केंद्रीय भूमि जल बोर्ड

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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

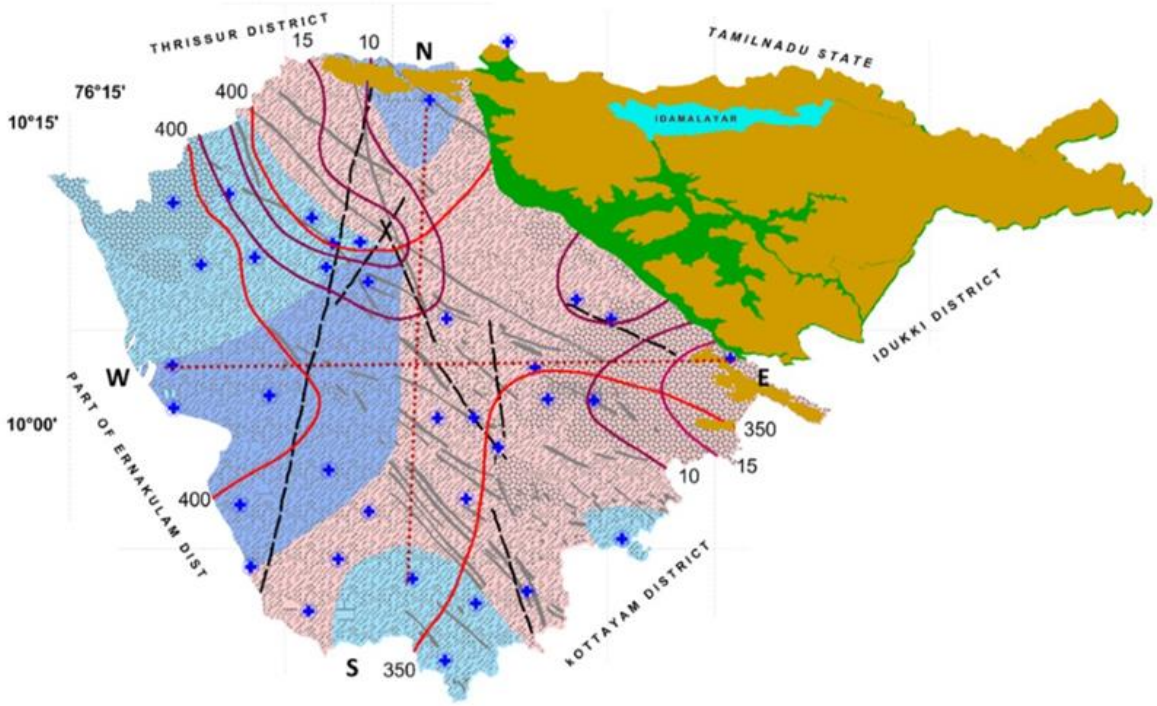
ERNAKULAM DISTRICT, KERALA

केरल क्षेत्र, तिरुवनंतपुरम

Kerala Region, Thiruvananthapuram

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
CENTRAL GROUND WATER BOARD

AQUIFER MAPPING AND MANAGEMENT PLAN FOR HARD ROCK TERRAINS OF ERNAKULAM DISTRICT, KERALA
(AAP: 2018-19)



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Kerala Region
Thiruvananthapuram
December,2019

FOREWARD

The National Project on Aquifer Mapping (NAQUIM) is an initiative of the Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, 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 Ernakulam 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 for hard rock terrains, Ernakulam 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, ground water regime monitoring, ground water quality, exploratory drilling, geophysical studies etc. 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 Ernakulam district.

This document has been prepared under the guidance of Dr. N. Vinayachandran, Scientist D & Nodal Officer, and Smt. Rani. V.R, Scientist C & Team leader. The painstaking efforts of the field hydrogeologist Sh. Roopesh G. Krishnan in carrying out the aquifer mapping and preparation of this report are well appreciated. 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, Thiruvananthapuram and 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.

This report evolved in the present form through incorporations and modifications as suggested during the presentation of the report before the State Ground Water Coordination Committee (SGWCC), Chaired by the Water Resources Secretary, Kerala State, Sh. B. Ashok, IAS and before the Deputy Collector & District Magistrate, Ernakulam district, Sh. S. Suhas, IAS. Their sincere efforts and encouragements for improvising the content of this report are acknowledged with gratitude.

I hope this compilation will be of much 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 Ernakulam district based on sound scientific foot.

Thiruvananthapuram,
December 2019

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AQUIFER MAPPING AND MANAGEMENT PLAN FOR HARD ROCK TERRAINS OF ERNAKULAM DISTRICT, KERALA (AAP- 2018-19)

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1.0 INTRODUCTION

1.1 Introduction

The Central Ground Water Board, Kerala Region carried out aquifer mapping under National Aquifer Mapping Programme (NAQUIM) in Hard Rock Terrains of Ernakulam district, during the annual action plan of 2018-2019. A better understanding of the hydrogeological processes that control the distribution and availability of groundwater in the weathered and fracture zones of the aquifer system is imperative for sustainable resource management. The sustainable development and management of hard rock aquifer system involves development of strategies for balancing the water draft and water availability. Integrated studies on various aspects of the groundwater regime have been carried out to know the disposition and productivity of the aquifer systems.

As per the Report of the Working Group on Sustainable Ground Water Management, "It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose. This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. The aquifer mapping approach can help to integrate ground water availability with ground water accessibility and quality aspects.

1.2 Objectives

The primary objective of the Aquifer Mapping can be summed up as "Know your Aquifer, Manage your Aquifer". Demystify the Science behind the storage and movement of groundwater to empower the stake holders in groundwater management is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst the stakeholders. This is an activity where the Government and the Community work in tandem. Greater the harmony between the two, greater will be the chances of successful implementation and achievement of the goals of the Project.

The National Aquifer Mapping envisages integration of information available on soil types, agro-climatic conditions, geomorphology, geology, hydrogeology, hydrochemistry, cropping pattern, irrigation statistics, forest cover etc., on a GIS platform and formulation of the ground water management plan for individual units of optimal size in accordance with the nature of the aquifer, its quality of water, sustainability and the stress on the resource.

In short, the main objective of aquifer mapping is to generate an aquifer map of the area in 1:50,000 scale and to develop aquifer management plan for aquifer sustainability. The mapping of the hard rock aquifer system has the following objectives.

- Define the aquifer geometry and characterize the aquifer systems
- Evaluate the spatio-temporal chemical quality of groundwater
- Identify the quantitative and qualitative issues of the aquifer systems
- Evaluation of the groundwater resources in each aquifer system
- Prepare an aquifer map of the area
- Evolve an effective Aquifer management Plan

1.3 Scope of the study

The important aspect of the aquifer mapping programme is the analysis of the large volume of data already generated during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set encompasses a host of activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of

additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale in GIS platform.

Water resources development in hard rock terrain in many parts of Kerala state poses a key issue in the management strategy. The sustainable aspect of the water resources in this state necessitates the need for a better water resources management. Thus, the present aquifer mapping on the hard rock area of Ernakulam district envisages the ground water requirement and its utilisation, thereby an environmentally sustainable management plan is proposed/finalised.

1.4 Approach and Methodology

National Aquifer Mapping Programme basically aims at characterizing the geometry, parameters, behaviour of ground water levels and status of ground water development in various aquifer systems to facilitate planning of their sustainable management. The major activities involved in this process include compilation of existing data, identification of data gaps, and generation of data for filling data gaps and preparation of various thematic maps depicting hydrogeology, hydrology, geomorphology, water quality etc. and cross-sections, panel diagrams and elevation models depicting aquifer geometry and dispositions on 1:50,000 scale Aquifer Maps and preparation of 2-D and 3-D models.

Based on the above studies, management strategies have been evolved for augmentation of groundwater through water conservation and formulated plans for sustainable management of the resource.

1.5 Basic Geography and Administration

The hard rock terrain of Kerala covers an area of about 33,500 sq.km which is about eighty-eight percentage of the geographical area of the State. Current study (AAP 2018 - 19) area is located eastern part of the Coastal Aquifer System of Ernakulam district, which, was mapped during the AAP-2014-15. In Ernakulam district, out of 3068 sq.km area, hard rocks area covers 1,638 sq.km followed by hilly and forest area of 706 sq.km in the eastern part mainly covers the highland and a good portion of midland area.

Geographically, the hard rock aquifers of Ernakulam district are located between North latitude of 9°47'54", & 10° 17' 33" and East longitude of 76° 14' 04" & 76° 50' 2" comprising an area of 1638 sq.km. The study area falls in the Survey of India Topographic sheets 58C/5,9 & 58B/7,8 ,11 ,12 &16 (1:50,000 scale). The area of study covers four taluks viz. Aluva, Muvattupuzha, Kothamangalam & Kunnathunad, nine municipalities (Aluva, Angamaly, Muvattupuzha, Koothattukulam, Kothamangalam, Tripunithura, Perumbavoor) in which Elur and Trikkakara are partly covered, six blocks completely (Angamaly, Koovapady, Kothamangalam, Muvattupuzha, Pambakuda and Vazhakulam), five blocks partly covered (Alangad, Edappally, Mulanthuruthy ,Parakkadavu and Vaduvacode) comprising 61 gram panchayaths and 74 revenue villages. The administrative division map of the study area is given in Fig. 1.1. The study area is bordering on the north by Thrissur District, east by Idukki District & Tamil Nadu State, south by Kottayam District and west by coastal sediments of Ernakulam District.

Population of the district is 32,82,388 as per 2011 census. The total population of the study area is 16,38,781 which is about 50% of the total population of the district. The average population density is 1000 persons per sq km. The population details as per census 2011 of the study area are given in Table 1.1. The study area is well connected by good networks of roads and rails and with other parts of the state. The National Highway (NH 544 and NH 66) passes through the western part of the study area and the State Highways viz., Main Central Road, SH-1,

SH-416, SH-41, SH-43 & SH-44 is connected in all major cities in the area. In addition to road network & rail, water transport system exists in the western part of the district. The Nedumbassery International airport is in the district.

Fig. 1.1 Administrative divisions of the study area

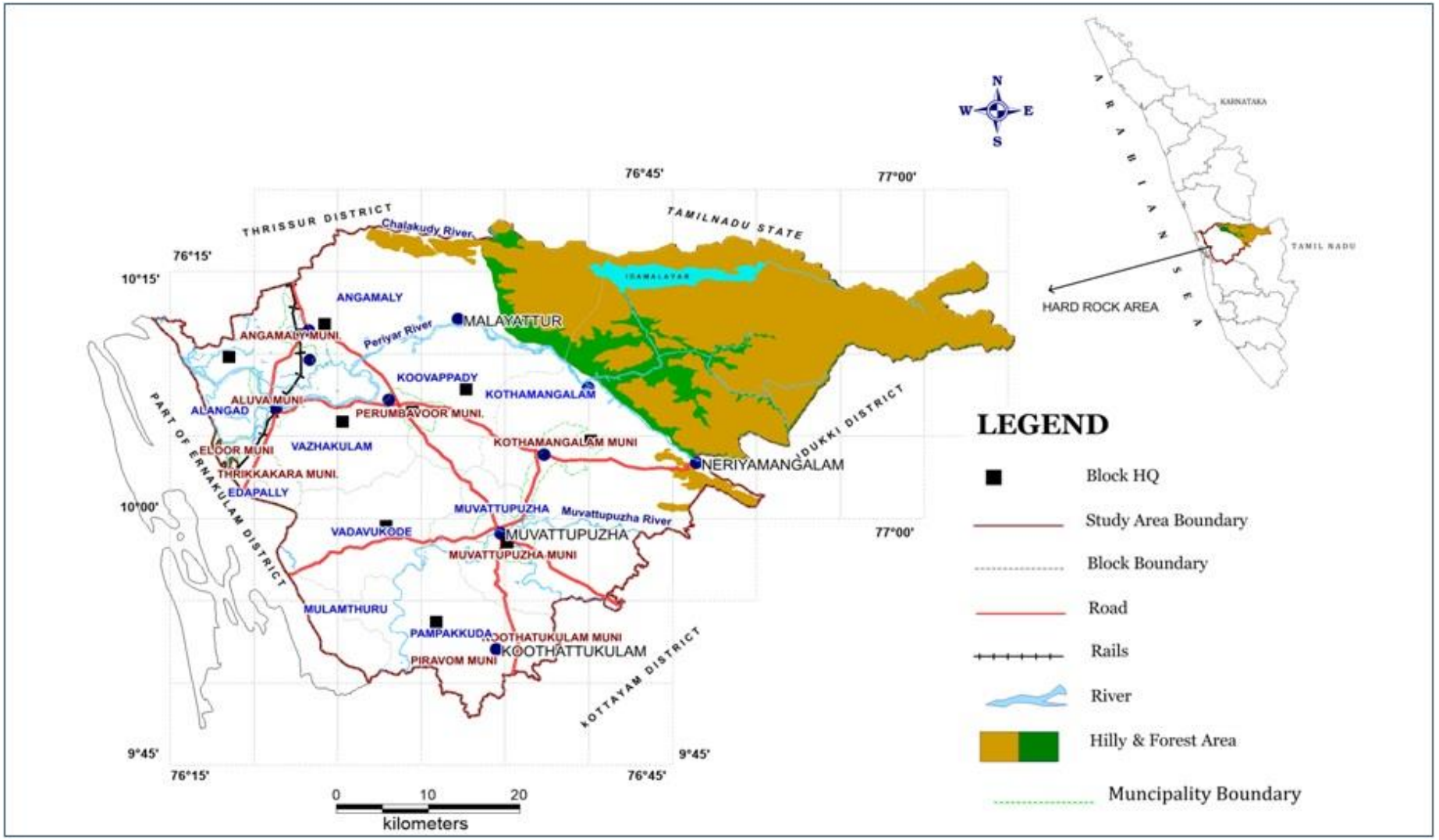


Table 1.1: Population data of the study area

Block	Area, sq.km	Population as on 2011	Rural Population	Urban Population
Alangad (p)	30	56555	0	56555
Angamaly	211.97	201449	113930	87519
Edappally (p)	4	26077	546	25531
Koovappady	355.61	155752	100384	55368
Kothamangalam	229.97	201588	167759	33829
Moovattupuzha	199.8	162329	150753	11576
Mulamthuruthy (p)	35	154992	32428	122564
Pampakkuda	177.4	141476	141476	0
Parakkadavu(p)	70	139853	47199	92654
Vadavukodu(p)	131	159833	114574	45259
Vazhakkulam	193.28	238877	51142	187735
Total	1638	1638781	920191	718590

Source: Census 2011

1.6. Data availability

During the Aquifer mapping, existing data of CGWB on groundwater exploration, water level, water quality, geophysical logging and groundwater resource data have been collected and compiled. In addition to this, Borewell data, Water quality, Water level data and Groundwater exploration data have been collected from Ground water Department, Ernakulam. Cropping pattern, Minor irrigation data and Soil data has been collected from Agricultural and Soil conservation Department. Thematic layers such as geology (GSI), soils, land use/land cover, geomorphology, etc., from various State Government agencies were collected, complied and used in this study.

1.7. Data adequacy

Exploratory well data is available for 46 wells drilled by CGWB and State Departments. Water level monitoring data for 193 Observation wells and Water Quality monitoring data for 134 Observation wells is available. Land use, Cropping and irrigation data has been collected from Agriculture department. After plotting the available historical data on 1:50,000 scale, data gaps were identified and data generation process was taken up in those gap areas to complete the Aquifer map on the desired resolution of 1:50,000 scale.

1.8. Data gap analysis & Data generation

Scientific data on groundwater regime available with State and central agencies were utilised for optimizing additional data requirements. Additional data were generated on ground water levels, litholog, aquifer properties, water quality were incorporated and interpreted with the objectives of generating a 3-D visualization of the aquifer systems in the area. Identification of gaps in the existing data on various aspects of the aquifer being mapped.

The study area has 113 monitoring wells of CGWB and 80 monitoring wells of State departments, tapping the phreatic aquifer system. Ten observation wells tap both phreatic and fracture aquifers. Additional 60 key wells for hydrogeological studies and 68 wells for water quality monitoring were established in the phreatic aquifer. Six bore wells drilled in data gap area, down to a depth of 200m to know the litholog, aquifer properties and water quality of confined aquifer system. Similarly, based on the data gap analysis 50 new VES data have been generated to know the vertical characteristics of the aquifer systems. The details of data gap analysis and data generation is compiled (Table 1.2).

Table 1.2: Data gap analysis and data generation

#	Items	Data available with State /central govt. Agencies	Data available with CGWB	Total	Additional Data generated
1	Ground water level data	70 DW+ 10Pz	97 DW+ 16 PZ	193	60
2	Groundwater quality Data	70	Dug wells-30nos. Bore wells -34 nos.	134	72
3	Borehole Lithology Data	12	34	46	6
4	Geophysical Data (VES)	0	35	35	50
5	Pumping Test (EW/DW)	55	10	65	66
6	Land use and Land Cover	Kerala State Land Use Board & NRSC			
7	Drainage	Kerala State Land Use Board			
8	Geology	Geological Survey of India			
9	Soil	National Bureau of Soil Survey (NBSS)			
10	Rainfall / Meteorological data	Indian Meteorological Department / Irrigation Design and Research Board (IDRB)			

1.9 Climate and Rainfall

Wet type of climatic conditions prevails in the study area. The district experiences heavy rainfall during southwest monsoon season followed by northeast monsoon and records less rainfall during January to May months. March, April and May are the hottest months. December to February is the coldest months. The district receives on an average 3549 mm (based on 1901-99 data) of rainfall annually. Based on the rainfall data isohyetal map were prepared for the study area (Fig 1.2). The annual rainfall ranges from 3233 to 3456 mm at different places of the district with an average of 3360m. The rainfall is less in the western part of the district and gradually increases towards the east. Maximum rainfall is received around Neriamangalam area in the eastern part where the normal annual rainfall is found to be 5883 mm. The annual average rainfall of Ernakulam district from 2007 to 2018 is given in Table 1.3. South-west monsoon season contributes nearly 67.4% of total rainfall of the year, followed by the north-east monsoon which contributes nearly 16.6% and the balance of 16% is received during the month of January to May as summer showers. The area faced unprecedented flood during 01.06.2018 to 22.08.2018 due to heavy downpour of 2477.8mm against the normal rainfall 1680.4 mm.

Table 1.3: Monthly Rainfall of Ernakulam district (2007-2018)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2007	1.9	1.4	9.2	146.5	193.5	815	1133	480.1	667.3	522	66.1	9.8	**2883.21**
2008	3	30.8	329.6	129.1	137.7	455.1	539	326.2	555.1	304	37.4	36.9	**4045.8**
2009	10.4	0	45.8	89.5	315.7	615.1	839	312.2	497.4	177	290	70.1	**3262.2**
2010	9.8	0	30.5	233.8	239.9	849.9	691	356.5	456.9	625	517.5	63.2	**4074**
2011	26.3	98.2	37.3	147.1	241	897.5	605.4	605.5	527.8	156.5	123.8	34.3	**3500.7**
2012	7.1	18	43	401.8	100.9	414.1	370.9	494.7	274.6	299.4	176	9.7	**2610.2**
2013	6.3	65.3	48.8	37.8	151	1258.7	826.5	374.7	314.2	318.7	211	45.2	**3658.2**
2014	0	11.1	22.4	90.7	287.9	550.1	650.2	877	298.8	434.8	119	94	**3435.5**
2015	2.4	0.5	37.2	229.3	176.2	573.9	367.2	241.2	393.8	355	333	182	**2891.5**
2016	0.4	91.4	3.4	43.8	322.8	624.6	620.4	238.7	85.7	160.5	115	19.5	**2326.3**
2017	16.8	0	97.9	31.4	306	706.3	435.4	415.8	445.3	293	217.8	28.1	**2993.8**
2018	1.4	7.1	52.5	193.2	324.9	833.5	1044.2	648.4	63.1	402.7	246.9	56.6	**3874.5**

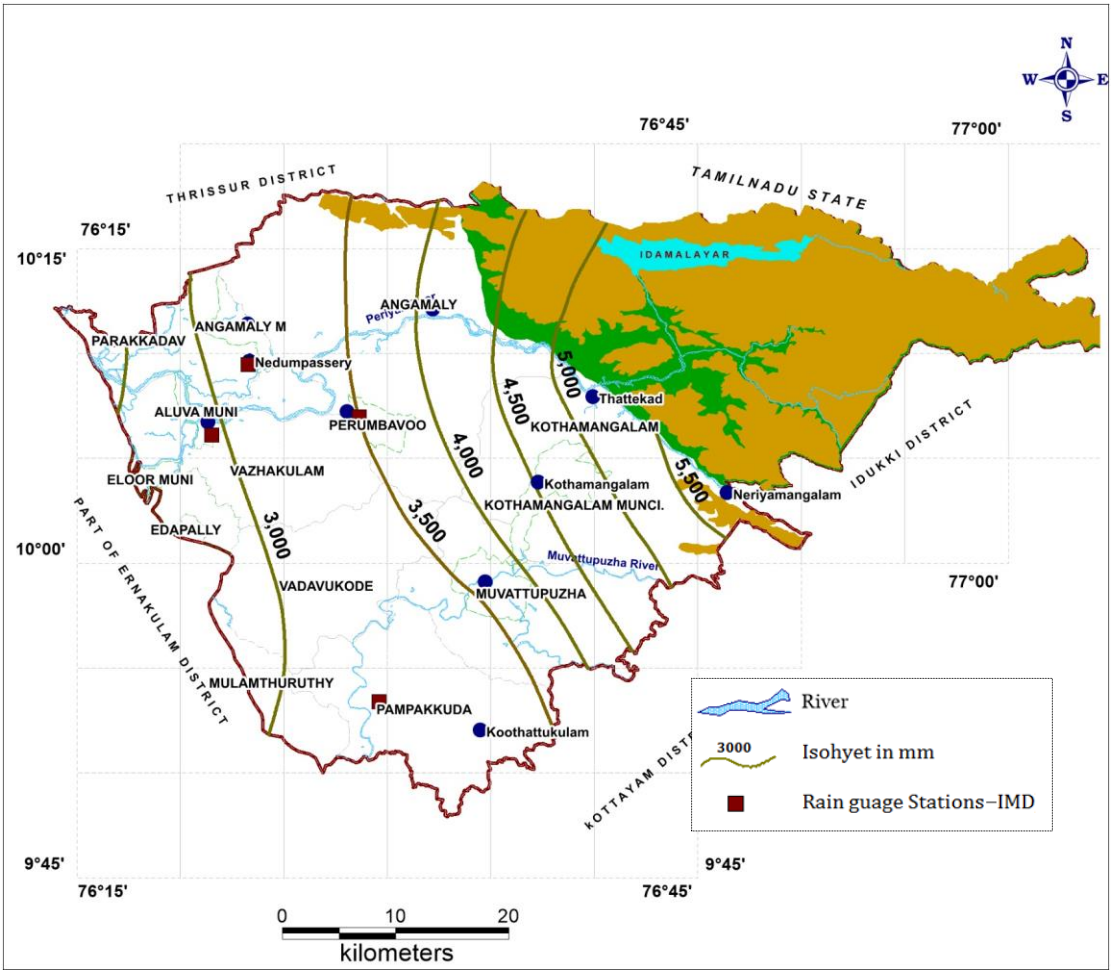
Source: IMD, Thiruvananthapuram

Meteorological parameters

The mean monthly maximum temperature ranges from 32.1 to 38^{0}C and the minimum ranges from 23.2 to 25 ^{o}C. The maximum temperature occurs during March and April months and the minimum temperature occurs during December and January months. Relative Humidity ranges from 68 to 89% during morning hours and 64 to 87% during evening hours. The maximum humidity is observed during May to October months. Evaporation is more during summer months of January to April and it is low during the rainy months May to August. The maximum rate of 4.8 mm per day is recorded in March and the lowest rate of 2.6 mm is recorded during July. Sunshine ranges from 4.3 to 9.7 hours/day. Maximum sunshine is during the month of February. The months from June to August record the minimum sunshine due to the cloudy sky. Generally good sunshine hours are recorded in the months from November to May. The wind speed ranges from 6.7 to 10.9 km/hour with mean speed of 9.1 km/hour. The wind speed is high during the period from March to September.

Potential Evapotranspiration (PET) ranges from 94.5 to 159.2 mm. The maximum PET occurs during March and minimum occurs during June. The PET is less than the rainfall from May to November indicating water surplus for recharge into ground water regime.

Fig. 1.2: Isohyet map of the Study Area



1.10 Physiography

Physiographically, the district can be divided into three distinct units lowland region (coastal plains), midland region and highland region. The various landforms seen in the area are carved out by a combination of fluvial and denudational activities. The lowland or coastal plain is the area with an elevation of less than 7.6 m above msl dominated by the presence of number of back waters (Vembanad back water) channels with a gently sloping terrain made up of Tertiary and Quaternary Formation which fringes the western part of the study area.

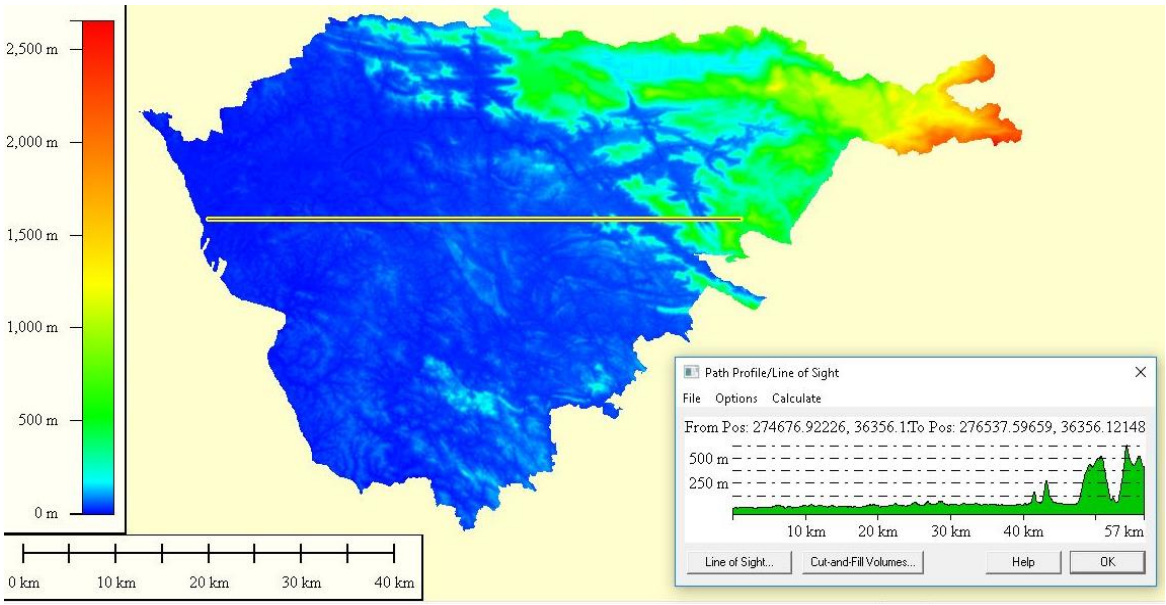
In midland region, with an area of 1218 sq.km rises gently from coastal plain in the west to an elevation of 76 m amsl characterised by rugged topography comprising small flat-topped low mounds and broad valleys and having a maximum width of about 45 km. This region is partly covered by laterite on the west and has exposures of crystalline rocks in the east. The Tertiaries and the basement crystalline rocks of the midland area are extensively lateritised. The thick column of lateritic soil in this region supports the growth of coconut and rubber. This region is intensively cultivated.

The highly rugged terrain in the eastern part of the district represents the highland where the elevation is more than 76 m above msl which is covered mainly by forests and are characterised by steep hills, narrow gorges and precipitous escarpments. Natural growth and urban development take place in the midland and low land regions.

The midland to highland region which occupies the maximum part of the study area. Major parts of the catchment of river Periyar and Muvattupuzha fall within this unit. The height of Ghats generally decreases from North to South. There are several peaks above 500 meter and the highest elevation is noticed to be 2567m amsl. For a clear understanding of the topography, Digital Elevation Model (DEM) of the study area draped over the hill shade map is given in Fig. 1.3.

From the DEM, it is very clear that study area is occupied by plateaus and flat-topped hills on the western to central part while the eastern part is represented by highly rugged topography with several peaks. The general slope is towards west. It is depicted from the DEM major portion of Kothamangalam block is in highland while in the remaining blocks midland predominates.

Fig. 1.3: Digital Elevation Model (DEM) of the study area



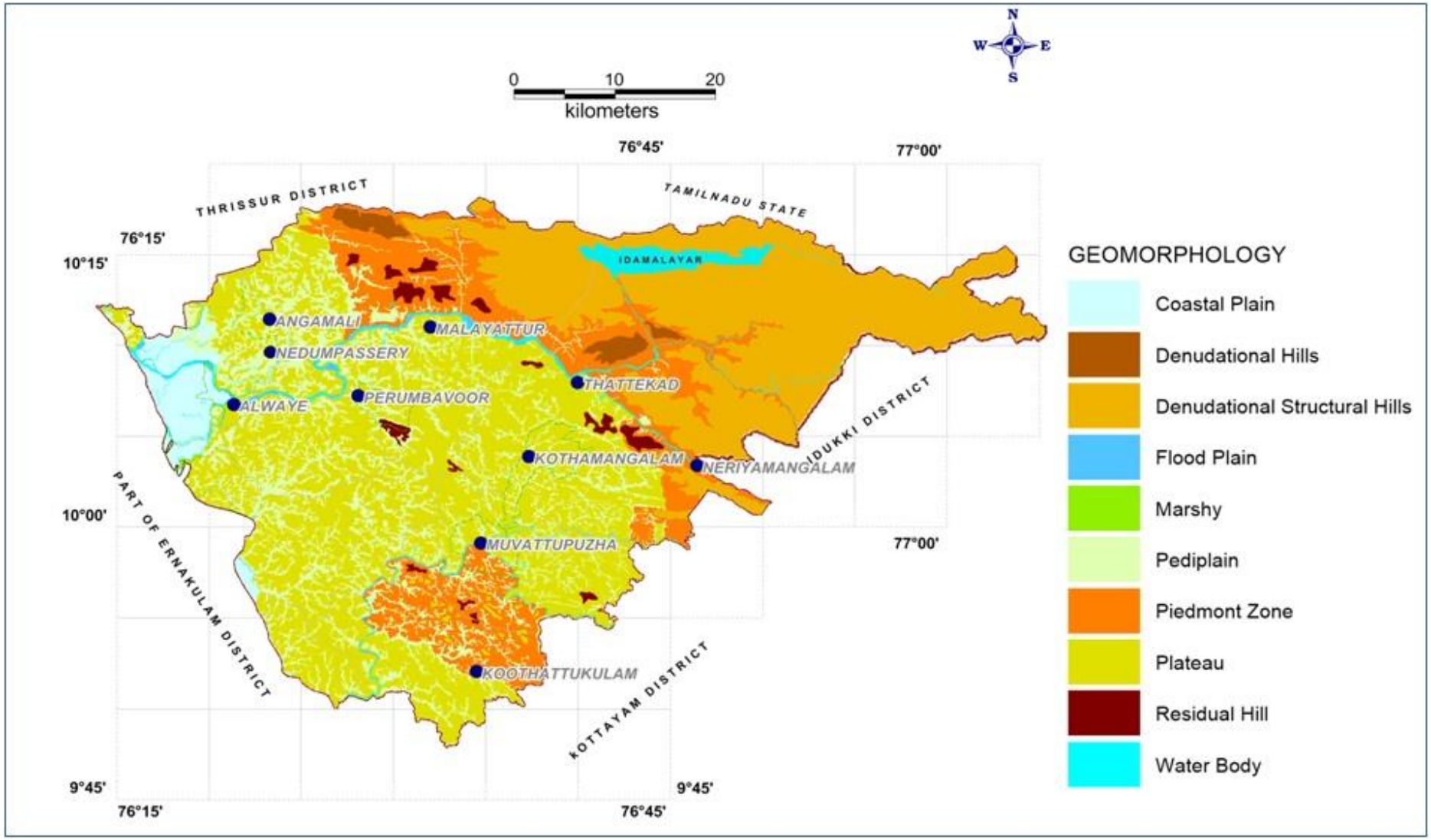
1.11 Geomorphology

Geomorphologically, the landforms in the study area are carved out by a combination of fluvial and denudational activities which can be grouped into erosional and depositional landforms. The various geomorphic units seen in the area are plateaus, pediplains, piedmont zone, flood plain, residual hill, denudational hills and structural hills (Fig. 1.4). A portion of coastal plain with few meters thickness is observed in north western part near to Elur area.

The narrow coastal plain on the west is flanked by highly dissected pediplain towards east that represent erosional landforms formed as a result of fluvial and denudational activities. These undulating pediplain are dissected with broad valleys and isolated low mounds. Majority of the area are characterised by plateaus with pediplain

The lower dissected piedmont plains are characterised by undulating to rolling topography with low hills and narrow valleys. The hills are generally covered with laterite or lateritic soils and the valleys are alleviated. The easternmost part is a rugged terrain with steep sloped hills and small summits. It forms the foothills of the Western Ghats. Elevation of this terrain is generally more that 80m above mean sea level and the area is covered by thick reserved forest.

Fig. 1.4: Geomorphology of the study area



1.12 Land Use/ land cover

Land use/ land cover pattern of an area is very important from groundwater point of view since the availability and development of this resource depends upon the surface run-off and infiltration which are controlled to a large extent by the type of land use/ land cover. Based on land use, the study area is divided into three units – arable, forest land and waste land. Major part of the district is arable land which includes irrigated and unirrigated land. Forest is mostly in the east in part of the study area, within which some areas are developed as rubber and cashew plantations. Extensive waste land formed of hard laterite which is unsuitable for cultivation lies in the midland region.

According to Agricultural Statistics for 2017-18 and District Irrigation Plan of Ernakulam District, the data on land use pattern of the study area reveals that agriculture area is 64 % and forest and hilly area occupies around 24 % for the eastern part of the study area and is not being mapped, shown in Fig 1.5. The land use classification of the district has been classified into 15 different types of land uses and the details are given in Table 1.4 and 1.5.

Table 1.4: Classification of area based on land utilisation of Ernakulam district

Land Units	Area (Sq. Km)
Forest	706.17
Land put to non-agricultural use	452.56
Barren & uncultivable land	3.49
Land under misc. tree crops	1.13
Cultivable waste	150.40
Fallow other than current fallow	65.91
Current fallow	79.99
Still Water	111.71
Water Logged Area	2.90
Social Forestry	1.05
Net area sown	1482.95
Area sown more than once	163.01
Total cropped area	1645.96

Source: Agricultural Statistics 2017-18

Table 1.5: Classification of area based on land utilisation of study area

Land Units	Area (Sq.Km.)
Net sown area	1048
Gross cropped area	1083
Cropping intensity %	1.03
Land under non-agricultural use	186.64
Cultivable wasteland	41.7
Barren and uncultivable land	13.06
Current fallows (up to 1 year)	37.89
Other fallows (up to 1 to 5 year)	45.69

Source: District Irrigation Plan, Ernakulam district (2018)

The block wise distribution of various land use units in different blocks of the study area is given in Table 1.6. From the pie chart (Fig. 1.6) it is very clear that agricultural land is the

predominant land use in the study area, which was main control on the occurrence and availability of groundwater. But while formulating the ground water management plans the cultivable waste land should be considered.

Fig. 1.5: Land use /land cover map of the study area

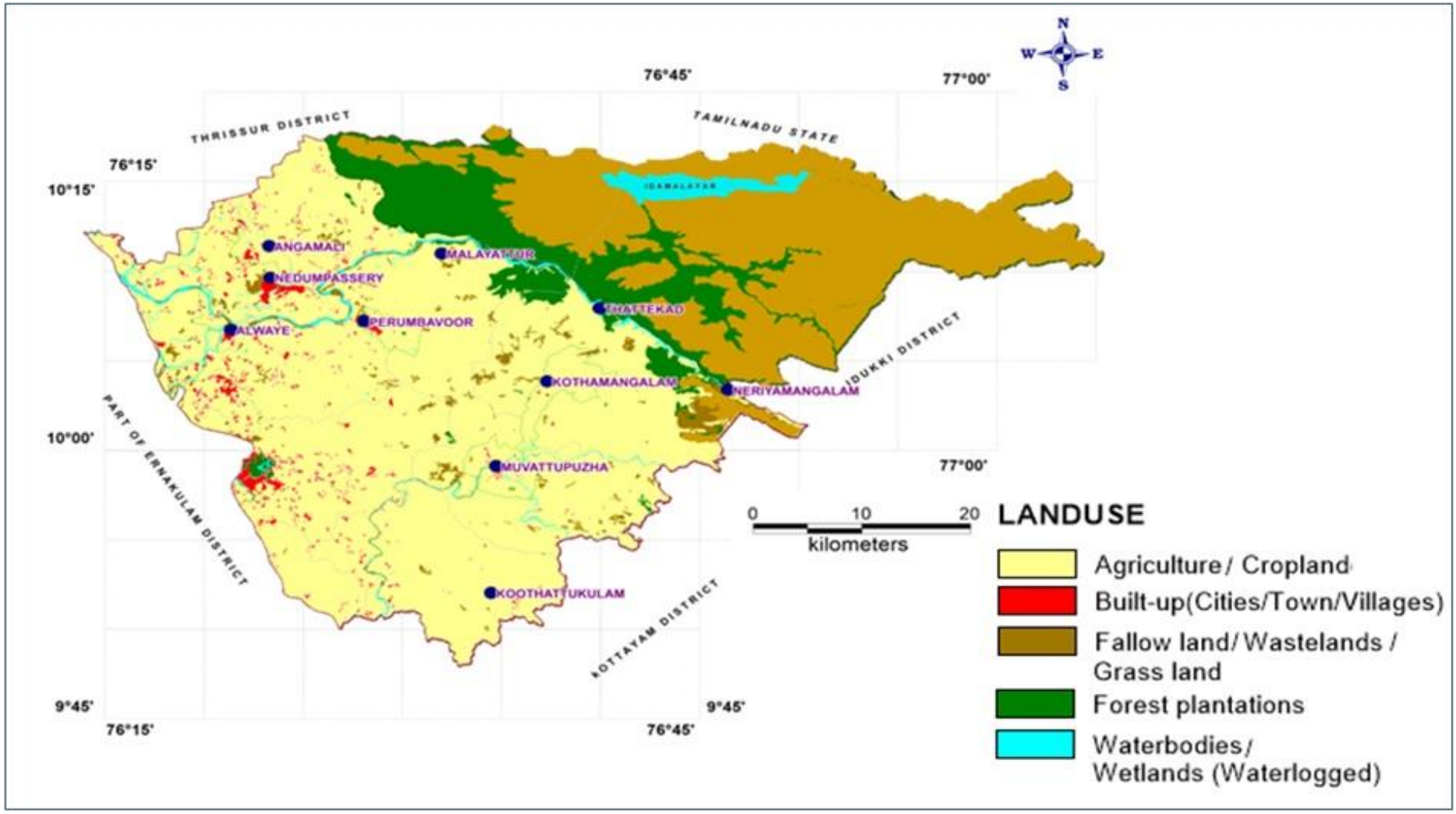
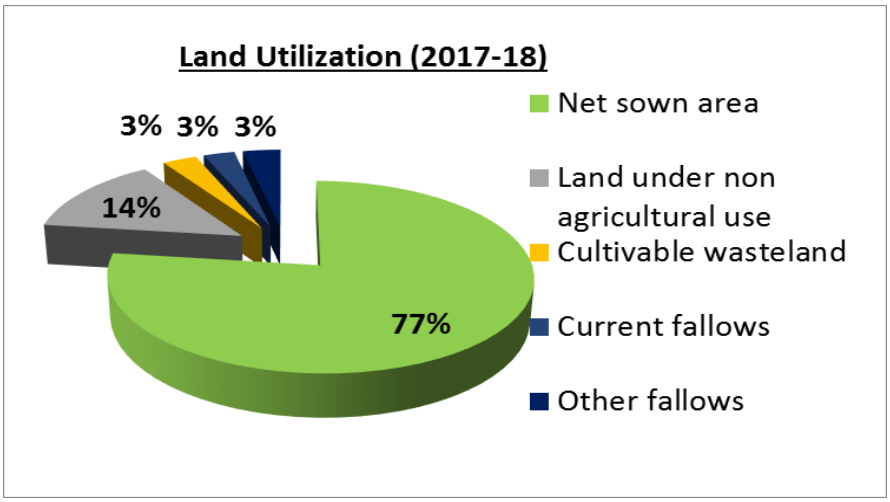


Table 1.6: Block-wise distribution of various land use units in sq.km.

