinfra	633	84	9948	-	-	-	2.9	36.6	Ext.	-	-	39.5	120
46	Pirappancode1	508	256	1148	104	6341	-	2.1	2.1	4.4	12.2	Ext.	21	140
47	Pirappancode2	2679	148	1168	98	7570	-	2.7	2.3	5.0	12.5	Ext.	22.5	200
48	Poojappura	261	79	213	59	994	-	1.71	7.71	5.35	15.78	Ext.	-	
49	Poojappura 2	490	84	331	230	-	-	3.11	10.35	21.64	Ext.	-	-	
50	Poojappura 3	741	4008	367	131	612	-	0.61	0.92	11.61	106.6	Ext.	-	
51	Poojappura 4	358	843	156	1236	-	-	1.21	5.32	54.79	Ext.	-	-	
52	Poojappura 5	498	744	425	186	-	-	0.52	1.15	6.23	Ext.	-	-	
53	Vellanad1	430	818	165	5389	-	-	5.54	24.4	36.06	Ext.	-	-	400
54	Vellanad2	403	965	85	1394	53	VH	2.98	1.83	3.91	7.91	13.86	30.5	320
55	Vellanad 3	778	226	54	VH	-	-	3.11	11.53	9.41	Ext.	-	24.0	400
56	Vellanad 4	2266	1032	716	88	VH	-	0.65	1.93	14.52	12.44	Ext.	29.5	160
57	Vellanad 5	586	842	414	260	3375	-	0.89	1.99	14.14	60.49	Ext.	-	400
58	Mangalapuram	5166	973	97	VH	-		0.72	6.80	16.06	-		24	
59	Chantavila 2	429	581	224	1225			0.45	6.14	30.39	-		37	
60	Sreekariyam 1	648	2810	200	102			1.75	1.65	37.64	-			
61	Sreekariyam 2	350	80	9	VH	-		1.3	7.7	41	-		50	
62	Kulathoor	170	811	204	53	837	44	1.65	1.74	14.56	19.47	43.66	81	
63	Venpackal	5227	246	75	12	158		0.27	4.02	15.90	27.07		47	

3.2.2 Groundwater and its relation to Geological Structures

Geological structures like fractures, lineaments, faults, joints, intrusive rocks etc influence the occurrence and movement of groundwater. Such information extracted from field investigations as well as from the study of topo-sheets and imagery was utilized to identify potential lineaments and fractures in the area. The lineaments and dykes identified in the basin trend various directions such as NW-SE, N-S, NNE-SSW and E-W. The prominent lineaments in the area mainly trend in NW-SE and N-S direction. The rose diagram of lineament and dykes are given in the Fig.3.15 and 3.16 respectively. The prominent trend of dykes of the area is similar to the lineaments of the area.

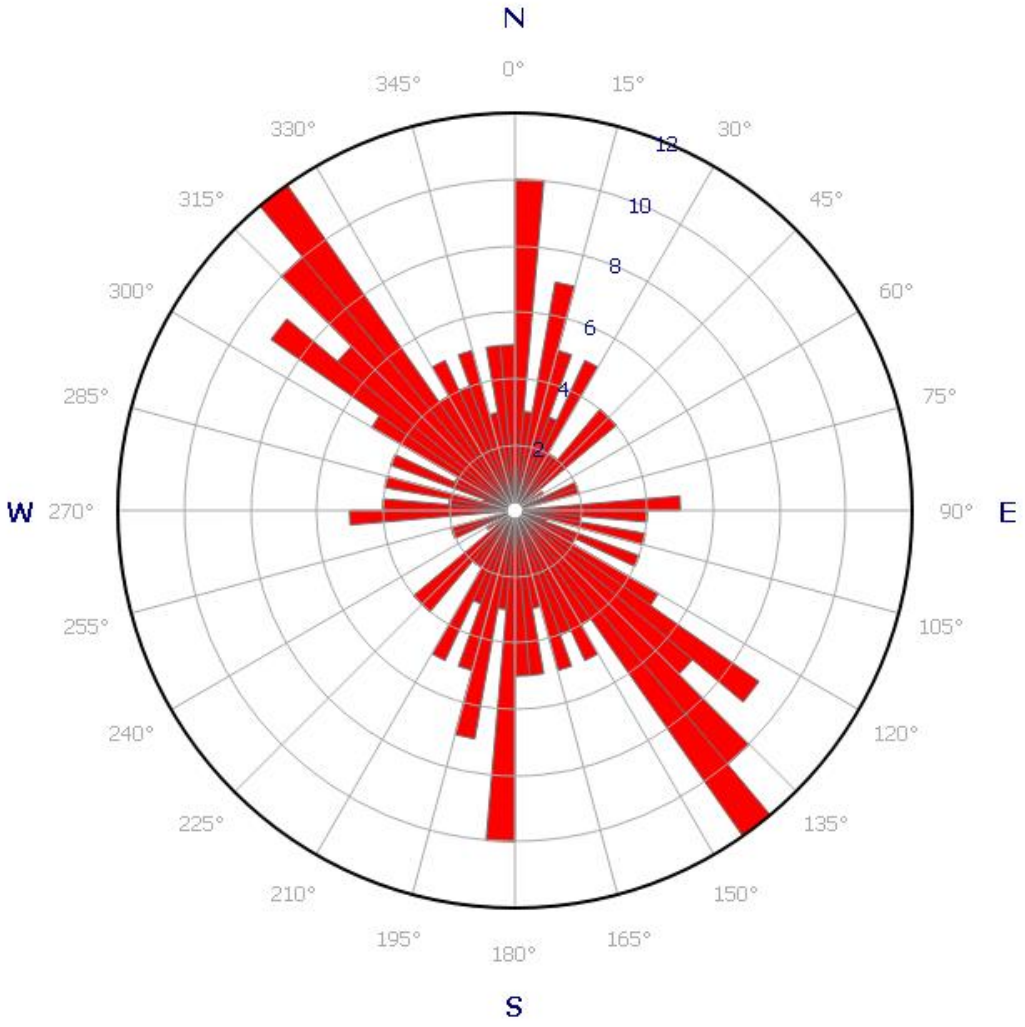


Fig.3.15: Rose diagram of lineament

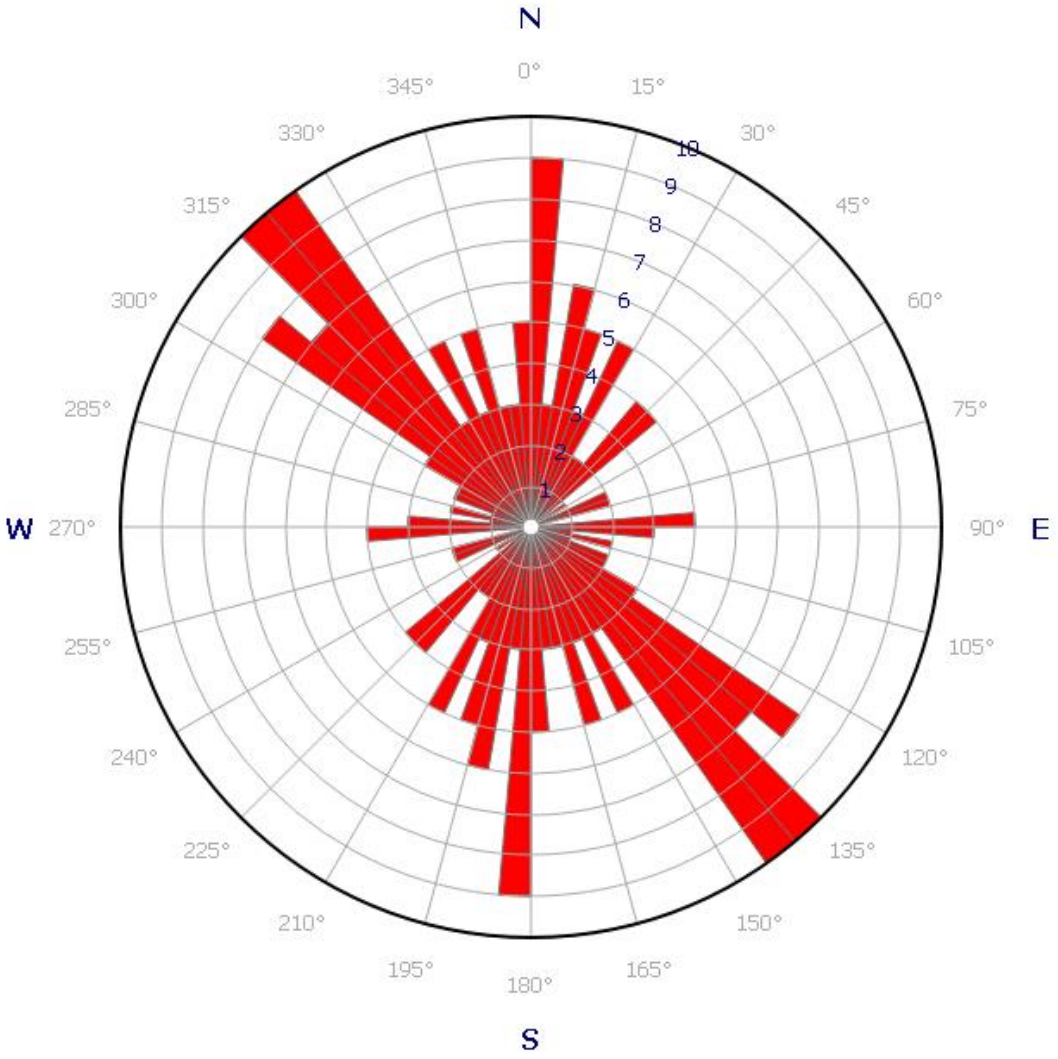


Fig.3.16: Rose diagram of dyke

The yield of the boreholes had a direct bearing on the Tectonic history and the rock types. The yield from bore wells varies in the area. Within the same geological formation, the spatial variation in yield is very common. The comparative study of the yield of the well with lineament indicates that the NW-SE lineaments are potential. The number of wells having varying yield ranges and details of high yielding wells and lineaments are given in Table.3.6 and 3.7 respectively.

Table 3.6: Frequency of bore wells in different Yield ranges

Yield of Exploratory Wells	**No of wells**
>3 lps	10
1 to 3 lps	14
< 1 lps to dry	12

Table 3.7:Details of high yielding wells and lineaments

#	Name of Exploratory well	Yield	Formation	Lineament
1	Tholikuzhy	10	Khondalites	NE-SW
2	Korani	20	Khondalites	NW-SE
3	Chemburu	5	Khondalites	NW-SE
4	Vamanapuram	8.3	Khondalites	NW-SE & NNW-SSE
5	Chenkavila	3	Khondalites	-
6	Neyyattinkara	6	Khondalites	NW-SE
7	Kuravara	5	Khondalites	NW-SE
8	Malayadi	7	Garnetiferous Gneiss	NNW-SSE
9	Vithura	3	Khondalites	NNW-SSE
10	Melattumuzhy	10	Gabbro	NW-SE
11	Mamam	7	Khondalites	NW-SE
12	Nagarur	7	Khondalites	NE-SW
13	Anad	3	Leptynite	NW-SE

3.2.3 Aquifer characteristics

The hydraulic properties of fracture systems are evaluated from pumping tests and the results of which are given in table. The Transmissivity value varies from 0.54 to 17.58 m^2/day and the Storativity values varies from 0.00007to0.001. The details of exploratory wells are given in table 3.8.

3.2.4 Chemical quality of water in fractured aquifer

Water samples were collected from fractured aquifers of bore wells and peizometers during their construction and were analysed for EC, pH, major cations, anions and Fluoride. They include samples from same well but of different depth also. The details of the samples are given in the Table 3.9. The analysis of the data shows that water in the fractured zones of hard rock terrain in Thiruvananthapuram district is of alkaline nature and quality of the water is generally good. The epm values of the samples were plotted in Hill- Piper diagram. Out of the 47 samples analysed majority of the samples (26) falls in the Ca-HCO_3 type and 15 falls in Na- HCO_3 type water (Fig. 3.17). To Know the origin of water in fractured aquifer the chemical analysis data of ground water samples collected from fractured aquifers has been plotted on the Gibbs diagram - TDS *vs* $(Na^{+}+ K^{+})/(Na^{+}+ K^{+})+Ca^{2+}$ and TDS *vs* $Cl^{-}/Cl^{-}+HCO_3^{-}$ and is shown in Fig. 3.18.

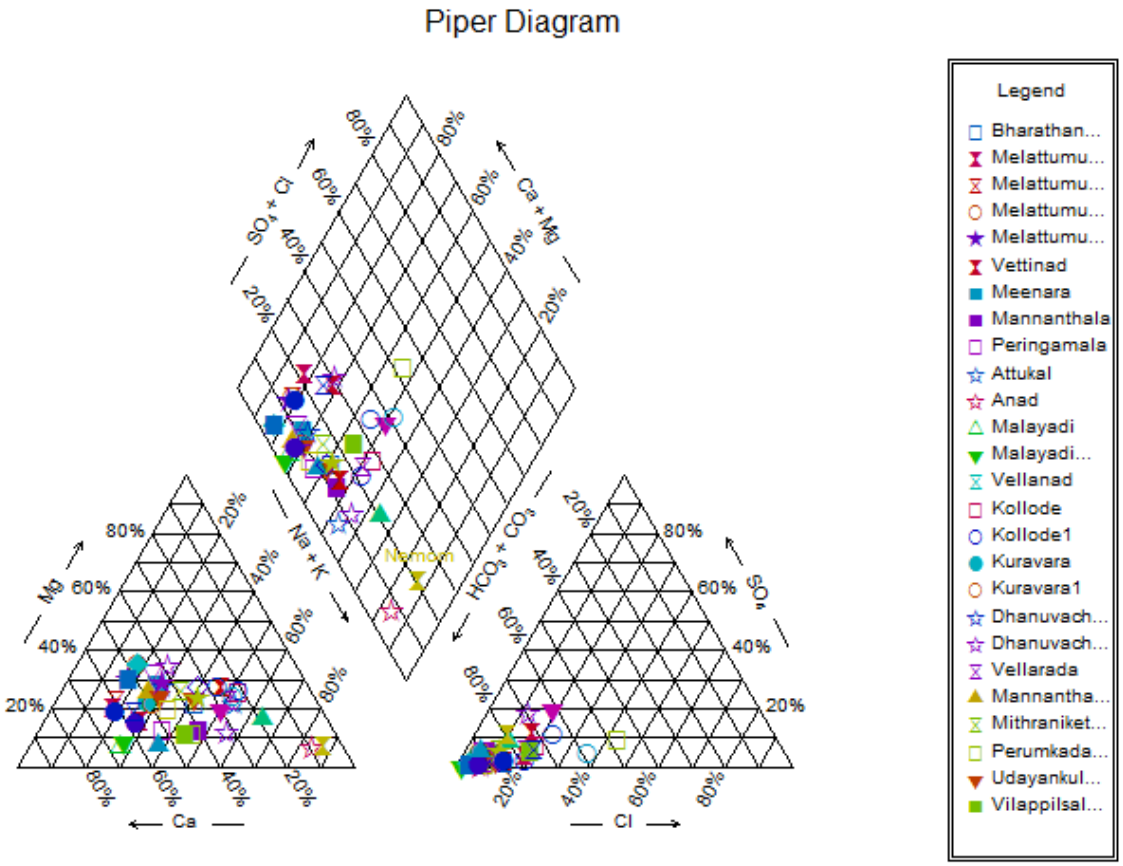
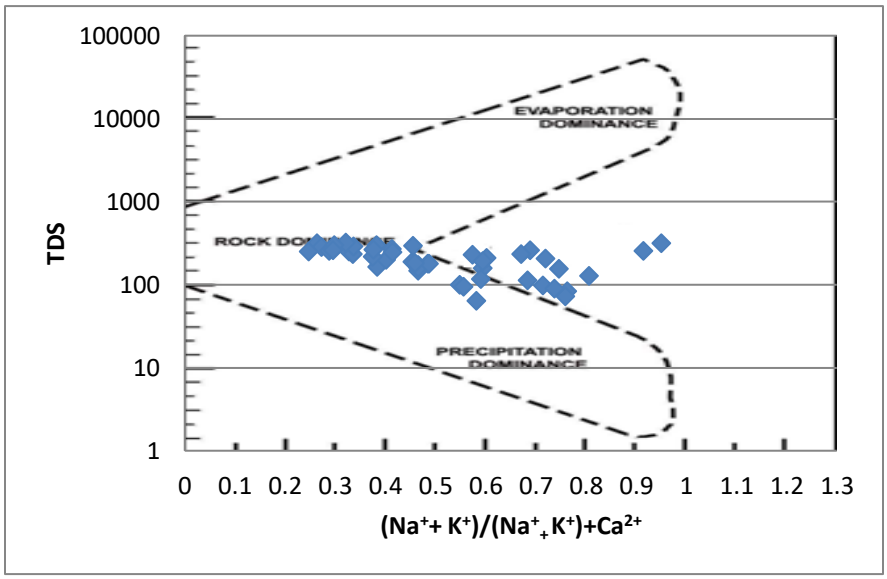


Fig.3.17: Piper Diagram of Samples from Deeper Aquifer



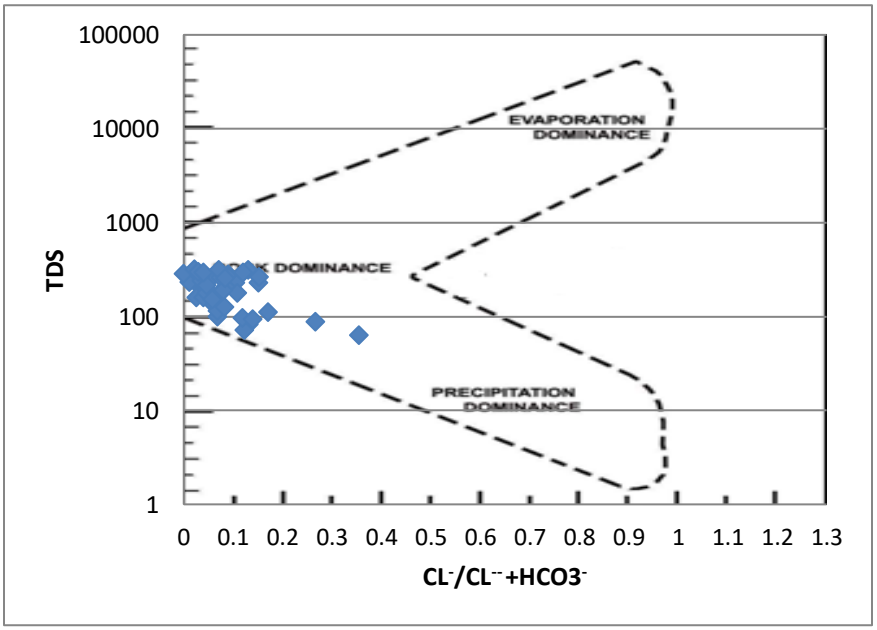


Fig.3.18: Gibbs Diagram of samples from Deeper Aquifer

Table 3.8: Aquifer Parameters of bore well

#	Village/ Location	Topo sheet No.	Lat	Long	Depth	Dia (mm)	SWL (mbgl)	pumping test Discharge (lps)	Draw Down	Transmisivity (m^2/day)	Storativity/ S.Yield
1	Tholikuzhy EW	58D/13	8°47'10"	76°55'03"	125	165			18.41	6.41	0.0007
2	Vamanapuram EW	58D/14	8°34’20	76°50’74”	200.53		12.5	3.25	24.91	4.52	0.00082
3	Vamanapuram OW	58D/14	8°34’20	76°50’74”	200.87		11.71	3.25	12.21	5.3	0.000815
4	Mamam EW	58D/14	8°40’43”	76°49’28”	200	177.8	3.15	4	20.54	9.54	0.00072
5	Chembur	58D/14	8°43’20”	76°53’55”	191		14.92	0.94	24.19	1.17	
6	Melattumuzhi EW	58D/14	8°42’40”	76°55’25”	144.5	165	5.1	5	15.23	17.58	0.001
7	Melattumuzhi	58D/14	8°42’40”	76°55’25”	190	165	6.19	2.5	5.07	15.21	
8	Nagarur EW	58D/14	8°44’20”	76°51’24”	141.5	165	5.61	3.5	20.68	5.89	0.0005
9	Korani	58D/14	8°39’10”	76°50’25”	183.29		5.36	20	18.89	9.03	
10	Vettinad	58D/14	8°36’10”	76°56’33”	200	165	1.4	0.8	26.12	1.24	
11	Vempayam	58D/14	8°38’05”	76°56’30”	200.53		1.48	1	32.48	0.93	
12	Palayam	58D/14	8°30’02”	76°56’52”	200	165	2.35	0.5		0.54	
13	Peringamala	58H/2	8°43’41”	77°02’51”	200	165	2.65	0.8	30	0.904	
14	Nanniyode EW	58H/2	8°41'55"	77°01'42"	52		4.05	1.5	22.45	6.45	0.00007
15	Anad	58H/2	8°37’50”	77°00’38”	200	165	1.96	2	25.75	4.65	
16	Malayadi	58H/2	8°38’00”	77°04’30”	172.6	165	3.35	7	17.02	16.84	
17	Vithura EW	58H/2	8°40’25”	77°05’50”	200	165	6.56	1.5	31.89	0.94	
18	Kollode	58H/3	8°29’37”	77°03’53”	200	165	6.53	1.3	23.14	1.2	
19	Kuravara	58H/3	8°29’17”	77°67’35”	98.8	165	1.02	2	21.4	2.59	
20	Dhanuvachapuram	58H/3	8°22’47”	77°08’05”	161.8	165	11.43	1	25.67	1.13	
21	Neyyatinkara EW	58H/3	8°24’25”	77°04’55”	129.3	165	2.67	6	31.24	5.54	
22	Vellarada	58H/3	8°26'56"	77°11'43"	200	165	3.22	1	36	1.04	

Table 3.9: Chemical quality of fractured aquifer

#.	Location	Depth (m bgl)	pH	EC (µS/cm at 25⁰C)	TDS	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	NO_3	F
					----------(mg/L)----------										
1	Bharathannur	200	9.23	332	212	24	8.5	30	2.3	18	146	17	2		0.14
2	Melattumuzhi EW	56	8.32	454	291	60	12	20	1.5	12	220	33	9		0.47
3	Melattumuzhi EW	107	8.33	408	261	52	12	18	1.5	12	213	21	3		0.5
4	Melattumuzhi OW	144	8.59	398	255	42	19	19	1..1	18	207	20	5		0.53
5	Melattumuzhi OW	190	8.34	367	235	44	15	17	0.8	18	195	17	3		0.25
6	Vettinad	200	7.66	430	275	46	7.8	24	4.6	0	198	27	24		0.11
7	Meenara	80.5	7.22	272	174	24	9.2	13	7	0	161	8.5	4		0.25
8	Mannanthala	200	8.64	228	146	18	3.4	22	4.4	14	112	7.1	5		0.16
9	Peringamala	200	8.36	212	136	24	3.4	19	1.9	9.6	124	7.1	1	3.3	0.03
10	Nanniyode EW	52	8.89	360	230	44	4.9	12	2.5	18	177	9.9	tr		0.2
11	Attukal	200	8.22	297	190	17	8.8	40	3.7	0	207	7.1	2		0.08
12	Anad	200	8.82	371	237	7.2	2.9	76	1	24	171	9.9	tr		0.12
13	Malayadi	172.6	8.78	364	233	51	2.9	24	0.85	14	227	5.7	0	0.89	0.02
14	Malayadi OW	163	8.9	337	216	50	3.9	24	1.2	4.8	244	2.8	0	0.56	0.02
15	Vellanad	200	7.54	413	264	42	9.7	17	4.4	0				0.08	

16	Vithura EW	200	8.17	234	150	26	6.3	15	1.2	0	161	4.3	0	0.81	0
17	Kollode	50	7.47	120	76.8	4.8	3.4	11	4.5	0	56	8.5	4	4.7	0.02
18	Kollode	200	7.63	105	67.2	4	2.9	9.2	3.4	0	51	7.1	1	1	0
19	Kuravara	42	8.23	4240	2713	50	13	30	2.3	0	300	9.9	11	0.83	0
20	Kuravara	98.8	8.5	391	250	42	11	28	1.6	6	250	8.5	11	0.22	0
21	Dhanuvachapuram	51	8.74	251	161	22	8.3	14	5.2	6	141	11	4	3.8	0.16
22	Dhanuvachapuram	161.8	8.5	260	166	20	11	14	4.8	12	115	14	26	3.5	0.23
23	Vellarada	200	7.93	140	89.6	5.6	2.9	11	3	0	63	8.5	3.8	1.6	0.08
24	Mannanthala Pz	65.5	9.45	289	184.96	32	10	18	3.5	0.01	178	8.5	1	1.5	0.18
25	Mithranikethan Pz	30.5	8.49	144	92.2	12	4.9	10	4.6	0.01	78	5.7	4	0	0.54
26	Perumkadavila Pz	61	8.79	92	58.9	6.4	1	6.8	2.1	0.01	20	11	3	1.5	0.1
27	UdayankulangaraPz	61	8.08	167	107	8.8	3.4	10	2.7	0	59	4.3	1		0.06
28	Vilappilsala Pz	41.2	8.94	136	87	13	1.9	13	3.3	0.01	68	11	3.5		0.18
29	Tholikuzhy EW	25	8.15	352	225	30	14	16	5.3	0	229	8.5	13		0.2
30	Tholikuzhy EW	125	8.13	464	297	46	21	19	2.8	0	317	7.1	3		0.17
31	Tholikuzhy OW	125	8.6	433	277	46	16	17	2.6	30	232	7.1	1		0.2
32	Thattathumala	200	7.3	233	149	20	6.3	13	4.4	0	137	5.7	3.5		0.2
33	Nagarur EW	141.5	8.44	258	165	24	6.1	19	3.8	7.2	146	8.5	1		0.45
34	Nagarur OW	200	8.35	261	167	24	9.7	17	3.4	tr	173	8.5	0.5		0.53
35	Mamam EW	76	8.41	223	143	22	4.9	15	50	9.6	115	7.1	4.5		0.64

36	Mamam EW	200	8.72	314	201	40	6.1	20	4	17	176	8.5	0.5		0.6
37	Mamam OW	196	8.81	426	273	48	3.6	37	3.2	24	207	8.5	10		0.24
38	Pattom	200	8.59	185	118	5.6	2.9	20	3.4	tr	95	8.5	8	6.9	0.11
39	Palayam EW	120	8.01	377	241	17	11	33	4.6	0	210	17	5.7	0.47	0.3
40	Palayam EW	200	8.07	334	214	16	6.3	30	2.6	0	146	26	36	0.98	0.16
41	Nemom	200	8.29	459	294	4.8	3.9	89	2.4	12	237	18	27	1	0.15
42	Neyyattinkara EW	77	8.79	304	195	18	9.2	24	3.3	14	151	14	2.7	0.28	0.18
43	Neyyattinkara EW	129	8.66	275	176	17	6.8	22	3	14	127	11	6.4	0.78	0.14
44	Neyyattinkara OW	117	8.17	162	104	7.2	4.4	12	3.6	0	68	14	8.9	4.7	0.08
45	Neyyattinkara OW	190	7.99	128	81.9	4.8	2.9	9.8	3.7	0	44	16	2.5	1.3	0.02
46	Chenkavila	40	7.92	373	239	45	8.3	14	4.9	0	217	20	2.9	1.7	0.16
47	Chenkavila	63	8.48	383	245	41	8.3	17	7.7	17	156	28	11	8.9	0.14

Tr-traces

3.3. Ground Water Resource Estimation

The occurrence of groundwater availability varies from place to place. Increasing population, rapid urbanization and industrialization has resulted in increasing use of ground water resources. Judicious and planned development of ground water and its scientific management have become necessary to ensure long-term sustainability of this precious natural resource Judicious and planned development of ground water and its scientific management have become necessary to ensure long-term sustainability of this precious natural resource. Phreatic aquifers are the major source of water in the area in the study area. Any decision about future utilizations depend on having a clear understanding of the status of the resource, the amount that has already been extracted, the amount remaining, and the impact of further depletion. The ground water resources in the area are estimated based on the Groundwater estimation methodology 1997. The data pertaining to Command and non-command area are not available hence the entire area is considered as non-command area. The block wise groundwater resources in the area is estimated as per ground water estimation methodology 1997.

Ground water draft in the study area is mainly for irrigation and domestic uses. In view of the non-availability of data on the number of wells being used for domestic purposes, the ground water draft for domestic uses has been computed block-wise on the basis of 2011 population, projected to the year of assessment (2013). Domestic requirement of water in the study area has been computed as the product of the population and the per-capita water requirement (assumed as 150 L/day/person). The ground water draft has been computed from the data on the block-wise number of irrigation wells collected by the State Ground Water Dept., Government of Kerala. The ground water draft Figures are arrived at by multiplying the number of wells with the corresponding unit draft. As per GEC 2013 Net annual ground water availability of the district is **263.54 MCM** and the stage of ground water development is 55 **%**. Out of 11 blocks, 3 are 'Semi critical' and 8are 'Safe'. Block-wise groundwater resources in the study area are given in table 3.10.

Table 3.10 Block-wise Groundwater Resources in the study area

Sl. No.	Assessment Unit/ Block	Mappable area of hard rock (Sq km)	Net Annual Ground Water Availability	Existing Gross Ground Water Draft for irrigation	Existing Gross Ground Water Draft for domestic and industrial water supply	Existing Gross Ground Water Draft for All uses	Provision for domestic, and industrial use up to 2025	Net Ground Water Availability for future irrigation development	Stage of Ground Water Development {(7/4) * 100} (%)
1	Athiyannur	38.53	715.89	169.03	446.30	615.33	458.28	88.58	85.95
2	Chirayinkil	65.63	1127.56	215.47	628.98	844.46	645.83	266.26	74.89
3	Kilimanoor	182.2	3079.05	443.70	1069.94	1513.64	1098.70	1536.65	49.16
4	Nedumangad	145.69	1936.66	431.98	972.14	1404.13	998.28	506.40	72.50
5	Nemom	243.2	3779.87	379.20	2397.82	2777.02	2462.27	938.40	73.47
6	Parassala	52.27	1076.62	424.06	503.50	927.57	517.04	135.52	86.16
7	Perumkadavila	265.73	3528.54	566.54	976.21	1542.74	1002.44	1959.57	43.72
8	Pothencode	35.76	756.06	283.93	310.48	594.42	312.85	159.27	78.62
9	Vamanapuram	390	5180.20	695.31	1368.29	2063.60	1405.06	3079.83	39.84
10	Varkala	36.49	650.44	109.09	314.35	423.45	322.80	218.55	65.10
11	Vellanad	344.5	4523.74	678.83	1208.50	1887.33	1240.99	2603.92	41.72
	Total (ha.m)		26354.63	4397.15	10196.52	14593.68	10464.54	11492.94	55.37
	Total (MCM)		263.54	43.97	101.96	145.93	104.64	114.92	55.37

In-storage in the weathered zone (phreatic aquifer) below the zone fluctuation is worked out as 487.31 MCM. In-storage in the weathered zone is the product of area, weathered zone thickness and specific yield. Block wise In-storage in the weathered zone is shown in table 3.11.

Table 3.11 In-storage in the weathered zone (Phreatic aquifer)

Block	Area of blocks in Hectare	Saturated Aquifer Thickness(m)	Average specific yield	Static resource in weathered zone (Ha.m)
Athiyannur	3853	10	0.025	963.25
Chirayinkeezh	6563	10	0.025	1640.75
Kilimanoor	18220	12	0.025	5466
Nedumangadu	14569	13	0.025	4734.925
Nemom	24320	10	0.025	6080
Parassala	5227	11	0.025	1437.425
Perumkadavila	26573	12	0.025	7971.9
Pothencode	3576	13	0.025	1162.2
Vamanapuram	39000	10	0.025	9750
Varkala	3649	10	0.025	912.25
Vellanad	34450	10	0.025	8612.5
Total (Ha.m)				48731.2
Total (MCM)				487.31

In-storage in the fractured zone

The ground Water resource in the fractured zone is worked out based on the common depth of occurrence of fracture, area and storativity and is shown in table 3.12.