Block	Agricultural Land	Forest	Waste land	Other uses
Alangad	41.35	0	8.55	35.19
Angamaly	95.13	200	12.64	71.35
Edapally	35.07	3	6.57	76.64
Vazhakulam	52.06	0	2.63	65.9
Kothamangalam	254.92	626.87	4.31	133.18
Mulanthuruthy	30.67	0	0.13	133.43
Muvattupuzha	140.47	0	4.22	69
Parakadavu	76.16	0	2.7	49.69
Vadavucode	135.15	0.68	2.06	46.85
Koovapady	105.39	16.67	1.65	58.82
Pampakuda	144.11	0	0.74	132.18

Source: District Irrigation Plan Ernakulam District, 2018

Fig. 1.6: Pie chart showing the distribution of land use units in study area



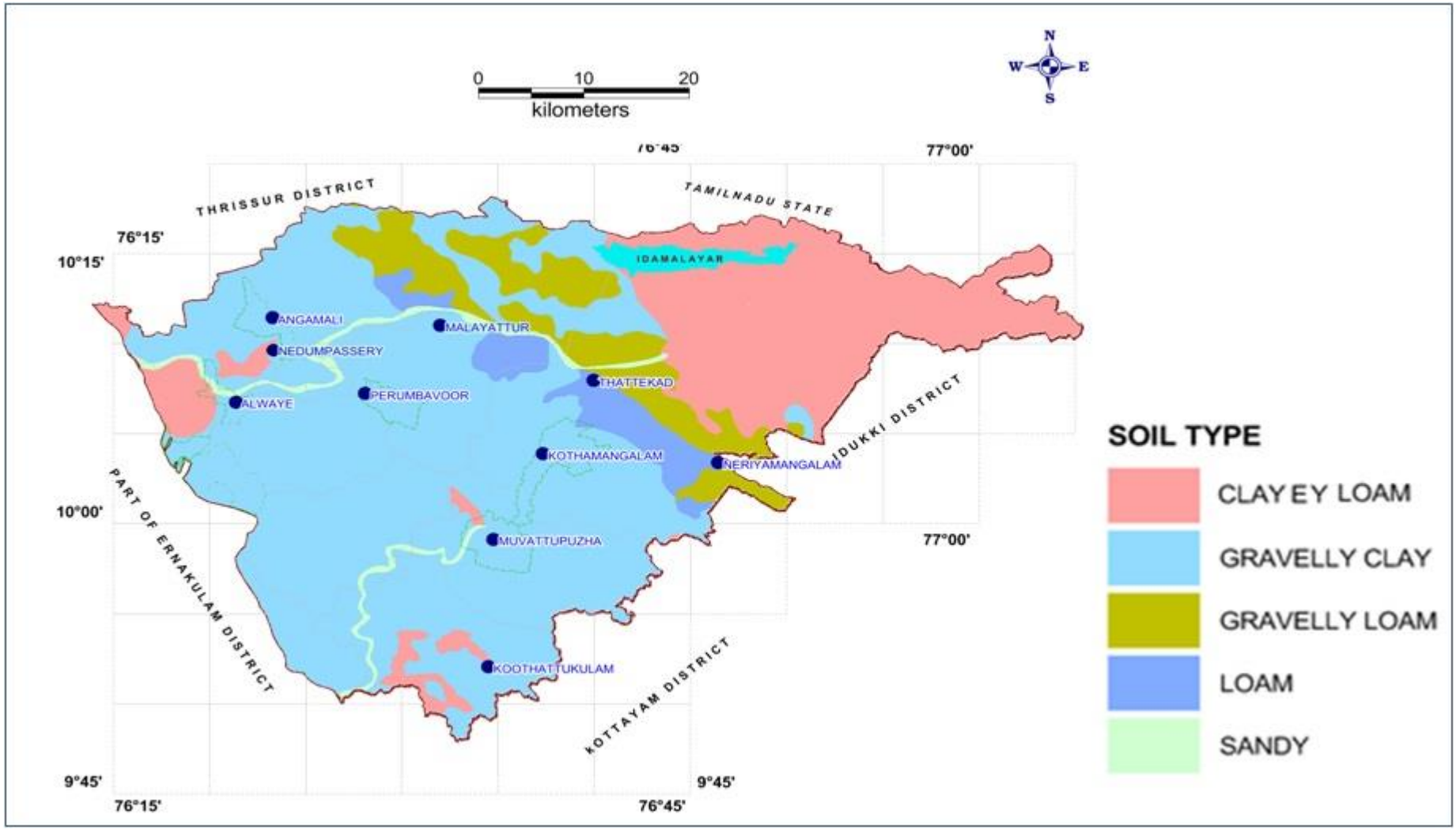
1.13 Soil

Based on soil type, the soils are classified as clayey loam, gravelly loam, gravelly clay, loam and sandy in which gravelly clay is predominant soil in the study area. Based on morphological features and physico-chemical properties, the soils of the study area are classified as Lateritic, Brown hydromorphic and Riverine alluvium.

Lateritic soil forms the most predominant soil in the midland region. In Muvattupuzha, Kothamangalam, Kunnathunadu and parts of Aluva taluks lateritic soil is encountered. These soils are well drained, low in organic matter and plant nutrients. The major crops grown are coconut, tapioca, rubber, arecanut, pepper, cashew and spices. Brown hydromorphic soil is the second most prevalent soil type of the study area and they are encountered in valley bottoms or undulating topography in the midland areas. They have formed as a result of transportation and sedimentation of material from adjoining hills and slopes and through deposition by rivers. The soil is enriched in clay content and plant nutrients. The soil is suited for paddy cultivation. Riverine alluvium is restricted to the banks of rivers and their tributaries. They are composed of sandy to clayey loam and are enriched in plant nutrients. It is suited for a large variety of crops

like coconut, paddy, arecanut, pepper, vegetables etc. In Aluva municipality, coastal alluvium is encountered and is composed of sand and clay. Coconut is the major crop in these soils. Soil map of the study area has been prepared (Fig1.7).

Fig. 1.7: Soil map of the study area



1 .14 Hydrology and Drainage

The study area is mainly drained by the Periyar River and its tributaries in the central to northern part, Muvattupuzha River and its tributaries in the southern part and Chalakudy River in the northern part. The Periyar River, which is the longest river in Kerala, is formed by several streams originating from Sivagiri group of hills in the Western Ghats. The river bifurcates at Alwaye into the Marthandavarma branch and the Mangalapuzha branch. Upstream of this point, a branch of the river loops off the main river near Kalady and joins the Mangalapuzha branch at Chengamanad. The Muvattupuzha River is formed by the confluence of three rivers namely, the Thodupuzha, the Kaliyar and the Kothamangalam rivers, in which Kaliyar river is drained in Idukki district. Muvattupuzha River flows in a westerly direction. In the upstream areas, the drainage pattern of both the rivers is trellis to Sub-trellis type. In the lower reaches, the drainage follows the dendritic pattern. The drainage characteristics of the three river basins are given in Table 1.7**.** The drainage map of the study area along with various drainage basins are compiled (Fig. 1.8).

Table 1.7: Details of catchment area in the NAQUIM area

Basin Name	Catchment Area (Sq. Km)		Percentage of Area	Stream order
	Total	Study Area		
Periyar	5398	798	14.78 %	6
Muvattupuzha	1554	750	48.26%	5
Chalakudy	1704	90	5.28 %	4

1.15 Cropping pattern – Agriculture and Irrigation

With diverse agroclimatic conditions brought about by natural physiographic divisions, a wide variety of crops are cultivated in the study area. These include plantation crops like coconut, arecanut, cashew, pepper, tea, rubber; food crops like paddy, tapioca, pulses; fruit crops like banana, mango; and vegetables. The net sown of the study area is 1043 ha. The area sown more than once accounts to 1083 ha. Changes in cropping pattern for last four decades in Ernakulam district is given in Table 1.8.

Table 1.8: Areas of principal crops in Ernakulam district (ha)

Crops	1975-76	1984-85	1988-89	2016-17
Rubber	23096	34319	54940	60170
Coconut	50726	55678	68988	43079
Paddy	88943	89183	71266	4370
Tapioca	17091	10364	7681	5415
Pulses	2476	1395	195	32

Source: District Statistics handbook & Agriculture Statistics, 2016-17

From the table, it is seen that paddy cultivation is decreasing trend from 88943 ha to 4370 ha. On the contrary Rubber has been going up steadily from 23096 ha to 60170 ha. The reasons for drastic reduction in paddy area are the low returns from paddy cultivation and high cost of investment needed towards labour charges, fertilizers and pesticides. Farming pattern in the study area shows coconut farming system prevails in mid lands with several inter-crops like pepper, arecanut, nutmeg, tapioca, cocoa, banana, pulses and oil seeds. In valleys, depending on the availability of water, two or three crops rice-based farming system is taken. Annual crops like vegetables, pulses and oil seeds are grown as intercrops or as summer crops. There is an oil palm plantation at Ezhattumugham and Ayyampuzha Area under the Oil Palm India Limited, a State Government undertaking. The block-wise area under different crops is given in Table 1.9. Data collected from irrigation department -Piravom is given in Annexure-I. Source wise area under Irrigation for the district is compiled (Table 1.10).

Fig. 1.8: Drainage map of the area

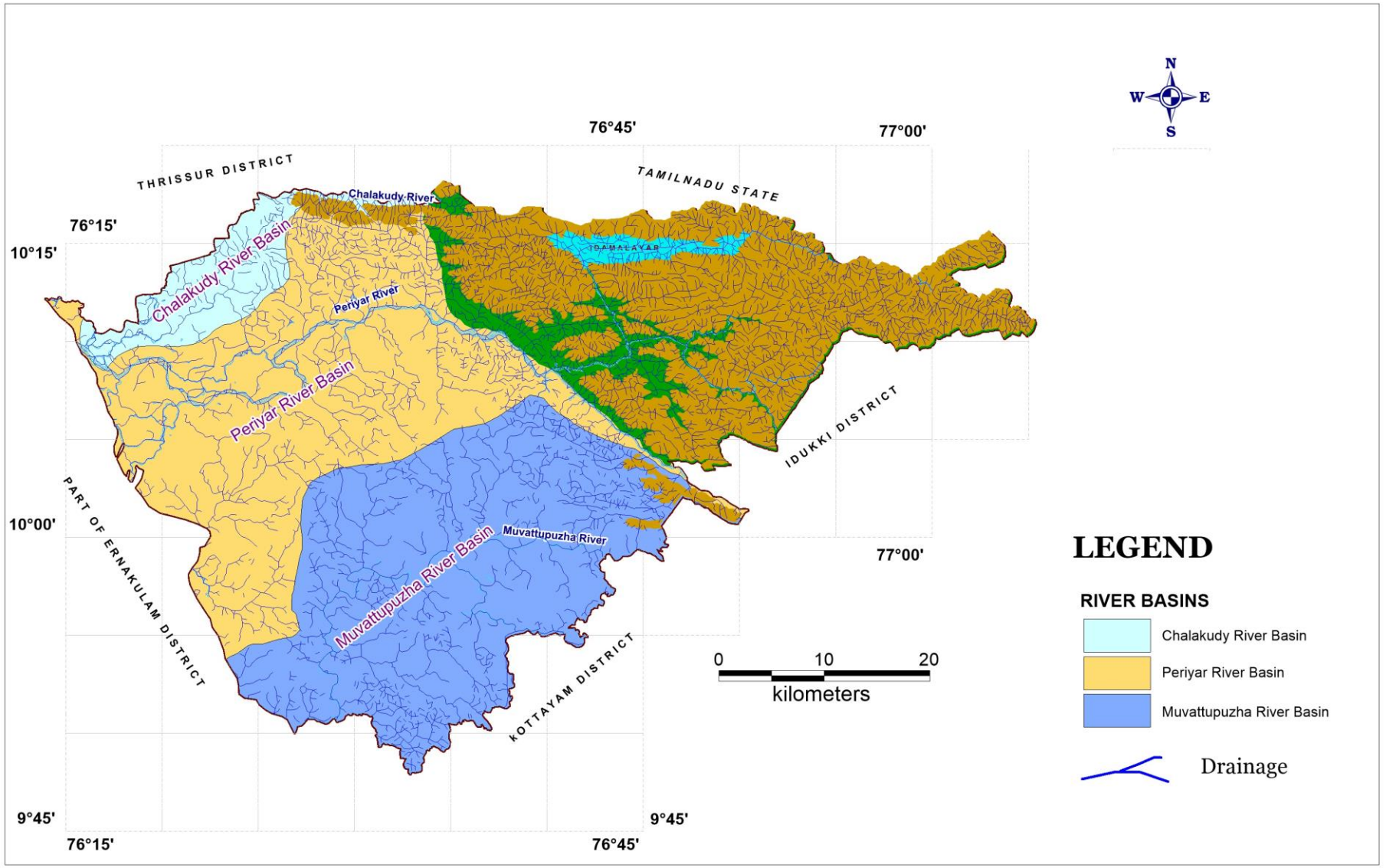


Table 1.9: Block-wise area under crops (2016-17) for the study area, ha

Block	Paddy	Pepper	Ginger	Turmeric	Arecanut	Tamarind	Nutmeg	Jackfruit	Mango	Plantain	Pineapple	Papaya	Cashew	Tapioca
Alangad	363.57	37.26	0.24	0.28	80.34	16.83	89.23	80.34	16.83	89.23	0.26	46.34	15.81	81
Angamaly	426.94	182.59	15.65	23.47	596.95	46.65	1521.15	596.95	46.65	1521.15	55.86	125.96	79.5	624.59
Edappally	82.34	50.53	0.11	0.07	135.37	29.41	5.71	135.37	29.41	5.71	0.29	60	7.81	6.5
Koovappady	710.92	100.34	24.37	17.12	281.61	41.11	741.95	281.61	41.11	741.95	276.31	72.57	29.86	774.56
Kothamangalam	551.25	228.37	14.43	79.56	416.44	41.65	457.14	416.44	41.65	457.14	888.06	81.97	31.84	860.14
Mulanthuruthy	822.97	145.96	1.24	3.53	285.57	29.75	175.31	285.57	29.75	175.31	258.85	118.19	21.76	126.96
Muvattupuzha	313.63	174.79	12.77	40.52	416.26	27.11	706.78	416.26	27.11	706.78	1321.68	71.72	15.55	781.01
Pampakuda	422.85	117.85	4.55	13.09	143.27	16.02	245.53	143.27	16.02	245.53	662.43	36.96	11.33	236.69
Parakkadavu	332.38	154.28	8.34	10.04	391.21	77.39	900.99	391.21	77.39	900.99	11.78	108.5	73.03	847.04
Vadavucode	589.37	157.78	3.44	7.16	320.87	38.14	370.54	320.87	38.14	370.54	767.38	63.68	52.23	397.73
Vazhakulam	357.27	128.04	6.15	11.18	185.18	27.87	504.27	185.18	27.87	504.27	363.42	153.3	20.66	449.28
Total	**4973.49**	**1477.79**	**91.29**	**206.02**	**3253.07**	**391.93**	**5718.6**	**3253.07**	**391.93**	**5718.6**	**4606.32**	**939.19**	**359.38**	**5185.5**

Source: Agriculture Statistics, 2017-18

Table 1.10: Net area irrigated (source wise)2016-17 in unit ha.

Small stream (Thodu/Canal)	Govt.	6903
	Private	5
Pond	Govt.	362
	Private	1753
Well	Govt.	1
	Private	6956
Borewell/Tubewell		454
Lift & Minor irrigation		3726
From River & Lake	Pump	664
	Other methods	488
Other sources		436

The data reveals that ground water irrigation is under infancy and needs a boost through proper development and management techniques. Periyar Valley Irrigation Project is the only major irrigation project in the study area. Other medium irrigation projects are Muvattupuzha River Valley Project and Edamalayar Project. The department of Agriculture, Minor Irrigation, Ground water and community development blocks are agencies implementing irrigation schemes. Under the Periyar Valley Irrigation project, the water from the Periyar river is diverted for irrigating the lands on the left bank of Periyar during the first and second crops.

The *Periyar Valley Irrigation scheme* in Ernakulam district envisages the utilization of the tail race discharge from the completed Hydel scheme in the Muthirapuzha tributary of river Periyar together with the controlled release from Ennackal dam constructed by Kerala State Electricity Board under Hydel scheme across the Idamalayar tributary and the dependable run off from the uncontrolled catchment of Periyar river. It is intended for irrigating an area of 32800 Ha of land lying on the left bank of Periyar river through a network of canal system and controlling devices. The scheme helps in stabilization of first and second crops in an area of 32800 Ha and raising an additional crop in an area of 20000 Ha of 3rd crop (Puncha). Thus, the gross potential ayacut of the scheme will be 85600 Ha and is spread over in Kothamangalam, Muvattupuzha, Kunnathunadu, Aluva, Kanayannoor and Parur Taluk in Ernakulam district. Apart from Irrigation on left bank of Periyar, the scheme also enables in the right bank of Periyar, supply of water to FACT, supply of minimum quantity of water through the river to check the intrusion of salinity at lower reaches as well as to meet the requirements of many lift Irrigation scheme of river Periyar. Supply of water for drinking, industrial purposes etc is met by a portion of storage water by the barrage of Bhoothathankettu ($76^0$40';$10^0$08'16"). The project was completed during the year 1992. Periyar Barrage at Bhoothathankettu having a length of 210.92m, Full Reservoir Level is 34.95 m, and having capacity of 169.791 Mm^3.

The Muvattupuzha Valley Irrigation Project (MVIP) is the one of the medium irrigation projects having canal network in the district. The project envisages the utilization of the tail race discharge from the Moolamattam power house of the Idukki Hydro Electro Project by constructing a dam across Thodupuzha river at Malankara. The water from the reservoir is intended to irrigate the cultivable command area in Ernakulam, Idukki and Kottayam districts through its left and right bank canal system. The project was partially commissioned in 1994 and is yet to be completed. Dam and connected works are completed. In addition to irrigation purpose, the project envisages to supplement canal water for drinking water supply schemes, industrial benefit to the Hindustan Newsprint Factory, generation of hydel power at the toe of the dam with an installed capacity of 10.5MW. The project MVIP consists of two canal system on the right bank and the other on the left bank. The left bank main canal is 37.10 km long and has five branches namely Murady, Ramamangalam, Piravom, Mulakkulam and Ettumanoor. The left bank canal supplies water for irrigation in Kottayam district, particularly in the north-western part. The right bank main canal is 28.33 km long has only one branch canal; Muvattupuzha branch. Total ayacut comes to 36129 Ha. Since 1994, water distribution is being carried out in the completed stretches of canals. Out of the 36129 Ha potential envisaged through the project, 32308 Ha has been created till date. Since some intervening missing links could not be completed till date, the gross potential achieved through the project is 25959 Ha.

1.16 Recharge practices

The study area is having ideal site for implementing ground water conservation structures and rainwater harvesting structures. The subsurface dam constructed at Odakkali in the premises of Aromatic and Medicinal Plant Research Station, Kerala Agricultural University has improved the ground water conditions of the area and it ensures sustain water for irrigation for the farm area of the university. The structure was constructed during 1988 with a cost of Rs. 1.67 lakhs. The length of the dam is 80 m and the depth about 6m. Similar structures can be constructed along the narrow valleys of the study area.

Groundwater is being augmented through the recharge structures by departments/ agencies of State such as, Agricultural Department, Agricultural University, Coconut Development Board, PWD, Soil Conservation Department and Irrigation department. Recently, Irrigation department is taking up Repair, Renovation and Restoration (RRR) of surface water bodies which will be of immense use in groundwater augmentation in addition to the increase in storage capacity of the tanks.

1.17 Geology

Geologically the entire area is covered mainly with Charnockite group and Migmatite of crystalline rocks of Archean Age followed by residual laterite formations of Sub-recent Age. Unconsolidated alluvium of Recent age comprising sands and clays are found in small patches in flood plains of Periyar river in the area. The eastern part is occupied by hard rocks representing Precambrian metamorphosed rocks. The charnockites group is composed of pyroxene granulite, magnetite quartzite and charnockites. Charnockite, which is very widely distributed, is coarse grained, granulitic and dark coloured. Pyroxene granulite and magnetite quartzite occur as linear bands. Calc-gneiss and quartzite of Khondalites group are the oldest rocks of the area and they are linear lensoidal bodies within the charnockites. The migmatite group includes biotite gneiss, hornblende biotite gneiss and garnet biotite gneiss which are next to charnockites in abundance. These older rocks are intruded by both acid (syenite) and basic (gabbro and dolerite) intrusives. Basement rocks are subjected to intense lateritisation, which is confined to the midland region only. Regional Geological setting of the Study area is given in Table 1.11 and Geology of the study area is shown in Fig. 1.9

Table 1.11: Regional Geological setting of the study area

ERA	AGE	FORMATION	LITHOLOGY
QUATERNARY	Recent	Alluvium	Sands, Clay
	Sub-recent	Laterites	Laterites derived from crystalline rocks.
PRECAMBRIAN	Proterozoic	Intrusives	Dolerite, Gabbro, Pegmatites and Quartz veins.
	Archaean	Migmatite Group	Hornblende biotite gneiss, Biotite gneisses and Garnet biotite gneiss.
		Charnockite Group	Charnockites

1.18 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. 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 crystalline rocks occurring in the study area has undergone several phases of tectonic deformations resulting in the development of numerous sets of foliation, lineaments and fractures. Foliation and joints are important structural features in addition to the folds. The general trend in the crystalline rocks is NW-SE with dips of 50^0 to 80^0 in SW direction. The prominent fractures are

in the NNW-SSE, NW-SE, E-W, NE-SW and NNE-SSW directions as per the study of landsat imageries and bhuvan -NRSC data. The drainage in the area is controlled by these fracture systems. The dolerite and gabbro dykes are trending in NNW-SSE direction and are highly fractured shown in rose diagram. Lineament map of the study area is shown in Fig. 1.10.

Fig. 1.9: Geology map of the area

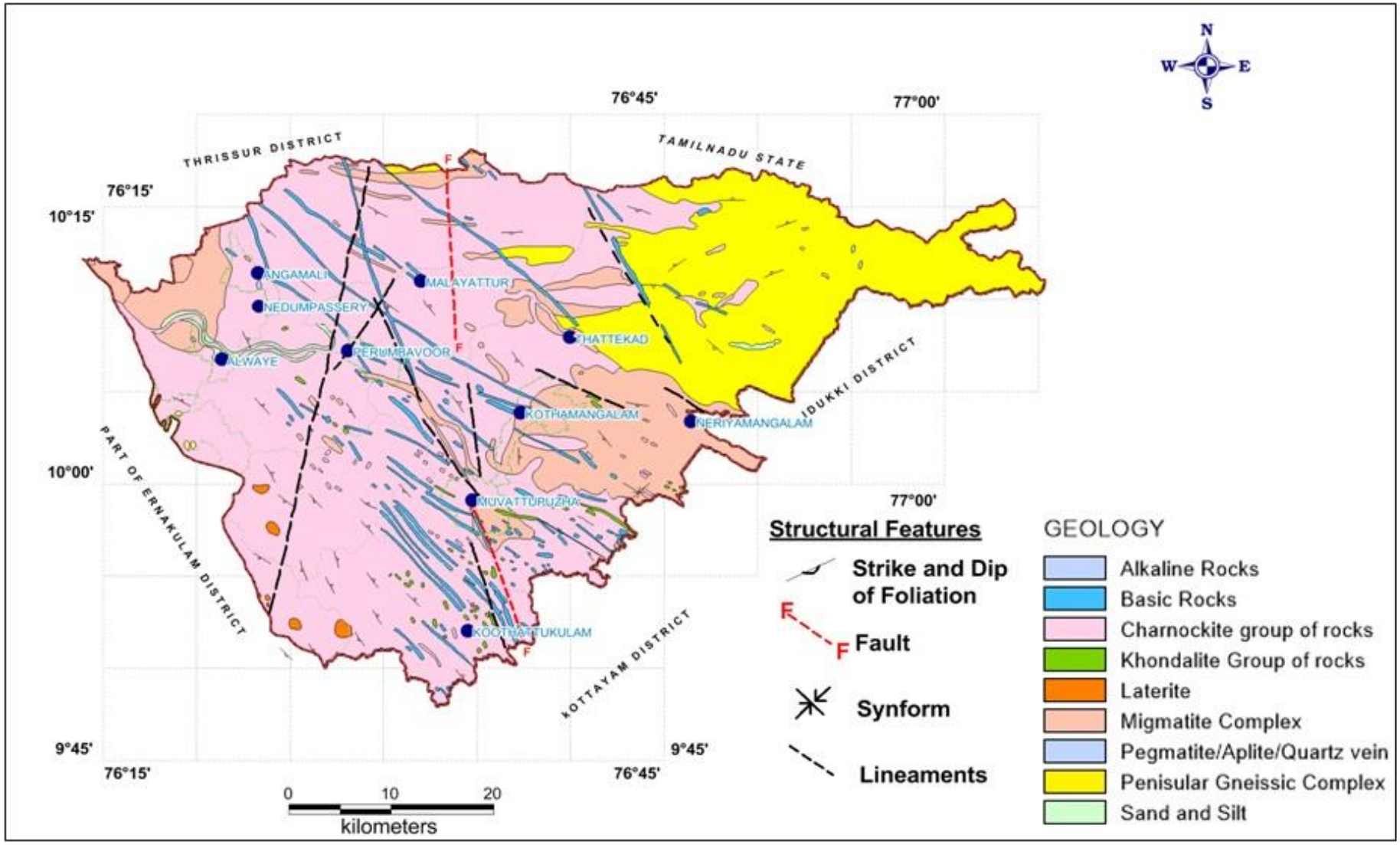
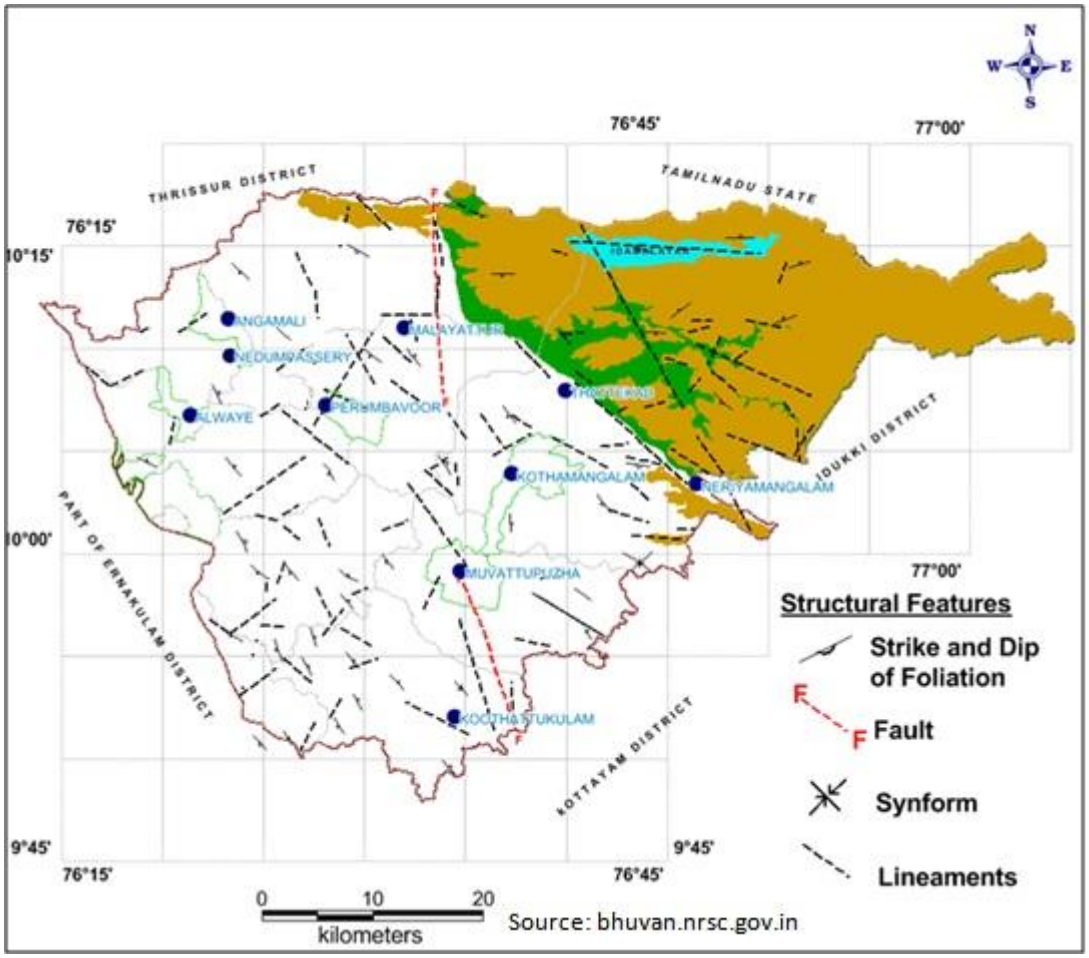
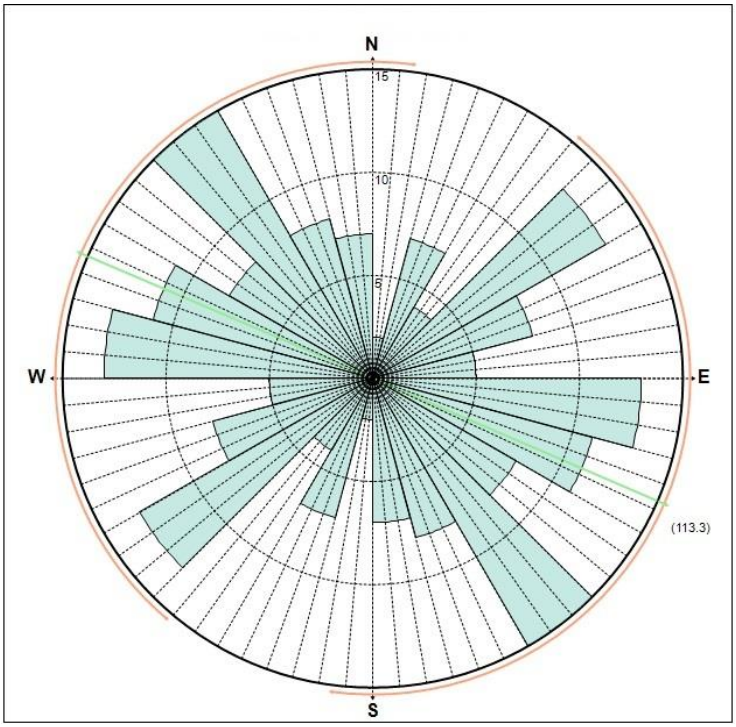


Fig. 1.10: Lineament map of the area



Rose diagram of the study area



1.19 Previous work and present status of data

Central Ground Water Board has carried out Ground water Exploration (1973-74), Systematic hydrogeological surveys (1977-78, 1982-83), Studies in Comparative Utilisation of surface and groundwater in the command area of Periyar Valley Irrigation Project (1980-81). In 1983-88, the SIDA assisted Coastal Kerala Ground Water Project of CGWB has carried out detailed hydrogeological studies with exploration in the western part of the district. Later Reappraisal Ground Water Management studies have been done during (1987-88, 2000-01 and 2007-08). In addition to the routine work, CGWB has also taken up several short-term investigation studies, exploration activities, pollution studies, geophysical activities in the district.

In the present study, CGWB has drilled 39 exploratory wells in crystallines such as charnockites, garnetiferous-biotite gneiss & hornblende gneiss. The wells drilled in Charnockites were in the maximum depth range of 237 m bgl and the discharge ranges from 180 to 1320 lpm. The transmissivity ranges from 67 to 304 m^2/day. The wells drilled in the garnetiferous-biotite gneiss were in the maximum depth range of 201 m bgl and the yield ranges from 10-23 lpm. The bore wells tapping NNW, NE, NW lineaments in the district gives high yield.

In order to get a realistic picture about the groundwater conditions in the study area, CGWB has established 113 Ground Water Monitoring Wells which includes 97 dug wells and 16 piezometers tapping various formations. In addition to these monitoring wells, SGWD has established 80 wells in the study area which includes 70 dug wells and 10 piezometers which are monitored monthly. The groundwater monitoring wells established by CGWB are monitored four times a year and for the qualitative analysis, water samples have been collected during premonsoon (April) monitoring.

1.20 Industries and Mineral resources

The major minerals found in the district are graphite and china clay. Graphite is found in association with the Khondalite Group of rocks. Good deposits of graphite are noticed in places like Avoli, Peringazha, Memadangu and Kuthattukulam. One mining lease is granted to M/s Thomson Graphite Mines and Crucible Works, Vellanad, Thiruvananthapuram to mine graphite in 1.2544 hectares of land in Kalloorkad village, Muvatupuzha Taluk. Iron ore is reported from Mangalam and Nadarayan areas. The district has fairly good resources of china clay. China clay of primary origin is reported from Amballoor and other areas. China clay is not mined in this district. Usually ordinary earth is mined for levelling of ground for construction of buildings. The area comes under zone III and indicates moderate seismicity.

Charnockites occupying the major part of the area are a good source of granite dimension stone as well as building material Localised quarrying for Granite building stones are highly rampant in Oorakkad of Vazhakulam block. Medium to small scale industries like Plywoods, plastics, Rubber and Rice are in Perumbavoor municipality, Aluva, Angamali areas.

2.0 DATA COLLECTION AND GENERATION

2.1 Data collection and data gap analysis

Collection, compilation and generation for aquifer mapping studies are carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various activities (Table - 2.1).

Table 2.1: Brief activities showing data compilation and generations.

#	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and subsurface geoelectrical and gravity data generation	Vertical Electrical Sounding (VES), borehole logging, TEM etc.
		Hydrological Parameters on ground water recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of subsurface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters including heavy metals.
3	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydrochemical data.
4	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain

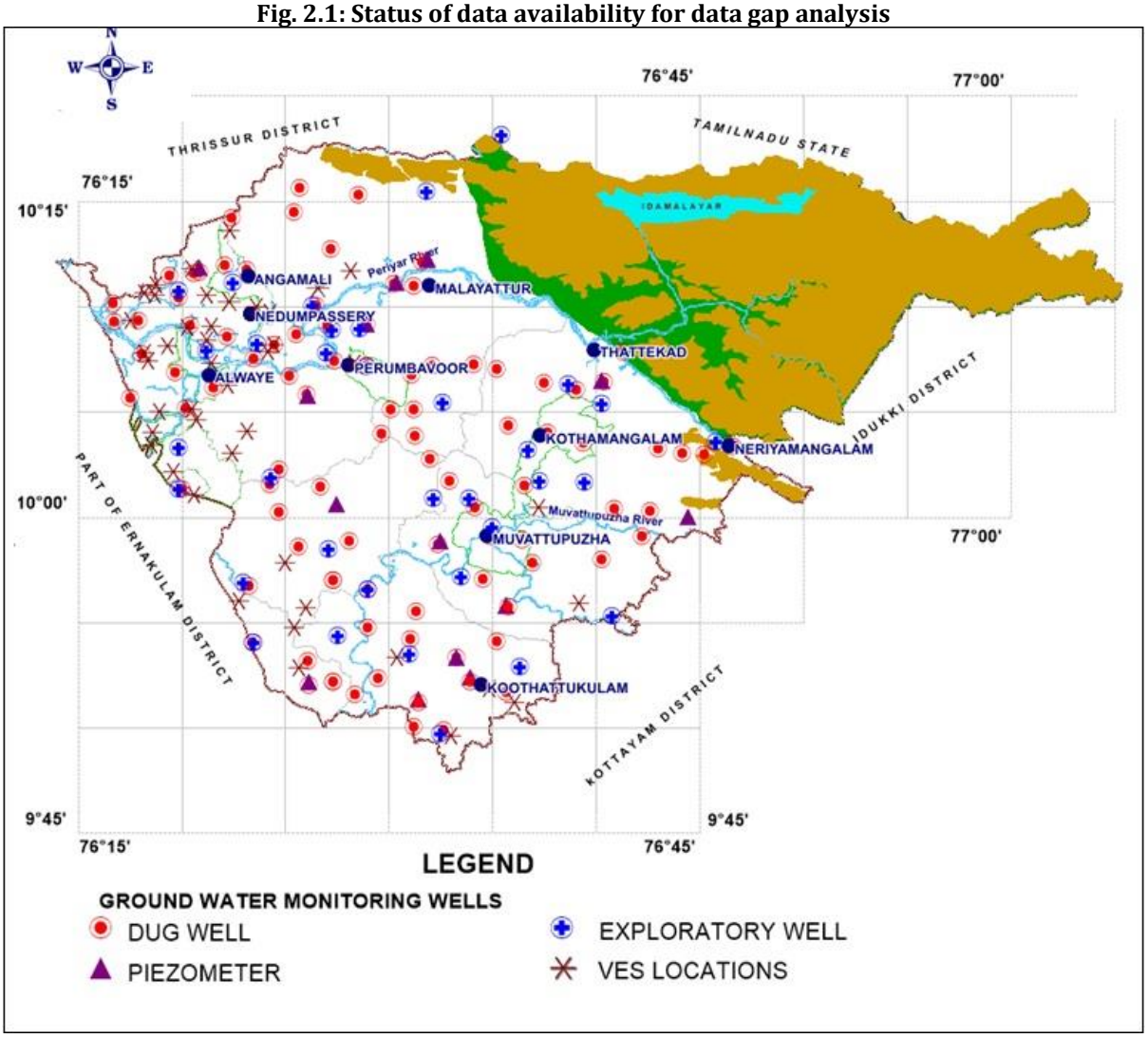
Periodical data pertaining to water levels, pumping tests were collected during aquifer mapping studies apart from water sample collection to assess the groundwater quality. In addition, geophysical data has been generated through conducting geo-electrical soundings after evaluation of data gap analysis.