Table 3.12 In-storage in the fracture zone

Block	Area of blocks in Hectare	Thickness of Hard rock With fractures	Average Storativity	Ground Water Resource
Athiyannur	3853	83	0.0014	447.72
Chirayinkizh	6563	83	0.0014	762.62
Kilimanoor	18220	83	0.0014	2117.16
Nedumangadu	14569	83	0.0014	1692.92
Nemom	24320	83	0.0014	2825.98
Parassala	5227	83	0.0014	607.38
Perumkadavila	26573	83	0.0014	3087.78
Pothencode	3576	83	0.0014	415.52
Vamanapuram	39000	83	0.0014	4531.8
Varkala	3649	83	0.0014	424.02
Vellanad	34450	83	0.0014	4003.08
Total (Ha.m)				20916
Total (MCM)				209.16

3.4Ground Water related problems

As per the Ground Water Resource estimation of the 11 blocks, 3 blocks fall under Semi Critical category whereas the remaining 8 falls under safe category.These semi critical blocks are covered by both sedimentary and hard rock area . As the present study is confined to hard rock area, these semi critical blocks are not fully covered. Even though the blocks in the study area falls in safe and semi critical category these area experiences drying up of wells during summer season and in rain deficient years.

In the study area groundwater is developed mostly through dug wells. Now a days in high land terrain bore wells are also common, as the dug wells in this area usually dries up.In high land area springs are also a good source for drinking water. The physiography and geological settings of the area as well as the anthropogenic activities further worsen the ground water situation.. Except for iron and nitrate, above the permissible limits specified for drinking in certain locations, the water quality is generally good.

Anthropogenic activities like rapid urbanization, change in land-use and cropping pattern, indiscriminate dumping of bio-degradable and non-biodegradable waste into abandoned wells,

surface water sources, wet land filling, cultivable land encroachments, Latrine pits, illegal sand mining in River beds and paddy fields have adverse effects on the quantity and quality of the water. Khondalite group of rocks occupying the highland and midland region of the study area are good sources of building materials. Quarrying of these rocks create localized ground water problems.

GWD Kerala has noticed from their regular analysis of public water sample that about 70% of the wells of Thiruvananthapuram are contaminated with coliform. Water samples collected from the open wells near the Vilappilsala garbage factory were analysed for chemical and bacteriological parameters by GWD. Study showed the presence of coliform bacteria in wells around the factory and it is suspected due to leaching from the waste dumped. Another study conducted by GWD in association with an NGO on deterioration of quality of Karamana River, the main source of municipal water supply for the city of Thiruvananthapuram. The study concluded that parameters like conductivity, total hardness, chloride etc are increasing towards the river mouth and all the samples were highly affected with faecal coliform. Human activities are polluting the river in many ways; sand mining, brick making, waste disposal, sewage disposal etc are some of them.

In spite of these apparently rich water resources, it is ironic that parts of the district are facing acute water scarcity, especially during summer months. The reason for water scarcity can be concluded as follows

- Inability to conserve the surplus run-off available during the monsoons, due to topographic characteristics and destruction of traditional water storage structures such as ponds, tanks and wet lands.
- Rapid urbanization resulting in increased water consumption and reduced water conservation and ground water recharge.
- Recent changes in land use and cropping pattern, resulting in conversion of land from agricultural to non-agricultural uses and consequent reduction in water conservation and groundwater recharge.
- Deterioration of water quality from natural (iron) and anthropogenic (Nitrate, E-coli etc.) sources.

3.5 Aquifer map

An aquifer map of the area is evolved out of various studies on aquifer geometry, aquifer characteristics and water resources in the aquifer systems, yield characteristics and water quality described above. The aquifer map of the phreatic (weathered zone) and fracture aquifer systems are shown in fig. 3.19 and 3.20.

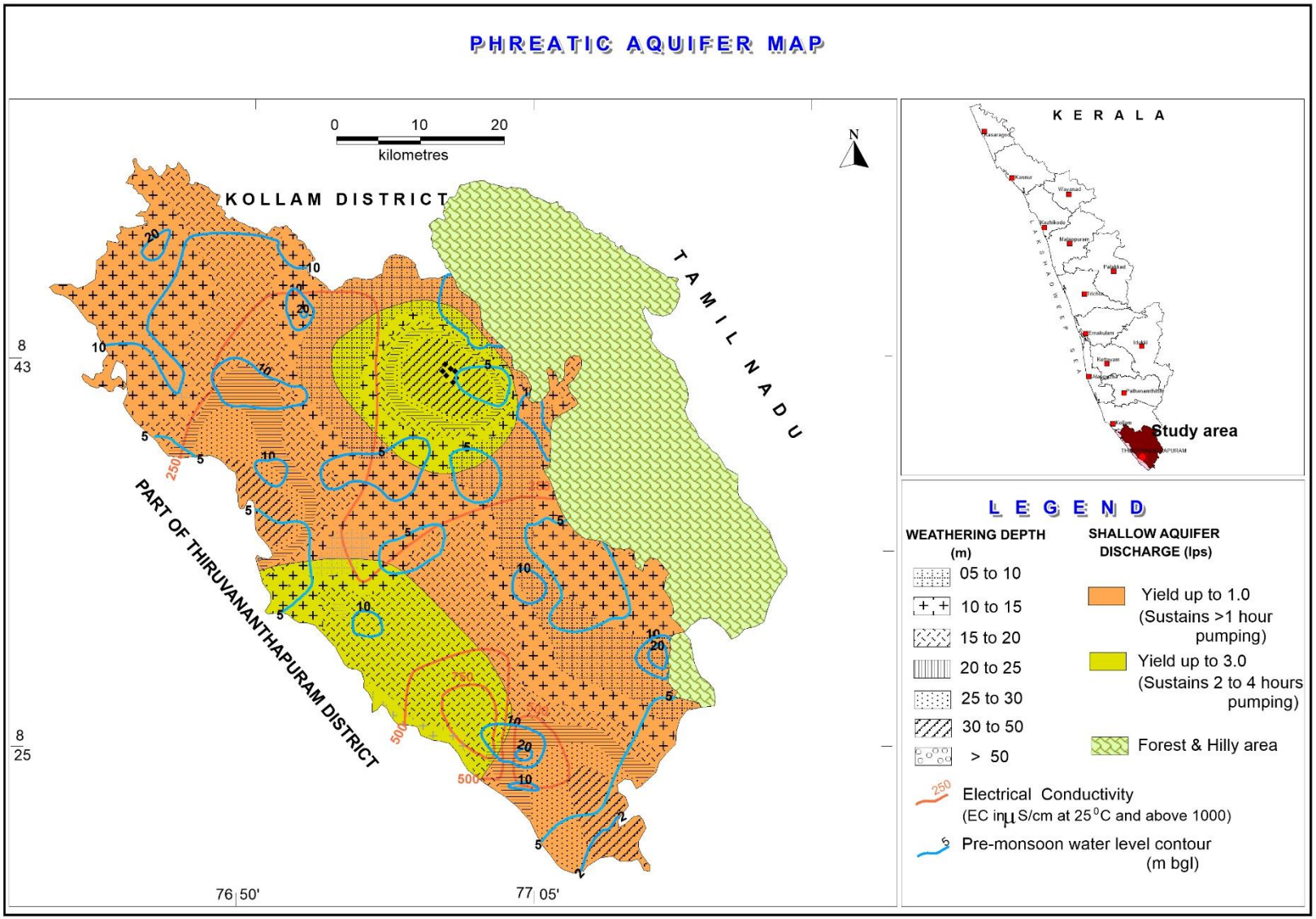


Fig.3.19 Aquifer map of the Phreatic zone (weathered zone)

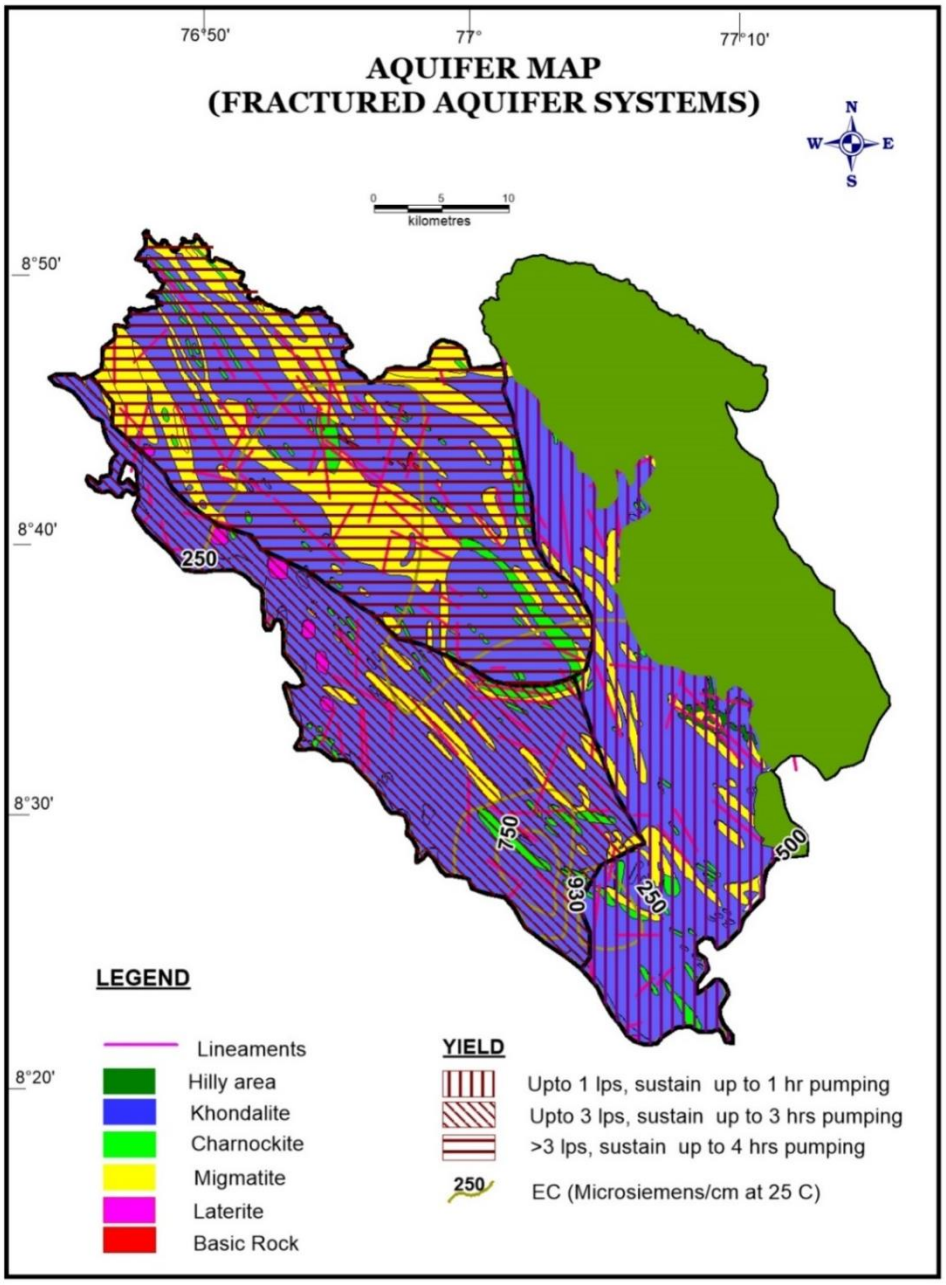


Fig.3.20 Aquifer map of the area

4. Ground Water Management

The households in the study area have own drinking water wells, either dug or bore wells. The dependence on bore wells has gained momentum during the last few decades. Groundwater conservation and augmentation requires effective management of rainwater and surface water resources. As the area receives good rainfall and is well drained there is sufficient scope for aquifer management through effective utilization of both rainwater and surface water.

Since the blocks in the study area falls in Safe and semi-critical category, there is sufficient scope for irrigated agriculture. Some of the fallow lands in the area can be converted through irrigated agriculture. About 200 ha of barren land and 2869ha current fallow land are identified in the area and irrigated agriculture can be promoted in about 2000 ha land. Even though the groundwater utilization is low (about 55%) the spatial availability of groundwater is highly uneven due to limited water holding capacity of the aquifer systems in the phreatic zone and aquifer thickness variation controlled by geology and topography. Thus, mild drought is frequent whenever there a delay in the onset of monsoon. This necessitates artificial recharge and conservation structures in the area.

The short term and immediate measures that can be practiced in areas experiencing water scarcity in summer season include:

Maintenances and renovation of water resources through scientific and biological ways help to improve the quality of water as well as it augments the recharge. Identification and regular maintenance of perennial ponds or tanks in each panchayath will be helpful to tackle the water scarcity during the summer season. Ensure the collection of monsoon water in these tanks. Regular de-siltation of existing check dams, bunds and ponds are suggested for augmenting recharge to the phreatic aquifers. About 1500 panchayath ponds are reported in the study area.

Identification of high yielding, government bore wells drilled by various agencies with potable water quality helps to mitigate the drinking water needs of the populace especially during summer but this is can only be considered as a short-term measure. Details of high yielding bore wells (10000lph) drilled by CGWB and SGWD in the study area is compiled in **table 4.1**

The long-term measures that can be practised in the area to address the water problem include:

New mini water supply schemes by constructing a check dam across the rivers at strategic locations after feasibility study can be practised. These schemes can make utilising of perennial springs also. The irrigation and water supply schemes in the study area require regular maintenance and attention. Priority should be given to mini water supply projects.or by extending the piped water supply to these areas

Table 4.1 Details of high yielding bore wells (10000lph) drilled by CGWB and SGWD

Location	Agency	Village	Block	Bore well Discharge (lph)	Discharge (8 hours pumping)	Well can mitigate the drinking water needs of a Population @ 60 l/day/person
Chemburu	CGWB	Elamba	Chirayinkil	18000	144000	2400
Vamanapuram	CGWB	Vamanapuram	Vamanapuram	28800	230400	3840
Neyyattinkara	CGWB	Neyyattinkara	Neyyattinkara	21600	172800	2880
Kuravara	CGWB	Ottashekaramangalam	Perumkadavila	18000	144000	2400
Malayadi	CGWB	Tholicode	Vellanad	25200	201600	3360
Melattumuzhi	CGWB	Vamanapuram	Vamanapuram	36000	288000	4800
Nagarur	CGWB	NAGARUR	Kilimanur	25200	201600	3360
Mamam	CGWB	Attingal	Attingal	25200	201600	3360
Tholikuzhy	CGWB	Pazhayakunnumel	Kilimanur	36000	288000	4800
Vithura	CGWB	Vithura	Vellanad	10800	86400	1440
Chenkavila	CGWB	Kulathoor	Parassala	10800	86400	1440
Neyyattinkara Boys H S	SGWD	Neyyattinkara	Neyyattinkara	15000	120000	2000
Naruvamoodu	SGWD	Pallichal	Nemom	10000	80000	1333
Kannanpara	SGWD	Pangode	Vamanapuram	10000	80000	1333
Mankunnu	SGWD	Malayinkeezhu	Nemom	10000	80000	1333

More stress should be given for watershed development and management with an integrated approach to conserve soil and water so as to increase infiltration, water holding capacity and to reduce soil erosion. Water management practices include both agronomical measures and engineering measures. Agronomical measures which can be practiced include strip cropping, grass land farming and pasture cropping (maintaining the living plant cover of the soil).Avoid plantation of acacia and eucalyptus especially in the high lands and in the catchment areas of reservoirs. Engineering measures include contour bunding , terracing, construction of check dams, earthen

embankments, farm ponds and providing vegetative and stone barriers. Planting horticulture species on bunds, irrigation water management through drip and sprinkler irrigation, furrow ridge method of cultivation are the means of soil and water harvesting that can be practiced in the area.