The status of availability of existing data for various items are described in the subsequent section and its summary is given in Table 2.2 and shown in Fig. 2.1.

Table 2.2 Status of data availability for data gap analysis

#	Item	Data Availability		Total
		CGWB	State Departments	
1	Ground Water Monitoring stations – Dug Wells	97	70	167
2	Ground Water Monitoring stations – Piezometers	16	10	26
3	Ground Water Exploration	34	12	46
4	Geophysical	35	-	35
5	Ground Water Quality Stations	59	70	129

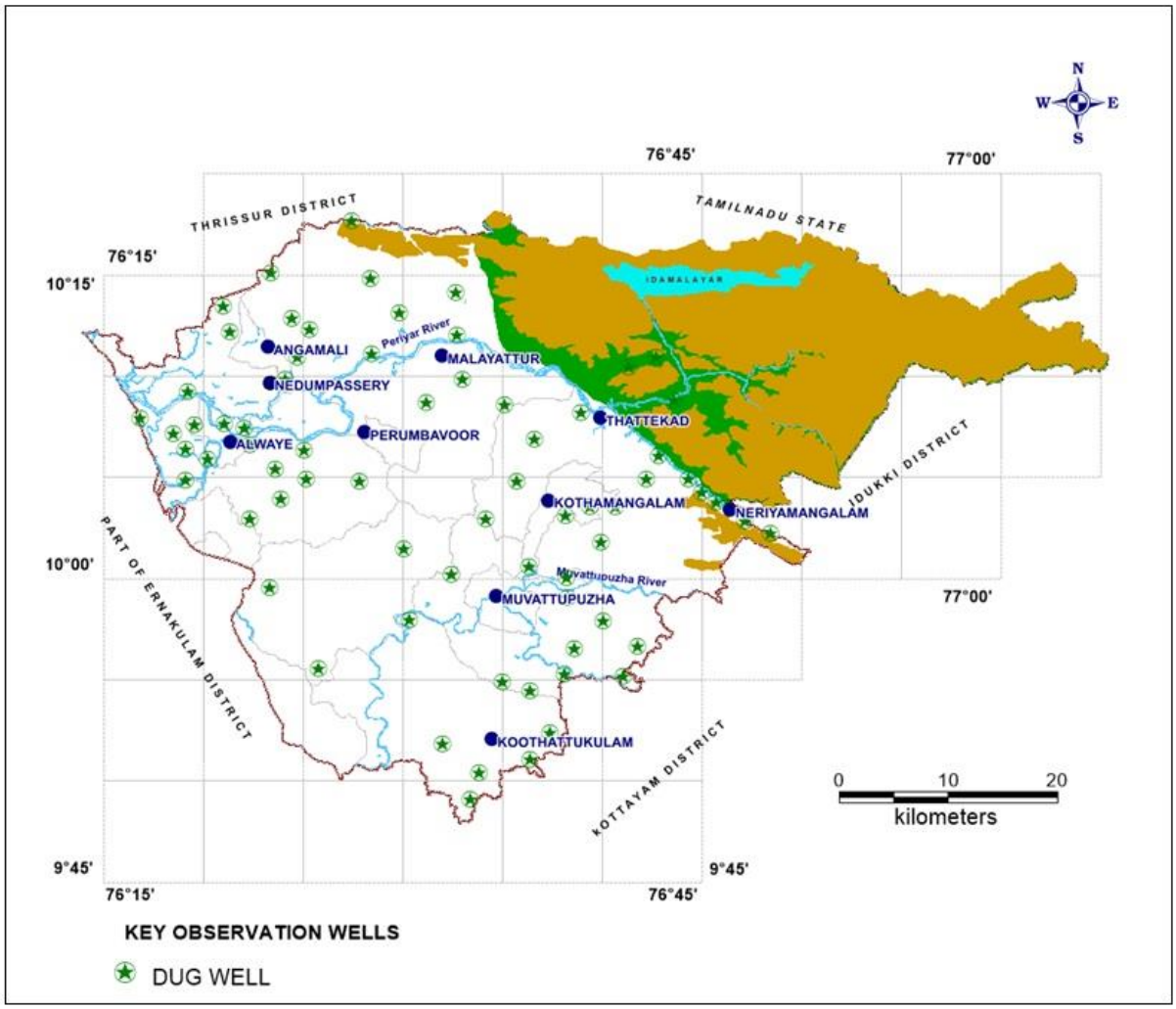
Fig. 2.1: Status of data availability for data gap analysis



2.2 Hydrogeological data

The periodical monitoring of groundwater level implies the groundwater recharge and discharge (natural and manmade) occurring in the aquifer systems. There were 167 (Nos.) of groundwater monitoring wells existed earlier, to the present studies, which were monitored periodically (Fig. 2.1). To fill data gap in the study area, 60 Nos. of additional key observation wells and is shown in Fig. 2.2, were established and monitored two times (Pre and Post monsoon) during the aquifer mapping field studies, in order to record the temporal and special changes in aquifer system. The details of monitoring wells are presented as Annexure - II. The groundwater level monitoring was carried out four times in a year since April 2018 to Jan 2019.

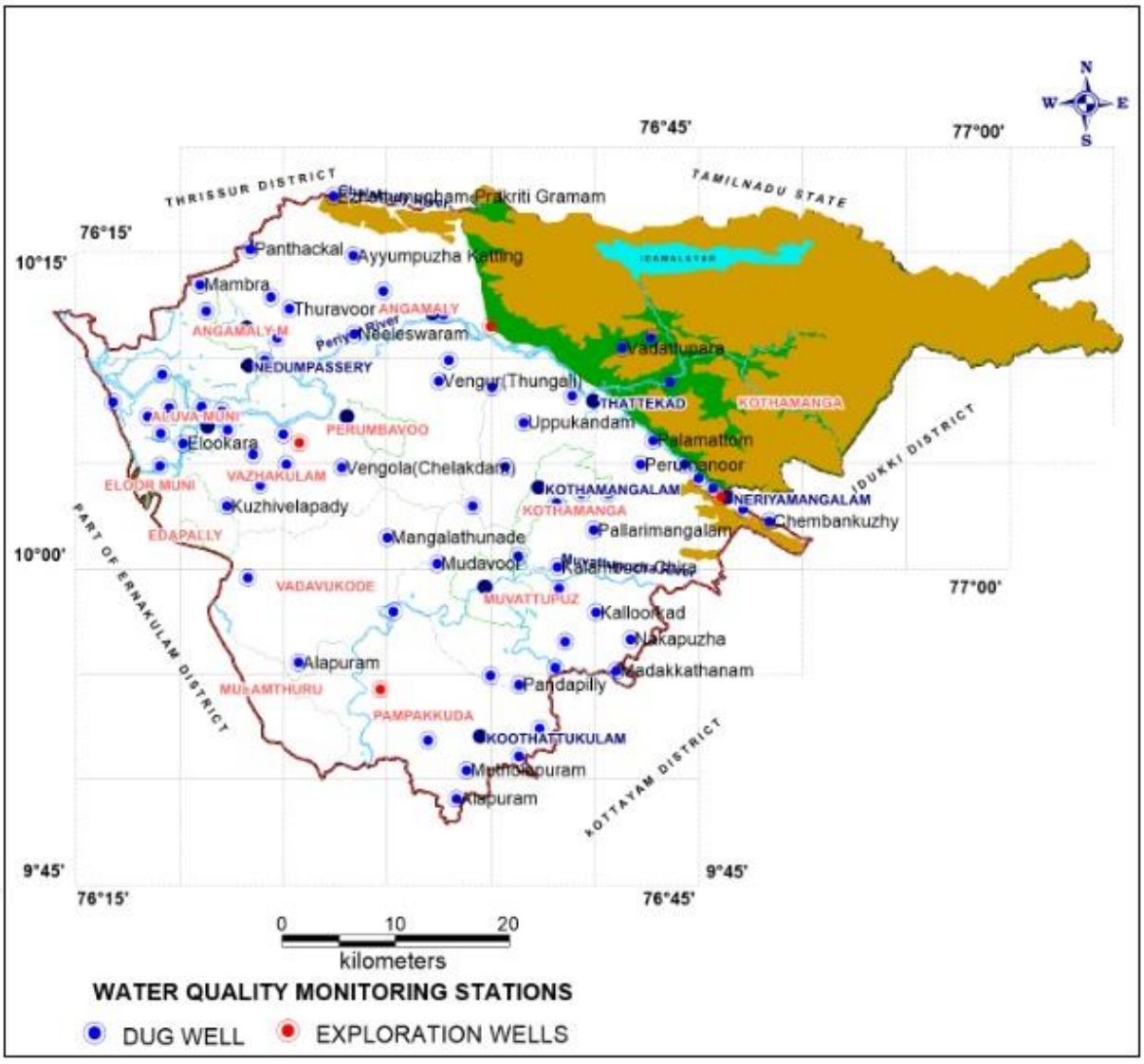
Fig. 2.2: Key observation wells for monitoring regime



2.3 Hydrochemical data

The groundwater quality of the study area was studied by collecting water samples from 29 Nos. Ground water monitoring stations (dug wells) was monitored periodically. 30 Nos. of water samples were collected during exploration studies in different aquifers. To fill data gap in the study area, 68 Nos. of water samples were collected during micro level study and special studies along Periyar river (Fig. 2.3). For the deeper aquifer 4 Nos. samples were collected during ground water exploration. The details of water quality monitoring stations are given in Annexure – III. In addition to that 20 Nos. Water Samples were collected from Dug wells and bore wells for Heavy metal analysis to assess the groundwater quality for drinking and irrigation purpose.

Fig. 2.3: Water quality stations for groundwater parameters



2.4 Geophysical data

The geophysical survey was conducted in the study area consisting of Vertical Electrical Soundings (VESs) by employing Schlumberger configuration with maximum half current electrode separation of 400m. The objective of the study was to decipher the sub-surface conditions such as; weathered and fractured layer resistivity and thicknesses, and massive formations, down to the depth of 200 mbgl. The data was acquired by deploying the CRM 500 Aquameter and WDDS-2/2B Digital Resistivity meter by adopting the Schlumberger electrode configuration with a maximum current electrode separation (AB) of 400m. The data was processed and interpreted by IPI2Win software developed by Moscow State University, after marginally modifying the manually interpreted results keeping in view the local geology and hydrogeology.

As per the earlier studies from 1986-2017, 35 VES were carried out in hard rock area. Out of this 35 VES only at 11 sites, the depth to massive formation was estimated which is varying in the range of 10-125 m. The obtained VES curves are of H, A, KH, QH, HA, KHA, QHA, QQH AND HKH types and were interpreted by computer interpretational techniques by IPI2Win software. The interpreted results have given rise to 3 to 5- layered geo electric sections. At

about 20 sites the last layer was recorded as massive/ weathered basement formation and at the remaining 29 sites the last layer was extending with depth and the thickness could not be estimated due to non-availability of spread length. The depth to massive/ weathered basement is in the range of 10-125 m.

The resistivity of the first layer was varying in the range of 25-8500 Ohm.m which is clay soil, soil to lateritic soil in nature with thickness varying in the range of 0.8 to 5 m. except at two sites where it was 7 and 8 m. respectively. At three sites namely, Nayathode, Eddayapuram and Udyogmandal the first layer resistivity was varying in the range of 25.75 Ohm.m with thickness in the range of 1.5-3 m. which is clayey soil. At two sites namely Alwaye and Chengamanad the first layer resistivity was varying in the range of 120-160 Ohm.m with thickness in the range of 0.8-1.3 m. which is red soil. At the remaining sites the first layer resistivity was varying in the range of 215-8500 Ohm.m which is laterite in nature. The thickness of this formation is varying in the range of 0.8-8 m.

The second layer resistivity was varying in the range of 20-9999 Ohm.m with thickness in the range of 3-42m. At eleven sites the second layer resistivity in the range of 300-9999 Ohm.m which was also considered as lateritic formation. The thickness of this formation is varying in the range of 3-13m. At about thirteen sites the second layer resistivity was varying in the range of 23-110 Ohm.m which is weathered formation in nature. The thickness of this formation at these sites varying in the range of 2.7-42m. Out of these thirteen sites at three sites namely Kakkanad, Muppattadam and Edathala the second layer resistivity was varying in the range of 85-130 Ohm.m with thickness in the range of 20-42m. Which is expected as weathered to semi weathered in nature. At two sites namely Thiruvaniyoor and Sreemoolanagaram the second layer resistivity was around 220 and 330 Ohm.m which is expected as hard formation. The thickness of this formation is 22.5 and 20.4 m respectively. At two sites namely Udyogmandal and Ayiroor the second layer resistivity was varying in the range of 5-40 Ohm.m with thickness in the range of 8.5-13.7 m, which is expected as clay formation.

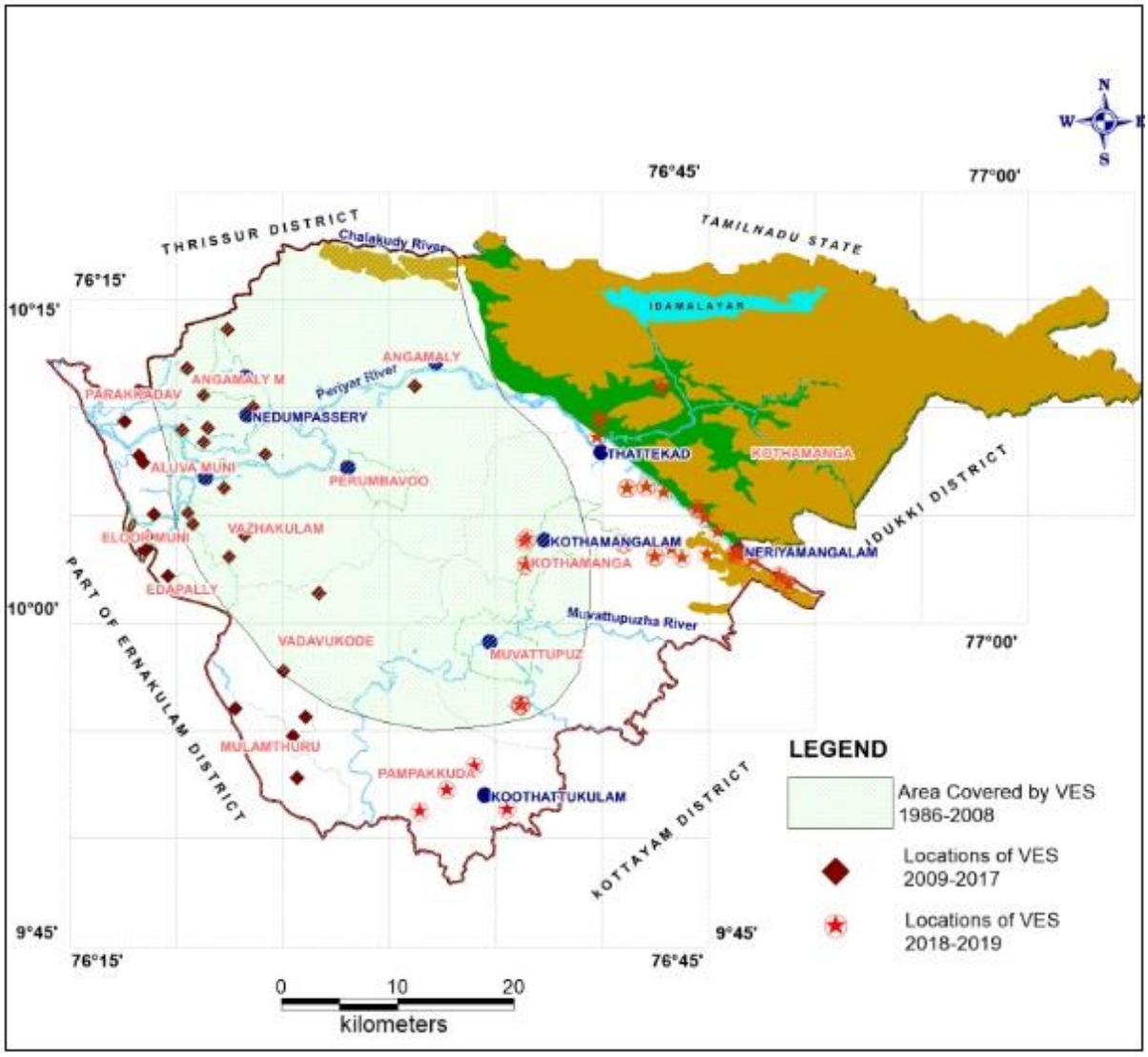
The third layer resistivity was varying in the range of 15-850 Ohm.m with thickness in the range of 3.7-100m. At eight sites this layer is extending in nature and at three sites this layer was recorded as massive formation. At ten sites namely Alwaye, Kunnara, Parakadavu, Mulanthurthy, Arakunnam, Kottayattupara, Eddayapuram, S. Kalamassery, Ayiroor and Parambiyam the third layer resistivity was varying in the range of 15-120 Ohm.m which was expected as weathered formation. The thickness of this formation is varying in the range of 6.5-47m. By considering the obtained curve type and the interpreted results the weathered formation at Alwaye, Kunnara, Arakunnam and S Kalamassery can be expected as weathered to semi weathered in nature. At about sixteen sites the third layer resistivity was recorded in the range of 110-850 Ohm.m with thickness in the range of 3.7 m to extending in nature which was hard formation. At Sreemoolanagaram this layer resistivity was varying around 85 Ohm.m which was hard to massive formation. At Kakkanad, Edathala, Muppattadam and Kuzhuvilapady this formation was expected to be fractured in nature. Also, the massive formation at Vattaparambu and Nayathode is expected to be fractured in nature.

The fourth layer was recorded at eighteen sites only. Out of these eighteen sites at seven sites this layer was recorded as massive in nature. At the remaining eleven sites this layer resistivity was varying in the range of 140-1100 Ohm.m (except at one site where it was 70m.) which was hard to massive in nature with thickness varying in the range of 18m to extending in nature. At Puthankurissu this layer resistivity was varying in the range of 600-1100which was hard to massive in nature. At the remaining sites namely Alwaye, Kunnara, Parakadavu, Pallipuram, Arakunnam and S. Kalamassery this layer resistivity was varying in the range of 140-250 Ohm.m which is expected to be fractured in nature.

The fifth layer was recorded at only three sites namely Alwaye, Chengamanad and S. Kalamassery. Only at Chengamanad this layer resistivity was varying around 250 Ohm.m with extending in nature whereas at the remaining two sites it was massive in nature as per earlier studies.

After the dap gap analysis, 50 Nos of VES survey carried out during micro level survey and geo-electric layers inferred through interpretation of the results obtained. The location map of VES survey carried out in Ernakulam district has been presented (Fig. 2.4).

Fig. 2.4: Location of VES survey in study area

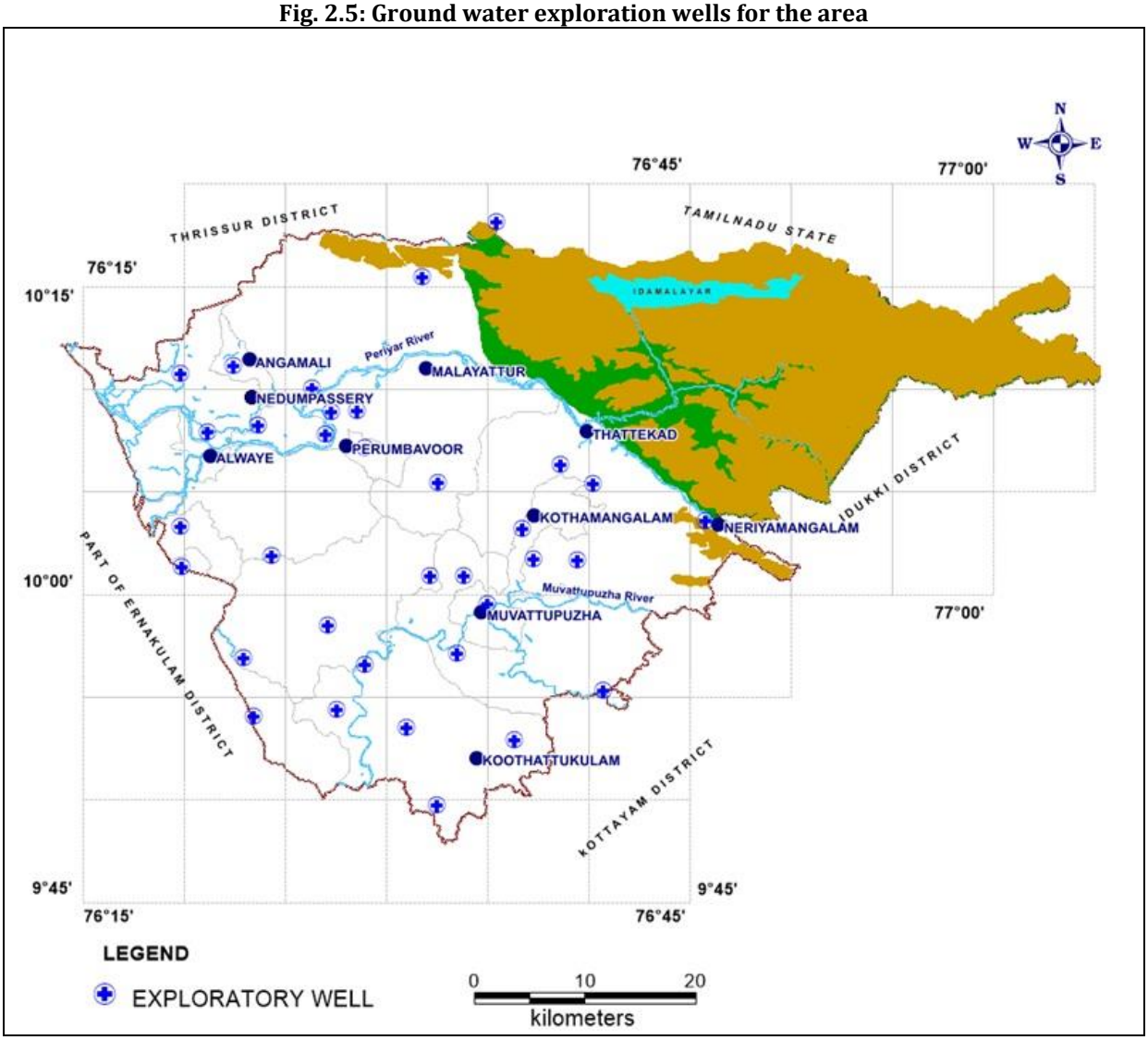


2.5 Groundwater exploration data

A total of 34 Nos. of exploratory wells (Fig. 2.4) were drilled in the study area under groundwater exploration activity of the CGWB prior to National Aquifer Mapping project. Other than exploration wells 14Nos. piezometers are also constructed in the study area. These wells were plotted on the 1:50,000 scale topographical map. As per the National Aquifer Mapping guidelines for the hard rock, data requirements were identified on the plotted topographical map. Similarly, 12 Nos. data of exploration wells drilled by state department and other agencies had been collected. Based on the data requirements, 5 Nos. of exploratory wells and 1 nos. Observation well was drilled in the micro level aquifer mapping area as part of the data

generation. The data such as lithology, fracture depth, yield, water level, aquifer properties were generated and utilized to depict the prevailing aquifer systems of the area and is compiled (Annexure IV).

Fig. 2.5: Ground water exploration wells for the area



2.6 Hydrological Parameters on ground water recharge

As a part of aquifer mapping, to collect the information on Hydrological parameters on ground water recharge, Soil Infiltration test was conducted. The present study is carried out under NAQUIM for the AAP 2018-19 to understand the infiltration process at EEC, Muvattupuzha, Muvattupuzha Block and PVIP, Perumbavoor, Koovapady block by using instrument double-ring infiltrometer. The equipment consists of two concentric rings made of mild steel. These two rings are driven into the earth up to about 15cms. Water is poured into both the rings and fall of water in the inner ring is a measure of water infiltrated. A scale is used to measure the rate of fall and water replenished in the ring to a predetermined level. The outer ring prevents the water in the inner ring from lateral flow.

Main objectivities of the study are to evaluate rate of infiltration to calculate the recharge through infiltration to ground water and to assess changes in hydrology and hydrometeorological parameters of the study area and evaluate the sensitivity to climatic factors and human interfaces. Infiltration depends upon the chemical-physical condition of the sediments and the chemical hydraulic characteristics of the water in those sediments, both of

which may change with time. The rate of infiltration is affected greatly by the permeability of the sediments.

The quantity of water discharge at a time interval is not measured here, because the method adopted is falling head method. If constant head method is adopted, then the quantity will be known from that the permeability can be calculated.

Trend analysis determines whether the measured values of an infiltration rate with increase or decrease over a period. There are several statistical techniques available for trend analysis depending upon the characteristics data. The graphs and tables show the best fit trend line and the values of R^2 from the equation extracted and the results are compiled (Annexure V).

2.7 Determination of storage parameters for shallow aquifers

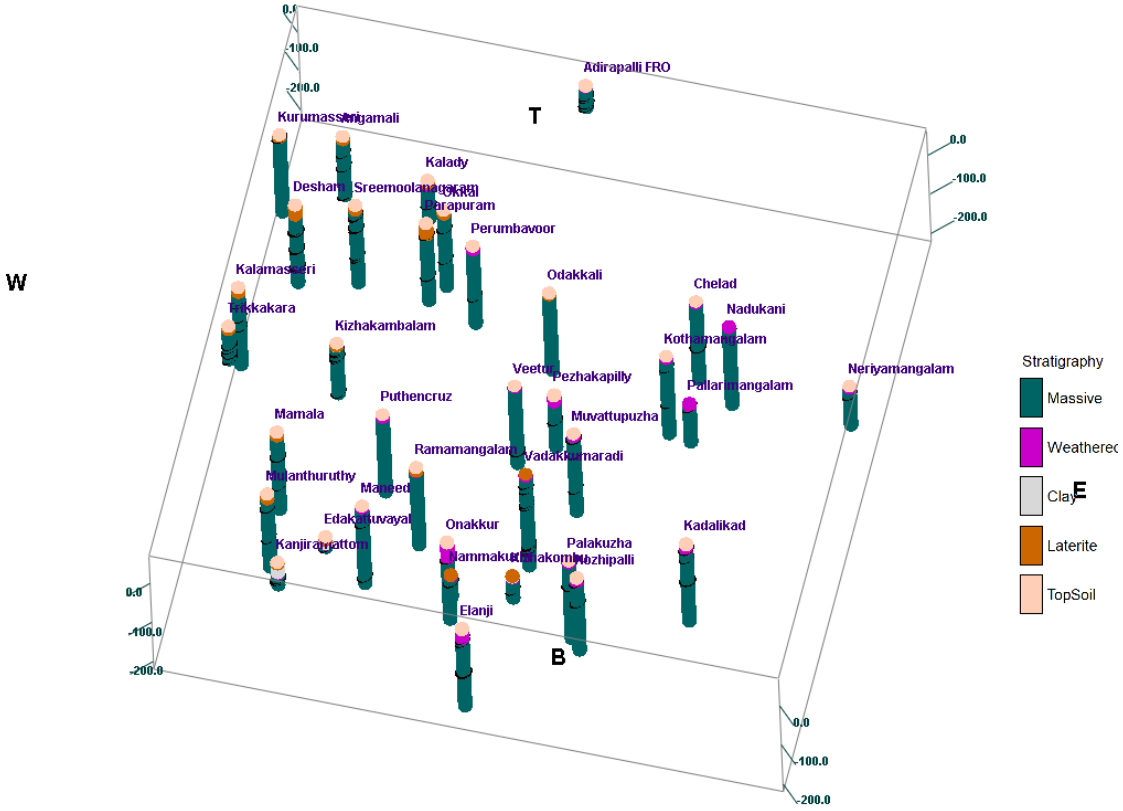
To determine the storage parameters for the shallow aquifers in the study area, large diameter dug well pumping test was conducted on Pezhakapilly, Muvattupuzha block. Large diameter dug wells are the main source of water supply in mid to high lands of the study area. They are particularly useful in shallow aquifer with a low transmissivity. The main objective is to find out the storage properties and physical properties that characterize the capacity of an aquifer to release groundwater and to determine the yield chacteristics of a well.

The specific yield is primarily used for unconfined aquifers, since the elastic storage components is relatively small and usually has an insignificant contribution. The recuperation/ recovery well data is analysed using applicable method Papadopulos-Cooper Method (1967) for the evaluation of yield characteristics is calculated to be 1.2% and the transmissivity is 28.662 m^2/day. The details of the large diameter pump test in Pezhakapilly are given in Annexure-VI.

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The optimized wells of CGWB and State departments used to prepare the elevation map to identify the topographic variations on the ground surface so that it can give the synoptic picture of gradient variations in the water levels. Three dimensional locations of validated exploratory wells with litholog are compiled (Annexure – VII) and strip logs of the bore wells with respect to topographic elevation are shown in Fig. 3.1.

Fig. 3.1: Strip log of exploratory wells with lithology



3.2. Hydrogeological data interpretation

3.2.1 Groundwater level

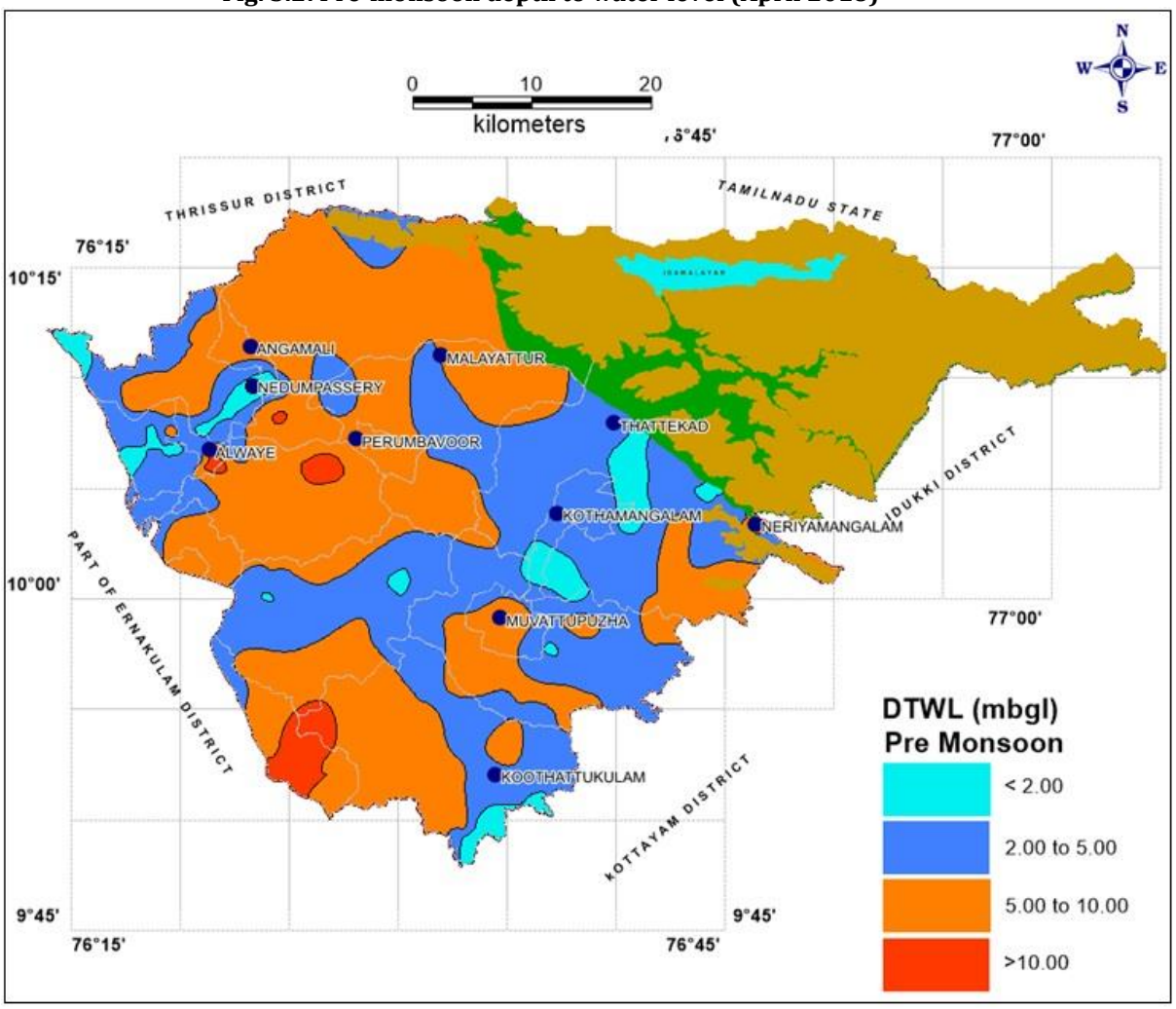
During Aquifer Mapping studies in hard rock terrains of Ernakulam district, 113 National Ground water observation wells (GWMW) and 60 key wells established in different formations were used to study the behaviour of the groundwater regime. Out of total 60 key wells, 30 wells were established in Charnockite, 20 in Migmatite Complex formations, 6 in laterite and 4 wells in basic dykes (gabbro / dolerite). The water levels were monitored from April 2018 to April 2019, four times in a year from ground water observation wells and during pre and post monsoon periods from key wells. The depth of observation wells ranged from 2.10 to 14.80 mbgl.

Pre-monsoon depth to water level (April 2018)

The water level data from GWMWs and Key wells, pertaining to the period of April 2018 (pre monsoon), was used to prepare the depth to water level map (Fig. 3.1) of the study area. The depth to water level varies from 1.85 mbgl (Chettiyod-Nayithode of Angamali Block) to 12.80 mbgl (Alwaye, Alwaye municipality, Vazhakulam Block). Water level range from 0 to 2 mbgl in about 4 % of the study area, >2 to 5 mbgl in 32%, >5 to 10 mbgl in 62% and >10 mbgl in

3% of the study area. Major part of the study area shows water level in the range of 5 to 10 mbgl and is observed in Northern, Central and South western part, followed by >2 to 5 mbgl water level together covering about 97% of the area as shown in Fig. 3.2.

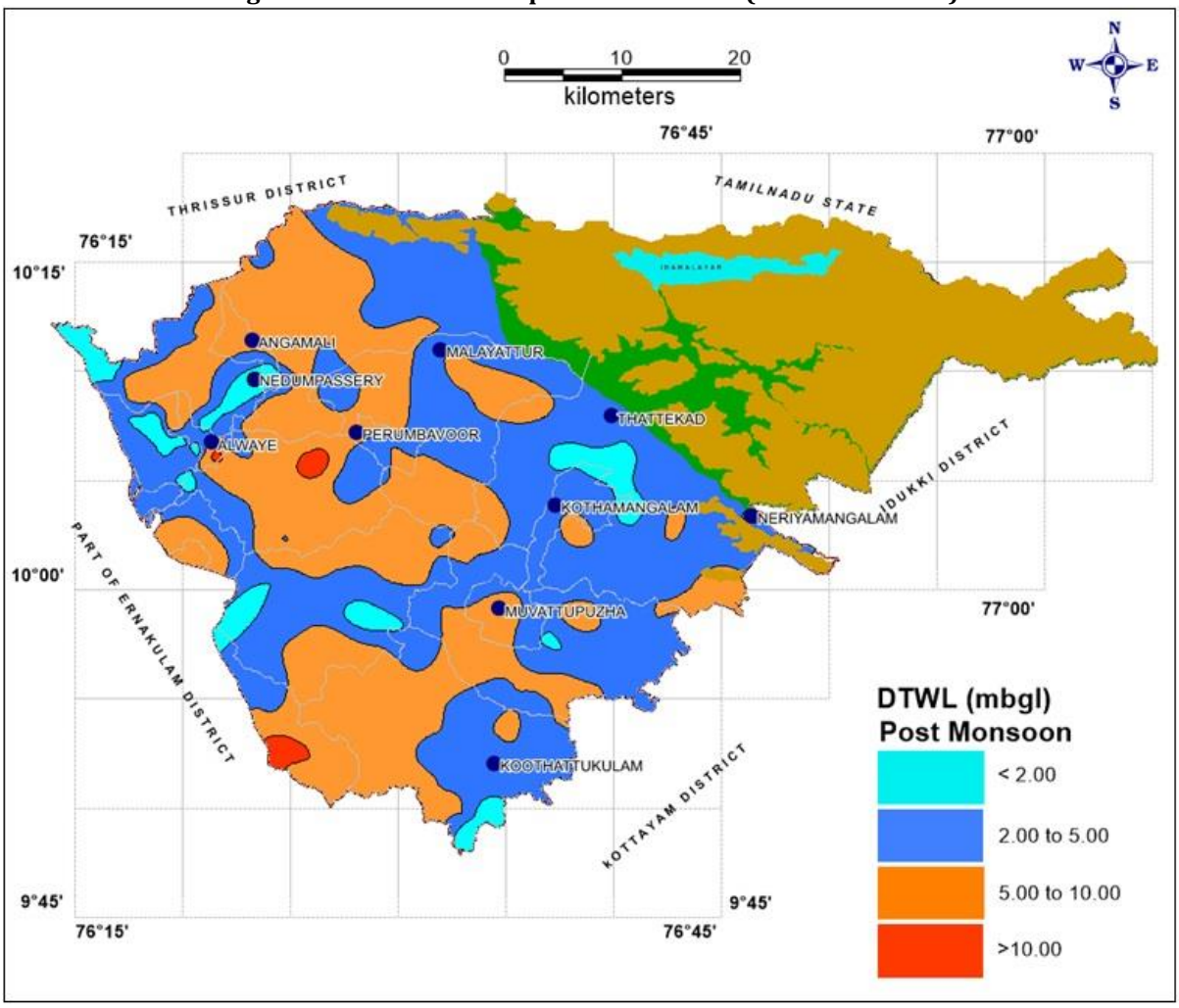
Fig. 3.2: Pre-monsoon depth to water level (April 2018)



Post-monsoon depth to water level (November 2018)

The depth to water level map for the post monsoon period (November 2018) is prepared based on the key wells and national groundwater monitoring wells data of the study area is presented as (Fig. 3.4). The depth to water levels during this period is varied from 1.80 mbgl (Chettiyod-Nayithode of Angamali Block) to 10.65 mbgl (Sreemoolanagaram, Vazhakulam Block). Water levels ranging from 0 to 2 mbgl is about 5 % of the study area, whereas >2 to 5 mbgl is about 52%. Water levels ranging from >5 to 10 mbgl is about 42%. Water levels ranging from >10 mbgl is 1% of the study area. Major part of the study area shows water level in the range of >2 to 5 mbgl and is observed in Eastern, North eastern and South eastern part of the study area and followed by >5 to 10 mbgl water level in northern and south western part and is shown in Fig. 3.3.