It is observed that many surface water structures like ponds, tanks, irrigation canal and even cultivable land are being encroached and filled up which reduce natural recharge. The existing water resources and dug wells, ponds, streams, need to be cleaned, protected and conserved so as to augment the groundwater resources in the area.

Rainwater harvesting through pits and ferro cement structures, well recharge and artificial recharge schemes should be practiced in the study area. Large scale implementation of Roof top rainwater harvesting particularly in areas with dry wells in summer season may be facilitated, so that their will not be any shortage of water for domestic purposes. In situ collection of rainwater coupled with artificial recharge to groundwater can be practiced in the mid land regions.

Regular de-siltation of reservoirs and other water bodies, reducing paved areas and other impervious layers facilitates infiltration. Making use of abandoned quarries for water harvesting can also be practiced in the areas.

Areas having deep water level with slope less than 10° with moderate to high runoff is suitable for farm ponds and percolation ponds. In almost all blocks except in the high land area where slope is more than 10°we can practice this.Check dams can be constructed in the second order and fourth order streams where runoff potential is moderate to high and infiltration is low. Gully plugging can be practiced in high land area with slope greater than 10°.

CGWB has implemented a number of demonstrative artificial recharge structures and rainwater harvesting schemes in the area. The demonstrative schemes of CGWB on artificial recharge are given in **Table 4.2.** These schemes are successful and can be replicated at other suitable locations identified in the area.

Table 4.2 Artificial Recharge Schemes implemented by CGWB in Thiruvananthapuram district

#	**Location**	**Type of Structure and Year**	**District**
1	Ayilam, Chirayinkil Block	Sub-surface Dam (2000)	Thiruvanan
2	Mambazhakara,	Sub-surface Dam (1997)	Thiruvanan
3	Thalayilmottakavu,	Sub-surface Dam (2003)	Thiruvanan
4	Secretariat Building, Thiruvananthapuram	Rainwater Harvesting, Artificial recharge (2003)	Thiruvanan thapuram

As per Master Plan for Artificial Recharge to Ground Water in India published by CGWB 2013, the details of structures proposed are given in the table below.

Block Name	Area feasible for artificial recharge structure	Volume of water required for recharge	Volume of surplus local/distant source available for recharge (MCM)	Type	Unit Capacity	Number of Structure feasible	No of structure already constructed by various agencies	Net number of structure feasible	Unit cost	Total cost (Unit cost* number)
Kilimanoor	115	20	85	C	0.033	51	6	45	20	900
				P	0.033	51	8	43	20	860
				SSD	0.003	11	1	11	15	165
				GP	0.0001	6400	239	6161	0.15	924
				NB	0.00225	1050	60	991	2	1982
				CB	0.00075	449	12	437	2	874
Nedumangadu	38	7	28	C	0.033	17	2	15	20	300
				P	0.033	17	3	14	20	280
				SSD	0.003	4	0	3	15	45
				GP	0.0001	2100	79	2021	0.15	303
				NB	0.00225	347	20	327	2	654
				CB	0.00075	147	4	143	2	286
Perumkadavila	86	15	63	C	0.033	38	3	35	20	700
				P	0.033	38	5	33	20	660
				SSD	0.003	8	0	8	15	120
				GP	0.0001	4766	137	4629	0.15	694
				NB	0.00225	781	34	746	2	1492

				CB	0.00075	333	7	326	2	652
Vamanapuram	104	18	77	C	0.033	46	5	41	20	820
				P	0.033	46	8	39	20	780
				SSD	0.003	10	1	10	15	150
				GP	0.0001	5800	216	5584	0.15	838
				NB	0.00225	951	54	897	2	1794
				CB	0.00075	404	11	394	2	788
Vellanad	177	31	129	C	0.033	78	9	69	20	1380
				P	0.033	78	13	65	20	1300
				SSD	0.003	17	1	16	15	240
				GP	0.0001	9800	368	9432	0.15	1415
				NB	0.00225	1609	92	1517	2	3034
				CB	0.00075	689	18	670	2	1340
Nemom	140	25	103	C	0.033	62	7	55	20	1100
				P	0.033	62	10	52	20	1040
				SSD	0.003	14	1	13	15	195
				GP	0.0001	7800	291	7509	0.15	1126
				NB	0.00225	1279	73	1206	2	2412
				CB	0.00075	547	15	532	2	1064
Athiyannur	30	5	22	C	0.033	13	2	11	20	220
				P	0.033	13	2	11	20	225
				SSD	0.003	3	0	3	15	43
				GP	0.0001	1633	62	1571	0.15	236
				NB	0.00225	271	16	255	2	510
				CB	0.00075	116	3	113	2	225

Chirayinkizh	19	3	14	C	0.033	9	1	8	20	160
				P	0.033	9	1	7	20	140
				SSD	0.003	2	0	2	15	30
				GP	0.0001	1066	40	1026	0.15	154
				NB	0.00225	176	10	166	2	332
				CB	0.00075	333	2	331	2	662
Parassala	33	6	24	C	0.033	14	2	12	20	240
				P	0.033	14	2	12	20	240
				SSD	0.003	3	0	3	15	45
				GP	0.0001	1800	69	1731	0.15	260
				NB	0.00225	296	17	279	2	558
				CB	0.00075	124	3	121	2	242
Pothencode	89	16	65	C	0.033	39	5	35	20	700
				P	0.033	39	6	33	20	660
				SSD	0.003	9	0	8	15	120
				GP	0.0001	4933	185	4748	0.15	712
				NB	0.00225	809	46	763	2	1526
				CB	0.00075	347	9	337	2	674
Varkala	130	23	95	C	0.033	58	7	51	20	1020
				P	0.033	58	9	48	20	960
				SSD	0.003	13	1	12	15	180
				GP	0.0001	7233	271	6962	0.15	1044
				NB	0.00225	1185	68	1118	2	2236
				CB	0.00075	507	14	493	2	986

C-Check dam, P-Percolation tank, SSD-Sub-surface dyke, GP-Gully Plug, NB-Nala bund, CB-contour bund

5. Thiruvananthapuram Urban Area

Thiruvananthapuram Urban Area (TUA), which house the capital city is located between North Latitude of 8°21' and 8°40' , east longitude of 76°47' & 77°3'. The Urban area is bordered by Nedumangadu, Vellanad and Perumkadavila block in the east, Lakshadweep sea in the west, Parassala in the south and Kilimanoorand Varkala blocks in the north. Earlier Thiruvananthapuram Metro Corporation was only considered as Urban area. Later while considering the population growth and other facilities in the outskirts of the city, adjoining panchayaths were also included. Thus, TUA is broadly divided into municipal Corporation and the adjacent 14 panchayths.

Thiruvananthapuram metropolitan area registered a population of 1687406 as per census 2011.The city experiences a humid type climate. The city is the first along the path of South-west monsoon and gets its first showers in the early June and also gets North-east Monsoon. The average annual rainfall is 1687mm.

Physiographically, Thiruvananthapuram Urban Area can be categorized as Lowland and midlands. The lowland is comparatively narrow covered by coconut while midland consist of hillocks and valleys and is an area of intense agriculture activity. The main type of soil are coastal alluvium, riverine alluvium, Lateritic soil and Brown hydromorphic soil. The TUA is mainly drained by Karamana River and its tributary Killiyar.Vellayani is the only freshwater lake in TUA and it serves as the main source of drinking water in Nemom block.

Ground Water Scenario

TUA is underlain predominantly by Precambrian crystalline rocks. Sedimentary formations ranging in the age from Miocene to Recent overlie these formations. The Precambrian rocks include Khondalite suite of rocks which is exposed in eastern part and charnockite which are seen mainly in Vizhinjam and Venganoor area. The sedimentary formations comprise the Recent alluvium mainly composed of sand and clay that occurs along the coastal plain and in the valleys, Tertiary formations such as Warkali and Quilon and Laterites which occur as a capping over crystallines.

Central Ground Water Board has drilled exploratory wells in hard rock and soft rock area to delineate the aquifer geometry. The wells drilled in Khondalites are in the depth range of 60-200m bgl and discharge ranges from 12 to 90 lpm. The deep tube wells have depth range of 150-200m. In the sedimentary formations wells of medium yields have been encountered from the granular zones of Tertiary formations down to maximum depth of 100 m bgl. The Warkalai formation has a limited potential in Thiruvananthapuram. The wells drilled in this formation have low discharge. Recent alluvium formation is thinner and maximum thickness of 18m is encountered at Chakkai. The most potential aquifer in the urban area is alluvial deposits, which are composed of sand and clays with the average yield is about 10 to 60 m^3/day.

The main ground water abstraction structures for domestic and agricultural purposes are dug wells and bore wells in the crystalline and lateritic terrain and tube wells and filter point wells in the coastal alluvium. In the corporation area the practice of using dug wells have diminished in the recent

years and construction of private tube as well as bore wells increased. Dependence on surface water sources like pond have almost vanished but in panchayath area people still depend on dug wells for domestic needs. The main source of water for Thiruvananthapuram Urban Water Supply scheme by Kerala Water Authority is the Karamana River. The water supply is designed for 24 hrs after proper treatment at various treatment plants.

CGWB has established 31 wells in the urban area of the district to understand ground water scenario of the area and to know the impact of urbanization in the ground water level. The water level data reveals that deepest water level is noticed in the pre-monsoon period (April) and shallowest in the month of November i.e. in the post monsoon period.

The premonsoon (April 2016) and post monsoon (November 2016) water level data is analysed. The depth to water level data in the premonsoon period ranges from 2.05 m bgl to 18.28 m bgl. During pre-monsoon period 27 % of wells analysed show water level in the range of 0 to 5 m bgl, 42 % shows water level in the range of 5-10 m bgl and water level between 10-20 m bgl is noticed in 31 % of the wells analysed.

The depth to water level data in the post monsoon period ranges from 2 m bgl to 17.89 m bgl. During post monsoon period 27 % of wells analysed show water level in the range of 0 to 5 m bgl, 46 % shows water level in the range of 5-10 m bgl and water level between 10-20 m bgl is noticed in 27 % of the wells analysed.

Seasonal fluctuation indicates that 58 % of wells show rise in water level, 35% show fall and 7 % of wells show neither rise nor fall in the year 2016.

The Ground water in the area is generally potable except in areas adjacent to seacoast and in area polluted by industrial effluents. The water is generally alkaline in nature and all the major constituents are within permissible limit.

As per the GEC 2013, the stage of development in the urban area is generally low hence scope of further ground water development is possible in the area.

Major Ground Water Related Problems

The important ground water related problems in TUA are

1. Over exploitation of Ground Water: with construction of more Bore well as well as tube wells for domestic as well as agriculture needs.

2. Pollution of Ground Water: Unscientific waste disposal in the urban area coupled with improper sewage treatment pollutes the ground water.

3. Water Marketing: Heavy with drawal of ground water mainly in the summer months for water marketing results in the decline of water level.

Ground Water Management

Urbanisation has affected the quantity and quality of ground water in the district hence it is necessary to take steps to protect the ground water in the urban area. Artificial recharge and rainwater harvesting are the best suited and most effective method to augment ground water resource in the area (CGWB, 2009). The Thiruvananthapuram urban area consists of both hard rock and alluvium. Since water level in the alluvial area is shallow, artificial recharge can be considered only in the hard rock area. Usually in the urban area rainwater causes flood in some parts of the city and later the runoff is drained into the sea. Through roof top rain water harvesting and by using the excess filtered rain water to recharge ground water through dug wells and other abstraction structures the run off can be arrested to some extent.

A large number of ponds and water tanks are available in the urban area. Regular desiltation and scientific restoration of these ponds enhances recharge in the urban area. Gully plugs, recharge pits and trenches can be practiced in the midlands. Abandoned quarries present in and around urban areas like Pothencode and Venganoor can be effectively used for rainwater harvesting.

The successful demonstrative artificial scheme implemented by CGWB in the Secretariatbuilding, Thiruvananthapuram (2003) through Rain water harvesting and Artificial recharge can be replicated in other government buildings and educational institutions in the area.