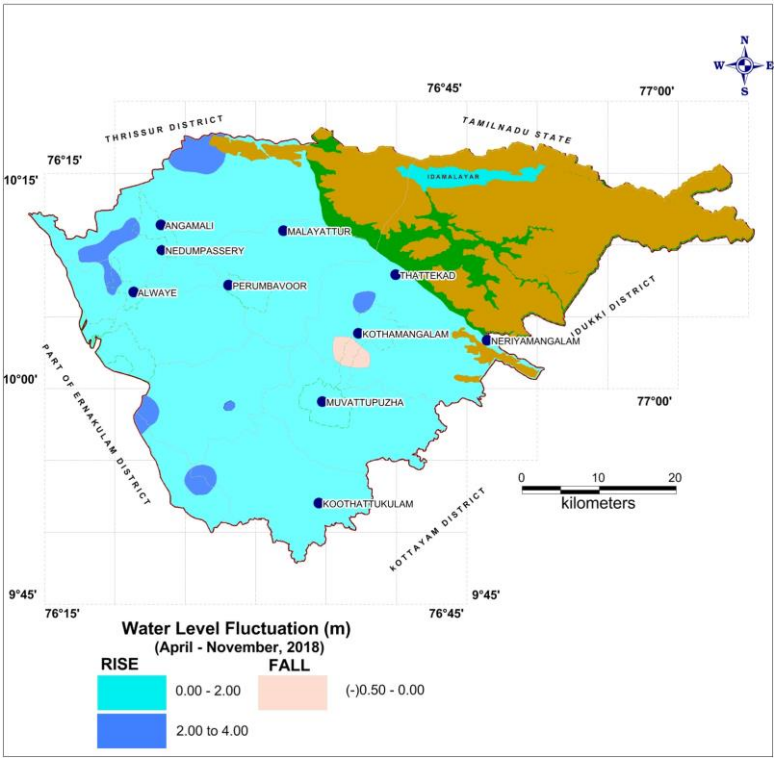
Fig. 3.3: Post-Monsoon depth to water level (November 2018)



Water level fluctuation

Water level fluctuation in the observation wells in an area between two periods is indicative of the net changes in the groundwater storage during the period in response to the recharge and discharge components and is an important parameter for planning for sustainable groundwater development. The seasonal water level fluctuation in the area has been analyzed using the water level data of April 2018 and November 2018, which indicate the extent of replenishment of the shallow aquifer due to the monsoon rainfall. The water level fluctuation in the study area ranged from a decline of 0.50 m (Kothamangalam) to a rise of 2 m (Aluva block) in phreatic aquifer (Aquifer - I) during the period of study and is shown in Fig. 3.4. The long-term water level fluctuation (2009-2018) specifies that in premonsoon period fluctuation varies maximum rise of 0.325 m/yr at Pampakuda and fall of (-) 0.298 m/yr at Kizhakombu and in post monsoon period having maximum rise of 0.338 at Kanjiramattom and fall of (-) 0.362 at Mullankunnu and the details are given in Table 3.1 and shown in hydrographs in Fig. 3.6.

Fig. 3.4: Water level fluctuation (April Vs November 2018)



Water table elevation

Water table elevation maps of Phreatic Aquifer - I of the study area during April 2018, along with flow lines showing the direction of groundwater movement are prepared and interpreted that the ground water is contributing to the river and as shown in Fig. 3.5 respectively.

Fig. 3.5: Water table elevation (April 2018)

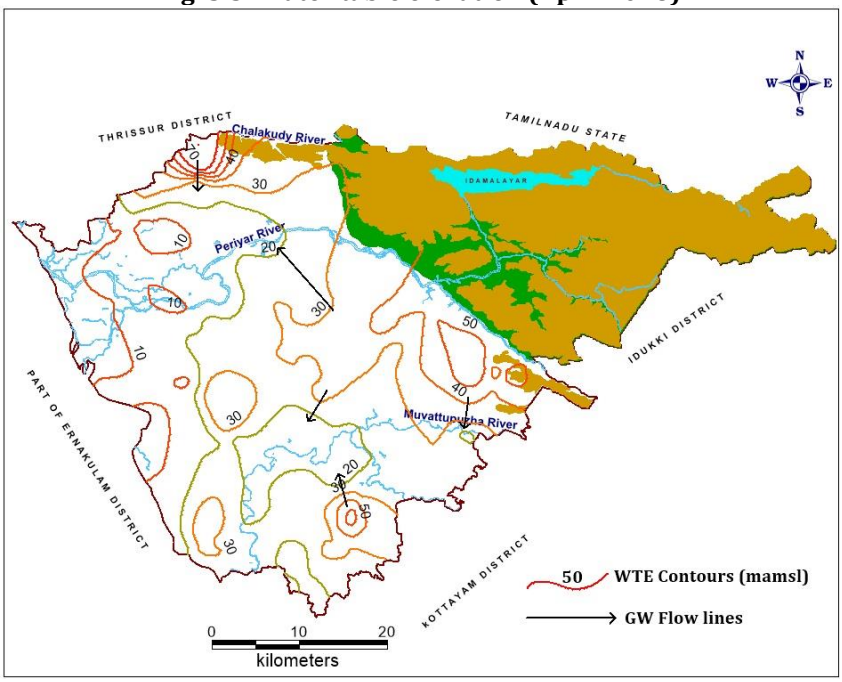
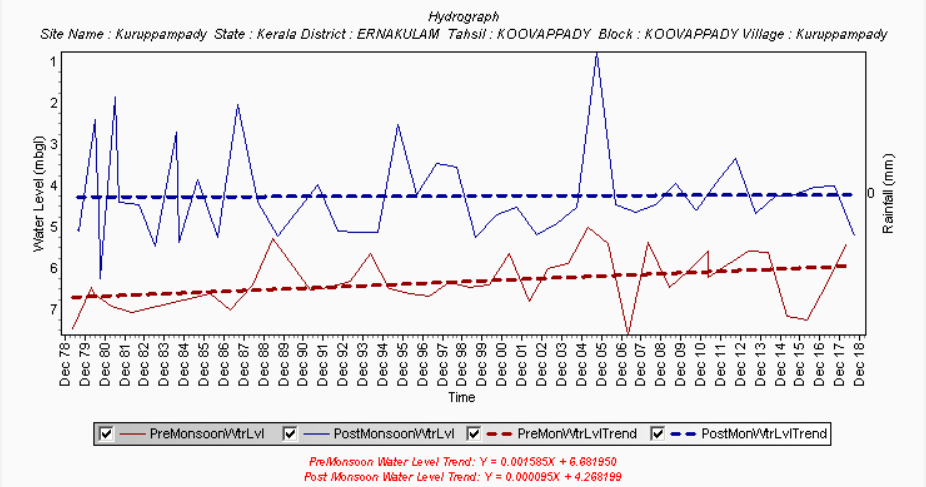
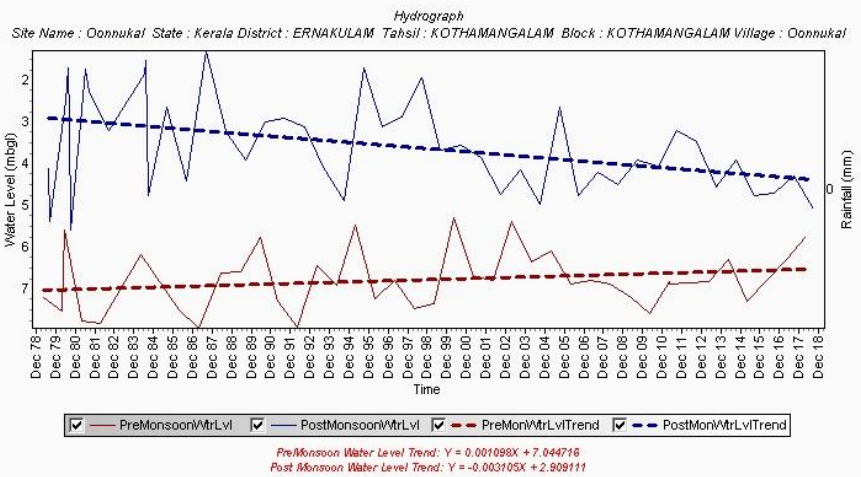


Fig. 3.6: Hydrographs showing long term trend of water level of monitoring stations

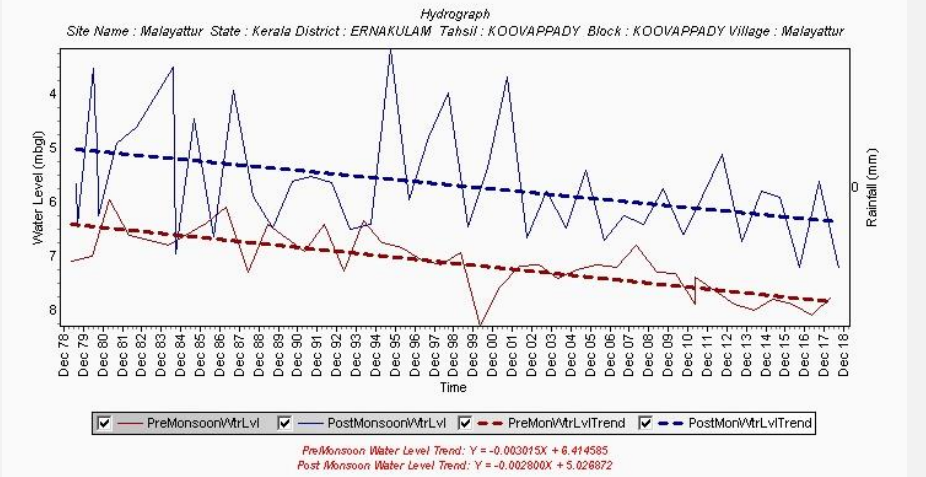
Location: Kuruppampady



Location: Oonukkal



Location: Malayattur



Location: Valayanchirangara

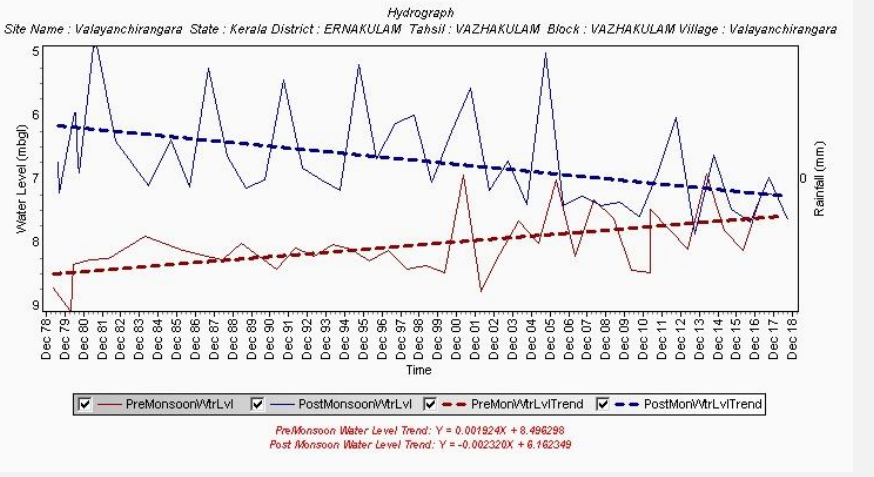


Table 3.1 Long term trend of water level (2009-2018) of the study area

Location	Pre-Monsoon		Post-Monsoon	
	Rise (m/year)	Fall (m/year)	Rise (m/year)	Fall (m/year)
Punnakad Pz	-	0.2066	-	0.0577
Perumbavoor (R1)	-	-	0.0136	-
Alwaye (Aluva)	0.0024	-	-	0.0371
Kuruppampady	-	0.0198	-	0.0412
Vallom (R1)	-	0.0410	-	0.0479
Chowara (R1)	0.0237	-	-	0.2915
Kottapuram (Alangadu)	-	0.1050	-	0.0418
Kanjur	-	0.2229	-	0.1018
Vazhakkulam North	0.0510	-	-	0.0501
Kottapadi	-	0.0554	-	0.0677
Thattekad (R1)	0.0559	-	-	0.0212
Koovapady	0.0368	-	0.1799	-
Koovapady2	0.0242	-	-	0.0970
Chengamanad	0.1944	-	-	0.1089
Mullankunnu	-	0.0962	-	0.1427
Keerampara	0.0063	-	0.2029	-
Kuthukuzhi	0.1749	-	-	0.0662
Parakkadavu	-	0.0414	-	0.0868
Malayattur	-	0.0666	-	0.0619
Malayattur1	-	0.1104	-	0.0268
Angamali (R1)	-	0.1125	-	0.1529
Kodussery	0.2420	-	0.0970	
Illithode	0.2620	-	-	0.1512
Manjapra	-	0.0450	-	0.1684
Attara (Kokunnu)	-	0.1531	-	0.0326
Chulli (R1)	0.1339	-	-	0.1219
Kanjiramattom	0.1079	-	-	0.1514
Namakuzhi Pz	-	0.0748	-	0.1746
Piravom	-	0.2011	-	0.2739
Koothattukulam (R1)	-	0.1109	0.0025	-
Veliyanad Pz	0.0260			0.0627
Edakkattuvoyal PZ	-	0.0688		0.0853
Kizhakombu	-	0.2981	0.0138	-
Edakkatuvayal	-	0.0154	-	0.1734
Pulluvazhi	0.0145	-	-	-
Thirumaradi DW	0.1221	-	-	0.1073
Thirumaradi	0.0107	-	0.1306	-
Mulanthuruthi	-	0.0485		0.1063
Anchalpetty-R1	0.0182	-	0.0064	-
Pambakuda	0.3253	-	-	0.2466
Palakuzha North	-	0.0567	-	0.2475
Kalloorkad	-	0.0797	0.0932	-
Kanjiramattom DW	-	0.0581	0.3382	-

Namakuzhi	0.3475	-	-	-
Arakuzha Pz	-	0.0465	0.0298	-
Ramamangalam	-	0.0651	-	0.2349
Perumbadavam	0.0989	-	-	0.1011
Tripunithura	0.0383	-	0.0018	
Poothrikka Pz	-	0.1970		0.1191
Puthankurisu (Kolencherry)	0.0498	-	0.0366	-
Kizhakombu DW	0.3999	-		0.1789
Vazhakam Pz	0.0290	-	0.0952	-
Kalur	-	0.0424	-	0.0689
Muvattupuzha	0.0248	-	-	0.0964
Aikaranad1 (Kadayiruppu)	0.1694	-	-	0.1250
Pothanikad	-	0.0162	-	0.0915
Aikaranad	-	0.0765	-	0.1271
Edapally	-	0.0379	-	0.0277
Trikkakara	-	0.1021	-	0.0133
Oonnukal	0.1260	-	-	0.1264
Neriyamangalam	-	0.1341	-	0.0284
Kothamangalam	-	-	-	0.2385
Valayanchirangara	0.0751	-	-	0.0135
Thalakode	-	-	-	0.0407
Elur North (R1)	-	0.0066	0.0099	-
Mullankunnu	0.1644	-	-	0.362

The water table elevation ranges from 10 m amsl (western part) to 70 m amsl (North to North eastern part) in the study area. The groundwater movement is from east to west and groundwater is contributing water to rivers, and from south to north and again towards west, where the Periyar and Muvattupuzha Rivers takes a flow of west direction.

3.2.2 Pumping test of phreatic aquifer

To find out the storage parameters dug well pump test were carried out in Pezhakapilly, Muvattupuzha Block and various pump test data from state ground water department were collected. Many of dug wells in the area have less than one-meter water column during most of the years and about 50% of wells get dry during summers especially in the highland areas. Most of the time dug wells are used as storage tanks to collect water from bore wells and to distribute the collected water for irrigation as the yield of each bore well is much less to support irrigation. The wells located in favourable hydrogeological settings like shear zones, topographic lows, river alluvium, etc., can sustain at a rate up to 50 m^3/day for 3 to 6 hrs of pumping. The yield of large diameter wells tapping the weathered mantle of crystalline rocks sustains at rate up to 30m^3/day for a drawdown of 2 to 3 m and can sustain 1 to 3 hours of pumping. In high land areas yield varies up to 5 m^3/day.

3.3 Hydro chemical data interpretation

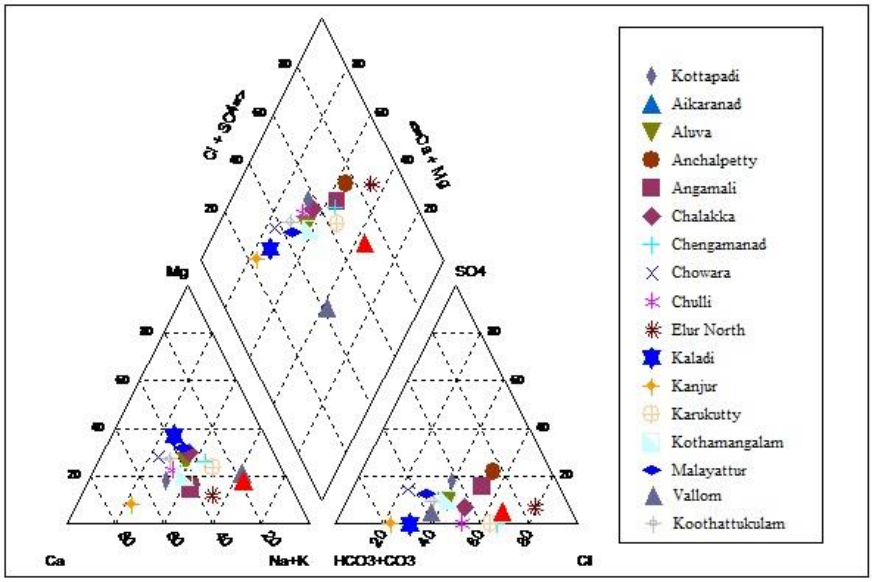
The chemistry of water is very dynamic, largely controlled and modified by its medium of contact. Since the chemistry of water directly hints the quality of water for various purposes, its monitoring and assessment gained substantial importance in the present century. Water type/ hydrochemical facies evaluation is extremely useful in providing a preliminary idea about the complex hydrochemical processes in the subsurface. Determination of hydrochemical facies was extensively used in the chemical assessment of groundwater for several decades.

Chemical composition of Groundwater in aquifer is influenced by various factors such as the chemical composition of litho units, composition and permeability of soils, degree and pattern of weathering etc. It is also influenced by agricultural, drainage and irrigation practices prevalent in the area. The chemical characteristics of ground water in the phreatic zone in hard rock areas of Ernakulam district has been studied using the analytical data of groundwater samples collected from exploration and Network stations of Central Ground Water Board. The ground water quality is good and Electrical Conductivity ranges from 40 to 580 (µs/cm at 25°C) one exception at Elur N having EC 2900 µs/cm at 25°C. For the deeper aquifer, the ground water quality is good and electrical conductivity ranges from 178 to 430 (µs/cm at 25°C).

Groundwater chemistry was assessed, and natural processes are identified as the controlling factors of hydrochemistry. The Piper-Hill diagram is used to infer hydro-geochemical facies. These plots include two triangles, one for plotting Cations and the other for plotting anions. The Cations and anion fields are combined to show a single point in a diamond-shaped field, from which inference is drawn based on hydro-geochemical facies concept. These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than with other possible plotting methods.

Chemical data of representative samples from the study area presented by plotting them on a Hill Piper-tri-linear diagram for pre-monsoon water samples. These diagrams reveal the analogies, dissimilarities and different types of waters in the study area, which are identified and listed in Annexure-VIII. The concept of hydrochemical facies was developed in order to understand and identify the water composition in different classes. Majority of the samples were behaved in same way except few samples. The prominent type was Mg- HCO_3 type, Mixed Type, No Dominant Type, HCO_3 type of water in this method and is shown in Fig. 3.7.

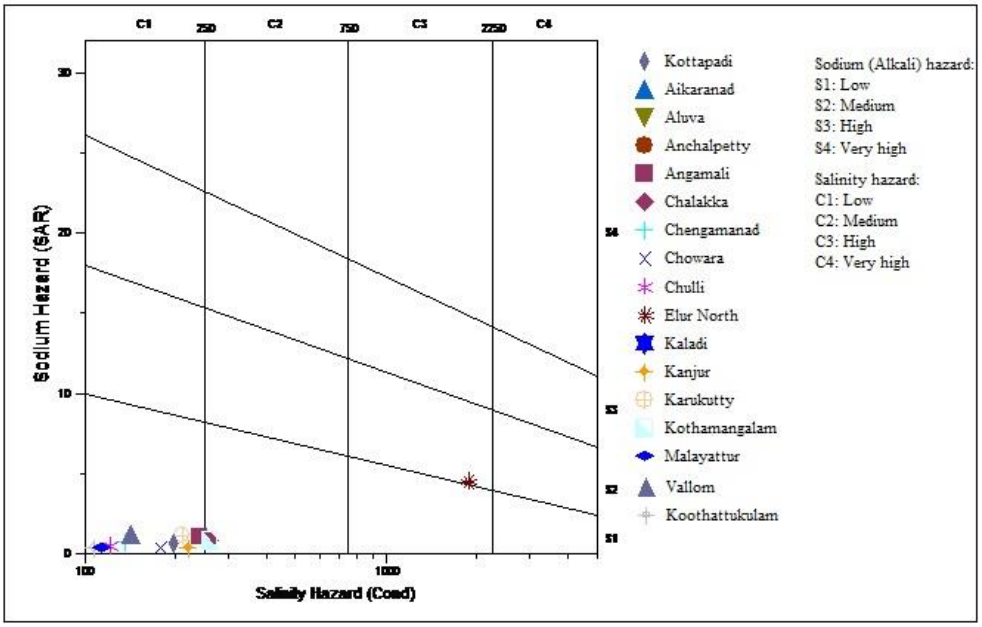
Fig. 3.7: Hill piper diagram of phreatic aquifer



Wilcox classified groundwater for irrigation purposes based on per cent sodium and Electrical conductivity. The US Salinity Laboratory of the Department of Agriculture adopted certain techniques based on which the suitability of water for agriculture is explained. When the Sodium Absorption Ratio (SAR) and specific conductance of water are known, the classification of water for irrigation can be determined by graphically plotting these values on the US salinity (USSL) diagram (Fig. 3.8). The groundwater of Ernakulam district is in general Mg- HCO3 type & mixed type during both pre- post monsoons. About 98% of the samples are grouped within C1S1 and C2S1 classes. Based on Wilcox diagram, samples fall in Low conductivity zone and are suitable for Irrigation.

Groundwater in phreatic aquifers in the study area is colourless, odourless, and slightly alkaline in nature. And the ground water is potable & fit for domestic, drinking, irrigation & industrial purpose.

Fig. 3.8: Wilcox diagram of phreatic aquifer



Quality of groundwater in the fractured zones at depth has been studied using the analytical data of water samples (34 Nos.) collected from during exploratory bore wells drilled by CGWB. However, these samples have been collected represent the cumulative quality of all water yielding fractures in the well, they have been used only to get an idea about the water quality of the deeper aquifer as a whole and is potable. Results of 68Nos. water quality monitoring stations analysis is on progress and will be update in the report.

3.4 Geophysical studies

Geophysical surveys play an important role in ground water exploration as they help in better understanding the ground water occurrence based on surface investigations. Geophysical methods can be classified into surface and subsurface methods depending upon whether measurement made on the ground surface and below the ground in drilled boreholes.

3.4.1 Surface geophysical survey

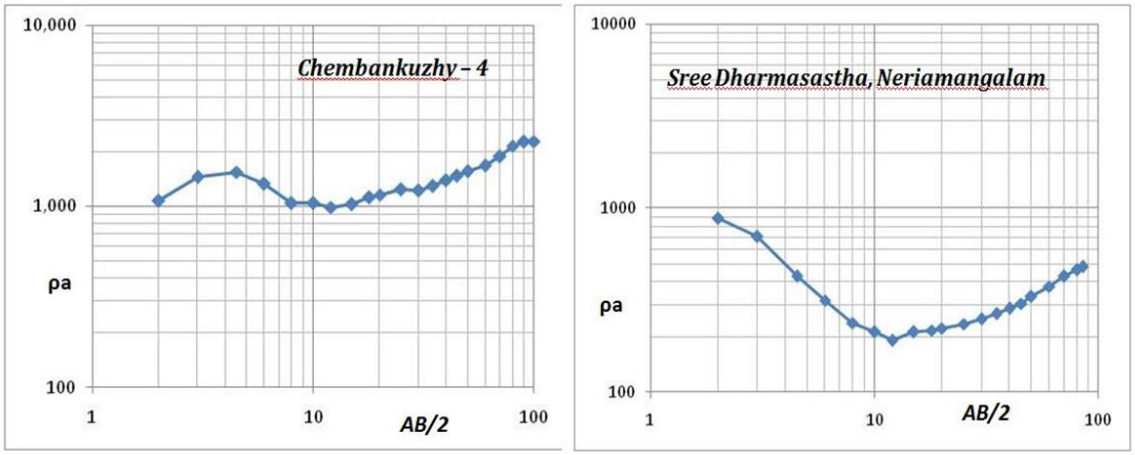
In hard rock terrain, electrical resistivity techniques such as profiling and gradient/ radial arrays are quite effective in detecting presence of fractures at depth. In Ernakulam district, a total of 85 Vertical Electrical Soundings (VES) were carried out covering 54 villages by employing the Schlumberger & Half Schlumberger electrode configuration apart from that 5-line km resistivity profiling in order to know the sub surface conditions to recommend sites for ground water exploration also to provide additional information for aquifer mapping and management studies and 50 VES were generated after data gap analysis. The obtained VES data was interpreted by using the computer interpretational techniques. The interpreted results obtained were presented in Annexure-IX.

The interpreted results have given rise to maximum of 6 layered geoelectric sections. The first layer resistivity value was varying in the range of 29-VH Ohm.m with thickness in the range of 0.19-12.7 m which is topsoil. The second layer resistivity value was varying in the range of 44-VHohm.m. Within this range, at some sites the resistivity was encountered <200 Ohm.m

which was considered as weathered formation and at some sites the resistivity was varying in the range of 200–VH Ohm.m which was considered as hard laterite formation. The thickness of this layer was varying in the range of 0.57-20.54m. The third layer resistivity was varying in the range of 34-VH Ohm.m, which is fractured to hard formation. The thickness of this layer was varying in the range of 1.34-49.49m and at some sites this layer was extending in nature. The fourth layer resistivity was varying in the range of 45-VH Ohm.m. The thickness of this layer was varying in the range of 2.45-35.5m and at some sites this layer was extending in nature. The fifth layer resistivity was varying in the range of 50-VHohm.m. The thickness of this layer was varying in the range of 8.9-29m and at some sites this layer was extending in nature. The last layer (sixth layer) was encountered in the few of sites with resistivity range of 52-VH Ohm.m.

The representation of different field curves in Chembankuzhy and Neriamangalam of Ernakulam district has been presented in Fig. 3.9. The Wenner Profiling Plots of Elambra Bypass, Kothamangalam and Sree Dharmasastha Temple, Neriamangalam, Ernakulam has been presented in Figs 3.10 & 3.11.

Fig. 3.9: Representation of different field curves in Chembankuzhy & Neriyamangalam



Based on the results of geophysical surveys (VES), borewells have been recommended at some sites. Eg. Chembankuzhy, Neriamangalam, Vadattupara, Boothathankettu, Palamattam, Oonukkal, Nellimattom, Elambra, Vazhakkulam, Kodanad & Kothamangalam, etc., also drilling activities have been conducted in some of these sites and have given meagre to good yield. Eg: Neriamangalam (8.5 lps) &Vazhakkulam (0.5 lps), etc.

Fig. 3.10: Wenner profiling plot on Elambra bypass, Kothamangalam, Ernakulam

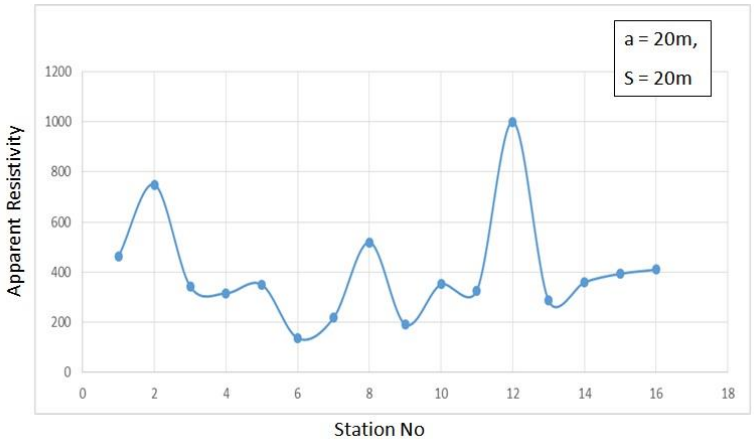
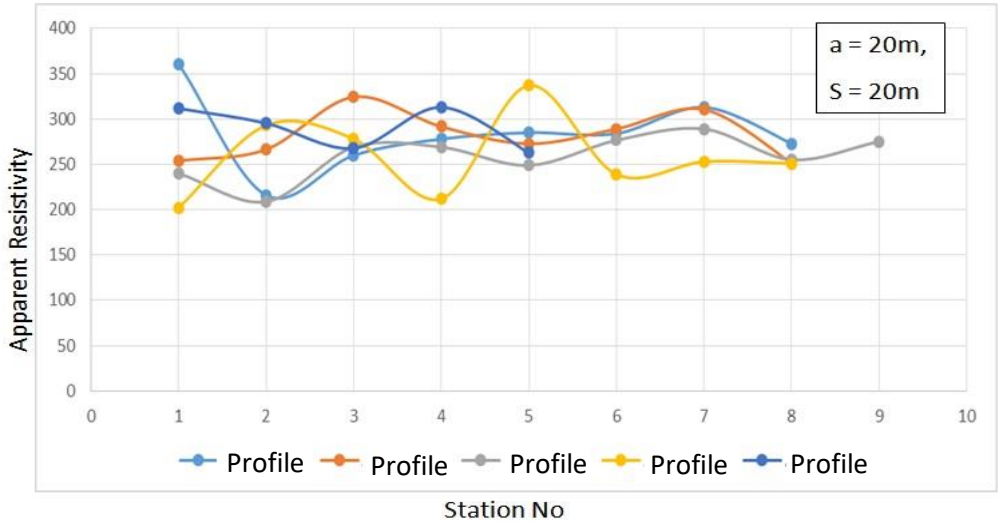


Fig. 3.11: Wenner profiling (parallel) plot on Sree Dharmasastha temple, Neriamangalam.



3.5 Soil infiltration test data results

In the present study the infiltration tests are carried out at 2 sites namely EEC, Muvattupuzha and PVIP, Perumbavoor of Ernakulam district. All the sites are selected based on covering different soil types, soil moisture condition, texture, soil cover and slope etc. The experiments are conducted during March, 2019 using Double ring infiltrometer. The measurement of the water volume is done on the inner ring only. The experiment is carried out till a constant infiltration rate is obtained (K Subramanya, 2015). Soils are considered divided into four groups known as hydrologic soil groups. The steady state infiltration capacity, being one of the main parameters in this soil classification, is divided into four infiltration classes as mentioned in below table 3.2.

Table 3.2 Classification of infiltration capacities (K Subramanya,2015)

Classification of infiltration capacities		
Infiltration Class	Infiltration Capacity (mm/hr)	Remarks
Very Low	< 2.5	Highly clayey soils
Low	2.5 to 12.5	Shallow soils, Clay soils, Soils low in organic matter
Medium	12.5 to 25	Sandy loam, Silt
High	>25	Deep sands, well drained aggregated soils

Curves of infiltration capacity and cumulative infiltration capacity of two sites at Muvattupuzha and Perumbavoor are plotted and are shown in Fig. 3.12 & 3.13 respectively.

Table 3.3 Summarised results of soil infiltration tests

#	Location details	Date	Soil Type	Dura-tion (min.)	Cumulative depth of infiltration (cm)	Final Infiltration rate (cm/hr)
1	Agricultural Rural Wholesale market, EEC, Muvattupuzha	02.03.19	Laterite Soil partially compacted	200	38	7.8

2	Minor Irrigation Department, Sub Division-II (PVIP), Perumbavoor	07.03.19	Laterite soil, loosely packed, well drained soils	200	143.2	35.4

Fig. 3.12: Curves of cumulative infiltration capacity of EEC, Muvattupuzha

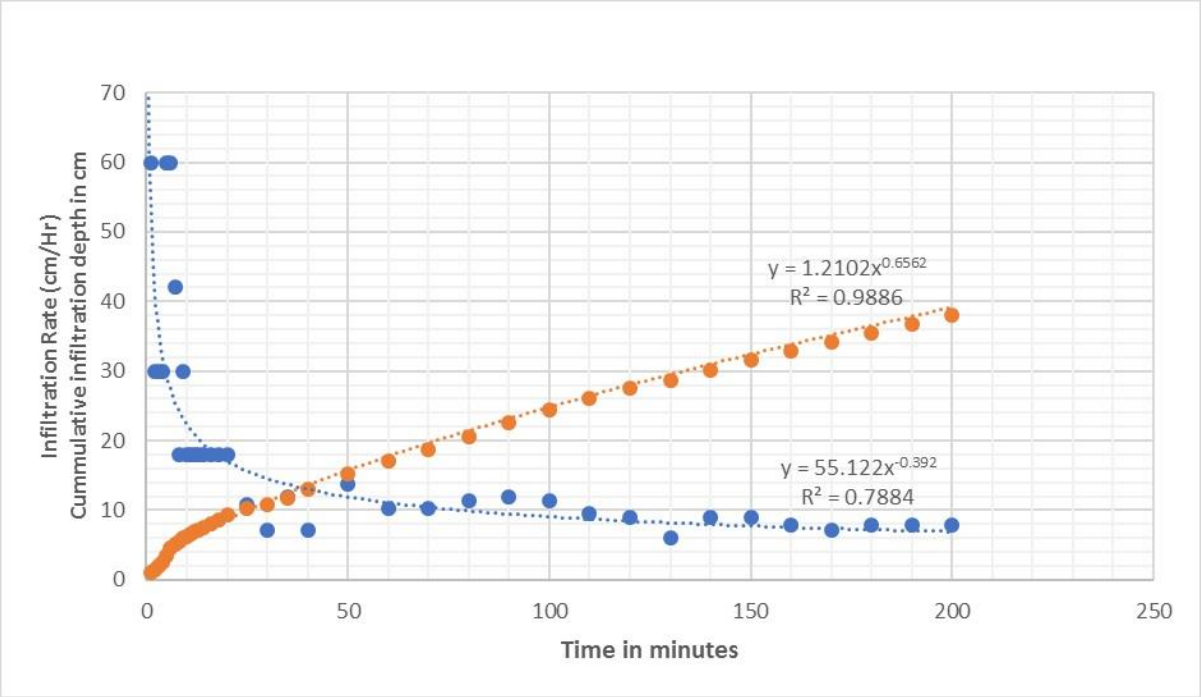
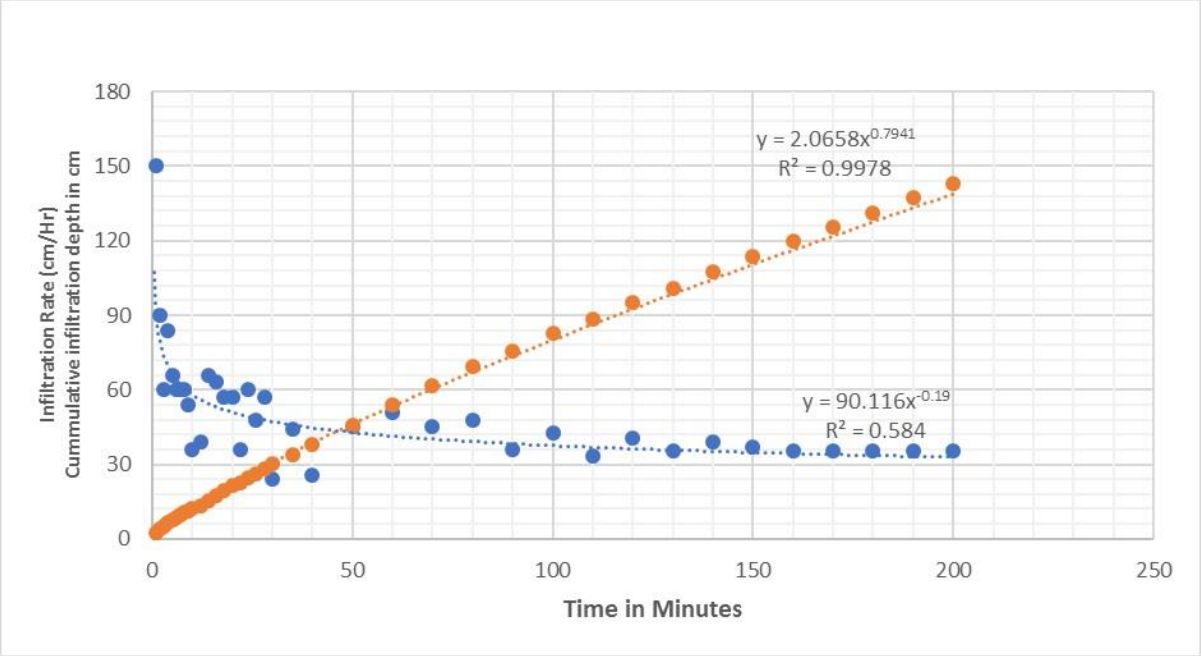


Fig. 3.13: Curves of infiltration cumulative infiltration capacity of PVIP, Perumbavoor



The lowest rate of infiltration is observed at Muvattupuzha where the test was conducted on agriculture land having Deep sands /gravelly clay. The highest rate of infiltration is observed at Perumbavoor which is carried out on well drained aggregated soils/ gravelly clay. It is observed from the results that the soil infiltration rate varies from 7.8 cm/hr to 35.4 cm/hr. The total cumulative depth of infiltration varies from 38 cm to 143.2 cm. and is given in table 3.3

Based on the test results as compared to the classification of infiltration capacities given in Table 3.2, it is observed that the infiltration capacities in the study area fall in high class. The results also indicate the characteristics of different soil types and Land use.

3.6 Groundwater exploration data results

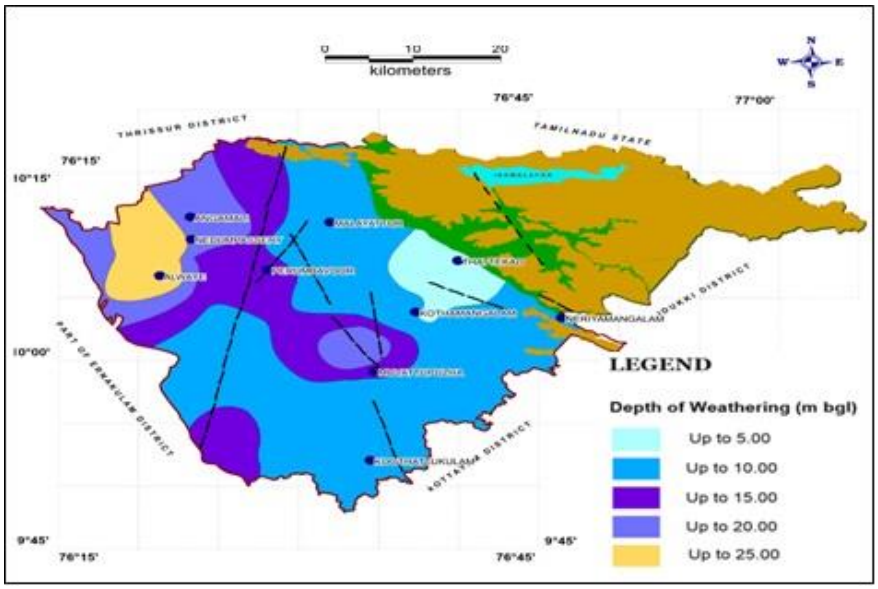
The data generated, as discussed in section 2.5, such as lithology, fracture depth, yield, water level, aquifer properties were and utilized to depict the prevailing aquifer systems of the study area. Depth of Exploratory wells drilled in the hard rock area of Ernakulam district ranging from 59 mbgl (Athirapally, 9th block) to 237 m.bgl (Vadakumaradi). Drilling data of the exploratory wells has revealed the presence of productive fractures in charnockites and gneisses in the study area. Overall productive fracture zones have been encountered in crystalline rocks at the depth range of 19 to 194m.bgl in the study area. Discharge of the bore wells varies from 6 to 1320 lpm. As per the data integration, wells drilled in Charnockite yield more than the wells drilled in biotite gneiss. A few of the wells have been abandoned due to poor yield. 39 bore wells data have been utilized for fracture analysis. It shows that 1st fracture encountered in 15 wells with depth vary from 9.00 to 38.00 mbgl. 2 nd fracture encountered in 15 bore wells with depth varying from 38.00 to 80.00 mbgl. Similarly, 3 rd fracture encountered in 14 bore wells with depth vary from 84 to 142 mbgl and 4th fractures encountered in 6 bore wells with depth vary from 149 to 194 mbgl. Shallow to Intermediate fractures forms the potential aquifers in the crystallines. Borewells in the study area are generally tapped in the ranges of 40 to 70 m depth below ground level.

The aquifer mapping studies reveal that the presence of two distinct aquifers in the hard rock formations. They are;

3.6.1. Phreatic aquifer – I

It comprises of laterite/ weathered partially weathered and first fracture to some extent in Hornblende biotite gneisses, Charnockites and Migmatite complex. Laterite forms the potential aquifer in the study area, and it is hydraulically connected with deeper fracture zones. Weathered thickness of the phreatic Aquifer ranges from 2 to up to 25 mbgl and depth to weathering is increasing towards north western part. Depth to weathering of study area is depicting in Fig. 3.14.

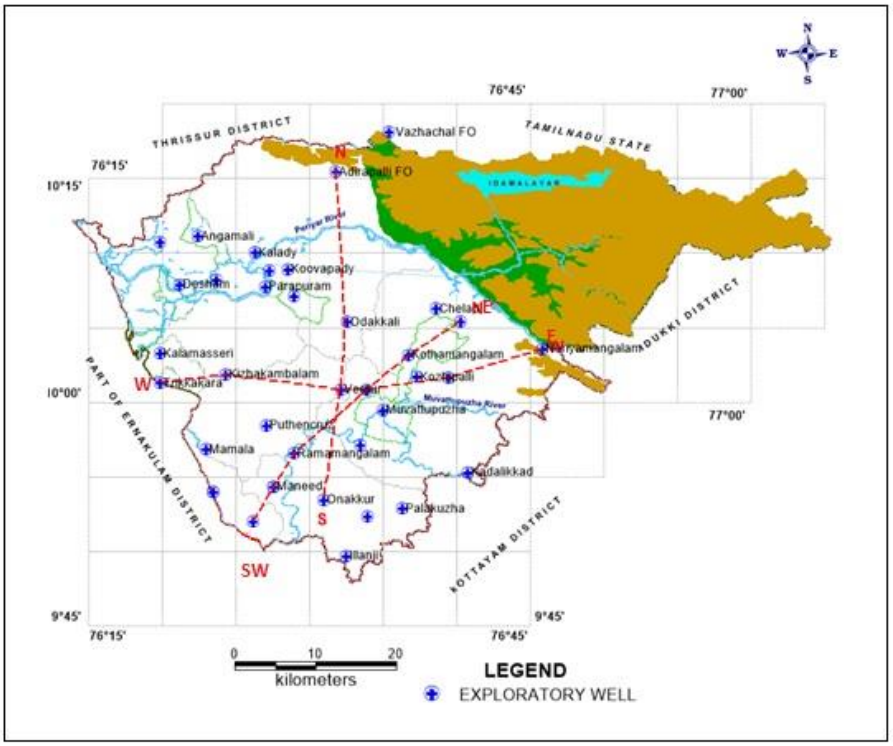
Fig. 3.14: Depth to weathering map



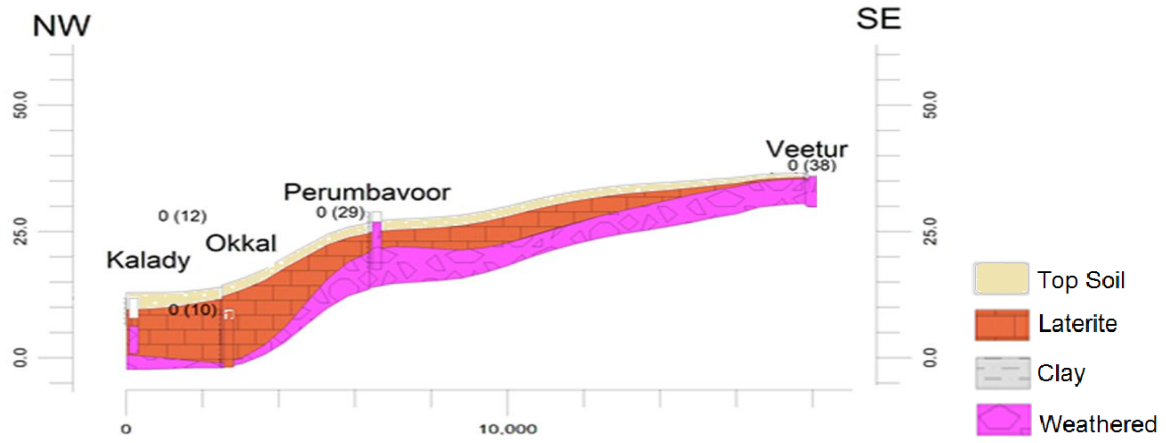
Depth of dug wells ranges from 2.10 to 14.80 mbgl and Depth to water level ranges from 1.85 to 12.20 m bgl in premonsoon and 1.80 to 10.65 mbgl in post monsoon period. The wells located in this aquifer zone yield groundwater of <5 to 50 m^3/day and sustains 1 to 6 hrs of pumping. Shallow to Intermediate fractures forms the potential aquifers in the crystallines.

To understand the sub surface disposition in the study area, geological sections have been prepared by synthesizing the various sub-surface sections on the basis of study of the lithological logs and electrical logs of boreholes drilled by CGWB, and State government using the RockWorks15 software and 2D lithological sections were prepared. The 2D lithology cross section lines are shown in Fig.3.15.

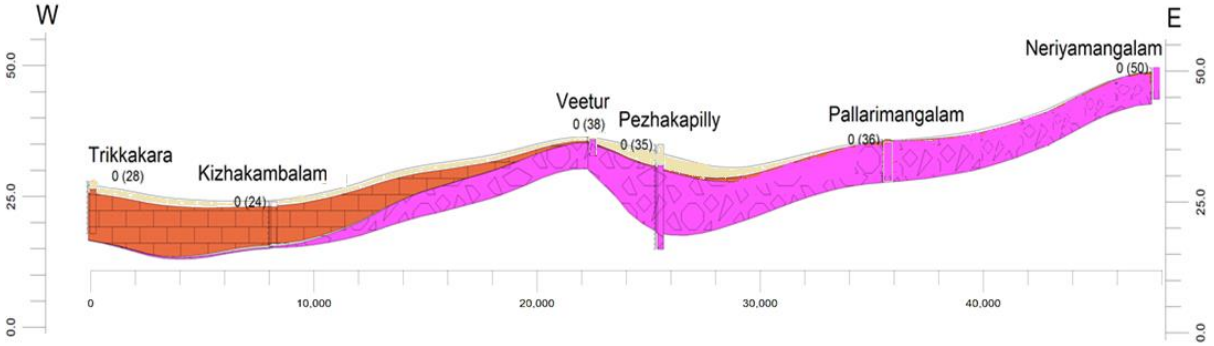
Fig. 3.15: Section lines for 2D Aquifer disposition



Section along NW- SE direction (Fig. 3.15) from Kalady to Veetur indicates that weathered aquifer spreads about 3.5 to 14 m thickness and it thins out at Veetur, where the thickness is minimum of 3.5 m. Laterite thickness is reducing towards South east direction and makes hydraulic continuity with shallow fracture/weathered zone.



Section along W- E direction from Thrikkakara to Neriyamangalam (Fig. 3.15) shows that the area is having an undulating topography and aquifer spreads about 1 to 15 m. Laterite thickness is high in western part and thins out at Veetur and thickness of weathered formation is increasing towards eastern side.



3.6.2 Deeper aquifer – II

It comprises of mainly of fractures (secondary porosity) developed during tectonic disturbances, occurs at depth generally ranges from 19 to 194 mbgl. The maximum yield of wells tapping this aquifer varies up to 10 lps. The Transmissivity value of the aquifer ranges between 15.6 and 319 m^2 /day while the discharge values vary from 6 to 1320 lpm. Storativity of the aquifer ranges from 0.00007 to 0.001 in the study area. Groundwater occurs under semi-confined to confined conditions.

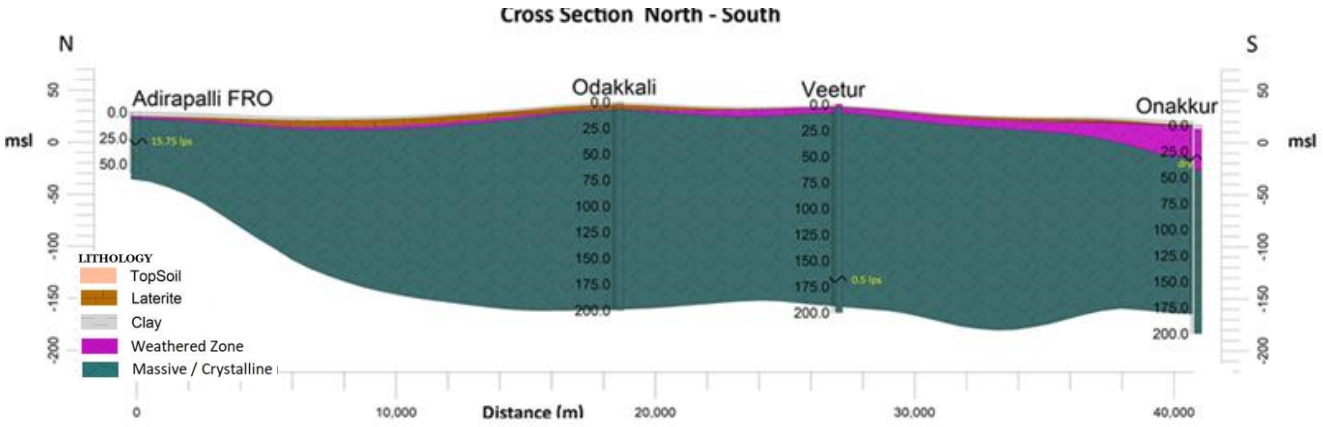
3.7 Aquifer disposition

3.7.1 2D models showing aquifer disposition

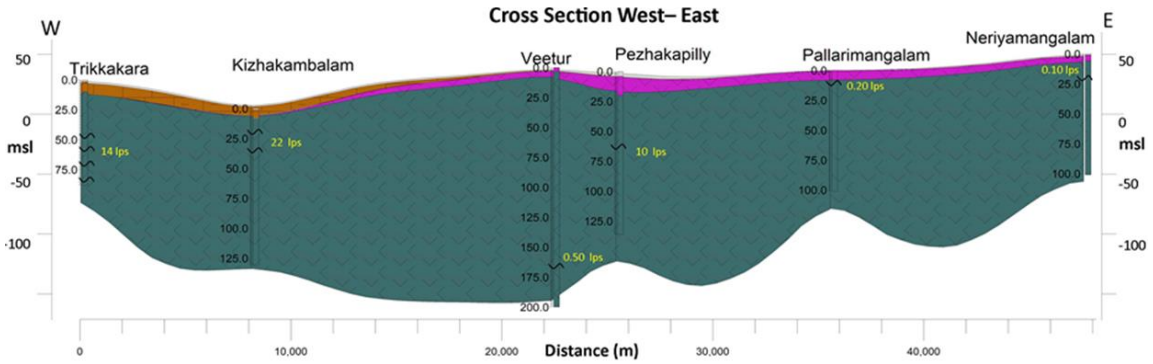
Based on the validated lithologs of the exploratory wells and the geophysical data interpretations during field studies as part of Aquifer Mapping, 2D models and sections of the aquifer system of the study area has been deciphered by using ROCKWORKS software. Lithological cross-sections have been prepared using the lithologs of boreholes drilled in the crystalline rocks for a better perspective of the subsurface geology and the panel diagram and the details of the formations encountered in the boreholes (litholog) are shown in Fig. 3.14.

The lateral and vertical variation in the thickness of weathered zone has been elucidated from the data collected from the exploratory drilling activities of CGWB- 39 wells in the study area.

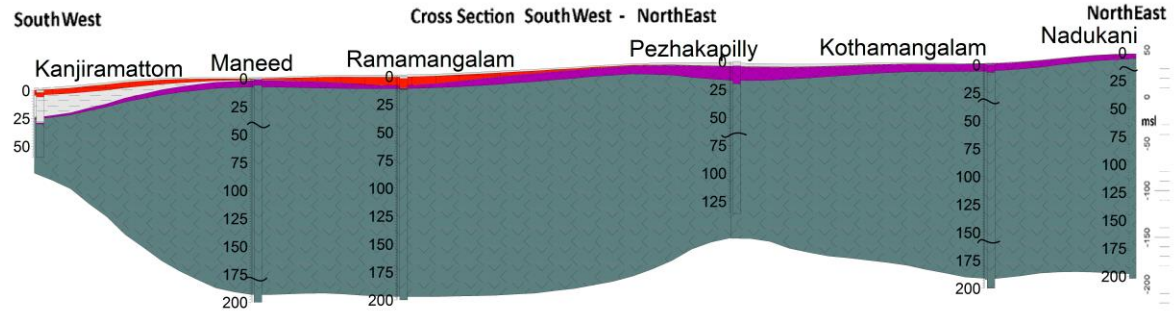
Section along North– South direction in the study area covers the Phreatic and deeper aquifer, Phreatic aquifer having thickness varying from 3.46 to 23.00 m. Deeper Aquifer is having maximum thickness up to 200m bgl depth. The shallow fractures are encountered at a depth of 25 m in Adirapalli and Onakkur in which Adirapalli have a discharge of 15.75 lps. Another fracture has encountered at a depth of 165 mbgl at Veetur with 0.5lps discharge.



Section along W- E direction (Fig. 3.14) shows that laterite make hydraulic continuity with weathered formation and is thins out at Veetur. Mainly, two sets of fractures are observed in this section in which first set of fracture are encountered at a depth of 12 to 38m with maximum discharge of 0.20lps and second set of fracture at depth of 48 to 86m bgl with discharge varies from 10 to 22 lps. Third fracture is encountered at a depth of 167 mbgl with discharge of 0.50lps.



Section along SW- NE direction (Fig. 3.14) shows that thick clay beds are observed in Kanjiramattom. Shallow fractures are encountered at Nadukani and deeper two sets of fractures are encountered at 40 to 73 m and 167 to 183 respectively.



3.7.2. 3D models showing aquifer disposition

To understand the aquifer disposition in the study area, geological models and fence diagram have been prepared by synthesizing the various sub-surface sections on the basis of study of the lithological logs of boreholes drilled by CGWB and geophysical borehole logging and resistivity profiling 3D lithological model has been prepared shown in Fig. 3.16 and to depict the vertical and lateral thickness of the area fence diagram is prepared based on the fence lines connecting with the bore wells and is shown in Fig. 3.17.

Fig. 3.16: 3D Model showing aquifer disposition

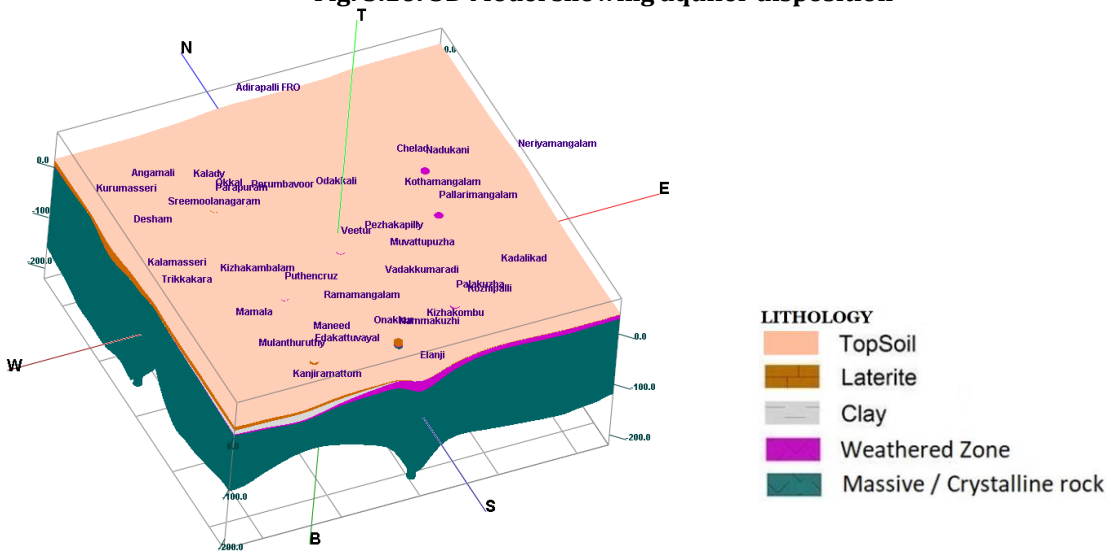
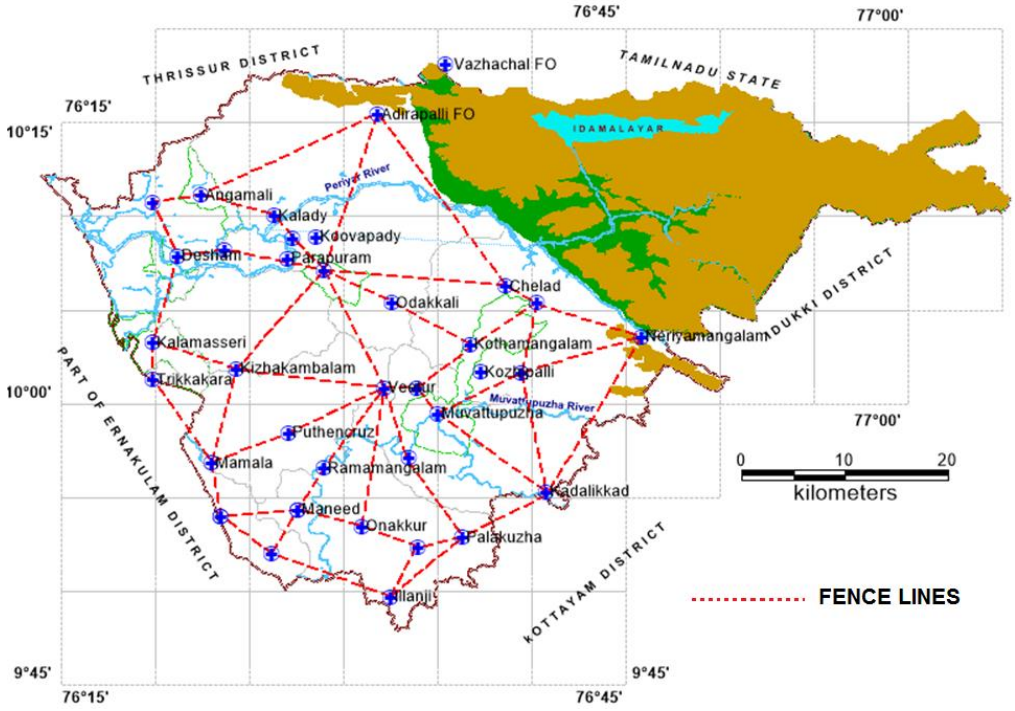
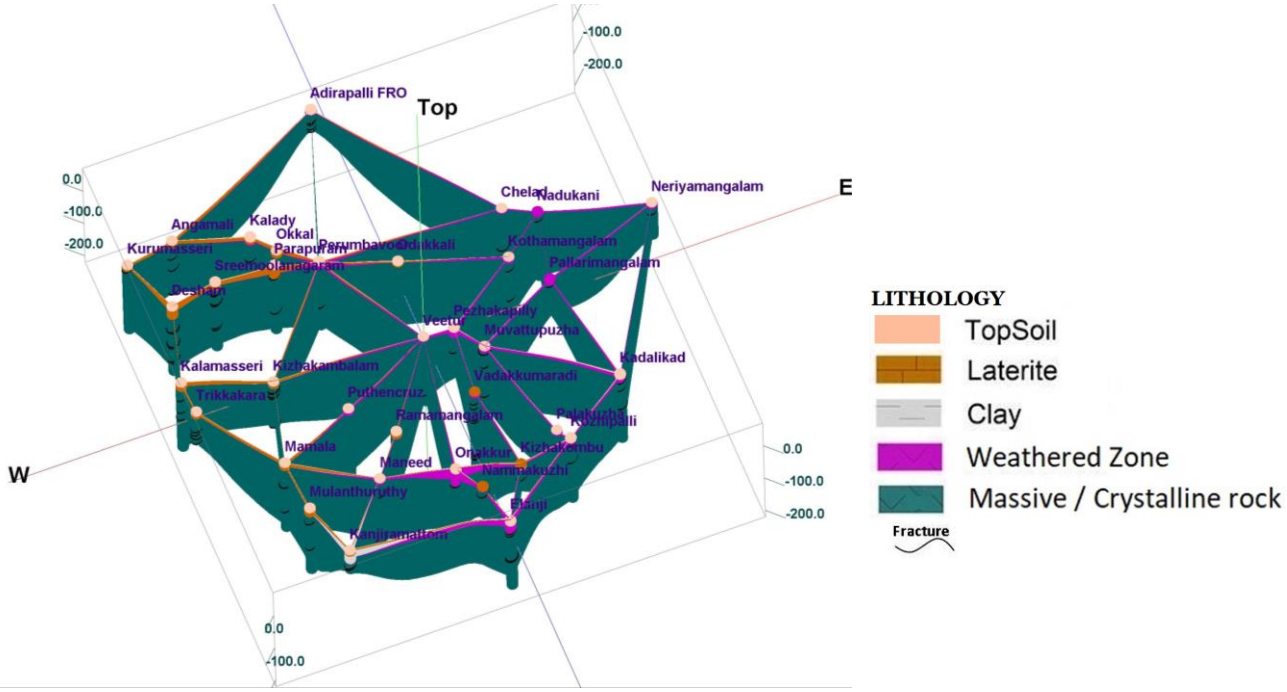


Fig. 3.17: Fence diagram section lines for aquifer disposition



The 3D lithological fence will represent the much clear representation of sub-surface lithology in space. The fence diagram depicts the vertical and laterial variation of aquifer along all directions and represents an undulating terrain with laterite formation at western side and weathered formation on eastern side. Maximum clay formation is encountered in the bore hole of Kanjiramattom. Thickness of fractured aquifer is considerably high in North & East compare to, West and South of the area and is shown in Fig. 3.18.

Fig. 3.18: Panel diagram showing aquifer disposition



3.8 Aquifer maps

Once the collection, compilation, data gap analysis and additional data generation to fill the identified data gap are completed, the final and most important step is the preparation of the aquifer map, which brings together various aspects of the aquifers and their ground water resources in the form of a map, which can then be used by the stakeholders to plan their sustainable development and management.

The processes of digitisation, preparing GIS dataset of aquifer thickness, depth of occurrences of water bearing zones, their water bearing and transmission properties, depicting geophysical parameters, water quality parameters, ground water resources and visualization of the aquifer units in three dimension including fence and cross section is used for the preparation of aquifer maps.

3.8.1 Aquifer map of phreatic aquifer

Based on the weathered zone thickness, aquifer geometry, water levels, ground water yield and hydraulic properties, the aquifer map of the phreatic aquifer system is prepared. The central and north western part of the study area shows high ground water potential is up to 50 cum/day of 2 to 6 hours of pumping, southern part ground water potential is up to 30 cum/day of 1 to 4 hours of pumping, in eastern part the weathered thickness is limited and the ground water potential is up to 5 cum/day of 1 to 2 hours of pumping. By integrating the available data along with aquifer mapping, an aquifer map of the phreatic aquifer has been prepared and is shown in Fig. 3.19. The Phreatic Aquifer map categorised the area into three categories based on the type of aquifer, depth to water level, average depth of the wells, sustainable yield, ground water quality as well as the groundwater prospects.

Category I- Alluvium: Mainly seen along the flood plains, alluvial plains and sand bars of Periyar River which are the more promising sites of groundwater. The aquifer materials possess high porosity and permeability. The depth to water level is shallow with a yield up to 50 cum/day. These are the main recharge zones mainly composed of loose sediments and homogeneity exists

in the aquifer material, but these areas are under the high threat of sand mining and waste disposal.

Category II - Laterite: The weathered laterite seen in the north western part and western part of the study area where the thickness of this aquifer varies from 10 -20 m belongs to this category. Normally, dug wells collapse at the lithomargic zone and groundwater occurs at a deep-water level. Wells dry during summer shows the less yielding capacity of this aquifer. Recharge pits and percolation tanks can be suggested in this aquifer to maintain the groundwater level during lean period.

Category III - Massive rocks: The hilly area seen on the eastern part of the study area are characterised by structural and denudational hills with high drainage density and thin soil cover are included under this category. This represents the run-off zone with low groundwater prospects. The intervening valleys with gentle to moderate slopes where having high degree of weathering contribute moderate to high groundwater potential yield.

3.8.2 Aquifer map of fractured aquifer

By integrating the available exploration details such as lithologs, casing depth, pumping details, depth to water level, lineaments, ground water quality, lithological cross sections and aquifer properties an aquifer map for fractured aquifer is prepared and is depict in Fig. 3.20. The success rate of wells drilled in hard rocks depends upon the development of interconnected secondary porosity. Lineament controlled valleys hold promising sites for borewell. Based on the available data two to three sets of fractures are identified in the study area. Borewells generally tapped in the second set of fracture i.e. intermediate are generally good and potential in ranges from 40 to 70m bgl of the study area.

Fig. 3.19: Aquifer map of phreatic aquifer

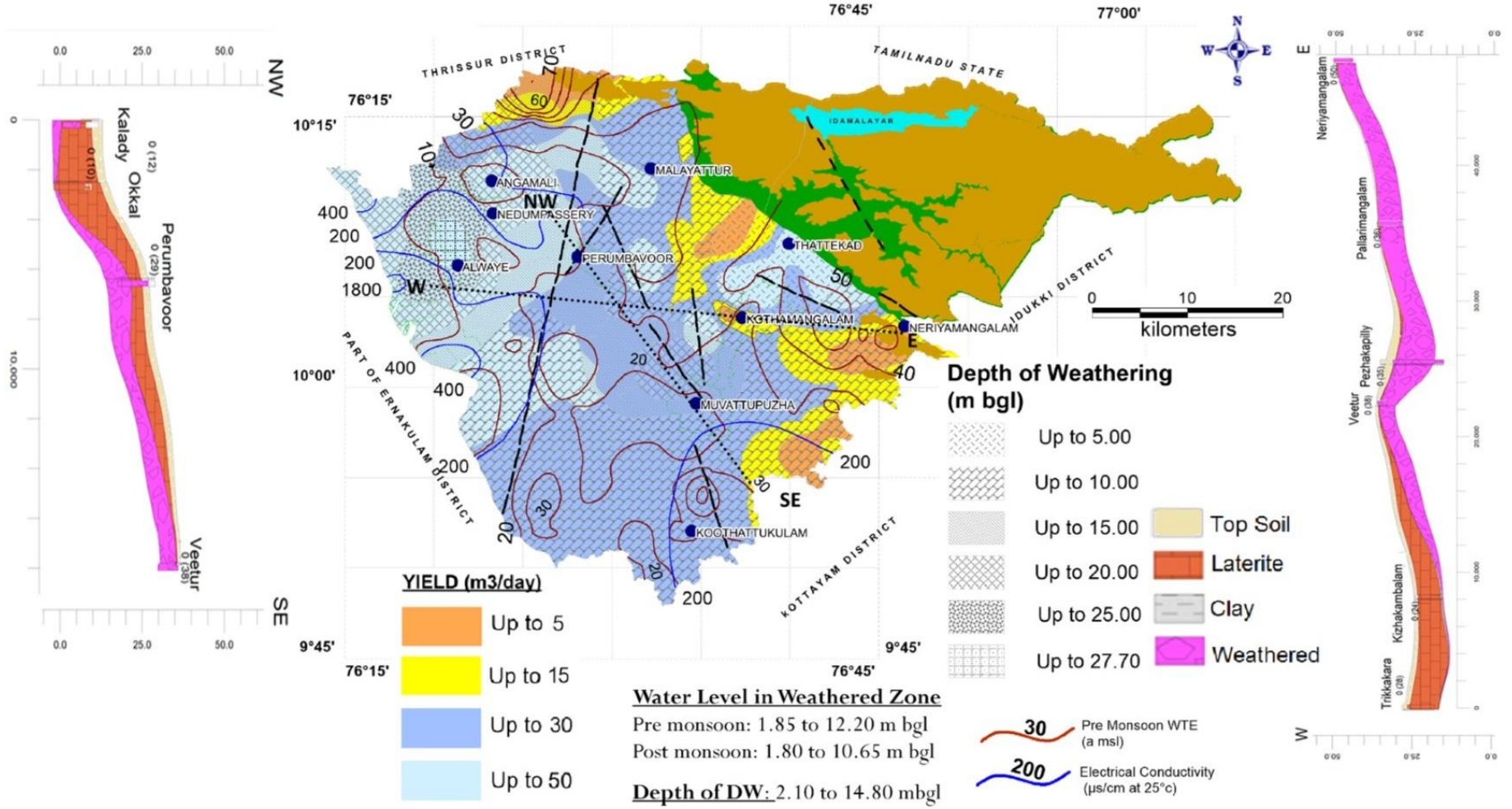
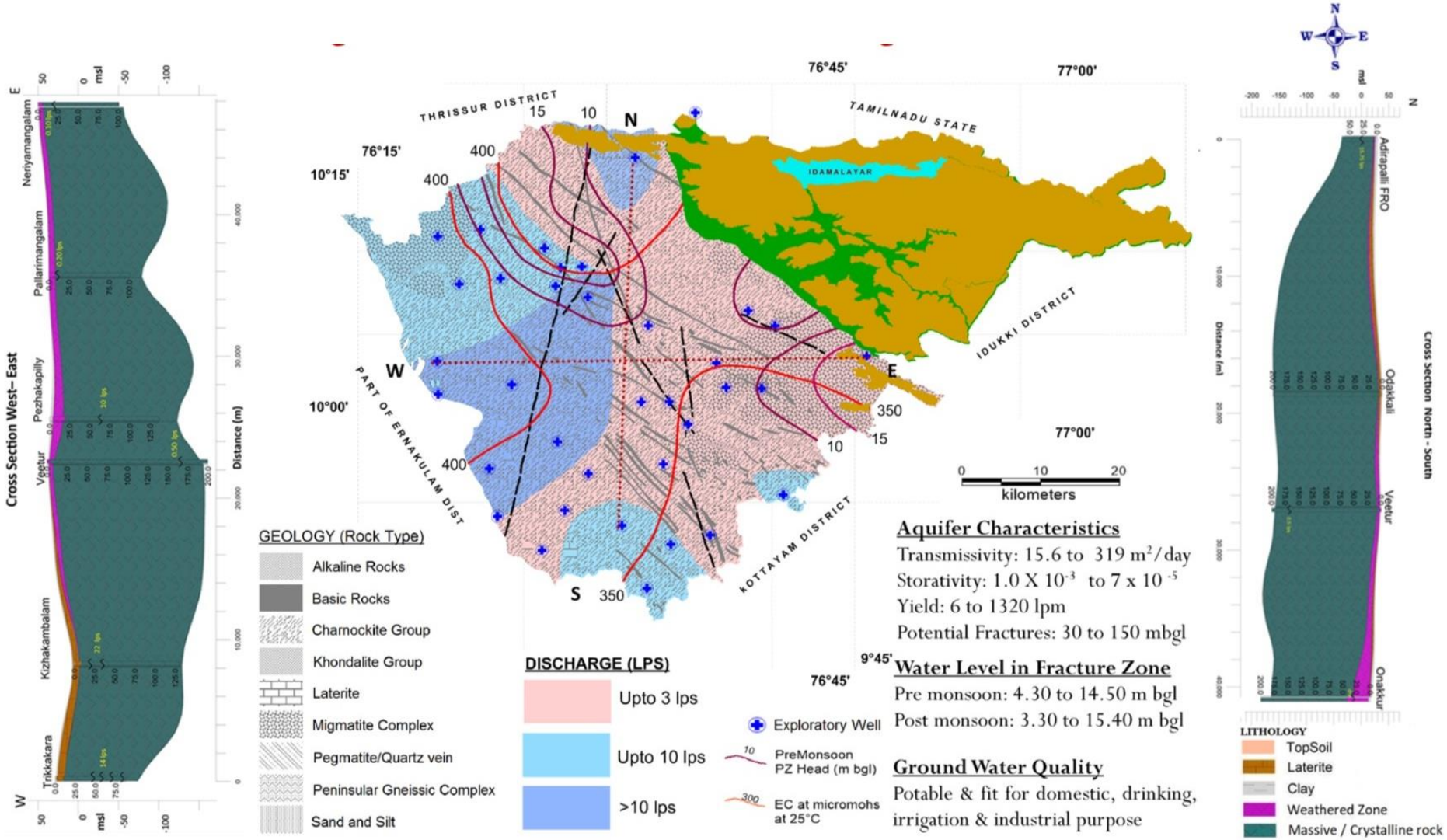


Fig. 3.20: Aquifer Map of fractured aquifer



4.0 GROUNDWATER RESOURCES

Ground water resource estimation of the area have been carried out by taking Dynamic and In-storage resources of unconfined aquifer and confined aquifers present up to 200m depth. The assessment of dynamic ground water Resources of the study area has been carried out jointly by CGWB and State Ground water Department, Govt. of Kerala based on Ground Water Estimation Committee (2015) methodology. The occurrence of potential aquifers (productive zones) up to 200 m depth has been demarcated on basis of aquifer wise subsurface mapping. The ground water resource of this zone has been calculated considering 12% specific yield of the formation. The specific yield value for the unconfined aquifer has been taken as 0.03 to 0.16 whereas for the confined aquifer, the storativity value has been considered.