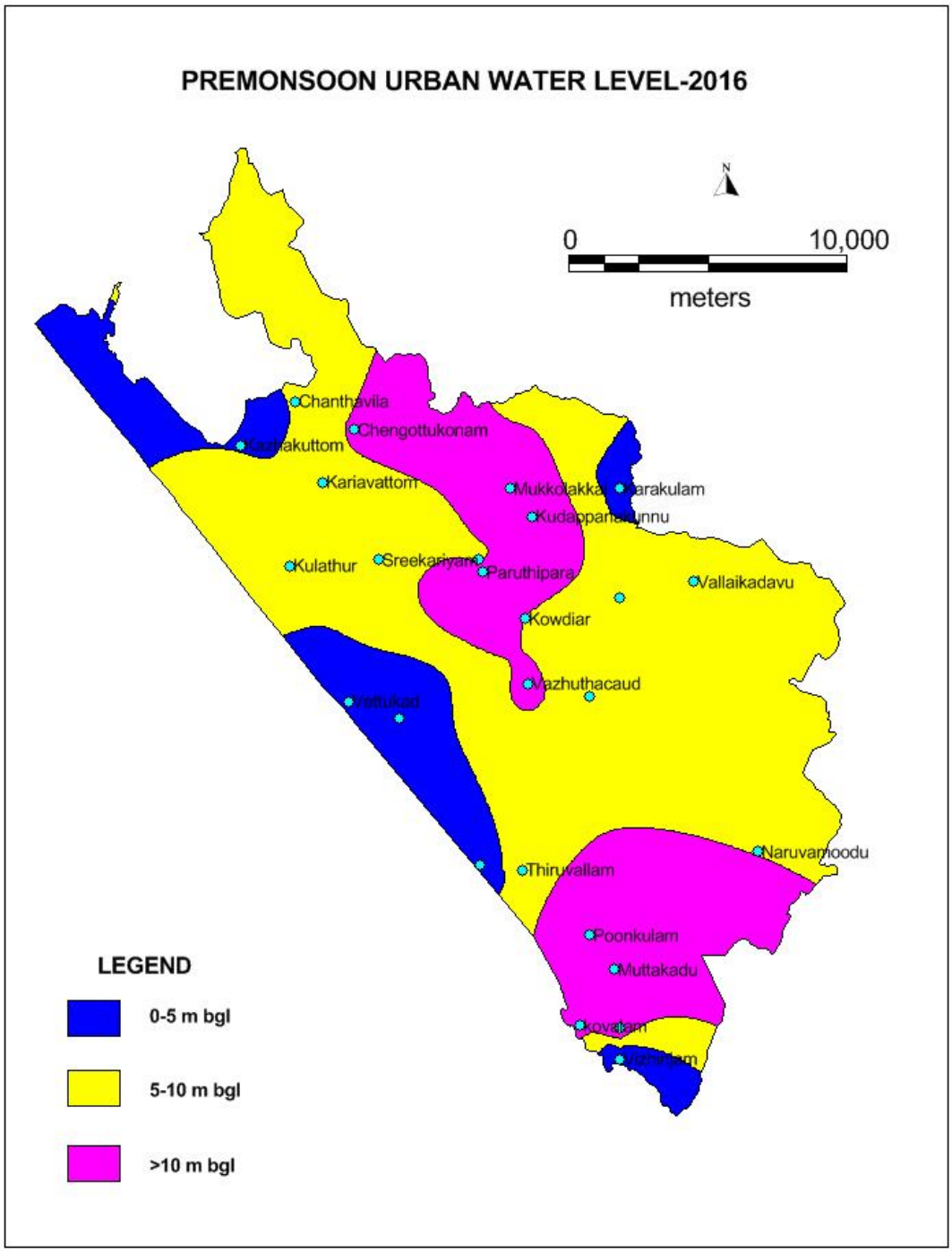


Fig.5.1: Pre monsoon Uraban Water level

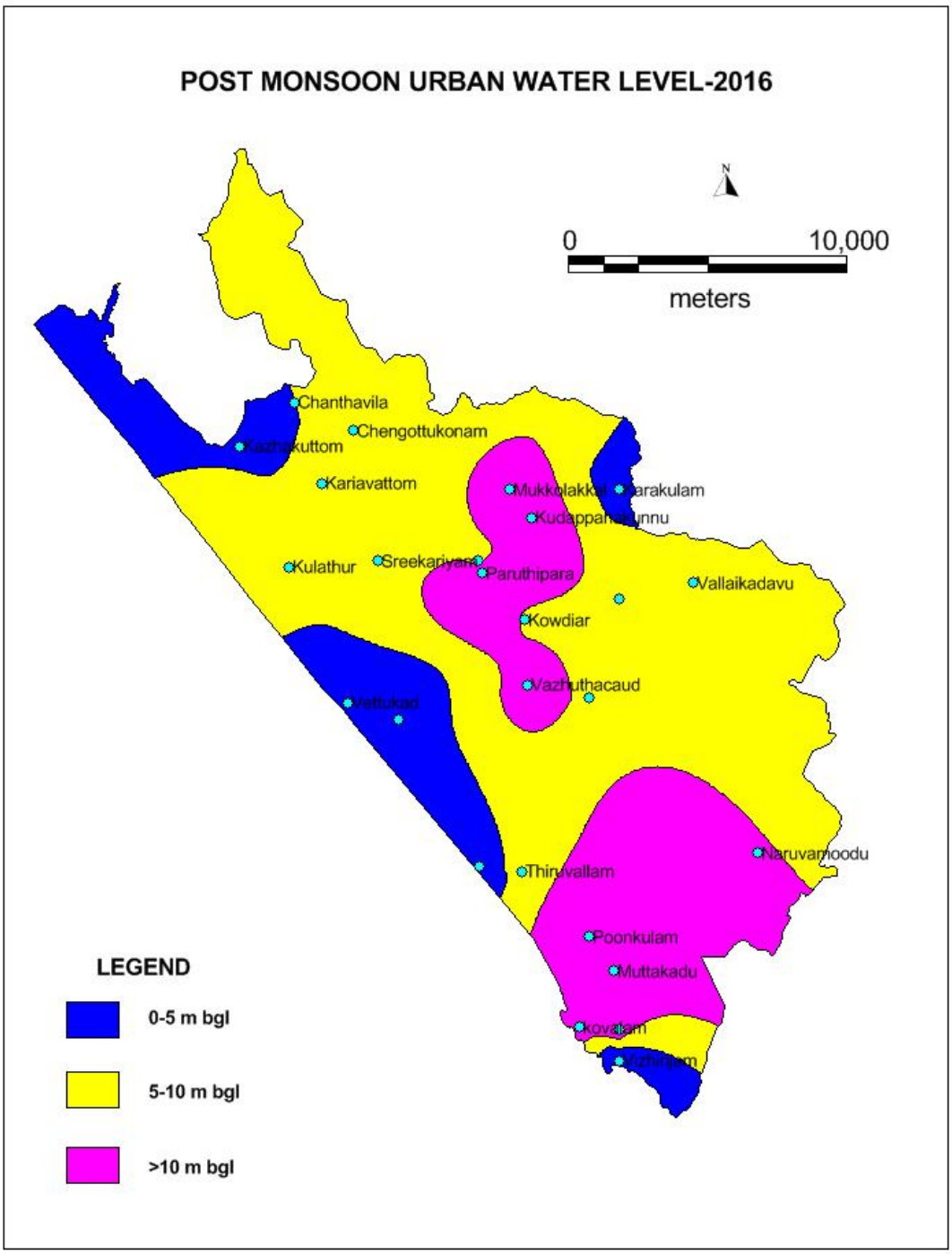


Fig.5.2: Post monsoon Uraban Water level

Annexure I: Litholog of exploratory wells drilled in the study area

Anad

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brownish, sticky	00.00 to 4.00	4.00	
Leptymite: Weathered, fine grained, leucocratic, pieces of quartz	04.00 to 10.50	6.50	
Leptymite: Massive, fine grained, leucocratic	10.50 to 17.00	6.50	
Leptymite: Well fractured, pieces of quartz and feldspar, feldspar partly altered	17.00 to 20.00	3.00	Water struck Discharge 0.5 lps
Leptymite: Massive, fine grained, leucocratic, more concentration of garnet	20.00 to 56.00	36.00	
Leptymite: Massive, fine grained, leucocratic, predominantly light coloured minerals and lesser amount of garnet	56.00 to 92.00	36.00	
Leptymite: Fractured, fine grained, pieces of quartz and altered pieces of feldspar	92.00 to 94.00	2.00	Discharge increased to 1.0 lps
Leptymite: Massive, fine grained, leucocratic, predominently light coloured minerals, few small fractures	946.00 to 128.00	34.00	
Leptymite: Massive, fine grained, leucocratic, more concentration of garnet	128.00 to 160.00	32.00	
Leptymite: Fractured, big pieces of quartz and concentration of garnet, leucocratic	160.00 to 163.00	3.00	Discharge increased to 3.0 lps
Leptymite: Massive, fine grained, leucocratic, predominently light coloured minerals	163.00 to 200.00	37.00	

Attukal

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to yellowish, hard at top	00.00 to 10.30	10.30	

Lithomargic clay: Yellowish to white, sticky	10.30 to 12.00	1.70	
Khondalite: Highly Weathered, partly clayey with pieces of quartz	12.00 to 16.50	4.50	
Khondalite: Massive, fine grained, leucocratic	16.50 to 38.00	21.50	
Khondalite: Massive, fine grained leucocratic, concentration of garnet	38.00 to 76.40	38.40	
Khondalite: Fractured, leucocratic good concentration of garnet, pieces of quartz	76.40 to 78.00	1.60	Water struck Discharge 0.5 lps
Khondalite: Massive, leucocratic, fine grained, more concentration of garnet and black minerals	78.00 to 111.00	33.00	
Khondalite: Massive, leucocratic mostly quartz and feldspar and less concentration of garnet	111.00 to 136.00	25.00	
Khondalite: Massive, fine grained, leucocratic few small fractures	136.00 to 172.00	36.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	172.00 to 200.00	28.00	

Bharathanoor

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brownish	00.00 to 2.00	2.00	
Khondalite: Weathred, grayish black, pieces of quartz	02.00 to 06.00	4.00	
Khondalite: Massive, fine grained, leucocratic	06.00 to 10.50	4.50	
Khondalite: Well fractured, medium grained, leucocratic, pieces of quartz and feldspar	10.50 to 14.00	3.50	
Khondalite: Massive, fine grained, leucocratic, presence of black minerals in minimum amount	14.00 to 38.00	24.00	
Khondalite: Well fractured, medium grained, leucocratic, presence of free graphite	38.00 to 41.00	3.00	
Khondalite: Massive, medium grained, leucocratic	41.00 to 57.00	16.00	

Khondalite: Massive, coarse grained, leucocratic, less amount of black minerals	57.00 to 77.00	20.00	
Khondalite: Massive, coarse grained, leucocratic, more concentration of garnet and black minerals	77.00 to 111.00	34.00	
Khondalite: Massive, fine grained, more concentration of graphite, few small fractures	111.00 to 145.00	34.00	
Khondalite: Massive, fine grained, leucocratic, few small fractures	145.00 to 166.00	21.00	
Khondalite: Well fractured, leucocratic, big pieces of quartz and feldspar	166.00 to 168.00	2.00	Water struck Discharge 0.3 lps
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	168.00 to 200.00	32.00	

Chenkavila

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to Yellow, hard at top	00.00 to 13.00	13.00	
Lithomargic clay: Yellowish and white coloured, soft	13.00 to 19.00	06.00	
Khondalite: Highly weathered grayish black, pieces of quartz	19.00 to 30.00	11.00	
Khondalite: Fractured, medium grained, grayish black	30.00 to 32.50	02.50	
Khondalite: massive, medium grained, grayish black	32.50 to 39.00	06.50	
Khondalite: Well fractured medium grained, grayish black	39.00 to 45.00	02.00	Water struck Discharge 2.0 lps
Khondalite: massive, medium to coarse grained, grayish black, good concentration of garnet and quartz veins	45.00 to 62.00	21.00	
Khondalite: Well fractured medium to coarse	62.00 to 68.80	06.80	Discharge increased to 3.0 lps

grained, grayish black, big pieces of quartz			
Drilling stopped at 68.30 m due to the falling of fractured rocks and subsequent struck up of drilling bit and drill rods			

Dhanuvachapuram

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to Yellowish Top hard and bottom clayey	00.00 to 10.00	10.00	
Clay: Yellowish to grayish hard, pieces of quartz	10.00 to 30.00	20.00	
Khondalite: Highly weathered, with pieces of quartz	30.00 to 32.00	2.00	
Khondalite: Massive, Fine grained leucocratic	32.00 to 36.80	4.80	
Khondalite: Fractured, medium grained, grayish black, pieces of quartz and pyrite mineralizations	36.80 to 39.00	2.20	Water struck Discharge 0.5 lps
Khondalite: Massive, medium grained, greyish black	39.00 to 49.00	10.00	
Khondalite: Fractured light coloured, Pieces of quartz, Pyrite concentration	49.00 to 53.00	4.00	Discharge increased to 1.0 lps
Khondalite: Massive, medium grained, more concentration of garnet	53.00 to 86.00	33.00	
Khondalite: Massive, medium grained, few small fractures, less concentration of garnet	86.00 to 128.00	42.00	
Khondalite: Massive, medium grained, few small fractures, more concentration of big garnet crystal	128.00 to 161.80	33.80	
Drilling stopped at 161.80 , because of very slow progress of drilling and massive nature of formation			

Kollode

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to yellowish	00.00 to 9.00	9.00	
Lithomargic clay: Yellowish to white, hard, sticky	09.00 to 13.00	4.00	
Khondalite: Weathered, coarse grained, pieces of quartz	13.00 to 16.40	3.40	
Khondalite: Fractured, coarse grained, leucocratic, pyrite mineralization	16.40 to 19.50	3.10	Water struck Discharge 0.3 lps
Khondalite: Massive, medium grained leucocratic, few small fractures	19.50 to 38.00	18.50	
Khondalite: Fractured, medium grained, pyrite mineralization	38.00 to 41.00	3.00	Discharge increased to 1.8 lps
Khondalite: Massive, leucocratic more concentration of feldspar and big pieces of quartz	41.00 to 56.00	15.00	
Khondalite: Massive, coarse grained, more concentration of garnet	56.00 to 75.00	19.00	
Khondalite: Fractured, coarse grained, more concentration of garnet and graphite	75.00 to 77.00	02.00	Discharge increased to 2.4 lps
Khondalite: Massive, medium grained, less concentration of black minerals	77.00 to 111.00	34.00	
Khondalite: Massive, medium grained, big pieces of quartz, few small fractures	111.00 to 120.00	9.00	
Khondalite: Massive, medium grained, leucocratic, more concentration of garnet	120.00 to 156.00	36.00	
Khondalite: Massive, medium grained, leucocratic, few small fractures	156.00 to 185.00	29.00	
Khondalite: Massive, medium grained, grayish black, more concentration of mica and graphite	185.00 to 200.00	15.00	

Kuravara

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clay: Brownish, sticky	00.00 to 4.00	4.00	
Khondalite: Weathered, medium grained, pieces of quartz	04.00 to 9.00	5.00	
Khondalite: Fractured, medium grained, leucocratic, concentration of graphite	09.00 to 12.00	3.00	Water struck Discharge 0.3 lps
Khondalite: Massive, fine grained grayish black, few small fractures, more concentration of garnet and dark minerals	12.00 to 40.00	28.00	
Khondalite: Highly fractured, big quartz pieces, feldspar, weathered	40.00 to 44.00	4.00	Discharge increased to 4.0 lps
Khondalite: Massive, fine grained, grayish black, quartz veins and pyrite mineralization	44.00 to 57.00	13.00	
Khondalite: Massive, fine grained, grayish black, rich concentration of garnet	57.00 to 77.00	20.00	
Khondalite: Highly weathered and fractured, big pieces, grayish black, concentration of free graphite	77.00 to 87.00	10.00	Discharge increased to 5.0 lps
Khondalite: Medium grained, grayish black, few small fractures	87.00 to 98.80	11.80	

Malayadi

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Garnetiferous gneiss: Weathered and fractured pieces of quartz	00.00 to 5.50	5.50	
Garnetiferous gneiss: Massive, fine grained, leucocratic few small fractures	05.50 to 40.00	34.50	
Garnetiferous gneiss: Fractured, leucocratic, pieces of quartz and feldspar	40.00 to 42.00	2.00	Water struck Discharge 0.2 lps

Garnetiferous gneiss: Massive fine grained, leucocratic	42.00 to 77.50	35.50	
Garnetiferous gneiss: Massive fine grained, leucocratic, more concentration of black minerals	77.50 to 86.50	9.00	
Garnetiferous gneiss: Massive fine grained, leucocratic, more concentration of garnet and less amount of black minerals	86.50 to 102.00	15.50	
Garnetiferous gneiss: Fractured, leucocratic, pieces of quartz and feldspar	102.00 to 104.00	2.00	Discharge increased to 0.5 lps
Garnetiferous gneiss: Massive, fine grained, leucocratic, few small fractures, more concentration of garnet	104.00 to 132.00	28.00	
Garnetiferous gneiss: Massive, fine grained, less amount of garnet and small pieces of quartz and feldspar	132.00 to 150.60	18.60	
Garnetiferous gneiss: Massive, fine grained, leucocratic, small grains of garnet	150.60 to 172.50	21.90	
Garnetiferous gneiss: Well fractured, leucocratic, pieces of quartz and feldspar	172.50 to 172.60	0.10	Discharge increased to 7.0 lps

Mammam EW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brownish	00.00 to 2.00	2.00	
Laterite: Brownish to yellowish, bottom clayey	02.00 to 07.50	5.50	
Khondalite: Weathered, pieces of quartz, medium grained, leucocratic	07.50 to 09.50	2.00	
Khondalite: Massive, fine grained, leucocratic, few small fractures	09.50 to 19.00	9.50	

Khondalite: Fractured, feldspar partly altered, concentration of black minerals	19.00 to 22.00	3.00	Water struck Discharge 1.0 lps
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	22.00 to 62.00	40.00	
Khondalite: Massive, fine grained, leucocratic less concentration of garnet	62.00 to 76.00	14.00	
Khondalite: Fractured and fracture filled with quartz and clayey materials	76.00 to 80.00	04.00	Discharge increased to 4.5 lps
Khondalite: Massive, fine grained, leucocratic less concentration of garnet	80.00 to 105.00	25.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet and black minerals	105.00 to 123.00	20.00	
Khondalite: Well fractured, pieces of quartz and feldspar, leucocratic	123.00 to 126.00	3.00	Discharge increased to 5.5 lps
Khondalite: Massive, fine grained, leucocratic, few small fractures	126.00 to 157.00	31.00	
Khondalite: Well fractured, pieces of quartz and feldspar, leucocratic	157.00 to 160.00	03.00	Discharge increased to 7.0 lps
Khondalite: Massive, fine grained, leucocratic, less concentration of garnet	160.00 to 175.00	15.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet and black minerals	175.00 to 200.00	25.00	

Mannanthala

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish, top hard and soft at bottom	00.00 to 04.50	4.50	
Khondalite: Weathered, Pieces of quartz	04.50 to 08.00	3.50	
Khondalite: Massive, fine grained, more concentration of garnet	08.00 to 12.00	4.00	
Khondalite: Fractured, leucocratic, pieces of quartz	12.00 to 14.00	2.00	Water struck Discharge 0.3 lps
Khondalite: Massive, fine grained, grayish black	14.00 to 48.00	34.00	

Khondalite: Massive, fine grained, concentration of black minerals	48.00 to 80.00	32.00	
Khondalite: Massive, fine grained, leucocratic, few small fractures	80.00 to 108.00	28.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	108.00 to 152.00	44.00	
Khondalite: Massive, fine grained, leucocratic, less concentration of garnet and black minerals	152.00 to 182.00	30.00	
Khondalite: Fractured, leucocratic, pieces of quartz	182.00 to 184.00	2.00	Discharge increased to 1.0 lps
Khondalite: Massive, fine grained, leucocratic	184.00 to 200.00	16.00	