4.1 Ground water resources in the phreatic aquifer

4.1.1 Dynamic ground water resources in the weathered zone

The study area is blessed with ground water resources in the weathered zone (phreatic aquifer) which can be developed in the future. The ground water in the shallow weathered zone is mostly developed through dug wells for domestic and agricultural purposes and to a limited extent for industrial and irrigation purposes. Despite these abundant resources, some areas experience shortage of ground water during summer months, which is due to the unplanned and non-scientific development of ground water besides the topographic control.

The total annual recharge of groundwater has been computed using average water level fluctuation in Ground Water Monitoring Wells and Specific Yield of the respective aquifers. Ground water extraction is mainly for domestic and irrigation purposes in the area. In view of the non-availability of data on the number of wells being used for domestic purposes, the ground water extraction for domestic uses has been computed as the product of the population (2011 projected for 2017) and the per-capita water requirement (assumed as 150 L/day/person) and the share of groundwater varying from 25 to 100% on the basis of availability of surface water sources for domestic water supply.

The groundwater extraction has been computed by multiplying the number of irrigation wells in each block with the corresponding unit draft. The Total Annual Extractable Groundwater Resource has been computed as 359.20 Million Cubic Metre (MCM) whereas the gross groundwater extraction is 144.75 MCM, thus keeping a balance of 209.24 MCM for future ground water development. Rainfall recharge accounts for about 90 percent of the annual recharge, with the remainder contributed by other sources. The stage of ground water extraction is 40.30%. Out of 11 blocks, only one block (Parakkadavu) is Semi critical and the rest are Safe.

4.1.2 In-storage in the weathered zone

The quantum of ground water available for development is usually restricted to long term average recharge or dynamic resources. Presently there is no fine demarcation to distinguish the dynamic resources from the static resources. For sustainable ground water development, it is necessary to restrict it to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage ground water resources be taken up at this stage.

The computation of the static or in-storage ground water resources of weathered zone has been done after delineating the aquifer thickness and specific yield of the aquifer material. Aquifer thickness is computed by taking the difference of average depth of weathering in each

block from groundwater exploration and average depth to water level in the pre-monsoon period. Since specific yield studies for the static zone of weathered zone is not readily available, 50% of the dynamic zone has been considered for computation. Thus, the total annual exploitable groundwater resource in the weathered zone (359.20 MCM) is the sum of dynamic resources and the in-storage (379.69 MCM) which comes about 738.89 MCM. The block wise ground water resources estimated for the area is given in Table 4.1.

Table 4.1 Ground water resources estimated for aquifer-I (Dynamic & Instorage) for the study area

#	Block	Total Geog. Area (Non-Command area)	Annual Extractable Ground Water Recharge of unconfined Aquifer/ Dynamic (mcm)	Existing Gross Ground Water Extraction for irrigation	Existing Gross Ground Water Extraction for domestic and industrial water supply	Existing Gross Ground Water Extraction for All uses (5+6)	Provision for domestic, and industrial use up to 2025	Net Ground Water Availability for future use (4-5-8)	Stage of Ground Water Extraction {(7/4) * 100} (%)	In storage Ground Water Resources of Unconfined Aquifer (mcm)	Ground Water Resources –Phreatic Aquifer-I (mcm) (4+11)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Alangad (p)	30	8.51	1.79	4.05	5.84	4.17	2.55	68.7	7.20	15.71
2	Angamaly	211.97	51.10	8.49	10.09	18.57	10.39	32.22	36.3	39.43	90.52
3	Edappally (p)	4	0.99	0.04	0.52	0.56	0.56	0.39	56.6	3.84	4.83
4	Koovappady	355.61	70.19	7.78	8.59	16.37	9.14	53.27	23.3	88.90	159.09
5	Kothamangalam	229.97	39.89	6.46	11.07	17.53	11.93	21.50	43.9	45.99	85.89
6	Moovattupuzha	199.8	35.90	10.90	11.13	22.03	11.93	13.07	61.4	29.97	65.87
7	Mulamthuruthy(p)	35	5.88	1.60	2.40	4.00	2.57	1.71	68.0	6.30	12.18
8	Pampakkuda	177.4	38.80	7.63	6.50	14.12	6.96	24.22	36.4	45.41	84.22
9	Parakkadavu (p)	70	13.24	5.94	4.54	10.48	4.85	2.45	79.1	22.40	35.64
10	Vadavukodu (p)	131	37.82	3.74	5.85	9.60	6.29	27.78	25.4	41.92	79.74
11	Vazhakkulam	193.28	56.87	10.29	15.36	25.64	16.51	30.07	45.1	48.32	105.19
	TOTAL (MCM)	**1638.03**	**359.20**	**64.66**	**80.08**	**144.75**	**85.30**	**209.24**	**40.3**	**379.69**	**738.89**

4.2 Ground water resources in the deep fractured aquifer

Assessment of ground water resources of confined aquifers assumes crucial importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than to those of shallow unconfined aquifers. In view of the small amounts of water released from storage in the confined aquifers, large scale pumpage from confined aquifers may cause decline in piezometric levels amounting to over a hundred metre and subsidence of land surface posing serious geo-tectonical problems. To assess the ground water resources of the confined aquifers, ground water storage approach is recommended. Moreover, there is a need of more observation wells tapping exclusively deeper aquifers. Storage Parameter for Fracture Aquifer-II (Semi confined to Confined In-storage) of the study area varies from 0.0012 to 0.008.

It is assumed that ground water developmental activity has not started from the fracture aquifer system of the study. The groundwater resources in the deep fracture aquifer system are estimated based on the depth of occurrence of fracture and on the assumption that the storativity/ specific yield of the fracture and associated matrix as about 10% of the in-storage of weathered zone. The total water resource in the fracture system thus computed is about 493.49 MCM (Table.4.2).

Table 4.2 In-storage ground water resources estimated for aquifer-II (Instorage) for the study area

#	Assessment Unit/ Block	Mapped Area in Sq.km.	Thickness (m)	Storativity/ Specific Yield (%)	In storage Ground Water Resources of Confined Aquifer (mcm)
1	2	3	5	6	7
1	Alangad (p)	30	200	0.002	9.00
2	Angamaly	211.97	200	0.0015	44.51
3	Edappally (p)	4	65	0.008	1.92
4	Koovappady	355.61	200	0.0025	133.35
5	Kothamangalam	229.97	200	0.002	68.99
6	Moovattupuzha	199.8	200	0.00125	34.97
7	Mulamthuruthy(p)	35	200	0.0015	7.35
8	Pampakkuda	177.4	200	0.002	51.45
9	Parakkadavu (p)	70	200	0.0025	23.63
10	Vadavukodu (p)	131	200	0.0025	45.85
11	Vazhakkulam	193.28	200	0.0025	72.48
	TOTAL (MCM)	**1638**			**493.49**

The total ground water resources of the study area are the sum of dynamic resources and static resources and calculated to be 1232.38 mcm.

5.0 GROUND WATER RELATED ISSUES

Ground water issues in the area can be categorised into natural or anthropogenic, which in turn affects natural resource either in a quantitative or, qualitative manner. 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. Quarrying of these rocks create localized ground water problems in the area.

As per the Ground Water Resource estimation for the study area for 11 development blocks in which 1 block fall under Semi Critical category whereas the remaining 10 falls under safe category. The semi critical block is 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 utilized 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. The physiography and geological settings of the area as well as the anthropogenic activities further worsen the situation. In high land area springs are also a good source for drinking water. Except for iron and nitrate above the permissible limits specified for drinking in certain locations the water quality is generally good in the area. Iron contamination more than permissible limits in certain pockets are observed in blocks of Alangad, Vazhakulam, Pampakuda and Angamaly as per National Rural Drinking Water Project (NRDWP) report, 2017.

In the study area, although there are no major problems to be highlighted, experience minor issues that can be rectified by adopting site specific management practices. A few issues are discussed here:

- *Water scarcity* - Acute water shortage during summer months are reported from eastern hilly areas. The panchayats having water scarcity problem are Elanji, Paingottur (Muvattupuzha Block); Varapetty, Pothanikad, Kottapady & Kuttampuzha (Kothamangalam Block); Keezhmad (Aluva Muncipality/ Vazhakulam Block). Dug wells in these panchayats usually gets dried-up during summer months as the laterite formations which are highly porous with low retention capacity loose water as base-flow in the summer months. 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 wetlands. The water availability is meagre especially in hilltops, steep slopes and isolated hillocks. 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.

- *Ground water depletion*– Concise depletion of ground water is observed in urbanised areas due to huge withdrawal of ground water. Unregulated and prolonged mining of sands from Periyar and Muvattupuzha rivers may impact the groundwater regime and adversely affect the recharge of groundwater near the river course and in the adjoining flood plains. This will ultimately result in the reversal of hydraulic gradient, inducing increased flow of groundwater from the aquifer into the river, causing deepening of water levels as shown in Figs. 5.1 & 5.2 respectively, drying up of shallow wells and reduction in the sustainability of groundwater abstraction structures. Various sand mining activities may also result in the contamination of the river water and the groundwater in hydraulic connection with it. This declining water table trend, if not

checked, would assume an alarming situation soon affecting the economy. Ground Water Recharge and Conservation may be carried out in these areas to overcome the depletion.

Fig. 5.1: Hydrograph of Angamali station shows Long term ground water table variation

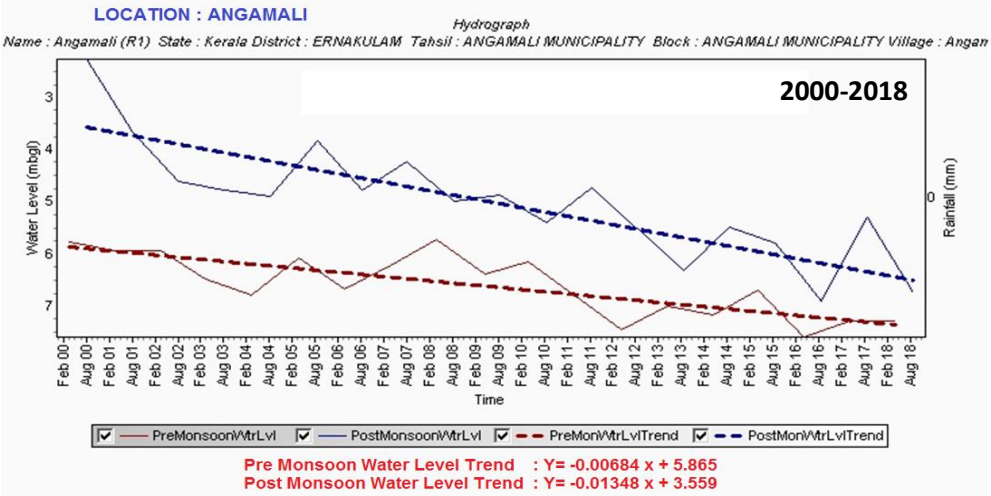
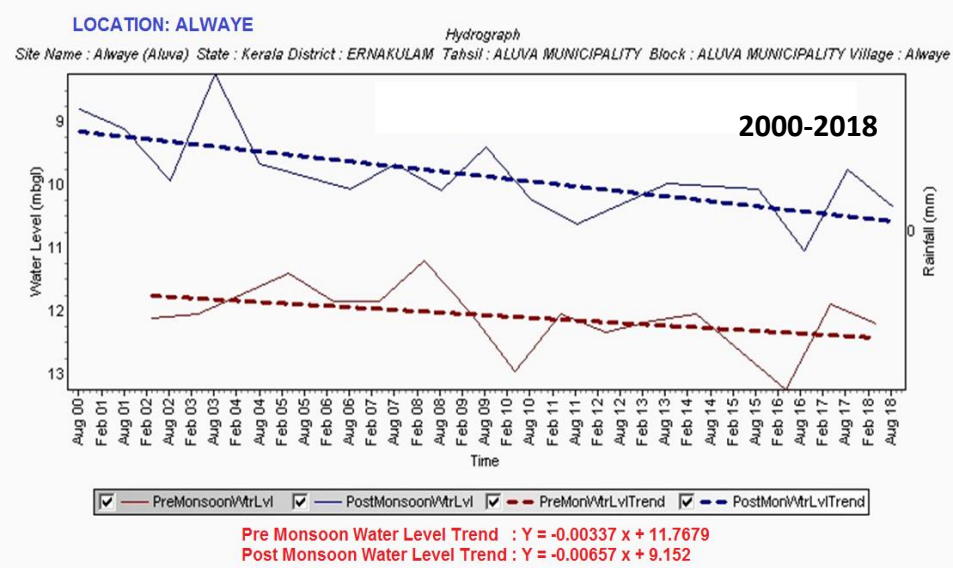


Fig. 5.2: Hydrograph of Alwaye station shows Long term ground water table variation



- *Waste Disposal* - High population density areas like Angamali, Aluva and Perumbavoor faces problems in the disposal of solid waste and sewage. Municipal solid waste and sewage are the major pollutants and are the main sources of pathogens in the eco-system.
- *Perchlorate contamination* – Perchlorate (rocket fuel) is an oxyanion (ClO_4^-), chemical that is extensively used in the arms and ammunition industry. It is an emerging water contaminant that disrupts normal functioning of human thyroid gland and poses serious threat to health, especially for pregnant women, fetus and children. The study carried out by National Institute for Interdisciplinary Science & Technology (NIIST), 2012 Thiruvananthapuram revealed high levels of perchlorate contamination in ground and surface water samples around Ammonium Perchlorate Experimental Plant (APEP), Aluva. The contamination was more severe in groundwater samples as compared to surface water r samples. The highest concentration observed were 6420 µg/L and 7270 µg/L in samples from household open well at Edathala and from a public open well at Kulakkad respectively (Keezhmad panchayat) (both places are ~500 meters away from APEP,

Aluva. These values are ~480 times higher than drinking water equivalent level (DWEL), 15 µg/L established by USEPA.

Perchlorate was detected in all the samples collected from Periyar river in the area with an average concentration 122 µg/L (n = 4) and the highest concentration observed was 355 µg/L. The study attentions that there needs to be frequent monitoring of groundwater samples around places where perchlorate is in majority. Also, detailed epidemiological studies need to be carried out in the contaminated areas to assess the connections between the presence of the contaminant and its impact on the health of the population in the area. This study also underlines the need to define water quality standards for perchlorate in India and to control the environmental release of perchlorate especially from point sources like manufacturing and using sites.

- *Quarrying* –Charnockites occupying the major part of the area are a good source of granite dimension stone as well as building material. Localised quarrying for Granite building stones are highly rampant in the Aluva, Angamaly, Karukutty, Kothamangalam, Kottapadi Koothattukulam, Malayattoor, Muvattupuzha, Neriyamangalam, Parakkadavu, Varapetty and Vengoor panchayat. In addition to granite building stone, quarrying/mining of laterite is common in the fringing area of soft rock and hard rock. Migmatite gneiss and biotite gneiss as building material are quarried at Pothanikad, Pindimana, and Varapetty etc. Quarrying of these rocks create localized ground water problems in the area.
- *Bacteriological Contamination* - Studies carried out by university and state departments shows that ground water samples collected from the area contains coliform bacteria. Post-monsoon showed significantly high coliforms compared to pre-monsoon. Thermo-tolerant coliforms are high during monsoon season. This seasonal change could be because of rainfall, overland flow, nutrient load and temperature change. Wide variations in the coliform counts are observed in wells situated near rivers, canals, paddy fields and in water bodies lying close to pilgrimage center, fertilizer industry, and public places in the study area.
- One of the major challenges faced by Kerala Water Authority is interruption in providing water supply to the public due to frequent leakages of pipes. Due to lack of preventive maintenance and replacement of old pipes, a considerable portion of the produced water has been reported as distributional loss in the study area.

5.1 Participatory ground water management Issues

Several groundwater approaches have failed owing to a lack of understanding of the importance of groundwater resources. Neglect the factors that govern groundwater resources like geological, climatic and socio-economic data. The focus is mostly on supply augmentation without regulating demand. A lack of understanding of groundwater as a 'common pool resource'. Failure to demystify the science of groundwater management. Due priority not given to drinking water. Missing policy and regulations on groundwater.

The approaches adopted so far lack a comprehensive understanding of groundwater resources and decentralised approaches that give rise to an engaged and well-informed participation by all stakeholders and communities. There is a need to bring about a fresh paradigm of looking at groundwater management – that includes supply augmentation, demand management and resource-based interventions.

Periodical checking of drinking water quality of wells and checking for leakage from drinking water and septic tank pipelines will ensure safe drinking water. Government, non-governmental organisations, and local institutions can come forward to analyse some important water quality parameters for free to provide a healthy and hygienic environment. Also, conducting awareness programmes to maintain hygienic conditions around drinking water sources by the concerned government, non-government organisations, and local institutions would lead to safer drinking water provisions. An ideal groundwater management approach

will be one that will not only construct structures but also make an effort to sensitize and involve the community to work on the issue. There is an urgent need for a concerted effort to integrate science and community participation for groundwater management.

6.0 MANAGEMENT STRATEGIES & AQUIFER MANGEMENT PLAN

The groundwater management strategies are inevitable either when there is much demand to the resource than the available quantity or when the quality of resource deteriorates due to contamination in each geographical unit. Hence, it is the need to formulate sustainable management of the groundwater resource in a more rational and scientific way. In the present study for hard rock terrains of Ernakulam District, the sustainable management plan for groundwater is being proposed after a detailed understanding of the aquifer disposition down to a depth of 200 m bgl.

Even though the study area receives good annual rainfall close to 3400mm and has best climatic conditions, it has been experiencing increasing incidents of water scarcity in summer for meeting the irrigation as well as domestic requirements. Even in the years of normal rainfall, summer water scarcity problems are there in the midland and highland regions of the study area. This ironic situation araised mainly due to natural reasons such as undulating topography with steep slopes resulted in high run-off and low recharge. Besides, this the limited thickness of aquifer material and shallow depth to massive bed rock in the eastern part of the area limits groundwater storage in the aquifer system. Development of water resources needs a scientific management system co-ordinating the efforts of all concerned agencies for a speedy development of the agricultural sector in the area. While formulating various ground water development and management plans, geology of the area should be given prior importance.

6.1 Sustainable plan

An effective ground water management practice must be preceded by an accurate account of the total available resources. From the estimation, out of 11 development blocks, only one block (Parakkadavu) is categorised as semi critical and the remaining are safe. So, there is scope for further ground water development for irrigation in majority of the blocks of the study area where the stage of extraction is low. Even though the scope for resource development is high; the availability of the resource is not uniformly distributed in the block. Hence, the ground water development should be coupled with management of water resources through rainwater harvesting and artificial recharge schemes by recommending 171 Nos. Contour bunding, 110 Nos. Nallah Bunds, 111 Nos. Gully plugs, 25 Nos. percolation ponds, 68 nos. check dams, 109 nos. vented cross bars and 10 Nos. of Sub surface dykes with limited field checks in hard rock terrains as given in table 6.5.

Farmers may be encouraged to adopt modern irrigation techniques like drip and micro irrigation to have optimal use of the available resources and community irrigation schemes must be encouraged in Semi critical block -Parakkadavu and adjacent blocks. An area of 30.87 sq. km. can be brought for adopting drip irrigation to increase the water-use efficiency by saving a substantial amount of water. Since it supplies water directly to the crop, rather than the land around, water losses occurring through evaporation and distribution are significantly reduced. There is water saving of 30-70 per cent for different crops like arecanut, nut meg, banana and plantains under drip method of irrigation.

6.2 Augmentation plan

Augmentation of groundwater can be achieved through periodic de-siltation as well as cleaning of existing water bodies (374 nos with an area of 29.80 sq.km.), check dams (48 nos.), bunds and ponds (242 Public & 128 Private ponds in which 100 nos. public ponds and 71 nos. private ponds are drought affected) is recommended for increasing the storage capacity as well as infiltration rate. Normally it can be achieved through capturing surface runoff. Topography of the area are suitable for various artificial recharge structures such as check dams, contour bunding, trenching, pitting, terrace cultivation and sub-surface dykes. It needs uncommitted

runoff from the adjoining localities to transport to the needy areas through diversion channels. In the uplands, wherever IInd/IIIrd order streams occur we may construct Check dams, Vented Cross Bars and Nallah Bunds to augment the groundwater recharge.

6.3 Aquifer Management Plan

6.3.1 Short-term local solutions for ground water management

To provide quality drinking water, there should be an integrated water resources management system in water supply. The distribution of water should be equitable across users particularly marginalised and poorer user groups in water scarced areas like Kottapadi, Kuttampuzha, Varapetty, Pampakuda, Keezhmad panchayaths. The main solutions are to prepare comprehensive water management system and water allocation plans on a participatory approach, involving users, planners and policy makers at all levels.

In views of rapid urbanization in urbanised areas Angamali, Perumbavoor, Muvattupuzha, Kothamangalam, Aluva the domestic water needs are increasing multifold and the water wastage component is increasing mainly because of leakages through distributor system areas. Wastewater collection and disposal are equally important like supply of protected water in maintaining public health.

Renovation of 15 nos. percolation ponds in Keezhmad, Poothrika panchayath for domestic/agricultural uses and effective implementation of roof top rainwater harvesting is essential for all areas for resource sustainability.

Use of existing yielding bore/tube wells drilled by Central Ground Water Board/ State Ground Water Department with potable water quality helps to mitigate the drinking water needs of the populace especially during summer in rural areas. Immediate attention is needed in the following panchayats for water supply schemes viz. Elanji, Kalady, Keezhmad, Manjallur, Paipra, Pampakuda, Vazhakulam and in municipalities of Aluva, Angamali Kothamangalam and Perumbavoor. These areas may be explored with adequate technical support. For solving the water crisis of the area, an integrated water management policy should be evolved.

Maintenance of existing irrigation canal system in Perumbavoor, Piravom, Poothrika, Pampakuda, and Mulanthuruthy which can improve irrigation in 1698 ha of land.

6.3.2 Long-term local solutions for ground water management

As per the Ground Water resource estimation, Net Ground Water Availability for future use is 209.24 MCM and Stage of Extraction is 40.30%. Ground water extraction for irrigation is low (44.67 % of the total Ground water extraction) and extraction for domestic and industrial use is the major component (55.32 %). So, it is proposed to construct ground water abstraction structures of 1688 Nos. Bore Wells/ Dug Wells for Additional irrigative measures in cultivable/Culturable waste land area about 4170 ha in the study area and the tentative details is given in Table 6.1, in which suitable abstraction structures will be taken up depend on the suitability of the area . Vegetable cultivation is ideal for the area.

Table 6.1: Block wise details of abstraction structures proposed for the study area

Block	Name of Village	Culturable Waste Land, ha	Nos. of abstraction structures proposed
Angamaly	Mookanoor	147	59
Angamaly	Ayyampuzha	2114	856

Angamaly	Manjapra	43.4	17
Angamaly	Malayattoor	50	20
Angamaly	Thuravoor	201	80
Koovapady	Kodanad	155	62
Koovapady	Asamannoor	168	67
Kothamangalam	Kuttampuzha	155	62
Kothamangalam	Varapetty	38.8	16
Muvattupuzha	Valakam	11	4
Muvattupuzha	Arakuzha	250	100
Pambakuda	Koothattukulam	10	4
Vaduvacode	Mazhavanoor	305	122
Vaduvacode	Aikranad North	28	11
Vaduvacode	Aikranad South	323	129
Vaduvacode	Thiruvaniyoor	21.4	9
Vazhakulam	Arakapady	150	60
	TOTAL	4170.6	1668

Industries are proposed in identified panchayats falling along the banks of major rivers without affecting the local ground water regime and the proposed list of panchayats is given in table 6.2.

Table 6.2: List of panchayaths/municipalities where industries can be promoted

#	Block	Panchayaths	Municipality
1	Angamali	Kalady	--
		Kanjur	--
		Sreemoolanagaram	--
2	Koovapady	Koovapady	--
		Okkal	--
		Vengoor	--
3	Vazhakulam	Vazhakulam	Aluva

To supplement the domestic demand in water scarce panchayats and also the depth of weathering ranges from a few meters (high land) , Low water storage capacity due to low volume of aquifer and high rates of base flow it is proposed to construct approximate of 48 Nos large diameter wells in identified low yielding panchayats to meet the domestic demand and the tentative proposed sites is given in table 6.3 and the sites and number will be changed depend on the suitability and availability of area . Proper site selection is needed to locate the wells in lineaments for better results.

Table 6.3: List of water scarce panchayaths were large diameter dug wells can be promoted

Block	Panchayath	No. of abstraction structures proposed	Panchayat Area, Sq. Km
Pampakuda	Elanji	6	30.5
Kothamangalam	Paingottur	6	30.1
Kothamangalam	Pallarimangalam	4	21.1
Kothamangalam	Kottapadi	6	30.2
Kothamangalam	Varapetty	4	22.0
Kothamangalam	Pothanikad	4	17.9
Kothamangalam	Kuttampuzha	14	70.5
Vazhakulam	Keezhmad	4	18.65
	Total	**48**	**241**

Identification of one or two perennial tanks in each panchayat, to be developed as sources of water for domestic and other uses in water scarce situations. Such tanks identified shall be de-silted, renovated and their supply channels repaired to ensure that they receive enough water during the monsoons. Steps shall also be taken to prevent contamination of water in such tanks. The maintenance of these tanks shall be the responsibility of PRI/ water user associations at the local level.

Several abandoned quarries are in the study area, which can be converted to water harvesting structures. Bases on available data on abandoned quarries (36.50 ha) collected from Kerala Land use Board , abandoned quarries of the study area is 36.50 ha and by taking an approximate of 2m water column in the quarries the quantum of water stored is estimated , and calculated to be 0.73 MCM and is given in table 6.4 .

The existed water stored in the quarries should be pumped out and the quarries should be completely cleaned after which a retaining wall should be constructed around them to prevent the inflow of polluted water from adjoining areas. If the inflow of water from surrounding areas is facilitated, then the water should be purified before usage. In that way, quarries can be used as rainwater storage tanks which is used for Domestic and irrigation purpose during lean period.

Table 6.4 Block wise area of abandoned quarries and water storage (mcm)

Block	Abandoned Quarry Area, ha	Water storage during Summer, MCM
Angamali	1.76	0.0352
Koovapadi	20.58	0.4116
Pampakuda	0.19	0.0038
Kothamangalam	8.95	0.179
Muvattupuzha	4.01	0.0802
Parakkadav	0.67	0.0134
Vaduvacode	0.02	0.0004
Vazhakulam	0.32	0.0064
Total	**36.50**	**0.73 (Approx. 1)**

Large scale implementation of roof-top rainwater harvesting through existing dug wells in highland areas on priority based on their vulnerability to droughts to be taken up. Recharge of monsoon rainfall through many such wells is expected to improve ground water availability over a period. Since the aquifer system is thin with high gradient leads to fast drain, rainwater harvesting as storage cum recharge is highly recommended.

Construction of a series of 68 nos. check dams ,109 nos. vented cross bars and along river courses and in second to third order streams at strategic locations having road/rail bridges after detailed feasibility studies, and construct of regulators, which will help in storing non-monsoon base flow along stretches of river without problems of land submergence. 171 Nos. Contour bunding, 110 Nos. Nallah Bunds, 111 Nos. Gully plugs, are proposed in formation have negligible and poor primary porosity, secondary openings like fractures, joints, shears give rise to limited porosity. Also, 25 Nos. percolation ponds are proposed to be normally constructed on second or third order streams of Periyar and Muvattupuzha River, as the catchment area of such streams would be of optimum size. The location of tank and its submergence area should be in non-cultivable land and in natural depressions requiring lesser land acquisition. Again, 10 Nos. of Sub surface dykes are proposed in the study area with limited field checks and the numbers will be changed due to suitability of land area. Details of block-wise feasible management structures proposed is given in Table 6.5 and is shown in Fig. 6.1.

Table 6.5: Details of management structures feasible in the area

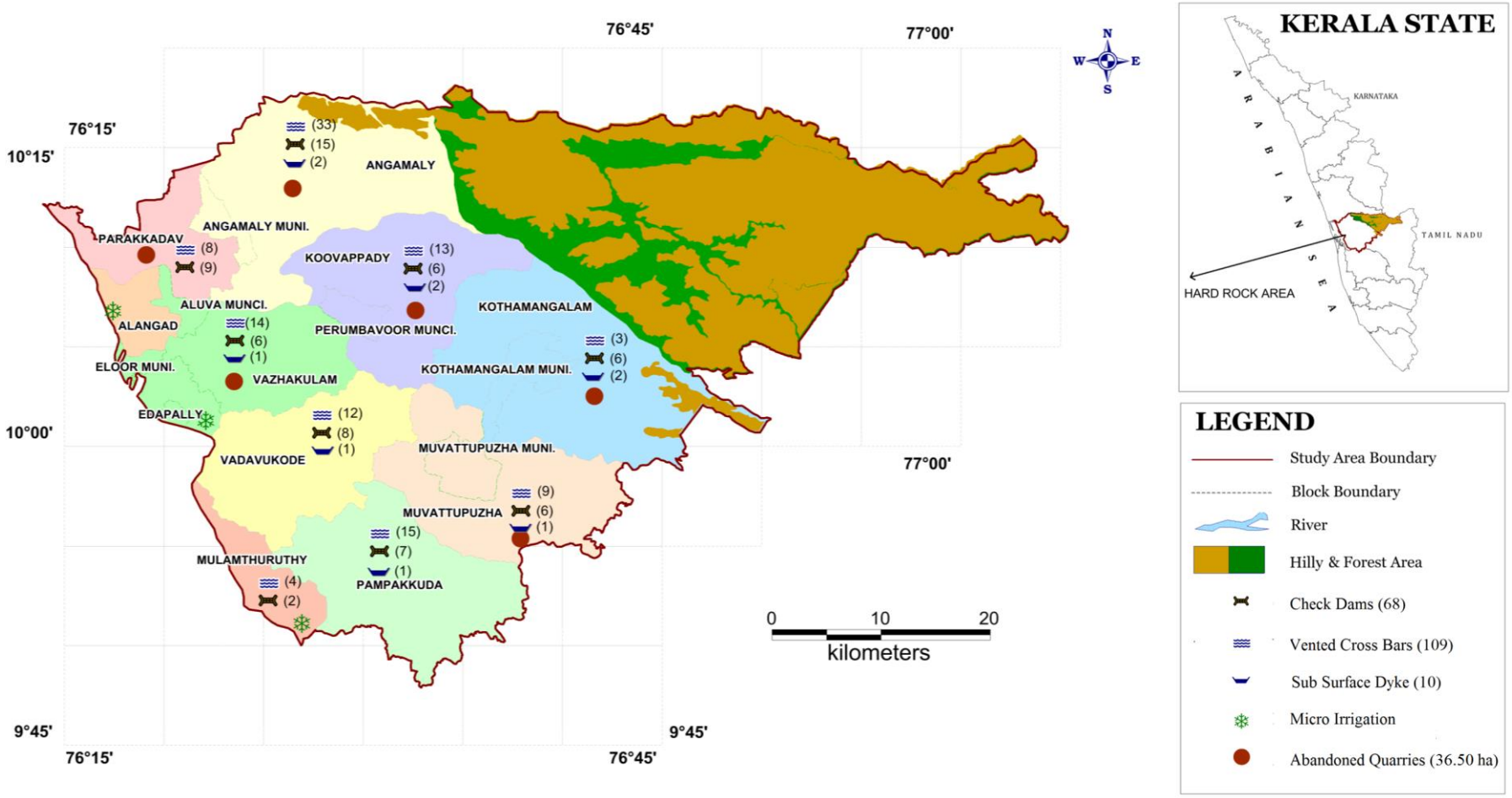
Block	Total Area, Sq.Km.	Area Feasible, Sq.Km.	Type	No. of Structures Feasible
Angamaly	211.97	148	Check dam	15
			Vented Cross Bars	33
			Sub Surface Dyke (SSD)	2
Koovappady	355.61	107	Check dam	6
			Vented Cross Bars	13
			Sub Surface Dyke (SSD)	2
Kothamangalam	229.97	22	Check dam	6
			Vented Cross Bars	3
			Sub Surface Dyke (SSD)	2
Moovattupuzha	199.8	51	Check dam	6
			Vented Cross Bars	9
			Sub Surface Dyke (SSD)	1
Mulamthuruthy(p)	35	10	Check dam	2
			Vented Cross Bars	4
Pampakkuda	177.4	104	Check dam	7
			Vented Cross Bars	15
			Sub Surface Dyke (SSD)	1
Parakkadavu (p)	70	40	Check dam	9
			Vented Cross Bars	8
Vadavukodu (p)	131	100	Check dam	8
			Vented Cross Bars	12
			Sub Surface Dyke (SSD)	1
Vazhakkulam	193.28	74	Check dam	6
			Vented Cross Bars	14
			Sub Surface Dyke (SSD)	1

Since groundwater is an invisible common pool resource, it brings with it a set of complexities about who uses and who provides. When a potential user overuses groundwater for personal consumption, it leads to a situation where it decreases the availability of water for a community. Similarly, dilemmas arise about who develops and manages the water and who uses it because with a common pool resource it becomes difficult to exclude users. Participation brings a discipline into this process of management. It brings users together to arrive at mutually agreed decisions on usage and recharge. Simultaneously, it builds in an ethos of self-regulation and sustainable use of groundwater to be followed by all.

Some of the local educated people may be identified and imparted basic training on ground water, relevance of aquifer mapping, participatory management, etc. These trained persons, called para- hydrogeologists will be responsible for basic data collection like water level monitoring, well inventory, awareness raising etc. They can also be entrusted with activities like water budgeting, assessment of crop water requirements etc.

Participatory Ground Water Management (PGWM) should be an aquifer-based and community-centric approach that has emerged as an alternative for managing groundwater as a common pool resource. The units of groundwater management should be aquifers, watersheds and habitations. Groundwater management requires long term engagement. Management should catalyse community action. Groundwater management should integrate formal and peoples' knowledge.

Fig. 6.1: Feasible water conservation structures in the study area



Annexure-I: DETAILS OF MINOR IRRIGATION DATA

FORMAT FOR MINOR IRRIGATION DATA (M I Structures)

Name	Latitude	Longitude	Taluk	Watershed	Command area
VCB at Chemmankuzhithazham	9.894408	76.46564	Muvattupuzha	Piravom	10 hectares
VCB at Karinkalchira	9.857601	76.4907	Muvattupuzha	Piravom	11 hectares
VCB at Kannakarithazham	9.850671	76.50678	Muvattupuzha	Piravom	12 hectares
VCB at Neerinalthazham	9.94001	76.4621	Muvattupuzha	Pambra	13 hectares
VCB at Parasserithazham	9.94264	76.4635	Muvattupuzha	Pambra	14 hectares

FORMAT FOR MAJOR, MEDIUM AND BIGGER MINOR IRRIGATION DATA

Name	Latitude	Longitude	Taluk	Canal		Command area
				Length(km)	Width(m)	Gross(ha)
Piravom LI Scheme	9.87009	76.48258	Muvattupuzha	9.557	0.9	153.80
Pazhoor LI Scheme	9.86469	76.4822	Muvattupuzha	5.796	0.75	115.10
Kakkad LI Scheme	9.90114	76.48053	Muvattupuzha	5.613	0.9	105.00
Kakkad tail end LI Scheme	9.87761	76.48771	Muvattupuzha	2.700	0.7	32.10
Mulakkulam North L I Scheme	9.85108	76.48502	Muvattupuzha	4.790	0.7	135.10
Mulakkulam Vadakekara L I Scheme	9.85711	76.48998	Muvattupuzha	4.810	0.7	99.52
Kalampoor North L I Scheme	9.85619	76.48644	Muvattupuzha	2.476	0.75	18.96
Kalampoor South L I Scheme	9.84306	76.48542	Muvattupuzha	4.545	0.75	111.80
Puthumanakkadavu L I scheme	9.93611	76.47196	Muvattupuzha	3.700	0.8	93.25
Nechoor L I Scheme	9.88842	76.46822	Muvattupuzha	3.725	0.7	90.86

FORMAT FOR WATER CONSERVATION STRUCTURES (KT WEIRS.GULLY PLUGS/CHECK DAM ETC.