Meenera

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to yellowish, hard at top and bottom clayey	00.00 to 13.50	13.50	
Khondalite: Weathered, slightly fractured, pieces of quartz	13.50 to 16.50	3.00	
Khondalite: Massive, medium grained, grayish black, more concentration of black minerals	16.50 to 38.00	21.50	
Khondalite: Fractured, grayish black, pieces of quartz	38.00 to 40.00	2.00	Wet sample
Khondalite: Massive, medium grained, grayish black, good concentration of black minerals	40.00 to 74.40	34.40	
Khondalite: Well fractured, pieces of quartz and feldspar, feldspar partly altered, grayish black	74.40 to 80.50	6.10	Water struck Discharge 1.0 lps

Nagarur

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brownish	00.00 to 2.00	2.00	
Laterite: Brownish to yellowish	02.00 to 6.00	4.00	
Lithomargic clay: Yellowish to white, sticky	6.00 to 10.00	4.00	
Khondalite: Weathered, pieces of quartz and feldspar, medium grained	10.00 to 16.50	6.50	
Khondalite: Massive, fine grained. leucocratic	16.50 to 22.00	5.50	
Khondalite: Fractured, fine grained, leucocratic	22.00 to 24.00	2.00	Water struck Discharge 1.0 lps
Khondalite: Massive, fine grained, leucocratic, more concentration of black minerals	24.00 to 57.00	33.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet and less amount of black minerals	57.00 to 90.00	33.00	
Khondalite: Fractured, big pieces of quartz and feldspar, feldspar partly altered	90.00 to 93.00	03.00	Discharge increased to 1.8 lps
Khondalite: Massive, fine grained, leucocratic	93.00 to 105.00	12.00	
Khondalite: Weathered and fractured, leucocratic, big pieces of quartz and feldspar, feldspar partly altered	105.00 to 109.00	4.00	Discharge increased to 7.0 lps
Khondalite: Massive, fine grained, leucocratic, few small fractures	109.00 to 141.50	32.50	

Nanniyode EW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brownish, sticky	00.00 to 2.00	2.00	

Clay: Grayish black, sticky	02.00 to 09.00	7.00	
Khondalite: Highly weathered to clayey, with pieces of quartz grayish black	09.00 to 16.40	7.40	
Khondalite: Highly weathered, mostly clay and sand	16.40 to 25.00	8.60	
Khondalite with pegmatite vein: Highly weathered and fractured, fractures filled with clay and concentration of graphite	25.00 to 42.00	17.00	
Khondalite with pegmatite vein: Weathered and fractured, big pieces feldspar and quartz	428.00 to 44.00	2.00	
Khondalite with pegmatite vein: Weathered, big pieces of quartz and feldspar, feldspar altered to clay	44.00 to 52,00	8.00	

Nemam EW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to Yellowish Top very hard and clayey at bottom	00.00 to 11.50	11.50	
Khondatlite: Weathered, grayish black, few fractures	11.50 to 19.50	8.00	
Khondalite: Massive, fine grained, grayish black	19.50 to 44.00	24.50	
Khondalite: Fractured, medium grained, more concentration of graphite	44.00 to 47.00	3.00	Water struck Discharge 0.1 lps
Khondalite: Massive, fine grained, more concentration of black minerals and less amount of garnet	47.00 to 78.00	31.00	
Khondalite: Massive, fine grained, few small fractures at different depth pieces of quartz, more concentration of garnet	78.00 to 128.00	50.00	

Khondalite: Massive, fine grained, grayish black, less amount of garnet	128.00 to 148.00	20.00	
Khondalite: Fractures, pieces of quartz, grayish black	148.00 to 150.00	2.00	Discharge increased to 0.2 lps
Khondalite: Massive, fine grained, varying concentration of garnet at different depths	150.00 to 193.00	43.00	
Khondalite: Fractured, grayish black, pieces of quartz	193.00 to 196.00	3.00	Discharge increased to 0.3 lps
Khondalite: Massive, fine grained, grayish black	196.00 to 200.00	4.00	

Neyyattinkara EW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to Yellowish	00.00 to 07.30	7.30	
Khondalite: Highly weathered, fractured, hard quartz pieces	07.30 to 19.50	12.20	
Khondalite: Weathered, fractured, coarse grained	19.50 to 22.50	3.00	
Khondalite: Slightly weathered, coarse grained, grayish black	22.50 to 25.00	2.50	
Khondalite: massive, medium grained, grayish black	25.00 to 31.70	6.70	
Khondalite: Fractured medium grained, grayish black, more concentration of garnet	31.70 to 36.70	5.00	Water struck at 32.0m Discharge 0.5 lps
Khondalite: Massive, medium grained, grayish black, garnet rich	36.70 to 47.00	10.30	
Khondalite: Well fractured medium grained, high concentration of garnet	47.00 to 50.00	3.00	Discharge increased to 2.8 lps
Khondalite: Medium grained, fear fractures, high concentration of garnet	50.00 to 57.00	7.00	

Khondalite: Well fractured, width mineralization of pyrite, medium grained	57.00 to 59.00	2.00	Discharge increased to 3.4 lps
Khondalite: Slightly fractured, less mineralization and less quantity of garnet, medium grained	59.00 to 62.20	3.20	
Khondalite: Massive, medium grained, less quantity of garnet	62.20 to 75.00	12.80	
Khondalite: Well fractured, medium grained, less garnet	75.00 to 77.50	2.50	Discharge increased to 6.0 lps
Khondalite: Massive, medium grained, few small fractures, less garnet	77.50 to 80.50	3.00	
Khondalite: Massive, medium grained, few small features, more concentration of garnet	80.50 to 101.80	21.30	

Neyyattinkara OW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to Yellowish	00.00 to 07.30	7.30	
Khondalite: Highly weathered, fractured, hard quartz pieces	07.30 to 19.00	11.70	
Khondalite: Fractured, coarse grained,hard quartz pieces	19.00 to 23.00	4.00	
Khondalite: Massive, medium grained, grayish black	23.00 to 26.60	3.60	
Khondalite: Fractured, medium grained	26.60 to 28.60	2.00	Water struck Discharge 0.5 lps
Khondalite: Massive, medium grained, grayish black concentration of garnet varies at different depths	28.60 to 65.20	36.60	
Khondalite: Massive, medium grained, more concentration of graphite and garnet	65.20 to 74.40	9.20	

Khondalite: Fractured, medium grained, pyrite mineralisations and more graphite	74.40 to 77.40	3.00	Discharge increased to 1.0 lps
Khondalite: Massive, medium grained, leucocratic, less concentration of garnet	74.40 to 89.60	15.2	
Khondalite: Massive, medium grained, few small fractures, leucocratic	89.60 to 129.30	39.70	
Khondalite: Massive, medium grained, concentration of graphite and garnet	129.30 to 151.00	21.70	
Khondalite: Fractured, medium grained, graphite concentration	151.00 to 153.00	2.00	Discharge increased to 1.8 lps
Khondalite: Massive, fine grained more concentration of graphite and varying concentration of garnet at different depths	153.00 to 190.300	37.30	Drilling stopped at 190.30 mtrs due to slow progress

Palayam EW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clay: Greyish to yellowish	00.00 to 09.00	09.00	
Garnetiferous Biotite Gneiss: Weathered, Greyish Black, mainly altered feldspar and quartz	09.00 to 18.00	09.00	
Garnetiferous Biotite Gneiss: Massive fine grained, leucocratic	18.00 to 44.00	26.00	
Garnetiferous Biotite Gneiss: Fractured, leucocratic, fine grained	44.00 to 47.00	03.00	
Garnetiferous Biotite Gneiss: Massive, fine grained, leucocratic, mainly quartz and feldspar. Garned and mica in small concentration	47.00 to 78.00	31.00	
Garnetiferous Biotite Gneiss: Fractured, leucocratic, pyrite mineralization	78.00 to 80.00	02.00	Wet sample
Garnetiferous Biotite Gneiss: Massive fine grained, leucocratic, varying concentration of garnet and Biotite at different depths	80.00 to 119.00	39.00	
Garnetiferous Biotite Gneiss: Fractured, leucocratic, feldspar partly altered	119.00 to 122.00	03.00	Water struck Discharge 0.5 lps

Garnetiferous Biotite Gneiss: Massive fine grained, leucocratic, more concentraition of garnet	122.00 to 154.00	32.00	
Garnetiferous Biotite Gneiss: Fractured, leucocratic, mainly quartz and feldspar and partly altered	154.00 to 192.00	2.00	Discharge increased to 1.5 lps
Garnetiferous Biotite Gneiss: massive fine grained, leucocratic, more concentration of biotote and less concentration of garnet	192.00 to 194.00	38.00	
Garnetiferous Biotite Gneiss: massive fine grained, leucocratic	194.00 to 200.00	06.00	

Peringamala

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brownish, fine grained	00.00 to 03.00	3.00	
Khondalite: Weathered, grayish black, pieces of quartz	03.00 to 07.00	4.00	
Khondalite: Massive, fine grained, grayish black	07.00 to 13.50	6.50	
Khondalite: Fractured, fine grained, grayish black	13.50 to 15.00	1.50	Water struck Discharge 0.4 lps
Khondalite: Massive, fine grained, more concentration of graphite	15.00 to 46.00	31.00	
Khondalite: Massive, fine grained leucocratic, more concentration of garnet, few small fractures	46.00 to 77.50	31.50	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	77.50 to 111.00	33.50	
Khondalite: Massive, fine grained more concentration of quartz and feldspar and less amount of garnet	111.00 to 142.00	31.00	
Khondalite: Fractured, fine grained, pieces of quartz	142.00 to 146.00	4.00	Discharge increased to 1.5 lps

Khondalite: Massive, fine grained, leucocratic, few small fractures	146.00 to 183.00	37.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	183.00 to 200.00	17.00	

Pattom

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to Yellowish top hard	00.00 to 09.00	9.00	
Lithomargic Clay: Yellowish to White coloures, soft	09.00 to 15.00	6.00	
Garnetiferous Biotite Gneiss: Highly weathered, Partly altered feldspar and quartz	15.00 to 21.00	6.00	
Garnetiferous Biotite Gneiss: Massive fine grained, leucocratic	21.00 to 30.00	9.00	
Garnetiferous Biotite Gneiss: Fractured, leucocratic, more concentration of quartz	30.00 to 33.00	3.00	
Garnetiferous Biotite Gneiss: Massive fine grained, leucocratic	33.00 to 59.00	26.00	
Garnetiferous Biotite Gneiss: Massive fine grained, leucocratic, more concentration of garnet	59.00 to 75.00	16.00	
Garnetiferous Biotite Gneiss: Fractured, leucocratic, fine grained, less amount of mica	75.00 to 78.00	3.00	Water struck Discharge 0.2 lps
Garnetiferous Biotite Gneiss: Massive light grey, mainly consists of quartz and feldspar	78.00 to 118.00	40.00	

Garnetiferous Biotite Gneiss: Massive light grey, fine grained, garnet and mica in small concentration	118.00 to 154.00	36.00	
Garnetiferous Biotite Gneiss: massive fine grained, mainly quartz and feldspar. Garnet and mica concentration varies at different depths.	154.00 to 200.00	46.00	

Thattathumala

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to yellowish, bottom clayey	00.00 to 9.00	9.00	
Khondalite: Weathered, coarse grained, grayish black, pieces of quartz	09.00 to 16.00	7.00	
Khondalite: Fractured, pieces of quartz and feldspar, grayish black, coarse grained	16.00 to 19.00	3.00	Water struck Discharge 0.2 lps
Khondalite: Massive, medium grained, grayish black, more concentration of black mineral	19.00 to 35.00	16.00	
Khondalite: Fractured, big pieces of quartz and feldspar, more concentration of black minerals	35.00 to 38.00	3.00	
Khondalite: Massive, fine grained, leucocratic	38.00 to 62.00	24.00	
Khondalite: Fractured, fine grained, leucocratic	62.00 to 65.00	3.00	
Khondalite: Massive, fine grained, more concentration of black minerals	65.00 to 98.00	33.00	
Khondalite: Massive, fine grained, leucocratic, mostly quartz and feldspar	98.00 to 120.00	22.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	120.00 to 150.00	30.00	

Khondalite: Massive, fine grained, more concentration of black minerals	1501.00 to 168.00	18.00	
Khondalite: Massive, fine grained, leucocratic, varying concentration of garnet and black minerals	168.00 to 200.00	32.00	

Tholikuzhy EW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to yellowish	00.00 to 7.50	7.50	
Khondalite: Weathered, pieces of quartz and feldspar, grayish black, coarse grained	7.50 to 11.00	3.50	
Pyroxene granulite: Well fractured, grayish black, coarse grained, fractures filled with secondary minerals	11.00 to 20.00	9.00	
Khondalite: Slightly fractured, coarse grained, grayish black	20.000 to 24.0050	4.00	
Khondalite: Well fractured, coarse grained, grayish black	24.00 to 27.00	3.00	Water struck Discharge 1.5 lps
Khondalite: Massive, fine grained, leucocratic, less amount of garnet	27.00 to 52.00	25.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of black minerals	52.00 to 81.00	29.00	
Khondalite: Massive, fine grained, more garnet and more	81.00 to102.00	21.00	

concentration of black minerals			
Khondalite: Massive fine grained, more concentration of garnet and less amount of black minerals	102.00 to 123.20	21.20	
Khondalite: Well fractured, big pieces of quartz and feldspar fractures filled with secondary minerals	123.20 to 125.00	01.80	Discharge increased to 10.0 lps

Tholikuzhy OW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Laterite: Brownish to yellowish	00.00 to 9.00	9.00	
Khondalite: Weathered and fractured pieces of quartz and feldspar, coarse grained	9.00 to 14.00	5.00	
Pyroxene granulite: Well fractured, coarse grained, grayish black	14.00 to 16.50	2.50	Water struck Discharge 0.5 lps
Khondalite: Massive, coarse grained, leucocratic, few small fractures	16.50 to 32.00	15.50	
Khondalite: Massive, fine grained, leucocratic, more concentration of black minerals	324.00 to 56.00	24.00	
Pyroxene granulite: Massive, coarse grained, few small fractures, grayish black	56.00 to 80.50	24.50	
Khondalite: Massive, fine grained, leucocratic	80.50 to 92.70	12.20	
Pyroxene granulite: Well fractured, coarse grained, grayish black	92.70 to 96.00	3.30	Discharge increased to 2.5 lps
Pyroxene granulite: Massive, grayish black, coarse grained	96.00 to 108.00	12.00	
Khondalite: Slightly fractured, leucocratic, fine grained	108.00 to 112.00	4.00	
Pyroxene granulite: Massive, grayish black, coarse grained	112.00 to 117.00	5.00	

Pyroxene granulite: Well fractured, coarse grained, grayish black, big pieces of rock	117.00 to 120.00	3.00	Discharge increased to 6.0 lps
Pyroxene granulite: Massive, coarse grained, grayish black, few small fractures	120.00 to 138.00	18.00	

Vellanad

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brown cloured	00.00 to 2.00	2.00	
Khondatlite: Weathered, coarse grained, pieces of quartz	02.00 to 10.00	8.00	
Khondalite: Fractured, coarse grained, leucocratic	10.00 to 20.00	10.00	
Khondalite: Massive, medium grained, leucocratic, more concentration of garnet	20.00 to 56.00	46.00	
Khondalite: Massive, medium grained, few small fractures, leucocratic	56.00 to 89.00	33.00	
Khondalite: Fractured, medium grained, leucocratic, pieces of quartz	89.00 to 92.00	03.00	Water struck Discharge 0.3 lps
Khondalite: Massive, fine grained, leucocratic, less concentration of black minerals	92.00 to 135.00	43.00	
Khondalite: Fractured, leucocratic, more concentration of garnet	135.00 to 137.00	02.00	Discharge increased to 0.5 lps
Khondalite: Massive, fine grained, leucocratic, less concentration of garnet	137.00 to 178.00	41.00	
Khondalite: Massive, fine grained, more concentration of black minerals	178.00 to 189.00	11.00	

Khondalite: Massive, fine grained, more concentration of light coloured minerals and less concentration of garnet	189.00 to 200.00	11.00	

Vellarada

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clay: Brownish to Yellowish	00.00 to 07.50	7.50	
Khondatlite: Weathered, medium grained, grayish black	07.50 to 08.50	1.00	
Khondalite: Massive, fine grained, grayish black, few small fractures, good concentration of graphite	08.50 to 44.00	35.50	
Khondalite: Fractured, light coloured, pyrite mineralization	44.00 to 46.00	2.00	Water struck Discharge 0.5 lps
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	46.00 to 74.00	28.00	
Khondalite: Fractured, pieces of quartz, more graphite concentration	74.00 to 77.00	03.00	Discharge increased to 1.3 lps
Khondalite: Massive, medium grained, leucocratic, few small fractures	77.00 to 112.00	35.00	
Khondalite: Massive, medium grained, more concentration of garnet, few small fractures	112.00 to 152.00	40.00	
Khondalite: Massive, medium grained, leucocratic	152.00 to 200.00	48.00	

Vettinad

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brownish, sticky	00.00 to 02.00	2.00	
Laterite: Brownish to yellowish , lithomorgic clay at bottom	2.00 to 08.00	6.00	

Khondalite: Weathered, grayish black, medium grained	08.00 to 16.00	8.00	
Khondalite: Fractured, pieces of quartz, concentration of black minerals	16.00 to 19.00	3.00	
Khondalite: Massive, fine grained leucocratic, mostly quartz and feldspar, black minerals are neligible	19.00 to 54.00	35.00	Water struck Discharge 0.8 lps
Khondalite: Massive, fine grained, leucocratic, more concentration of black minerals and garnet	54.00 to 77.00	23.00	
Khondalite: Massive, fine grained, leucocratic, mostly quartz feldspar and garnet	77.00 to 111.00	34.00	
Khondalite: Massive, fine grained, leucocratic, more black minerals and less concentration of garnet	111.00 to 129.00	18.00	
Khondalite: Fractured, leucocratic, pieces of quartz	129.00 to 132.00	3.00	Discharge increased to 1.5 lps
Khondalite: Massive, fine grained, leucocratic, less concentration of garnet and varying concentration of black minerals	132.00 to 172.00	40.00	
Khondalite: Massive, fine grained, leucocratic, few small fractures, varying concentration of garnet and mica	172.00 to 200.00	28.00	

Vithura EW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brownish to yellowish	00.00 to 04.00	4.00	

Clay: Brownish, sticky, pieces of Khondalite	04.00 to 07.00	3.00	
Khondalite: Weathered, medium grained, pieces of quartz	07.00 to 10.00	3.00	
Khondalite: Massive, medium grained, leucocratic, few small fractures	10.00 to 26.00	16.00	
Khondalite: Fractured, medium grained, pieces of quartz, pyrite mineralisation	26.00 to 29.00	3.00	Water struck Discharge 1.0 lps
Khondalite: Massive, fine grained leucocratic	29.00 to 35.00	6.00	
Khondalite: Fractured, fine grained, leucocratic, pieces of quartz and feldspar	35.00 to 41.00	6.00	Discharge increased to 3.0 lps
Khondalite: Massive, fine grained more concentration of graphite	41.00 to 75.00	34.00	
Khondalite: Massive, fine grained, pieces of quartz	75.00 to 111.00	36.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	111.00 to 124.00	13.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of black minerals	124.00 to152.00	28.00	
Khondalite: Massive, fine grained, leucocratic	152.00 to 178.00	26.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	178.00 to 200.00	22.00	

Vithura OW

Lithology	Depth Range (m bgl)	Thickness (m)	Remarks
Clayey soil: Brownish to yellowish	00.00 to 04.00	4.00	
Clay: Brownish, sticky, pieces of Khondalite	04.00 to 07.00	3.00	
Khondalite: Weathered and fractured, pieces of quartz	07.00 to 9.00	2.00	

Khondalite: Massive, fine grained, leucocratic, few small fractures	9.00 to 38.00	29.00	
Khondalite: Fractured, leucocratic, pieces of quartz	38.00 to 41.00	3.00	Water struck Discharge 1.0 lps
Khondalite: Massive, fine grained concentration of graphite	41.00 to 75.00	34.00	
Khondalite: Massive, fine grained, leucocratic, more concentration of garnet	75.00 to 92.70	17.70	Discharge increased to 3.0 lps

Annexure II: Water management practices proposed for some of the Panchayaths in the area

#	Panchayath	Area (sq km)	Block	Physiography	Other details	Management measures
1	Aaryanadu	104.92	Vellanad	Highland	Karamana river and its tributaries flows through the panchayath. ponds and wells are in plenty. 47 public wells and 42 bore wells. Water scarcity during summer.	Checkdam construction and rainwater harvesting pits
2	Kanjiramkulam	10.16	Athiyanoor	Midland (Plateau)	Drinking water schemes-kumili, karichal, nediyakala (borewell). 6 ponds and 5 thodu and springs. Of the 6 ponds 2 are polluted 7 useless. Drinking water scarcity and deep-water table. Neyyar canal flows through the panchayath but panchayath has no access to the canal water	Well renovation, new public water supply schemes by pipe line and from borewells. Pond renovation
3	Pulimathu	26.93	Kilimanoor	Midland	Vamanapuram river and Chittar a tributary of Vamanapuram river flows through the panchayath. Sand mining from river and paddy field is a major problem. Soil erosion. Water Scarcity in hilly terrain.	Rain water harvesting in public and private buildings. Pond renovation. Drinking water supply scheme. Cleaning and renovation of drinking water sources
4	Kilimanoor	19	Kilimanoor	Midland	Quarrying.	Cleaning and construction of Bunds in rivulets
5	Madavoor	18.53	Kilimanoor	Midland	Severe drinking water problem. Depends mainly on dug wells. Deep water level.	Check dam construction, renovation of ponds and rivulets. Drinking water

					Quarrying and land reclamation	supply schemes are needed. Rain water harvesting. Dug well recharge
6	Panavoor	21.9	Nedumangadu	Midland	Killi river originates in this panchayath and in summer the panchyath experiences drought. Dug wells, borewell, ponds and natural springs are the main source of Drinking water. Public pipped water supply is only in limited areas. Water from borewell not suitable for drinking.	Watershed management should start from the water divide to valley. Construction of bund in slopping areas. In gentle slopping area rain pit digging, Rainwater harvesting structure in drought hit areas. Hilly area- gullyplugging. Pond renovation, maintaining side wall of water resources through biological ways. Checkdam in the Aruvipuram area may mitigate the water scarcity problem of the area.
7	Aruvikkara	21.86	Nedumangadu	Midland	Killi and Karamana river flows through this panchayath. Aruvikkara Dam is located in this panchayath. Drinking water problem in summer months. Stone quarrying and sand mining	Extension of Piped water supply to drought hit areas. De-siltation of the Reservoir of Aruvikkara dam to increase the water holding capacity.
8	Anad	24.15	Nedumangadu	Midland	Killi river originates from this panchayath. muscovite	rain water harvesting through pits. Desiltation and side wall construction of ponds, rivulets and other water sources
9	Malayinkeezh	16.38	Nemom	Midland	Drinking water scarcity as no drinking water scheme exist in	conservation of Kombetti, Anappadu, machel-

					the panchayath. People depend on dug wells. Kallipara drinking water scheme (project on consideration) may fulfil the water needs to an extent. Mini water scheme (GWD) in Aruvippara, Mankunnu, Kottarakuzhi, Thachottukunnu is in final stage.	malayam micro watersheds. Pond renovation. Cleaning and retaining of ponds, rivulets and other water sources. Check dams in thodu. rain water harvesting through pits and ferrocement structures
10	Maranalloor	26.13	Nemom	Midland	30 thodu and 52 ponds. Stone quarry and land filling are problems. Neyyar canal and tributeries of Neyyar river flows through the panchayath. Drinking water scarcity during summer. Renovation of ponds and thodu. Rocky and hilly terrain.	Extension of pipelines
11	Parassala	20.02	Parassala	Midland		Watershed management. Mini water supply schemes. Renovation of public wells. Roof top rainwater harvesting structures
12	Ottashekaramangalam	18.14	Perumkadavila	Midland	Water scarcity in hilly area and in midland land areas during summer. Mainly depend on dug wells for drinking. Mandapathinkadavu drinking water scheme of Neyyar river provides drinking water through pipelines	Rainwater harvesting, soil and water conservation measures. Desiltation of ponds and the reservoir of Mandapathinkadavu water scheme. Public well cleaning and well recharge. Preservation of water sources.

13	Kunnathukal	26.85	Perumkadavila	highland	water scarcity, rocky terrain	Watershed management thorough soil and water conservation and rain water harvesting
14	Amboori	81	Perumkadavila	highland	Water scarcity in hilly area. 7 ponds, two large rivulets (thodu). Parts of Neyyar reservoir falls in this panchayath. Some tributeries of Neyyar river flows thorough the panchayath. Dug well is the main source of drinking water. Ongoing Kaalippara water supply scheme may fulfil the water needs of Amboori to some extent. rocky terrain	Rain water harvesting in ferrocement structures. Water shed management through soil and water conservation. Roof top rainwater harvesting and artificial recharge methods
15	Kollayil	13.73	Perumkadavila	Midland	Neyyar left canal flows through the panchayath. Rocky terrain, Water scarcity exists	Water and soil conservation. Renovation and maintenance of water sources. New irrigation methods like drip and sprinkler method. Rain water harvesting. Recharging of wells roof top rainwater harvesting
16	Kallikad	106.27	Perumkadavila	Midland	Neyyar reservoir and dam exists. Soil erosion, drinking water scarcity, drying up of water sources Land reclamations are the problems faced by the region.	Conserving the existing water resources, Rain pit, /piped water supply
17	Pothencode	20.85	Pothencode	Midland	Soil erosion, drinking water scarcity during summer. Rock quarry.	Renovation of ponds and other water sources. Make

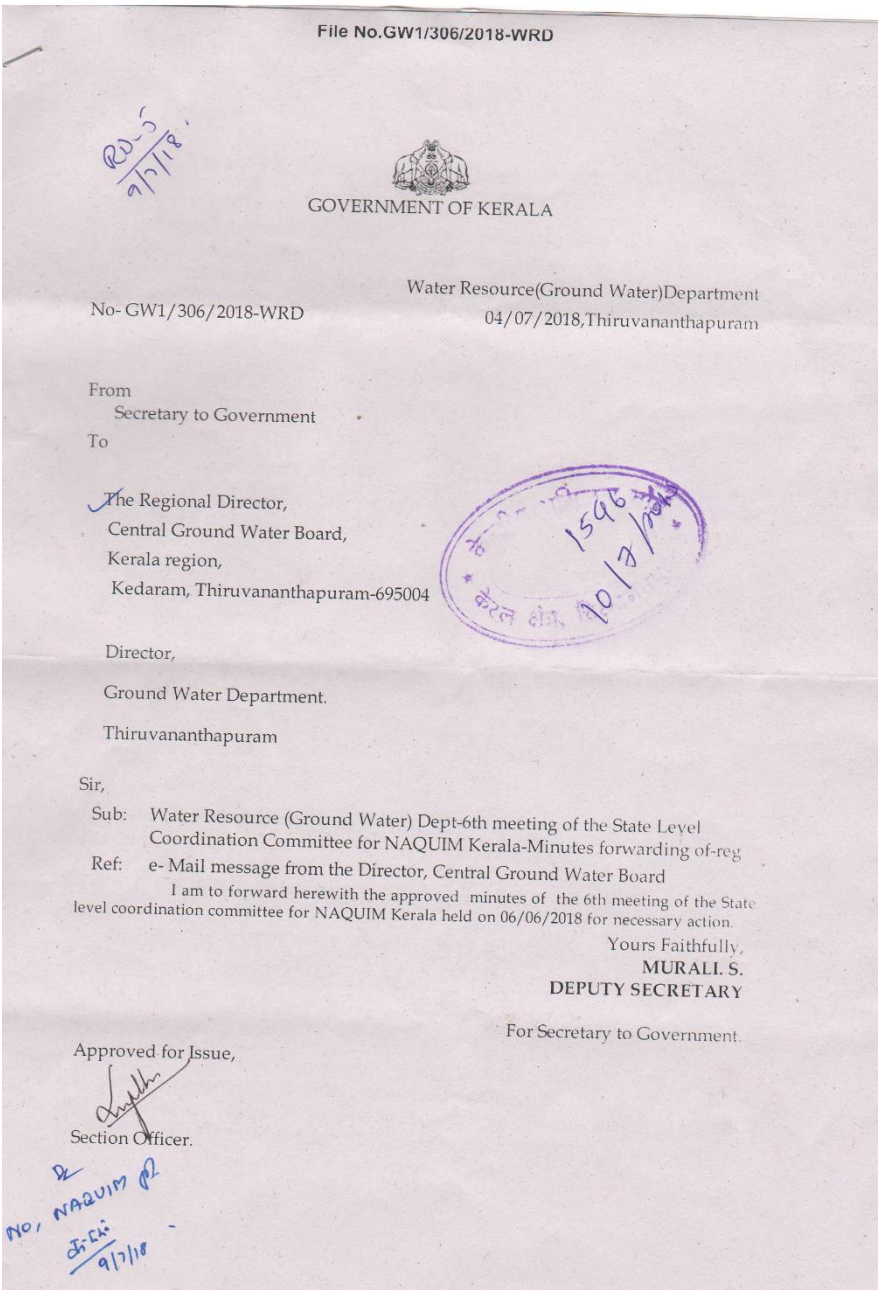
						use of abandoned stone quarries for water storage
18	Azhoor	12.52	Pothencode	Coastal	Water scarcity during summer. Mainly depend on dug wells for drinking.	Water shed has to be conserved. Renovation of ponds and wells. Make use of ponds
19	Andoorkonam	14.34	Pothencode	Coastal and mid	Drinking water through dug wells 15 public wells. High altitude area experiences water scarcity. No sufficient water supply schemes	Renovation and desilting of Aanathazhchira. Make use of Ootukulam for water supply. Rain water harvesting
20	Manikkal	32.59	Vamanapuram	Midland	Vellavoor thodu a tributary of Vamanapuram river flows through the panchayath. Water scarcity in hilly region especially during summer months and soil erosion are the problems	Renovation of ponds, and public wells. Recharge of Dug wells
21	Peringamala	217.94	Vamanapuram	highland	Tributeries of Vamanapuram river flows through the panchayath. Water scarcity during summer. Drinking purpose people depend on dug well, ponds and river	Side wall construction of thodu, Rain water harvesting pits. Construction of check dams. Soil and water conservation measures like contour bunding.
22	Nanniyode	38.85	Vamanapuram	Midland and high	Vamanapuram river flows through the panchayath. Water scarcity in hilly area in summer seasons	Rain pits and rain water harvesting structures.
23	Kallara		Vamanapuram	Midland	Vamanapuram and its tributeries which flows through the panchayath fulfil the water needs to some extent. Springs also exits here.	Scientifically management of the available water resources is needed. Mini Water supply schemes.

					Quarrying in some area and Sand mining and paddy field filling results in water scarcity. Muscovite and chrysoberyl. no much water scarcity. Scarcity in hilly area	
24	Pangode	36.47	Vamanapuram	Highland	Chittar a tributary of Vamanapuram river flows through the panchayath. Filling of field s and water canals results in severe water scarcity. Thodu (canals) dry during summer	Renovation of ponds. Rain water harvesting by check dam construction and other methods. Watershed management
25	Poovachal	30.06	Vellanad	highland	Hilly terrain experiences severe drinking water problem. Neyyar river flows thorough this area. 36 ponds and 18 public well. Neyyar irrigation Canal water is used for irrigation. Stone quarrying	Extension of Public piped water supply and by new mini water schemes. Checkdam construction in the Neyyar river help in recharging of the wells nearby. Rain water harvesting. Renovation of wter resources. Well recharge thorough rainwater. Cleaning of water sources.
26	Uzhamalakkal	18.74		High land	Karamana river, ponds and many rivulets flow through the panchayath. Water sources dry up in the summer	Maintenance and recharging of 25 panchayath wells. Watershed management. Rainwater harvesting. De siltation and conservation of rivulets and ponds.