Name	Latitude	Longitude	Taluk	Watershed	District
Chaliyathuchira checkdam	9.894408	76.49554	Muvattupuzha	Piravom	Ernakulam

Source: AE, MI, Piravom

Annexure-II

Details of Ground water observations wells for the study area

Longitude	Latitude	Location	Block	Measuring Point (m agl)	Depth (m bgl)	Dia. (m)	Reduced Level (a msl)	Water Level April 2018 (m bgl)	Water Level November 2018 (m bgl)	Water Level April 2019 (m bgl)	Project Type	Well Formation Encountered	Geology
76.58	9.92	Aaroor	Muvattupuzha	0.83	7.03	3.2	50.6	4.19	4.17	4.3	NAQUIM	LT	Basic rocks
76.32	10.15	Aduvassery	Parakkadavu	0.65	11	2.2	15.6	7.05	7.2	8.05	Special Study	AL	Sand & Silt
76.56	9.82	Alapuram	Pampakuda	0.76	6.8	1.7	35.9	1.14	0.92	4.41	NAQUIM	LT	Charnockite Group
76.75	10.07	Avolichal	Kothamangalam	0.9	5.62	2	50	3.17	3.3	3.98	Special Study	WG	Migmatite Complex
76.64	9.98	Ayavana	Muvattupuzha	0.8	7.5	0.8	35	5.9	6.28	6.77	NAQUIM	LT	Basic rocks
76.47	10.25	Ayyumpuzha	Angamaly	0.95	8.65	1.7	72.1	7.25	6.75	7.33	NAQUIM	LAC	Basic rocks
76.81	10.04	Chembankuzhy	Kothamangalam	0.8	6.67	2.1	57.1	5.45	4.6	5.34	NAQUIM	WG	Migmatite Complex
76.40	10.16	Nayitode	Angamaly	0.75	6.43	1.9	10.1	0.85	0.62	0.95	NAQUIM	LAC	Charnockite Group
76.39	9.92	Chottanikkara	Mulanthuruthy	1.15	13	2.2	19	11.86	11.59	12.2	NAQUIM	WFC	Charnockite Group
76.35	10.13	Desham	Parakkadavu	0.7	2.95	1.8	11.5	1.53	1.35	1.87	Special Study	AL	Sand & Silt
76.34	10.10	Elookara	Alangad	0.82	4.18	1.2	8	3.58	3.38	3.33	Special Study	AL	Charnockite Group
76.46	10.29	Ezhattumugham	Angamaly	0.7	5.5	3.4	51.8	3.35	3.35	5.5	NAQUIM	LAC	Charnockite Group
76.37	10.12	Gandhipuram	Parakkadavu	0.55	6.57	1.4	14.1	4	3.83	4.52	Special Study	LT	Charnockite Group
76.33	10.13	Kadoopadam	Vazhakulam	1.1	4.88	1.7	15.3	3.39	3.21	3.38	Special Study	LT	Sand & Silt

76.64	10.00	Kalamboor Chira	Muvattupuzha	1.29	5.91	2.8	33.2	1.72	3.41	4.21	NAQUIM	LT	Migmatite Complex
76.67	9.97	Kalloorkad	Muvattupuzha	0.85	7.6	1.1	49.4	3.53	4.1	5.45	NAQUIM	LT	Charnockite Group
76.50	10.22	Kunnamangalam	Angamaly	0.65	6.05	2.3	42.3	3.38	3.14	3.34	NAQUIM	LAC	Charnockite Group
76.62	9.86	Karamala	Pampakuda	1.08	3.92	2.9	71.9	2.72	2.96	3.42	NAQUIM	WFC	Charnockite Group
76.57	10.05	Cheruvattoor	Kothamangalam	0.76	7.84	2.2	54	5.38	6.1	4.54	NAQUIM	WG	Migmatite Complex
76.33	10.09	Kayantinkara	Alangad	0.74	5.06	2.1	9.7	2.91	2.51	2.61	Special Study	LT	Charnockite Group
76.55	10.16	Kombanad	Koovapady	0.65	10.09	2.3	41.8	8.2	8.65	7.03	NAQUIM	WFC	Charnockite Group
76.64	10.05	Kozhipilly	Kothamangalam	1	9.72	2.5	32.6	5.86	5.24	5.87	NAQUIM	WG	Migmatite Complex
76.53	9.86	Kulangarapady	Pampakuda	0.6	5.4	2.2	45.4	2.45	2.14	2.48	NAQUIM	WFC	Charnockite Group
76.66	10.06	Kuthukuzhi	Kothamangalam	0.8	7.2	2.2	44.2	1.8	2.45	3.02	NAQUIM	WG	Migmatite Complex
76.73	10.15	Kuttampuzha (Satrapadi)	Kothamangalam	0.79	7.61	1.7	50.7	6.24	6.04	6.16	NAQUIM	WG	Peninsular Gniess
76.37	10.05	Kuzhivelapady	Vazhakulam	0.79	6.27	1.5	10.7	3.86	3.16	3.76	NAQUIM	LT	Charnockite Group
76.68	9.92	Madakkathanam	Muvattupuzha	1.31	3.89	1.8	27.9	3.09	3.26	4.12	NAQUIM	LT	Charnockite Group
76.31	10.13	Malikampeedika	Alangad	0.68	3.42	1.4	7.2	1.62	0.53	0.77	Special Study	AL	Migmatite Complex
76.35	10.22	Mambra	Parakkadavu	1	5.55	2.1	19.2	4.25	4.38	2.09	NAQUIM	LT	Migmatite Complex
76.46	9.91	Maneed	Pampakuda	0.7	11	3	23.6	9.1	8.74	8.9	NAQUIM	LAC	Charnockite Group
76.50	10.02	Mangalathunade	Muvattupuzha	0.65	7.15	2.9	26.4	1.9	5.47	1.96	NAQUIM	LT	Basic rocks
76.61	9.85	Mangalathuthaze (Thottapuram)	Pampakuda	1	4	1.9	42	1.6	2.29	2.37	NAQUIM	WFC	Charnockite Group
76.34	10.12	Mangalapuzha	Vazhakulam	0.5	3.8	1.1	10.5	2.98	3	3.24	Special Study	AL	Sand & Silt

76.76	10.06	Manimaruthumchal	Kothamangalam	0.65	5.15	2.3	49.3	4.24	4.08	4.25	NAQUIM	WG	Migmatite Complex
76.57	10.14	Mekkappla	Koovapady	0.65	7.73	2.3	19.5	6.88	6.88	3.63	NAQUIM	WG	Migmatite Complex
76.64	9.92	Memadangu	Muvattupuzha	1.04	10.06	2.8	42.4	7.06	7.73	7.86	NAQUIM	LT	Basic rocks
76.41	10.21	Mookanoor	Angamaly	1.25	10.05	2.9	27.4	8.08	7.77	9.15	NAQUIM	LAC	Charnockite Group
76.55	10.00	Mudavoor	Muvattupuzha	1	7.92	1.6	34.4	3.38	3.24	3.47	NAQUIM	LAC	Charnockite Group
76.55	10.20	Mulamkuzhy Choondakavala	Angamaly	0.53	4.87	2.5	26.2	2.77	2.29	1.45	NAQUIM	LAC	Charnockite Group
76.31	10.09	Muppathidam	Alangad	0.55	6.61	1.6	14.7	4.71	4.43	4.6	Special Study	LT	Charnockite Group
76.56	9.83	Mutholapuram	Pampakuda	1	5.3	2	21.1	1.11	1.52	1.76	NAQUIM	WFC	Charnockite Group
76.70	9.94	Nakapuzha	Muvattupuzha	0.93	7.07	1.1	42.7	3.17	3.25	4.82	NAQUIM	LT	Basic rocks
76.39	10.09	Nalam Mile - Edathala	Vazhakulam	0.8	8.9	3	28.8	6.1	5.8	7.58	NAQUIM	LAC	Charnockite Group
76.47	10.19	Neeleswaram	Angamaly	0.85	8.7	2.3	16.6	5.41	5.81	5.68	NAQUIM	LT	Charnockite Group
76.60	10.07	Nellikuzhi	Kothamangalam	0.5	6.33	1.7	39.5	2.73	3.56	3.45	NAQUIM	WFC	Basic rocks
76.68	10.06	Nellimattom (Millumpady Jn)	Kothamangalam	0.65	6.25	1.4	57.1	1.3	1.26	3.77	NAQUIM	WG	Migmatite Complex
76.79	10.05	Neriyamangalam (Hindu Colony)	Kothamangalam	1.05	6.45	4.3	49.2	3.85	3.8	4	NAQUIM	WG	Migmatite Complex
76.42	10.11	North Vazhakulam	Vazhakulam	0.75	8.9	2.6	18.4	7.1	6.89	7.4	NAQUIM	LAC	
76.56	10.09	Odakkali	Koovapady	0.95	9.4		66.1	6.84	6.52	6.95	NAQUIM	LT	Basic Rocks
76.51	9.97	Ooramana (Shivali Jn)	Muvattupuzha	1.5	4.6	3.4	15.6	2.36	2.17	2.41	NAQUIM	LT	Basic rocks
76.71	10.10	Palamattom	Kothamangalam	2.08	6.77	2.1	52.4	4.52	4.02	4.61	NAQUIM	WG	Migmatite Complex
76.67	10.03	Pallarimangalam	Kothamangalam	1	6.3	3.2	41	3.65	4.52	5.92	NAQUIM	WG	Charnockite Group
76.61	9.91	Pandapilly	Muvattupuzha	1.15	6.81	1.3	37.2	2.75	3.12	2.66	NAQUIM	LT	Charnockite Group
76.39	10.25	Panthackal	Angamaly	0.92	7.38	1.8	33	5.98	4.64	4.3	NAQUIM	LT	Basic rocks

76.32	10.08	Pathalam Jn	Alangad	0.85	4.8	1.1	6.9	3.3	2.6	4.1	Special Study	AL	Charnockite Group
76.40	10.00	Peringala	Vaduvakode	0.35	6.21	1.4	7.6	1.97	1.97	2.37	NAQUIM	LAC	Charnockite Group
76.70	10.08	Perumanoor	Kothamangalam	0.55	5.05	3.3	58.3	2.6	3.53	5.72	NAQUIM	WFC	Charnockite Group
76.71	10.18	Poika	Kothamangalam	0.72	7.38	2	92.9	5.67	5.87	6.43	NAQUIM	WG	Migmatite Complex
76.66	10.13	Poochakuthu	Kothamangalam	0.45	7.45	2	55.5	4.13	4.03	4.79	NAQUIM	WFC	Charnockite Group
76.40	10.06	Pookatupady	Vazhakulam	0.68	7.67	1.3	14	5.62	5.43	5.7	NAQUIM	LAC	Charnockite Group
76.74	10.08	Pothupara	Kothamangalam	0.65	4.45	2.5	46.4	1.55	2	1.61	NAQUIM	WG	Migmatite Complex
76.36	10.20	Puliynam	Parakkadavu	0.7	8.4	2.8	16.6	6.85	6.4	7.45	NAQUIM	LT	Migmatite Complex
76.61	10.01	Puthupady	Kothamangalam	0.4	6	2.2	21.1	4.08	4.08	4.25	NAQUIM	WG	Migmatite Complex
76.41	10.09	South Vazhakulam	Vazhakulam	0.6	10	2.3	24.5	8.65	7.94	8.79	NAQUIM	LT	Charnockite Group
76.28	10.13	Thattampady	Alangad	0.55	5.45	1.3	12	2.23	2.18	2.46	NAQUIM	LT	Charnockite Group
76.37	10.11	Thottumugham	Vazhakulam	0.75	5.35	1.6	11.6	3.47	3.07	3.85	Special Study	LT	Sand & Silt
76.42	10.21	Thuravoor	Angamaly	1.13	6.49	2.8	24.4	5.27	5.46	4.5	NAQUIM	LAC	Charnockite Group
76.38	10.12	Thuruth	Vazhakulam	0.7	5.24	1.4	15	3.76	3.02	3.65	Special Study	AL	Sand & Silt
76.41	9.89	Thuruthikkara	Mulanthuruthy	0.78	5.14	2.1	12.3	4.51	3.86	4.06	Special Study	LT	Charnockite Group
76.34	10.11	Uliyanoor	Alangad	1.3	4.09	1.2	13	2.42	1.65	1.83	Special Study	AL	Charnockite Group
76.61	10.12	Uppukandam	Kothamangalam	0.83	5.93	1.8	49	3.85	3.89	4.86	NAQUIM	WFC	Charnockite Group
76.69	10.17	Vadattupara	Kothamangalam	1	7	2	87.4	4.09	4.3	2.35	NAQUIM	WFC	Charnockite Group
76.33	10.13	Valliyapanpady	Alangad	0.75	13.37	2.8	25.3	6.54	7.1	7.11	NAQUIM	LT	Migmatite Complex

76.64	9.94	Vazhakulam	Muvattupuzha	1.4	5.67	2.1	47	2.68	2.37	2.75	NAQUIM	LT	Basic rocks
76.47	10.09	Vengola (Chelakdam)	Vazhakulam	1.1	4.35	2.4	25.2	3.22	2.98	3.21	NAQUIM	LT	Charnockite Group
76.41	10.18	Vengoor	Angamaly	0.7	11.58	2.4	20.3	9.7	9.07	11	NAQUIM	LAC	Basic rocks
76.54	10.15	Vengur (Thungali)	Koovapady	0.88	5.92	3	43.8	2.2	2.76	5.5	NAQUIM	WFC	Charnockite Group
76.42	9.91	Vettikal	Vadavucode	1.15	10.18	2.7	44.7	6.6	6.12	7.03	NAQUIM	LAC	Charnockite Group
76.32	10.11	West Kandungaloor	Alangad	1	3.62	1.8	9.4	2.15	1.63	2.13	Special Study	AL	Charnockite Group

WFC: Weathered Fractured Charnockite, LT: Laterite, AL: Alluvium, LAC: Laterite after Charnockite, WG: Weathered Gneiss

Annexure-III

Details of Ground water quality monitoring wells generated for the study area

Sample ID/NO	Location Name	Block	Longitude (DD)	Latitude (DD)	Source of Water (DW/TW/BW)	Tem.
NAQ-ERN.1	Chottanikkara	Mulanthuruthi	76.389	9.931	DW	28.5
NAQ-ERN.2	Vettikal	Vaduvucode	76.422	9.914	DW	28.1
NAQ-ERN.3	Maneed	Pampakuda	76.458	9.905	DW	28.2
NAQ-ERN.4	Thuruthikara	Mulanthuruthi	76.407	9.888	DW	28.2
NAQ-ERN.5	Alapuram	Pampakuda	76.552	9.818	DW	28.5
NAQ-ERN.6	Mutholapuram	Pampakuda	76.564	9.827	DW	29.3
NAQ-ERN.7	Ooramana (Shivali Jn)	Pampakuda	76.505	9.966	DW	28.1
NAQ-ERN.8	Peringala	Vaduvucode	76.399	10.004	DW	28.5
NAQ-ERN.9	Kuzhivelapady	Vazhakulam	76.372	10.049	DW	28
NAQ-ERN.10	Pookatupady	Vazhakulam	76.395	10.058	DW	28.7
NAQ-ERN.11	Nalam Mile -Edathala	Vazhakulam	76.393	10.090	DW	28.5
NAQ-ERN.12	Puliynam	Parakadav	76.355	10.203	DW	27.8
NAQ-ERN.13	Mambra	Parakadav	76.350	10.224	DW	29.4
NAQ-ERN.14	Panthackal	Angamali	76.390	10.252	DW	28.2
NAQ-ERN.15	Mookanoor	Angamali	76.407	10.214	DW	29.5
NAQ-ERN.16	Thuravoor	Angamali	76.422	10.205	DW	29.3
NAQ-ERN.17	Ezhattumugham Prakriti Gramam	Angamali	76.457	10.294	DW	28.1
NAQ-ERN.18	Vettilapara DAM	Angamali	76.433	10.286	SW	28.5
NAQ-ERN.19	Neeleswaram	Angamali	76.474	10.185	DW	28
NAQ-ERN.20	Ayavana	Muvattupuzha	76.638	9.984	DW	28.7
NAQ-ERN.21	Kalamboor Chira	Muvattupuzha	76.637	10.001	DW	29.3
NAQ-ERN.22	Vazhakulam	Muvattupuzha	76.643	9.942	DW	28.1
NAQ-ERN.23	Memadangu	Muvattupuzha	76.635	9.921	DW	28.5
NAQ-ERN.24	Pandapilly	Muvattupuzha	76.606	9.908	DW	28
NAQ-ERN.25	Aaroor	Muvattupuzha	76.583	9.915	DW	28.7
NAQ-ERN.26	Mangalathuthaze (Thottapuram)	Pampakuda	76.606	9.851	DW	28.5
NAQ-ERN.27	Karamala	Pampakuda	76.622	9.859	DW	27.8
NAQ-ERN.28	Madakkathanam	Muvattupuzha	76.684	9.919	DW	29.4
NAQ-ERN.29	Nakapuzha	Muvattupuzha	76.696	9.944	DW	28.2
NAQ-ERN.30	Pallarimangalam	Kothamangalam	76.666	10.030	DW	28
NAQ-ERN.31	Kuthukuzhi	Kothamangalam	76.656	10.059	DW	27.8
NAQ-ERN.32	Nellimattom (Millumpady Jn)	Kothamangalam	76.678	10.059	DW	29.4
NAQ-ERN.33	Perumanoor	Kothamangalam	76.704	10.082	DW	28.2
NAQ-ERN.34	Neriyamangalam (Hindu Colony)	Kothamangalam	76.786	10.047	DW	28.1
NAQ-ERN.35	Puthupady	Kothamangalam	76.606	10.010	DW	28.5
NAQ-ERN.36	Kuttampuzha	Kothamangalam	76.742	10.155	DW	28
NAQ-ERN.37	Uppukandam	Kothamangalam	76.610	10.115	DW	28.7

NAQ-ERN.38	Mekkappla (Mekhpakavala)	Koovapady	76.572	10.144	DW	29.3
NAQ-ERN.39	Vengur (Thungali)	Koovapady	76.542	10.148	DW	28.1
NAQ-ERN.40	Kombanad	Koovapady	76.550	10.164	DW	28.5
NAQ-ERN.41	Mulamkuzhy	Angamali	76.546	10.200	DW	28
NAQ-ERN.42	Vengoor	Angamali	76.412	10.182	DW	28.7
NAQ-ERN.43	Chetikkodu-Nayitode	Angamali	76.402	10.164	DW	28.5
NAQ-ERN.44	Mangalathunade	Vaduvacodu	76.503	10.017	DW	27.8
NAQ-ERN.45	Ayyampuzha (Katting)	Angamali	76.473	10.247	DW	29.4
NAQ-ERN.46	Odakkali	Koovapady	76.559	10.095	DW	28.2
NAQ-ERN.47	Kashayapady Cheruvattoor	Kothamangalam	76.569	10.049	DW	28
NAQ-ERN.48	Mudavoor	Muvattupuzha	76.548	10.003	DW	28.7
NAQ-ERN.49	Kozhipilly	Kothamangalam	76.636	10.051	DW	29.3
NAQ-ERN.50	Chembankuzhy	Kothamangalam	76.807	10.037	DW	28.1
NAQ-ERN.51	Kalloorkad	Muvattupuzha	76.668	9.965	DW	28.5
NAQ-ERN.52	Vengola	Vazhakulam	76.467	10.086	DW	28.9
SS-ERN.1	Aduvassery	Parakkadavu	76.320	10.154	DW	28.7
SS-ERN.2	Avolichal	Kothamangalam	76.750	10.071	DW	29.3
SS-ERN.3	Desham	Parakkadavu	76.351	10.128	DW	28.1
SS-ERN.4	Elookara	Alangad	76.337	10.099	DW	28.5
SS-ERN.5	Gandhipuram	Parakkadavu	76.367	10.122	DW	28
SS-ERN.6	Kadoopadam	Vazhakulam	76.333	10.131	DW	28.7
SS-ERN.7	Kayantinkara	Alangad	76.332	10.092	DW	28.5
SS-ERN.8	Malikampeedika	Alangad	76.312	10.127	DW	27.8
SS-ERN.9	Mangalapuzha	Vazhakulam	76.340	10.122	DW	29.4
SS-ERN.10	Muppathidam	Alangad	76.315	10.088	DW	28.2
SS-ERN.11	Pathalam Jn	Alangad	76.318	10.081	DW	28
SS-ERN.12	Thottumugham	Vazhakulam	76.372	10.110	DW	28.7
SS-ERN.13	Thuruth	Vazhakulam	76.378	10.122	DW	27.8
SS-ERN.14	Thuruthikkara	Mulanthuruthy	76.407	9.888	DW	29.4
SS-ERN.15	Uliyanoor	Alangad	76.345	10.105	DW	28.1
SS-ERN.16	West Kandungaloor	Alangad	76.318	10.106	DW	28
NAQ-ERN.53	Neriyamangalam- EW 1	Kothamangalam	76.773	10.0539	BW	
NAQ-ERN.54	Vazhakulam (Nadukkara)	Muvattupuzha	76.615	9.941	BW	
NAQ-ERN.55	Piravom	Pampakuda	76.486	9.891	BW	
NAQ-ERN.56	Inchathotty	Kothamangalam	76.741	10.088	BW	

* DW: Dug well, TW: Tube Well, BW: Bore Well, SW: Surface Water

Annexure-IV

Format of Aquifer Parameters of the study area

Unique ID	Village/ Location	Taluk/ Block	Topo sheet No.	Lat	Long	Type of well	Depth	Date of Construction	SWL (mbgl)	Discharge (lps)	Draw Down	Transmisivity (m^2/day)	Storativity/S.Yield/ Storage Coefficient	Specific capacity (lpm/ m of dd)	Source/ Agency
NAQERN 1	Edakattuvayal	Mulanthuruthy	58 C/5	9.87	76.44	PZ	30	25.05.2004	5.4	0.4					CGWB
NAQERN 2	Kanjiramattom	Mulanthuruthy	58 C/5	9.85	76.41	PZ	60	31.05.2004	14	0.2					CGWB
NAQERN 3	Kizhakombu	Pampakuda	58 C/9	9.87	76.57	PZ	40	15.05.2004	3.1	0.2					CGWB
NAQERN 4	Namakuzhi	Pampakuda	58 C/9	9.86	76.53	PZ	60	04.05.2004	7.1	0.2					CGWB
NAQERN 5	Illanji	Pampakuda	58 C/9	9.83	76.54	BW	201	27.02.1987	1.9	7.6	14.4	319			CGWB
NAQERN 6	Kozhipalli	Pampakuda	58 C/9	9.87	76.61	BW	187	09.02.1987	2.1	10	14.5	35.9	7×10^{-5}		CGWB
NAQERN 7	Onakkur	Pampakuda	58 C/9	9.89	76.52	BW	200	02.03.1987	dry	nil					CGWB
NAQERN 8	Kadalikad	Muvattupuzha	58 C/9	9.92	76.68	BW	200	06.03.1987	1.2	10	15.2	69.3	0.028		CGWB
NAQERN 9	Vadakkumaradi	Muvattupuzha	58 C/9	9.95	76.56	BW	237	17.02.1987	4.5	1.12					CGWB
NAQERN 10	Nadukani	Kothamangalam	58 B/12	10.09	76.67	BW	201	1987	1.1	0.1					CGWB
NAQERN 11	Kizhakambalam	Vazhakulam	58 B/8	10.03	76.41	BW	131	1987	1.1	22					CGWB
NAQERN 12	Adirapalli FRO	Angamali	58 B/7	10.26	76.53	BW	59	2014	4	22	14.1	156	7×10^{-4}		CGWB
NAQERN 13	Kalady	Angamali	58 B/8	10.17	76.44	BW	101	2014	6	9.2	15.2	37.5			CGWB
NAQERN 14	Pallarimangalam	Kothamangalam	58 B/12	10.03	76.66	BW	101	2014	3.2	0.1	15.2				CGWB

NAQERN 15	Neriamangalam	Kothamangalam	58 B/16	10.06	76.76	BW	101	2014	6.2	0.1					CGWB
NAQERN 16	Desham	Parakkadav	58 B/8	10.13	76.35	BW	201	2015	4.5	2.8					CGWB
NAQERN 17	Sreemoolanagaram	Angamali	58 B/8	10.14	76.39	BW	201	2015	5.2	3.2	11.3	15.6			CGWB
NAQERN 18	Odakkali	Koovapady	58 B/12	10.09	76.54	BW	200	2015	5.2	3.2					CGWB
NAQERN 19	Pezhakapilly	Muvattupuzha	58 B/12	10.02	76.56	BW	136	2015	4.5	10	7.62	41.9	3×10^{-4}		CGWB
NAQERN 20	Okkal	Koovapady	58 B/8	10.15	76.46	BW	197	2015	5.2	3.3	6.81	25.9	1×10^{-4}		CGWB
NAQERN 21	Kothamangalam	Kothamangalam	58 B/12	10.06	76.63	BW	200	2015	5.2	5	9.43	14.5	1×10^{-4}		CGWB
NAQERN 22	Chelad	Kothamangalam	58 B/12	10.11	76.64	BW	200	2015	4.5	5					CGWB
NAQERN 23	Puthencruz	Vadavucode	58 C/5	9.98	76.45	BW	200	2015	4.9	0.5					CGWB
NAQERN 24	Palakuzha	Pampakuda	58 C/9	9.88	76.61	BW	200	2015	4.9	0.25					CGWB
NAQERN 25	Perumbavoor	Koovapady	58 B/8	10.12	76.48	BW	200	2015	4.9	0.5					CGWB
NAQERN 26	Parapuram	Angamali	58 B/8	10.13	76.45	BW	200	2015	4.9	4.36	10.2	14.1	1×10^{-4}		CGWB
NAQERN 27	Trikkakara	Edapally	58 B/8	10.02	76.33	BW	88	2015	9	14					CGWB
NAQERN 28	Kalamasseri	Vazhakulam	58 B/8	10.06	76.33	BW	200	2015	8.1	3.5					CGWB
NAQERN 29	Kurumasseri	Parakkadav	58 B/8	10.18	76.33	BW	200	2016	8.1	10					CGWB
NAQERN 30	Angamali	Angamali	58 B/8	10.19	76.37	BW	153	2015	9	10					CGWB
NAQERN 31	Veetur	Vadavucode	58 B/12	10.02	76.54	BW	200	2015	4	0.5					CGWB
NAQERN 32	Mamala	Vadavucode	58 C/5	9.95	76.38	BW	200	2015	4	2					CGWB
NAQERN 33	Maneed	Pampakuda	58 C/5	9.91	76.45	BW	200	2015	5.2	3.5					CGWB

NAQERN 34	Mulanthuruthy	Mulanthuruthy	58 C/5	9.90	76.39	BW	190	2015	10	3.5					CGWB
NAQERN 35	Neriamangalam2	Kothamangalam	58 B/16	10.05	76.77	BW	200	2014	7	9					CGWB
NAQERN 36	Ramamangalam	Pampakuda	58 C/5	9.94	76.48	BW	200	2012	dry	nil					CGWB
NAQERN 37	Muvattupuzha	Muvattupuzha	58 C/9	9.99	76.58	BW	153	2015	6.2	10					CGWB
NAQERN 38	Illithode	Angamali	58 B/12	10.20	76.52	BW	60	2018	dry	nil					CGWB
NAQERN 39	Kodanad	Angamali	58 B/11	10.18	76.51	BW	200	2019	5.5						CGWB
NAQERN 40	Koovapady	Koovapady	58 B/8	10.15	76.47	BW	60	2019	7	10.5	24.1	3.3	1×10^{-4}		CGWB
NAQERN 41	Malayatur	Angamali	58 B/11	10.19	76.51	BW	200	2019	10						CGWB
NAQERN 42	Inchathotty	Kothamangalam	58 B/16	10.09	76.74	BW	200	2018	4.6						CGWB
NAQERN 43	Punnakad Pz	Kothamangalam	58 B/12	10.11	76.67	PZ	60	2018	6.4						CGWB
NAQERN 44	Irumbanam Pz	Vadavucode	58 C/5	9.98	76.35	PZ	30	2018	4						CGWB
NAQERN 45	Veliyanad Pz	Mulanthuruthy	58 C/5	9.87	76.46	PZ	40	2018	6						CGWB
NAQERN 46	Arakuzha Pz	Muvattupuzha	58 C/9	9.93	76.58	PZ	60	2012	5.4						CGWB
NAQERN 47	Vazhakkulam	Muvattupuzha	58 C/9	9.94	76.60	PZ	200	2018	5.3						CGWB
NAQERN 48	Vazhakam Pz	Muvattupuzha	58 C/9	9.98	76.54	PZ	30	2012	6.2						CGWB
NAQERN 49	Piravom EW	Pampakuda	58 C/5	9.89	76.49	BW	200	2018	8						CGWB
NAQERN 50	Thirumaradi	Pampakuda	58 C/9	9.89	76.56	PZ	60	2012	5						CGWB
NAQERN 51	Kodussery	Parakkadav	58 B/8	10.19	76.35	PZ	40	2012	6						CGWB
NAQERN 52	Kadayiruppu	Vadavucode	58 C/5	10.00	76.46	PZ	30	2012	7						CGWB

NAQERN 53	Mullankunnu	Vazhakulam	58 B/8	10.10	76.43	PZ	40	2012	9						CGWB
NAQERN 54	Poothrikka Pz	Vadavucode	58 C/5	9.95	76.46	PZ	40	2012	6						CGWB
NAQERN 55	Vazhakam	Muvattupuzha	58 C/9	9.98	76.54	TW	30	2000				79.7	0.393		OTHER
NAQERN 56	Piravom	Pampakuda	58 C/5	9.90	76.49	TW	30	2000				115	0.362		OTHER
NAQERN 57	Maradi	Muvattupuzha	58 C/9	9.95	76.56	TW	30	2001				6.12	0.256		OTHER
NAQERN 58	Kizhimuri	Muvattupuzha	58 C/9	9.91	76.48	TW	30	2000				25.3	0.191		OTHER
NAQERN 59	Keezhillam	Muvattupuzha	58 C/9	10.03	76.55	TW	30	2000				109	0.294		OTHER
NAQERN 60	Adivad	Kothamangalam	58 B/12	10.03	76.66	TW	30	2000				75.1	0.299		OTHER
NAQERN 61	Avoli	Muvattupuzha	58 C/9	9.96	76.62	TW	30	2000				91.8	0.319		OTHER
NAQERN 62	Nagapuzha	Muvattupuzha	58 C/9	9.95	76.70	TW	30	2000				4.52	0.012		OTHER
GWE/323/16	Irapuram	Kunnathuna	58 B/12	10.05	76.51	DW	3.75	24.5.2016	0.3	6.47	1.94			200.68	GWD
GWE/1082/15	Aluva East	Vazhakulam	58 B/8	10.10	76.38	DW	7.14	18.3.2016	3.2	1.18	0.25			284	GWD
GWE/811/15	Thiruvaniy	Vadavucode	58 C/5	9.95	76.38	DW	8	03-10-2016	2.8	2.36	4.12			34.38	GWD
GWE/186/16	Valakam	Muvattupuz	58 C/9	9.96	76.56	DW	10.1	26-04-2016	4.2	6.17	1.48			250	GWD
GWE/593/15	Vengoor	Koovapady	58 B/12	10.14	76.58	DW	6	15-03-2016	3.8	1.5	0.7			2.16	GWD
GWE/898/15	Kakkanad	Edapally	58 B/8	10.01	76.35	DW	7.65	17-03-2016	2.6	7.78	3.93			118.75	GWD
GWE/170/16	Koothattuk	Pampakuda	58 C/9	9.85	76.61	DW	7.58	03-08-2016	1.6	6.67	1.95			205	GWD
GWE/587/16	Perumbavur	Koovapady	58 B/8	10.10	76.49	DW	6.9	03-03-2018	3.3	6.6	1.6			239.58	GWD
GWE/586/16	Perumbavur	Koovapady	58 B/8	10.10	76.49	DW	6.7	03-03-2018	3.8	6.28	1.75			215.85	GWD

GWE/1158/15	Moothakunn	Paravur	58 B/8	10.18	76.18	TW	100	03-06-2018	1.8	3.27	0.87			226.97	GWD
GWE/199/16	Kakkanad	Edapally	58 B/8	10.02	76.37	DW	6	03-11-2016	3.1	3.74	0.76			295	GWD
GWE/1561/16	Keezhmdu	Vazhakulam	58 B/8	10.10	76.38	BW	107	05-09-2015	4.7	2.33	24.6			5.69	GWD
GWE/88/16	Ikaranadu	Vazhakulam	58 B/8	10.07	76.44	DW	6.22	03-08-2018	3.1	6.17	2			185.62	GWD
GWE/470/16	Ikaranadu	Vadavucode	58 C/5	9.99	76.47	DW	6.06	03-01-2018	1.8	6.83	0.33			1261	GWD
GWE/79/16	Ikaranadu	Vadavucode	58 C/5	9.94	76.47	DW	3.45	03-02-2018	0.6	6.79	0.85			479.77	GWD
GWE/915/14	Asamannoor	Koovapady	58 B/12	10.11	76.55	DW	7.39	03-02-2018	1.8	3.47	0.1			2192.9	GWD
GWE/940/16	Vengola	Perumbavur	58 B/8	10.11	76.45	DW	5.77	05-08-2018	2	7.08	0.34			1259.9	GWD
GWE/990/16	Chowara	Angamaly	58 B/8	10.14	76.41	DW	8.13	03-07-2018	4.3	5.47	0.14			2293.7	GWD
GWE/05/17	Aluva East	Vazhakulam	58 B/8	10.12	76.40	DW	9.16	05-09-2018	6.9	14.2	0.17			5014.7	GWD
GWE/774/17	Aluva East	Vazhakulam	58 B/8	10.07	76.39	DW	3.1	04.09.2018	1.4	2.92	0.23			770	GWD
GWE/786/17	Koovapadyy	Koovapady	58 B/8	10.16	76.48	DW	6.4	16-05-2018	1.7	7.61	1.06			430.66	GWD
GWE/817/17	Marampilly	Vazhakulam	58 B/8	10.12	76.44	BW	100	03-08-2018	8.3	5.67	32.1			10.6	GWD
GWE/793/17	Vengoor	Koovapady	58 B/8	10.16	76.50	DW	5.9	16-05-2018	2.9	7.49	0.57			798.1	GWD
GWE/586/17	Ikaranadu	Vadavucode	58 C/5	9.95	76.47	DW	5.9	03-09-2018	3.7	7.14	0.86			497.48	GWD
GWE/876/17	Ikaranadu	Vadavucode	58 C/5	9.95	76.47	DW	5.91	03-09-2018	3.4	7.55	1.22			371.1	GWD
GWE/971/17	Angamaly	Angamaly	58 B/8	10.18	76.37	DW	6.5	05-10-2018	6	3.74	1.47			152.6	GWD
GWE/685/14	Aluva East	Vazhakulam	58 B/8	10.52	76.24	DW	9.49	23-02-2015	5.8	1.25	0.54			140.18	GWD
GWE/248/15	Thuravoor	Angamaly	58 B/8	10.12	76.25	DW	3.57	04-09-2015	1	5.56	0.62			542	GWD

GWE/521/15	Marady	Pampakuda	58 C/9	9.97	76.55	DW	10.5	03-09-2016	6.8	2.18	0.63			207.89	GWD
GWE/331/10	Keerampara	Kothamanga	58 B/12	10.74	76.42	DW	8.48	26-05-2010	6.8	3.93	0.92			4.3	GWD
GWE/321/13	Valakam	Muvattupuz	58 C/9	9.96	76.56	DW	13	24-05-2013	7.8	8	3.25			2.46	GWD
GWE/286/14	Ikaranadu	Vadavucode	58 C/5	9.95	76.47	DW	6.6	26-05-2014	2.3	6.95	1.69			4.11	GWD
GWE/339/14	Keerampara	Kothamanga	58 B/12	10.74	76.42	DW	3.86	22-05-2014	1.6	6.94	1.03			6.74	GWD
GWE/531/13	Airapuram	Vadavucode	58 B/12	10.04	76.52	DW	5.1	23-05-2013	3.6	3.67	1.73			2.12	GWD
GWE/1265/12	Rayamangal	Koovapady	58 B/12	10.10	76.52	DW	7.14	21-03-2013	2.6	3.5	1.69			2.07	GWD
GWE/1028/15	Mookannoor	Angamaly	58 B/8	10.21	76.41	DW	5.3	16-03-2016	2.5	2.6	0.51			5.13	GWD
GWE/709/12	Kuttamanga	Kothamanga	58 B/12	10.06	76.63	DW	3.69	02-05-2013	2.9	0.83	0.53			1.57	GWD
GWE/670/14	Keerampara	Kothamanga	58 B/12	10.74	76.42	DW	8.15	03-06-2015	1.7	2.22	1.36			1.63	GWD
GWE/1302/12	Mazhuvannu	Vadavucode	58 B/8	10.01	76.49	DW	5.85	02-06-2013	5.7	3.06	1.3			2.35	GWD
GWE/325/14	Eloor	Alangad	58 B/8	10.01	76.31	DW	3.73	24-05-2014	1.6	5.56	1.1			5.05	GWD
GWE/1267/13	Koovapady	Koovapady	58 B/8	10.16	76.48	DW	6.76	05-07-2014	4.5	4.17	0.8			5.21	GWD
GWE/390/13	Thrikkakar	Kalamasser	58 B/8	10.04	76.34	BW	90	06-07-2013	7.1	2.78	18.6			0.15	GWD
GWE/600/14	Vengoor	Koovapady	58 B/8	10.85	76.31	DW	5.87	24-02-2015	2.2	7.06	0.5			14.11	GWD
GWE/1146/12	Irapuram	Vadavucode	58 C/5	9.94	76.47	DW	6	02-10-2014	3.3	2.78	0.99			2.81	GWD
GWE/172/14	Velloorkun	Muvattupuz	58B/12	10.01	76.55	BW	90	02-05-2014	5.2	0.42	52.5			0.01	GWD
GWE/1091/13	Chengamana	Aluva	58 B/8	10.15	76.34	DW	8	02-12-2014	4.7	2.78	1.37			2.03	GWD
GWE/875/13	Alangad	Alangad	58 B/8	10.10	76.29	DW	5	02-11-2014	2.1	3.39	0.24			14.12	GWD

Annexure V

Data and Interpreted Results of Soil Infiltration Test

Site: 1

Date: 02.03.2019

Name of Officer: Roopesh G.Krishnan, Scientist-B

Project name: NAQUIM, Hard rock areas of Ernakulam district
Location details : In the premises of Agricultural Rural Wholesale market (EEC), Govt. of Kerala, Muvattupuzha

District: Ernakulam Block: Muvattupuzha

Elevation (m amsl): 15

Long: 76.58037

Lat: 9.992978
Soil type:
Clayey loam

Major Aquifer: Laterite followed by weathered charnockite

Site belongs to: EEC, Govt. of Kerala
Geomorphic Unit:
Plateau
Geology: Charnockite,
Weather condition: Semi arid

Time (mins)	Time taken (min)	Initial Head (cms) after filling	Innner reading Head (cms)	Difference (cms) falling head	Infiltration rate (cm/min)	Rate of Infiltration in cm/Hr	Cumulative Depth of Infiltration (cms)
0	0	21					
1	1		20	1	1	60	1
2	1		19.5	0.5	0.5	30	1.5
3	1		19	0.5	0.5	30	2
4	1		18.5	0.5	0.5	30	2.5
5	1		17.5	1	1	60	3.5
6	1		16.5	1	1	60	4.5
7	1		15.8	0.7	0.7	42	5.2
8	1		15.5	0.3	0.3	18	5.5
9	1		15	0.5	0.5	30	6
10	1		14.7	0.3	0.3	18	6.3
11	1		14.4	0.3	0.3	18	6.6
12	1		14.1	0.3	0.3	18	6.9
13	1		13.8	0.3	0.3	18	7.2
14	1		13.5	0.3	0.3	18	7.5
16	2		12.9	0.6	0.3	18	8.1
18	2		12.3	0.6	0.3	18	8.7
20	2		11.7	0.6	0.3	18	9.3
25	5		10.8	0.9	0.18	10.8	10.2
30	5	21	10.2	0.6	0.12	7.2	10.8
35	5		20	1	0.2	12	11.8
40	10		18.8	1.2	0.12	7.2	13
50	10		16.5	2.3	0.23	13.8	15.3

60	10		14.8	1.7	0.17	10.2	17
70	10		13.1	1.7	0.17	10.2	18.7
80	10	21	11	1.9	0.19	11.4	20.6
90	10		19	2	0.2	12	22.6
100	10		17.1	1.9	0.19	11.4	24.5
110	10		15.5	1.6	0.16	9.6	26.1
120	10		14	1.5	0.15	9	27.6
130	10	21	13	1	0.1	6	28.6
140	10		19.5	1.5	0.15	9	30.1
150	10	19	18	1.5	0.15	9	31.6
160	10		17.8	1.3	0.13	7.8	32.9
170	10		16.5	1.2	0.12	7.2	34.1
180	10		15.2	1.3	0.13	7.8	35.4
190	10		13.9	1.3	0.13	7.8	36.7
200	10		12.6	1.3	0.13	7.8	38