27	Kattakada	22.54	Vellanad		Water scarcity, land reclamation, non-maintenance of water sources, failure in water conservation, soil erosion, water quality problem due to poor sewage maintenance are the problems	augmentation of recharging of water by conserving top soil, constructing roof top rain water harvesting structure and allowing the excess water after harvesting to recharge the ground water. Maintenance of side walls of canals by biological method.

Sh. V.R. Vinod, Additional District Magistrate, Thiruvananthapuram receives Draft report of Mapping and Management Plan of Hard Rock Aquifer System in Thiruvananthapuram District, Kerala State from CGWB and SGWD Officers

Minutes



File No.GW1/306/2018-WRD

GOVERNMENT OF KERALA

No- GW1/306/2018-WRD

Water Resource(Ground Water)Department
04/07/2018,Thiruvananthapuram

From
Secretary to Government
To

The Regional Director,
Central Ground Water Board,
Kerala region,
Kedaram, Thiruvananthapuram-695004

Director,
Ground Water Department.
Thiruvananthapuram

Sir,

Sub: Water Resource (Ground Water) Dept-6th meeting of the State Level Coordination Committee for NAQUIM Kerala-Minutes forwarding of-reg

Ref: e- Mail message from the Director, Central Ground Water Board

I am to forward herewith the approved minutes of the 6th meeting of the State level coordination committee for NAQUIM Kerala held on 06/06/2018 for necessary action.

Yours Faithfully,
MURALI. S.
DEPUTY SECRETARY

For Secretary to Government.

Approved for Issue,

Section Officer.

Minutes of the 6th meeting of the State Level Coordination Committee for NAQUIM Kerala

The Sixth meeting of the State Level Coordination Committee of National Aquifer Mapping Programme of CGWB was held on 06.06.2018 at 10.30 hours in the South Conference hall, Secretariat. Smt. Tinku Biswal, IAS, Secretary, Water Resources Department, Govt. of Kerala and Chairperson, SLCC of NAQUIM chaired the meeting.

The following Members attended the meeting:

Sl.No	Name & Designation	Organization	Status
1.	Joshy K.A., CE (Irrigation & Admin)	Irrigation	Member
2.	Shri V.Kunhambu, Regional Director	CGWB	Member Secretary
3.	Shri John Kurian , Former CGM	NABARD	Member
4.	Shri John Koshy, Executive Engineer	KWA	Member
5.	Joshy K.A., CE (Irrigation & Admin)	Irrigation	Member
6.	Dr. Mary Regina F, Professor	College of Horticulture, KAU	Member
7.	Shri Jayakumaran Nair, Deputy Director	Industries & Commerce	Member
8.	Shri A. G. Gopakumar, Senior Hydrogeologist	GWD	Member
9.	Dr. C.P. Priju, Scientist	CWRDM	Member
10.	Shri. C.V Joy, ADDC	Commissioner for Rural Development	Member
11.	Dr.N.Vinayachandran, Scientist D	CGWB	Invitee
12.	Smt.T.S. Anitha Shyam, Scientist D	CGWB	Invitee
13.	Smt. Minichandran, Scientist D	CGWB	Invitee
14.	Smt. Rani V R, Scientist C	CGWB	Invitee

Director, Agriculture Department & Director of Panchayaths did not attend the meeting.

At the outset, the Chairperson welcomed the members and invited Regional Director, CGWB to appraise the members of the developments and progress of NAQUIM as per agenda set up for the meeting. Shri V Kunhambu, Regional Director, CGWB, Kerala Region informed that all

actions as decided in previous meeting have been completed. Regional Director, CGWB appraised that Ground water modeling studies including Bharathapuzha basin has been taken up in AAP 2018-19. Regional Director informed that 22 exploratory wells are to be constructed in sedimentary areas as per NAQUIM recommendations has been allocated to WAPCOS which has been retendered to identify eligible bidders to take up the work. Followed by this item, a power point presentation on Aquifer Mapping and Management plan of Pathanamthitta and Trivandrum district were presented by Dr N Vinayachandran, Sc- D and Nodal Officer (NAQUIM), CGWB. The committee appreciated and approved the report. Chairperson also desired that after completion of the report, the management plans recommended to be shared with various departments such as Jalanidhi, Irrigation Dept., KWA & GWD.

Action: CGWB

Additional item:

Regional Director, CGWB informed that biological analysis of water samples has not done in NAQUIM area due to non-availability of equipments. Chairperson advised to collect the ground water Quality analysis data for biological parameters from State Departments like KWA, Public Health Lab, GWD, etc.

Action: CGWB, KWA, GWD, PHL & Irrigation

Regional Director, CGWB informed that the report will be complete only if we add a chapter on surface water resources, storage supply details like dam storage and canal supply along with the drinking water supply and status source wise by KWA. Chairperson assured the same and mentioned that CGWB can approach irrigation Department and KWA for the required details.

Action: Irrigation Department & KWA

The meeting ended with thanks to the Chair.

Minutes of the

Fourth meeting of the National Level Expert Committee

held under the Chairmanship of Chairman, CGWB

29th May 2018, 1st June 2018& 6th June 2018 at Faridabad/ New Delhi**.**

List of participants is annexed. (Annexure-I)

Fourth meeting of the National Level Expert Committee for review and finalization of aquifer maps and management plans was held during 29th May 2018, 1st June 2018 & 6th June 2018 at CGWB Faridabad/ New Delhi under the Chairmanship of the Chairman, CGWB. Presentations were made in respect of area covered in the states of Uttar Pradesh, Uttarakhand, Madhya Pradesh, Maharashtra, Tamil Nadu, Puduchchery, Andhra Pradesh, Kerala, West Bengal, Bihar,

Jharkhand, Chhattisgarh, North Eastern States and Odisha. Major decisions that emerged during the presentations/deliberations are summarized hereinafter.

Uttar Pradesh (16892 sqkm)

The work carried out under NAQUIM by NR Lucknow was reviewed. Major modifications were recommended in respect of data, maps and management plans. Committee suggested to restrict the presentation as per the prevailing guidelines and focus more on the outcomes of Management Plans. Various other improvements and modifications as suggested by the Committee is to be incorporated and duly appraised to concern administrative Member before representing all presentations to the committee again.

– **Action**: Member (N&W) / RD, NR, Lucknow.

Uttarakhand (3000 sqkm)

Presentations in respect of areas covered under Aquifer mapping by the UR, Dehradun were made by the respective RD/HOO. Presentations on Uttarkashi and Doiwala (Dehradun), is approved by the Committee with minor modifications and suggestion in management plans. Committee suggested that management plans should be made more comprehensive including area specific management options.

Action: RD/HOO, UR Dehradun/Member(N&W)

Madhya Pradesh (12769 sqkm)

Presentations in respect of area of Panna districts (6631 sqkm) covered under Aquifer mapping by the NCR, Bhopal were made by the officer of NCR CGWB in presence of RD. The committee suggested to include ground water development measures and expansion of agriculture and horticulture in proposed management plan apart from several minor suggestions. Committee approved presentation after inclusion of modification suggested and duly vetted by concerned Member.

– **Action**: Member(N&W) / RD, NCR, Bhopal

Himachal Pradesh (2400 sqkm)

Presentation on Nalagarh valley, Himachal Pradesh was made by Officers representing RD, NHR

Dharamshala. Expert Committee suggested inclusion of existing data of exploratory drilling, and ground water quality studies carried out in past to ascertain ground water quality scenario in the area. Committee recommended to include area specific measures in quantitative terms in management plan instead of recommending generic suggestions. Committee approved study with rider to revise Management Plan and inclusions of suggestions of the committee and duly vetted by the concerned

administrative Member.

- **Action**: Member(N&W) / RD, NHR, Dharamshala

Tamil Nadu (14154 sqkm)

Presentation of Lower Cauvery basin made by RD SECR, Chennai was also approved by the Committee with rider to include suggestions of NLEC in Consultation with concern

Administrative Member.

– **Action**: Member(S)/RD, SECR, Chennai

Maharashtra (14626 sqkm)

Presentation of aquifer mapping areas of parts of Pune, Sangli, Satara and Dhule was made by RD CR, Nagpur. The presentation was accepted by NLEC.

– **Action**: RD, CR, Nagpur

Andhra Pradesh (6950 sqkm)

Presentations in respect of area of East Godavari & West Godavari districts covered under Aquifer mapping by the SR Hyderabad were made by RD, SR, Hyderabad. The committee suggested to include creek regulators in management plan to manage tidal water to prevent saline water ingress. Committee approved presentation after inclusion of modification suggested and duly vetted by concerned Member.

- **Action**: Member(S)/RD, SR, Hyderabad

Kerala (6400 sqkm)

Presentation on Pattenamittha district, Kerala was made by RD, KR, Trivendrum. Expert Committee suggested that ground water resources to be estimated as per aquifer dispositions and their resource potentials. Incorporating resources estimation as per GEC-2015 can be restricted depict the extent of variance from GEC-2015 and Aquifer-wise resources under NAQUIM. Committee recommended to modify the management plan and duly vetted from respective administrative Member, CGWB. Presentation deemed approved by Committee.

- **Action**: Member(S)/RD, KR, Trivendrum

North Eastern States (8679 sqkm)

Presentation of East Sing district was made by officer from NER, Guwahati. The aquifer maps and management plan. In the similar line, the aquifer maps and management plans of 8679 sqkm of NE states was prepared and submitted. The committee also suggested that detail data on springs particularly in and around Shillong city may be incorporated in this report.

-**Action**: RD, NER, Guwahati /SOU, Shillong

Odisha (3101 sqkm)

Presentation of Kendrapada district was made by officer from SER, Bhubaneshwar. Thorough revision is required for aquifer maps and management plan for the areas of 3101sqkm as recommended by committee. Revised presentation should made as the circulated template.

-Action: Member (East)/RD, SER, Bhubaneshwar

West Bengal (2261 sqkm)

The officer from ER, Kolkata has presented the aquifer maps and management plan for parts of Nadia, district. Committee suggested that the ground water resources should be estimated as per the finding of Aquifer Mapping. The revised aquifer maps and management plans may be prepared as suggested and duly approved by Member In- charge. With these modification and revision committee approved the aquifer maps and management plans.

-Action: Member (East)/ RD, ER, Kolkata

Bihar (4627sqkm)

Officer from MER, Patna was presented the aquifer maps and management plan for Bhojpur, Patna, Buxar, Bhagalpur and Kathiar districts. The sections and maps may be modified and the exploration & water quality data interpretation may be carried out by better methods as suggested by committee. With these modifications, the aquifer maps and management plan were approved by committee.

Jharkhand (1702 sqkm)

-Action: Member (East)/ RD, MER, Patna

Presentation was made by officer from SUO, Ranchi for Sahebganj district (1702 sqkm). The committee suggested to consult GSI geological maps for better understanding of disposition of lava flows and Rajmahal Traps. The management plan can be improvised by incorporating the feasibility of ground water development through wells with pumps (Solar/Diesel/Electric). The revised aquifer maps and management plans may be prepared as suggested and duly approved by Member In-charge. With these modification and revision committee approved the aquifer maps and management plans.

-Action: Member (East)/ RD, MER, Patna/SUO, Ranchi

Chhattisgarh (8906 sqkm)

For an area of 8906 sqkm, the aquifer maps and management plans were presentation by officer form NCCR, Raipur. Committee suggested that the ground water resources should be estimated as per the finding of Aquifer Mapping. Through aquifer management plan, the state government may be suggested for better management option instead of presentpractice used by Chhattisgarh state of withdrawing the ground water to fill the ponds/lakes. The committee approved the aquifer Maps and management plan for areas presented during the meeting.

Action: Member (East)/ RD, NCCR, Raipur

The Expert Committee once again emphasized that during aquifer mapping studies ground water estimations should be made on aquifer –wise resources. Reflecting ground water resources estimation as per GEC 2015 methodology is not objective of Aquifer mapping. Further, the objective of NAQUIM should always be kept in mind by all the Regional Directorates. Presentations should be focused on objectives and desired outputs and possible outcomes. It is not appropriate to incorporate artificial recharge measures in all management plans as a thumb rule for ground water management. Areas with low development of ground water should suggest ground water development plans with area to be developed appropriately demarcated on maps based on agriculture demand.

- **Action**: All Regional Directors

National Level Expert Committee recommended major revision and repeat presentation for the states of

Uttar Pradesh, Madhya Pradesh and Odisha.

Meeting ended with thanks to the Chair.

Annexure-I: List of participants

1.	Shri K C Naik, Chairman, CGWB - in Chair
2.	Dr G.C.Pati, Member (East)
3.	Dr. E Sampath Kumar, Member (South)
4.	Shri Alok Dubey, Member (North and West), CGWB
5.	Dr. D K Chadha, Ex-Chairman, CGWB
6.	Shri Sushil Gupta, Ex-Chairman, CGWB
7.	Dr. A. K. Keshari, Professor, IIT, Delhi
8.	Dr. S. Mukherjee, Professor, JNU, New Delhi
9.	Dr. Bharat Sharma, Scientist Emeritus (WR), IWMI
10.	Dr. P.K. Purchure, Regional Director, CR, Nagpur
11.	Shri Sunil Kumar, Regional Director, RGI
12.	Shri S Marwaha, Regional Director, CGWB, Faridabad
13.	Shri C Paul Prabhakar, RD, SECR, Chennai
14.	Shri. Subba Rao, Regional Director, SR, Nagpur
15.	Shri Parvinder Singh, RD, NCR, Bhopal
16.	Shri. Y.B. Kaushik, Regional Director, NR, Lucknow
17.	Shri. V. Kunhambu, Regional Director, KR, Thiruvananthapuram
18.	Shri. M. Muttukkannan, Suptdg. Hydrogeologist, SWR, Bangalore
19.	Shri Sujeet Sinha, Scientist-D, CHQ, Faridabad
20.	Shri. S. K. Junejha, Scientist-D, CGWA, New Delhi
21.	Shri. Anurag Khanna, HOO, UR, Dehradun
22.	Shri. A. Ashokan, Scientist-D, SECR, Chennai
23.	Shri. Devendra Joshi, Scientist D, NCR, Bhopal
24.	Shri. M.K.Garg, Scientist-D, CHQ, Faridabad
25.	Shri Vidhya Nand Negi, Scientist D, NHR, Dharamshala
26.	Shri. Ratikant Nayak, Scientist-D, CHQ, Faridabad
27.	Shri. T. B.N. Singh, Scientist-D, SUO, Ranchi
28.	Dr. S. Brahma, Scientist-D, ER, Kolkata
29.	Shri. Tapan Chakroborty, Scientist-D, SUO, Shillong
30.	Shri. P. K. Tripathi, Scientist-D, NR, Lucknow
31.	Dr. S. K. Srivastava, Scientist-D, CHQ, Faridabad
32.	Shri Gulab Prasad, Scientist D, CGWB, SER, Bhubaneswar
33.	Shri S.N. Dewivedi, Scientist-C, CHQ, Faridabad
34.	Smt. Rumi Mukherjee, Scientist-C, CHQ, Faridabad
35.	Shri. Ravikalyan Bussa, Scientist-C, UR, Dehradun
36.	Shri. Dr. Vikas Ranjan, Scientist-C, NR, Lucknow
37.	Shri, Vidya Bhooshan, STA, NHR, Dharamshala
38.	Shri S.K.Swaroop, Scientist B (JHG), CHQ, Faridabad
39.	Shri. Debashish Bagchi, Asst. Hydrogeologist, CGWB, UR, Dehradun
40.	Ms. Shilpi Gupta, Scientist B (JHG), CHQ, Faridabad
41.	Shri. T. Madhav, Scientist-B, CHQ, Faridabad
42.	Smt. Ritu K. Oraon, Scientist-B,NCR, Bhopal
43.	Shri. P Yadaiah, AHG,CGWB, NewDelhi

Contributors' Page

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