Site: 2

Date: 07.03.2019

Project name: NAQUIM, Hard rock areas of Ernakulam district
Location details : In the premises of Minor Irrigation Department, Sub Division-II (PVIP), Govt. of Kerala, Perumbavoor

District: Ernakulam Block: Koovapady

Elevation (m amsl): 17

Long: 76.4937

Lat: 10.11652

Soil type:Gravelly clay

Major Aquifer: Laterite followed by weathered charnockite

Site belongs to: PVIP, Govt. of Kerala

Geomorphic Unit: Plateau

Geology : Charnockite

Weather condition: Semi arid

Time (mins)	Time taken (min)	Initial Head (cms) after filling	Innner reading Head (cms)	Difference (cms) falling head	Infiltration rate (cm/min)	Rate of Infiltration in cm/Hr	Cumulative Depth of Infiltration (cms)
0	0	23.5	0				
1	1		21	2.5	2.5	150	2.5
2	1		19.5	1.5	1.5	90	4
3	1		18.5	1	1	60	5
4	1		17.1	1.4	1.4	84	6.4
5	1		16	1.1	1.1	66	7.5
6	1		15	1	1	60	8.5
7	1		14	1	1	60	9.5
8	1		13	1	1	60	10.5
9	1		12.1	0.9	0.9	54	11.4
10	1	23.5	11.5	0.6	0.6	36	12

12	2		22.2	1.3	0.65	39	13.3
14	2		20	2.2	1.1	66	15.5
16	2		17.9	2.1	1.05	63	17.6
18	2		16	1.9	0.95	57	19.5
20	2		14.1	1.9	0.95	57	21.4
22	2	23.5	12.9	1.2	0.6	36	22.6
24	2		21.5	2	1	60	24.6
26	2		19.9	1.6	0.8	48	26.2
28	2		18	1.9	0.95	57	28.1
30	5		16	2	0.4	24	30.1
35	5	23.5	12.3	3.7	0.74	44.4	33.8
40	10		19.2	4.3	0.43	25.8	38.1
50	10	23.5	11.7	7.5	0.75	45	45.6
60	10	23.5	15	8.5	0.85	51	54.1
70	10	24	16	7.5	0.75	45	61.6
80	10		16	8	0.8	48	69.6
90	10	23.5	10	6	0.6	36	75.6
100	10		16.4	7.1	0.71	42.6	82.7
110	10		10.8	5.6	0.56	33.6	88.3
120	10	23.5	16.7	6.8	0.68	40.8	95.1
130	10	23.5	10.8	5.9	0.59	35.4	101
140	10		17	6.5	0.65	39	107.5
150	10	23.5	10.8	6.2	0.62	37.2	113.7
160	10		17.6	5.9	0.59	35.4	119.6
170	10	23.5	11.7	5.9	0.59	35.4	125.5
180	10		17.6	5.9	0.59	35.4	131.4
190	10	23.5	11.7	5.9	0.59	35.4	137.3
200	10		17.6	5.9	0.59	35.4	143.2

Annexure VI

Storage Parameter test at Pezhakapilly, Muvattupuzha

YIELD TEST (WPT)

PUMPING DATA

Location	Lattitude	10.022916 N	Date	04.03.2019
	Longitude	76.557590 E	Type of well	Open well
Address	Sh. Bhaskaran Nair,		Depth of the well (m bmp)	7.1
	Kavanathayathu Puthen Veedu		Diameter of the well	2.30 mm
	Pezhakapilly, Muvattupuzha, Ernakulam		Static water level (mbmp)	5.97
Village:Pezhakapilly			Major zones (mbgl)	
Panchayath:Paipra			Average Discharge (lps)	2.5
Block:Muvattupuzha			Maxium Drawdowm	0.85
District: Ernakulam			Depth of Pump (mbgl)	
Name of Officer:Roopesh G.Krishnan			Period Pumped (min)	65
Designation:SC-B (JHG)			Geology:Laterite followed by Weathered Charnockite	
Capacity of Pump (HP):1.5HP Ht of Measuring Point (agl):0.85				

Pumping test

Time since pumping started (min)	Depth to Water Level (mbmp)	Drawdown (m)
0	5.97	0
1	5.99	0.02
2	6.03	0.06
3	6.05	0.08
4	6.06	0.09
5	6.055	0.085
6	6.07	0.1
7	6.09	0.12
8	6.1	0.13
9	6.11	0.14
10	6.14	0.17
12	6.18	0.21
14	6.18	0.21
16	6.2	0.23
18	6.23	0.26
20	6.25	0.28
22	6.27	0.3
25	6.3	0.33
30	6.35	0.38
35	6.38	0.41
38	6.42	0.45
40	6.49	0.52

Recouperation TEST

Time since pumping stopped(min)	Depth to Water Level (mbmp)	Drawdown (m)
66	6.75	0.78
67	6.75	0.78
68	6.74	0.77
69	6.74	0.77
70	6.73	0.76
71	6.73	0.76
72	6.72	0.75
73	6.71	0.74
74	6.69	0.72
75	6.68	0.71
77	6.68	0.71
79	6.68	0.71
81	6.67	0.7
83	6.66	0.69
85	6.65	0.68
90	6.62	0.65
95	6.6	0.63
135	6.45	0.48
195	6.31	0.34
255	6.19	0.22
315	6.1	0.13
360	6.03	0.06

45	6.54	0.57
50	6.59	0.62
55	6.63	0.66
60	6.69	0.72
62	6.72	0.75
63	6.75	0.78
64	6.81	0.84
65	6.82	0.85

400	6.01	0.04

Results analysed based on Papadopulos-Cooper Method (1967)

Specific Yield	1.20%	
Transmissivity (T)	28.6624	m^2/day

Annexure-VII

Format of Lithologs of existing borewells for the study area

Unique ID	NAQERN 1

Village	Edakattuvayal
Taluka/Block	Mulanthuruthy
District	Ernakulam
Toposheet No.	58C/5
Latitude	9.869
Longitude	76.436
RL(m amsl)	47.5
Drilled Depth	30
Casing	21.9
SWL (mbgl)	5.4
Discharge (lps)	0.4
Date/Year	25.05.2004

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Laterite
2	7	5	Laterite with minor clay
7	11	4	Laterite with yellowish brown clay
11	20	9	Clay
20	21	1	Gneiss,Weathered
21	22	1	Gneiss
22	24	2	Gneiss, Fractured
24	26	2	Gneiss
26	27	1	Gneiss, Fractured
27	30	3	Hornblende Gneiss

Unique ID	NAQERN 2
Village	Kanjiramattom
Taluka/Block	Mulanthuruthy
District	Ernakulam
Toposheet No.	58C/5
Latitude	9.854
Longitude	76.405
RL(m amsl)	9
Drilled Depth	60
Casing	31
SWL (mbgl)	13.45
Discharge (lps)	0.2
Date/Year	31.05.2004

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	6	6	Laterite
6	13	7	Clay, grey
13	25	12	Clar, red
25	29	4	Clay, brown
29	30	1	Gneiss,Weathered
30	42	12	Hornblende Biotite Gneiss

42	43	1	Hornblende Biotite Gneiss, Fractured
43	47	4	Hornblende Biotite Gneiss
47	48	1	Hornblende Biotite Gneiss, Fractured
48	60	12	Hornblende Biotite Gneiss

Unique ID	NAQERN 3
Village	Kizhakombu
Taluka/Block	Pampakuda
District	Ernakulam
Toposheet No.	58C/9
Latitude	9.871
Longitude	76.568
RL(m amsl)	33.8
Drilled Depth	40
Casing	8.05
SWL (mbgl)	3.1
Discharge (lps)	0.2
Date/Year	15.05.2004

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Laterite
4	6	2	Clay, yellowish brown
6	8	2	Gneiss,semi weathered and fractured
8	25	17	Hornblende Biotite Gneiss, grey coloured
25	31	6	Hornblende Biotite Gneiss, dark grey coloured
31	37	6	Hornblende Biotite Gneiss, slightly Fractured
37	38	1	Hornblende Biotite Gneiss, Fractured
38	40	2	Hornblende Biotite Gneiss, slightly Fractured

Unique ID	NAQERN 4
Village	Namakuzhi
Taluka/Block	Pampakuda
District	Ernakulam
Toposheet No.	58C/9
Latitude	9.857
Longitude	76.528
RL(m amsl)	53
Drilled Depth	60
Casing	5.6
SWL (mbgl)	7.1
Discharge (lps)	0.2
Date/Year	04.05.2004

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		

0	4	4	Laterite
4	5.5	1.5	Charnockite, semi- weathered
5.5	19	13.5	Charnockite
19	20	1	Charnockite,Fractured
20	60	40	Charnockite

Unique ID	NAQERN 5
Village	Illanji
Taluka/Block	Pampakuda
District	Ernakulam
Toposheet No.	58C/9
Latitude	9.829
Longitude	76.542
RL(m amsl)	13
Drilled Depth	200.53
Casing	6.6
SWL (mbgl)	1.87
Discharge (lps)	7.6
Date/Year	27.02.1987

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	5	5	Top soil, brown clayey
5	27.25	22.25	Charnockite, weathered and moderatly fractured
27.25	35	7.75	Charnockite, highly fractured
35	111	76	Charnockite, slightly fractured
111	114	3	Dolerite dyke in Charnockite
114	130	16	Charnockite, slightly fractured
130	165	35	Dolerite dyke, slightly fractured
165	187	22	Charnockite, hard and massive
187	200.53	13.53	Charnockite, with intrusion of pegmatite vein

Unique ID	NAQERN 6
Village	Kozhipalli
Taluka/Block	Pampakuda
District	Ernakulam
Toposheet No.	58C/9
Latitude	9.871
Longitude	76.614
RL(m amsl)	60.3
Drilled Depth	187.29
Casing	4.25
SWL (mbgl)	2.12
Discharge (lps)	10
Date/Year	09.02.1987

Depth Range (mbgl)		**Thickne**	**Litholog**

From	To	ss (m)	
0	5.1	5.1	Top soil, brown clayey
5.1	12	6.9	Charnockite, weathered and moderatly fractured
12	27.27	15.27	Charnockite, highly fractured
27.27	46	18.73	Charnockite, slightly fractured
46	76	30	Dyke, Dolerite
76	95.85	19.85	Charnockite, moderatly fractured
95.85	157	61.15	Charnockite, massive
157	160.43	3.43	Dyke, Dolerite
160.43	187.29	26.86	Charnockite, massive

Unique ID	NAQERN 7
Village	Onakkur
Taluka/Block	Pampakuda
District	Ernakulam
Toposheet No.	58C/9
Latitude	9.892
Longitude	76.517
RL(m amsl)	18.100
Drilled Depth	200.13
Casing	9.1
SWL (mbgl)	2.95
Discharge (lps)	nil
Date/Year	02.03.1987

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	4	4	Top soil, clayey,reddish brown
4	42.5	38.5	Charnockite, weathered and moderatly fractured
42.5	90	47.5	Charnockite, slightly fractured
90	200.53	110.53	Charnockite, hard and massive

Unique ID	NAQERN 8
Village	Kadalikad
Taluka/Block	Muvattupuzha
District	Ernakulam
Toposheet No.	58C/9
Latitude	9.922
Longitude	76.679
RL(m amsl)	28.2
Drilled Depth	200
Casing	6.46
SWL (mbgl)	1.2
Discharge (lps)	10
Date/Year	06.03.1987

Depth Range (mbgl)		Thickne	Litholog

From	To	ss (m)	
0	5.2	5.2	Top soil and Laterite,reddish brown
5.2	6.5	1.3	Charnockite, weathered and highly fractured
6.5	23.6	17.1	Charnockite, mylomatised and weathered highly fractured
23.6	92	68.4	Charnockite, moderatly fractured enrichment of biotite
92	107	15	Charnockite, highly fractured
107	168	61	Charnockite, slightly fractured
168	178	10	Dyke, Dolerite
178	200	22	Biotite gneiss with abundance of quartz

Unique ID	NAQERN 9
Village	Vadakkumaradi
Taluka/Block	Muvattupuzha
District	Ernakulam
Toposheet No.	58C/9
Latitude	9.953
Longitude	76.558
RL(m amsl)	25.4
Drilled Depth	237.15
Casing	6.5
SWL (mbgl)	4.46
Discharge (lps)	1.12
Date/Year	17.02.1987

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	5.43	5.43	Top soil and Laterite,reddish brown
5.43	34.6	29.17	Charnockite, weathered and moderately fractured
34.6	54	19.4	Charnockite, hard and massive
54	58	4	Charnockite, slightly fractured
58	73	15	Charnockite, hard and massive
73	80.61	7.61	Charnockite, slightly fractured
80.61	180	99.39	Charnockite, hard and massive
180	183	3	Charnockite, moderately fractured
183	191	8	Charnockite, hard and massive
191	194	3	Charnockite, moderately fractured
194	237.15	43.15	Charnockite, hard and massive with abundance of quartz

Unique ID	NAQERN 10
Village	Nadukani
Taluka/Block	Kothamangalam
District	Ernakulam

Toposheet No.	58B/12
Latitude	10.090
Longitude	76.671
RL(m amsl)	42.9
Drilled Depth	200.53
Casing	4.4
SWL (mbgl)	1.1
Discharge (lps)	0.1
Date/Year	1987

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	5.43	5.43	Top soil and Laterite,reddish brown
5.43	28	22.57	Charnockite, weathered and slightly fractured
28	54	26	Charnockite, hard and massive
54	58	4	Charnockite, slightly fractured
58	73	15	Charnockite, hard and massive
73	80.61	7.61	Charnockite, slightly fractured
80.61	180	99.39	Charnockite, hard and massive
180	183	3	Charnockite, moderately fractured
183	191	8	Charnockite, hard and massive
191	194	3	Charnockite, moderately fractured
194	237.15	43.15	Charnockite, hard and massive with abundance of quartz

Unique ID	NAQERN 11
Village	Kizhakambalam
Taluka/Block	Vazhakulam
District	Ernakulam
Toposheet No.	58B/8
Latitude	10.032
Longitude	76.406
RL(m amsl)	14.0
Drilled Depth	131.25
Casing	8.5
SWL (mbgl)	1.1
Discharge (lps)	22
Date/Year	1987

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	5.5	5.5	Top soil and Laterite,reddish brown
5.5	9	3.5	Charnockite, weathered and slightly fractured
9	19	10	Charnockite, massive
19	23	4	Charnockite, moderately fractured
23	34	11	Charnockite, hard and massive
34	38	4	Charnockite, highly fractured

38	79	41	Charnockite, hard and massive
79	80	1	Charnockite, moderately fractured
80	131.25	51.25	Charnockite, hard and massive

Unique ID	NAQERN 12
Village	Adirapalli FRO
Taluka/Block	Angamali
District	Ernakulam
Toposheet No.	58B/7
Latitude	10.258
Longitude	76.530
RL(m amsl)	31.0
Drilled Depth	59
Casing	6
SWL (mbgl)	4
Discharge (lps)	22
Date/Year	2014

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Top soil
4	6	2	Charnockite, weathered
6	27	21	Charnockite, massive
27	28	1	Charnockite, moderately fractured
28	33	5	Charnockite, hard and massive
33	34	1	Charnockite, highly fractured
34	48	14	Charnockite, hard and massive
48	49	1	Charnockite, moderately fractured
49	55	6	Charnockite, hard and massive
55	56	1	Charnockite, moderately fractured
56	59	3	Charnockite, hard and massive

Unique ID	NAQERN 13
Village	Kalady
Taluka/Block	Angamali
District	Ernakulam
Toposheet No.	58B/8
Latitude	10.168
Longitude	76.439
RL(m amsl)	11.8
Drilled Depth	101
Casing	14
SWL (mbgl)	6
Discharge (lps)	9.2
Date/Year	2014

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	11	11	Top soil and Laterite,reddish brown

11	13	2	Clay
13	14	1	Charnockite, weathered
14	63	49	Charnockite, hard and massive
63	64	1	Charnockite, moderately fractured
64	101	37	Charnockite gneiss, massive

Unique ID	NAQERN 14
Village	Pallarimangalam
Taluka/Block	Kothamanagalam
District	Ernakulam
Toposheet No.	58B/12
Latitude	10.028
Longitude	76.657
RL(m amsl)	35.9
Drilled Depth	101
Casing	7
SWL (mbgl)	3.2
Discharge (lps)	0.1
Date/Year	2014

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	7	7	Top soil and Laterite,reddish brown
7	10	3	Dolerite Dyke
10	11	1	Charnockite Gneiss , Slightly fractured
11	67	56	Dyke, Dolerite
67	101	34	Charnockite gneiss, massive

Unique ID	NAQERN 15
Village	Neriamangalam
Taluka/Block	Kothamangalam
District	Ernakulam
Toposheet No.	58B/16
Latitude	10.060
Longitude	76.763
RL(m amsl)	49.6
Drilled Depth	101
Casing	6
SWL (mbgl)	6.2
Discharge (lps)	0.1
Date/Year	2014

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Top soil and Laterite,reddish brown
4	6	2	Charnockite Gneiss , Weathered
6	22	16	Charnockite Gneiss ,hard and massive
22	23	1	Charnockite Gneiss ,moderately fractured
23	40	17	Charnockite gneiss, massive

40	41	1	Charnockite Gneiss , Slightly fractured
41	101	60	Charnockite gneiss, massive

Unique ID	NAQERN 16
Village	Desham
Taluka/Block	Parakkadav
District	Ernakulam
Toposheet No.	58B/8
Latitude	10.132
Longitude	76.353
RL(m amsl)	3.8
Drilled Depth	201
Casing	28
SWL (mbgl)	4.5
Discharge (lps)	2.8
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
2	27.7	25.7	Laterite,and weathered Charnockite reddish brown
27.7	65	37.3	Charnockite Gneiss ,hard and massive
65	68	3	Charnockite Gneiss ,moderately fractured
68	111	43	Charnockite gneiss, massive
111	114	3	Charnockite Gneiss , Slightly fractured
114	156	42	Charnockite gneiss, massive
156	160	4	Charnockite Gneiss ,moderately fractured
160	201	41	Charnockite gneiss, massive

Unique ID	NAQERN 17
Village	Sreemoolanagaram
Taluka/Block	Angamali
District	Ernakulam
Toposheet No.	58 B/8
Latitude	10.138
Longitude	76.394
RL(m amsl)	14.4
Drilled Depth	201
Casing	15
SWL (mbgl)	5.2
Discharge (lps)	3.2
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	3	3	Top soil
2	14.86	12.86	Laterite,and weathered Charnockite reddish brown

14.86	27	12.14	Charnockite Gneiss ,hard and massive
27	30	3	Charnockite Gneiss ,moderately fractured
30	57	27	Charnockite gneiss, massive
57	60	3	Charnockite Gneiss , Slightly fractured
60	129	69	Charnockite gneiss, massive
129	134	5	Charnockite Gneiss ,moderately fractured
134	201	67	Charnockite gneiss, massive

Unique ID	NAQERN 18
Village	Odakkali
Taluka/Block	Koovapady
District	Ernakulam
Toposheet No.	58 B/12
Latitude	10.091
Longitude	76.543
RL(m amsl)	40.6
Drilled Depth	200
Casing	8
SWL (mbgl)	5.2
Discharge (lps)	3.2
Date/Year	2015

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	2	2	Top soil
2	8	6	Laterite,and weathered Charnockite reddish brown
8	200	192	Charnockite Gneiss ,hard and massive

Unique ID	NAQERN 19
Village	Pezhakapilly
Taluka/Block	Muvattupuzha
District	Ernakulam
Toposheet No.	58 B/12
Latitude	10.015
Longitude	76.564
RL(m amsl)	34.9
Drilled Depth	136
Casing	20
SWL (mbgl)	4.5
Discharge (lps)	10
Date/Year	2015

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	4	4	Top soil
4	20	16	Laterite,and weathered Charnockite
20	65	45	Charnockite ,hard and massive
65	65.3	0.3	Charnockite ,highly fractured

65.3	136	70.7	Charnockite, hard and massive

Unique ID	NAQERN 20
Village	Okkal
Taluka/Block	Koovapady
District	Ernakulam
Toposheet No.	58B/8
Latitude	10.148
Longitude	76.455
RL (m amsl)	9.6
Drilled Depth	197
Casing	11.5
SWL (mbgl)	5.2
Discharge (lps)	3.3
Date/Year	2015

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	2	2	Top soil
2	11.5	9.5	Laterite, and weathered Charnockite
11.5	47	35.5	Charnockite, hard and massive
47	48	1	Charnockite, moderalety fractured
48	125	77	Charnockite, hard and massive
125	126	1	Charnockite, moderalety fractured
126	136	10	Charnockite, massive

Unique ID	NAQERN 21
Village	Kothamangalam
Taluka/Block	Kothamangalam
District	Ernakulam
Toposheet No.	58B/12
Latitude	10.062
Longitude	76.633
RL (m amsl)	32.0
Drilled Depth	200
Casing	7
SWL (mbgl)	5.2
Discharge (lps)	10.5
Date/Year	2015

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0	0.5	0.5	Top soil
0.5	7	6.5	Laterite, and weathered Charnockite
7	167	160	Charnockite, hard and massive
167	168	1	Charnockite, highly fractured
168	200	32	Charnockite, massive

Unique ID	NAQERN 22

Village	Chelad
Taluka/Block	Kothamangalam
District	Ernakulam
Toposheet No.	58B/12
Latitude	10.105
Longitude	76.644
RL (m amsl)	40.5
Drilled Depth	200
Casing	5
SWL (mbgl)	4.5
Discharge (lps)	5
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	0.5	0.5	Top soil
0.5	4.6	4.1	Laterite,and weathered Charnockite
4.6	28.5	23.9	Charnockite ,hard and massive
28.5	30	1.5	Charnockite ,moderately fractured
30	120	90	Charnockite ,hard and massive
120	121	1	Charnockite ,moderately fractured
121	200	79	Charnockite ,hard and massive

Unique ID	NAQERN 23
Village	Puthencruz
Taluka/Block	Vadavucode
District	Ernakulam
Toposheet No.	58C/5
Latitude	9.975
Longitude	76.452
RL(m amsl)	34.2
Drilled Depth	200
Casing	9
SWL (mbgl)	4.9
Discharge (lps)	0.5
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	1	1	Top soil
1	8.4	7.4	Laterite,and weathered Charnockite
8.4	117	108.6	Charnockite ,hard and massive
117	118	1	Charnockite ,moderately fractured
118	200	82	Charnockite ,hard and massive

Unique ID	NAQERN 24
Village	Palakuzha
Taluka/Block	Pampakuda
District	Ernakulam

Toposheet No.	58 C/9
Latitude	9.882
Longitude	76.606
RL(m amsl)	59.7
Drilled Depth	200
Casing	6
SWL (mbgl)	4.9
Discharge (lps)	0.25
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	0.75	0.75	Top soil
0.75	5.4	4.65	Laterite,and weathered Charnockite
5.4	62	56.6	Charnockite ,hard and massive
62	63	1	Charnockite ,moderately fractured
63	200	137	Charnockite ,hard and massive

Unique ID	NAQERN 25
Village	Perumbavoor
Taluka/Block	Koovapady
District	Ernakulam
Toposheet No.	58B/8
Latitude	10.119
Longitude	76.482
RL(m amsl)	28.9
Drilled Depth	200
Casing	12
SWL (mbgl)	4.9
Discharge (lps)	0.5
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
0.75	11.4	10.65	Laterite,and weathered Charnockite
11.4	129.3	117.9	Charnockite , massive
129.3	130	0.7	Charnockite ,moderately fractured
130	200	70	Charnockite ,hard and massive

Unique ID	NAQERN 26
Village	Parapuram
Taluka/Block	Angamali
District	Ernakulam
Toposheet No.	58B/8
Latitude	10.131
Longitude	76.446
RL(m amsl)	24.1
Drilled Depth	200

Casing	15
SWL (mbgl)	4.9
Discharge (lps)	4.36
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
2	15	13	Laterite,and weathered Charnockite
15	31	16	Charnockite, massive
31	34.5	3.5	Charnockite ,moderately fractured
34.5	135	100.5	Charnockite, massive
135	135.6	0.6	Charnockite ,moderately fractured
135.6	200	64.4	Charnockite ,hard and massive

Unique ID	NAQERN 27
Village	Trikkakara
Taluka/Block	Edapally
District	Ernakulam
Toposheet No.	58 B/8
Latitude	10.022
Longitude	76.331
RL(m amsl)	27.9
Drilled Depth	88
Casing	10
SWL (mbgl)	9
Discharge (lps)	14
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	1.5	1.5	Top soil
1.5	10	8.5	Laterite,and weathered Charnockite
10	48	38	Charnockite, massive
48	49	1	Charnockite ,moderately fractured
49	58	9	Charnockite, massive
58	59	1	Charnockite ,moderately fractured
59	70	11	Charnockite, massive
70	71	1	Charnockite ,moderately fractured
71	84	13	Charnockite, massive
84	86	2	Charnockite ,moderately fractured
86	88	2	Charnockite ,hard and massive

Unique ID	NAQERN 28
Village	Kalamasseri
Taluka/Block	Vazhakulam
District	Ernakulam
Toposheet No.	58 B/8
Latitude	10.055

Longitude	76.331
RL(m amsl)	22.3
Drilled Depth	200
Casing	15
SWL (mbgl)	8.1
Discharge (lps)	3.5
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
2	15	13	Laterite,and weathered Charnockite
15	42	27	Charnockite, massive
42	43	1	Charnockite ,moderately fractured
43	78	35	Charnockite, massive
78	79	1	Charnockite ,moderately fractured
79	101	22	Charnockite, massive
101	102	1	Charnockite ,moderately fractured
102	200	98	Charnockite ,hard and massive

Unique ID	NAQERN 29
Village	Kurumasseri
Taluka/Block	Parakkadav
District	Ernakulam
Toposheet No.	58 B/8
Latitude	10.179
Longitude	76.331
RL(m amsl)	18.0
Drilled Depth	200
Casing	15
SWL (mbgl)	8.1
Discharge (lps)	10
Date/Year	2016

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
2	15	13	Laterite,and weathered Charnockite
9	10	1	Charnockite ,moderately fractured
10	200	190	Charnockite, massive

Unique ID	NAQERN 30
Village	Angamali
Taluka/Block	Angamali
District	Ernakulam
Toposheet No.	58 B/8
Latitude	10.186
Longitude	76.374
RL(m amsl)	21.4

Drilled Depth	153
Casing	10
SWL (mbgl)	9
Discharge (lps)	10
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	1.5	1.5	Top soil
1.5	10	8.5	Laterite,and weathered Charnockite
10	42	32	Charnockite , massive
43	44	1	Charnockite ,moderately fractured
44	77	33	Charnockite, massive
77	78	1	Charnockite ,moderately fractured
78	149	71	Charnockite, massive
149	151	2	Charnockite ,moderately fractured
151	153	2	Charnockite ,hard and massive

Unique ID	NAQERN 31
Village	Veetur
Taluka/Block	Vadavucode
District	Ernakulam
Toposheet No.	58 B/12
Latitude	10.015
Longitude	76.536
RL(m amsl)	38.2
Drilled Depth	200
Casing	4
SWL (mbgl)	4
Discharge (lps)	0.5
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	0.25	0.25	Top soil
0.25	3.5	3.25	Laterite,and weathered Charnockite
3.5	166	162.5	Charnockite ,hard and massive
166	167	1	Charnockite ,moderately fractured
167	200	33	Charnockite ,hard and massive

Unique ID	NAQERN 32
Village	Mamala
Taluka/Block	Vadavucode
District	Ernakulam
Toposheet No.	58 B/12
Latitude	9.948
Longitude	76.383
RL(m amsl)	27.7
Drilled Depth	200

Casing	4
SWL (mbgl)	4
Discharge (lps)	2
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
2	9	7	Laterite
9	12	3	Weathered and slightly fractured Charnockite
12	63	51	Charnockite ,hard and massive
63	64	1	Charnockite ,moderately fractured
64	137	73	Charnockite ,hard and massive
137	138	1	Charnockite ,moderately fractured
138	200	62	Charnockite ,hard and massive

Unique ID	NAQERN 33
Village	Maneed
Taluka/Block	Pampakuda
District	Ernakulam
Toposheet No.	58C/5
Latitude	9.906
Longitude	76.453
RL(m amsl)	19.5
Drilled Depth	200
Casing	6
SWL (mbgl)	5.2
Discharge (lps)	3.5
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
2	12	10	Laterite,and weathered and slightly fractured Charnockite
12	44	32	Charnockite ,hard and massive
44	45	1	Charnockite ,moderately fractured
45	181	136	Charnockite ,hard and massive
181	182	1	Charnockite ,moderately fractured
182	200	18	Charnockite ,hard and massive

Unique ID	NAQERN 34
Village	Mulanthuruthy
Taluka/Block	Mulanthuruthy
District	Ernakulam
Toposheet No.	58C/5
Latitude	9.901
Longitude	76.387
RL(m amsl)	22.6

Drilled Depth	190
Casing	15
SWL (mbgl)	10
Discharge (lps)	3.5
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
2	15	13	Laterite,and weathered and slightly fractured Charnockite
15	35	20	Charnockite ,hard and massive
35	36	1	Charnockite ,moderately fractured
36	114	78	Charnockite ,hard and massive
114	117	3	Charnockite ,moderately fractured
117	190	73	Charnockite ,hard and massive

Unique ID	NAQERN 35
Village	Neriyamangalam-2
Taluka/Block	Kothamangalam
District	Ernakulam
Toposheet No.	58B/16
Latitude	10.053
Longitude	76.763
RL(m amsl)	60.0
Drilled Depth	200
Casing	6
SWL (mbgl)	6.2
Discharge (lps)	0.07
Date/Year	2014

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	6	6	Top soil
6	7	1	Charnockite Gneiss , Weathered
7	45	38	Charnockite Gneiss ,hard and massive
45	81	36	Granite Gneiss
81	99	18	Charnockite gneiss, massive
99	200	101	Charnockite gneiss, massive

Unique ID	NAQERN 36
Village	Ramamangalam
Taluka/Block	Pampakuda
District	Ernakulam
Toposheet No.	58C/5
Latitude	9.943
Longitude	76.483
RL(m amsl)	21.6
Drilled Depth	200

Casing	12
SWL (mbgl)	7
Discharge (lps)	nil
Date/Year	2012

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
2	11	9	Laterite,and weathered Charnockite
11	200	189	Charnockite ,hard and massive

Unique ID	NAQERN 37
Village	Muvattupuzha
Taluka/Block	Muvattupuzha
District	Ernakulam
Toposheet No.	58C/9
Latitude	9.992
Longitude	76.583
RL (m amsl)	20.4
Drilled Depth	153
Casing	8
SWL (mbgl)	6.2
Discharge (lps)	10
Date/Year	2015

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	2	2	Top soil
2	8	6	Laterite, and weathered and slightly fractured Charnockite
8	12	4	Charnockite, hard and massive
12	13	1	Charnockite, moderately fractured
13	51	38	Charnockite, hard and massive
51	52	1	Charnockite, highly fractured
52	141	89	Charnockite, hard and massive
141	142	1	Charnockite, moderately fractured
142	153	11	Charnockite, hard and massive

Unique ID	NAQERN 38
Village	Illithode
Taluka/Block	Angamali
District	Ernakulam
Toposheet No.	58 B/12
Latitude	10.201
Longitude	76.518
RL (m amsl)	24.0
Drilled Depth	60
Casing	8
SWL (mbgl)	dry

Discharge (lps)	nil
Date/Year	2018

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0	3	3	Top Soil with Laterite
3	8	5	Weathered Granetic Gneiss
8	18	10	Granite Gneiss
18	39	21	Granite gneiss, massive
39	50	11	Biotite Granite Gneiss
50	60	10	Granite Gneiss

Unique ID	NAQERN 39
Village	Kodanad
Taluka/Block	Angamali
District	Ernakulam
Toposheet No.	58 B/12
Latitude	10.186
Longitude	76.513
RL (m amsl)	21.0
Drilled Depth	200
Casing	13
SWL (mbgl)	5
Discharge (lps)	
Date/Year	2019

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	7.00	7	Clay with soil
7.00	13.00	6	Charnockite weathered
13.00	31.70	18.7	Charnockite
31.70	34.70	3	Charnockite fractured
34.70	50.00	15.3	Charnockite
50.00	53.00	3	Charnockite fractured
53.00	80.50	27.5	Charnockite
80.50	83.50	3	Charnockite fractured
83.50	107.90	24.4	Charnockite
107.90	111.00	3.1	Charnockite fractured
111.00	200.00	89	Charnockite

Unique ID	NAQERN 40
Village	Koovapady
Taluka/Block	Koovapady
District	Ernakulam
Toposheet No.	58B/8
Latitude	10.150
Longitude	76.468
RL (m amsl)	21.0
Drilled Depth	60

Casing	8
SWL (mbgl)	7
Discharge (lps)	
Date/Year	2019

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	1.50	1.5	Clay with soil
1.50	5.00	3.5	Laterite
5.00	6.50	1.5	Charnockite weathered
6.50	60.00	53.5	Charnockite

Unique ID	NAQERN 41
Village	Malayatur
Taluka/Block	Angamali
District	Ernakulam
Toposheet No.	58B/11
Latitude	10.184
Longitude	76.501
RL (m amsl)	19.0
Drilled Depth	200
Casing	13
SWL (mbgl)	10
Discharge (lps)	
Date/Year	2019

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	2.50	2.5	Top Soil
2.50	8.50	6	Lithomarge clay
8.50	60.00	51.5	Biotite Granite Gneiss

Unique ID	NAQERN 42
Village	Inchathotty
Taluka/Block	Kothamangalam
District	Ernakulam
Toposheet No.	58 B/16
Latitude	10.089
Longitude	76.742
RL (m amsl)	54.0
Drilled Depth	200
Casing	6
SWL (mbgl)	
Discharge (lps)	
Date/Year	2018

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	2.00	2	Clay with soil
2.00	6.00	4	Weathered gneiss with quartz

6.00	200.00	194	Granite Gneiss

Unique ID	NAQERN 43
Village	Punnakad Pz
Taluka/Block	Kothamangalam
District	Ernakulam
Toposheet No.	58B/12
Latitude	10.105
Longitude	76.671
RL (m amsl)	44.0
Drilled Depth	60
Casing	4
SWL (mbgl)	
Discharge (lps)	
Date/Year	2018

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	0.10	0.1	Clay with soil
0.10	2.50	2.4	Laterite
2.50	3.50	1	Charnockite, Weathered
3.50	60.00	56.5	Charnockite, Massive

Unique ID	NAQERN 44
Village	Irumbanam Pz
Taluka/Block	Vadavucode
District	Ernakulam
Toposheet No.	58 C/5
Latitude	9.982
Longitude	76.349
RL (m amsl)	8.0
Drilled Depth	30
Casing	12
SWL (mbgl)	
Discharge (lps)	
Date/Year	2018

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	1.50	1.5	Clay with soil
1.50	6.00	4.5	Sandy clay
6.00	9.00	3	Clayey sand
9.00	11.00	2	Charnockite, Weathered
11.00	21.00	10	Charnockite, Massive
21.00	30.00	9	Charnockite, slightly fractured

Unique ID	NAQERN 45
Village	Veliyanad Pz
Taluka/Block	Mulanthuruthy

District	Ernakulam
Toposheet No.	58 C/5
Latitude	9.872
Longitude	76.455
RL (m amsl)	24.0
Drilled Depth	40
Casing	7
SWL (mbgl)	
Discharge (lps)	
Date/Year	2018

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	1.00	1	Lateritic soil
1.00	4.00	3	Laterite
4.00	6.50	2.5	Charnockite, Weathered
6.50	40.00	33.5	Charnockite, Massive

Unique ID	NAQERN 46
Village	Arakuzha Pz
Taluka/Block	Muvattupuzha
District	Ernakulam
Toposheet No.	58 C/9
Latitude	9.928
Longitude	76.584
RL (m amsl)	33.0
Drilled Depth	60
Casing	8
SWL (mbgl)	
Discharge (lps)	
Date/Year	2012

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	2.00	2	Laterite
2.00	8.00	6	Charnockite, Weathered
8.00	60.00	52	Charnockite, Massive

Unique ID	NAQERN 47
Village	Nadukkara-Vazhakkulam
Taluka/Block	Muvattupuzha
District	Ernakulam
Toposheet No.	58 C/9
Latitude	9.937
Longitude	76.601
RL (m amsl)	28.0
Drilled Depth	200
Casing	6

SWL (mbgl)	
Discharge (lps)	
Date/Year	2018

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	3.00	3	Clayey sand
3.00	6.00	3	Charnockite, Weathered
6.00	27.00	21	Charnockite, Massive
27.00	30.00	3	Charnockite with quartz
30.00	43.90	13.9	Charnockite, Massive
43.90	46.90	3	Charnockite, Fractured
46.90	114.00	67.1	Charnockite, Massive
114.00	123.00	9	Charnockite with quartz
123.00	153.70	30.7	Charnockite, Massive
153.70	156.70	3	Charnockite, Fractured
156.70	200.00	43.3	Charnockite, Massive

Unique ID	NAQERN 48
Village	Vazhakam Pz
Taluka/Block	Muvattupuzha
District	Ernakulam
Toposheet No.	58 C/9
Latitude	9.980
Longitude	76.540
RL (m amsl)	19.0
Drilled Depth	30
Casing	12
SWL (mbgl)	
Discharge (lps)	
Date/Year	2012

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	2.00	2	Top Soil
2.00	12.00	10	Laterite
12.00	21.00	9	Lithomarge clay
21.00	30.00	9	Horblende Biotite Gneiss

Unique ID	NAQERN 49
Village	Piravom EW
Taluka/Block	Pampakuda
District	Ernakulam
Toposheet No.	58 C/5
Latitude	9.891
Longitude	76.486
RL (m amsl)	32.0
Drilled Depth	200
Casing	6

SWL (mbgl)	8
Discharge (lps)	
Date/Year	2018

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	3.00	3	Top Soil with Laterite
3.00	6.00	3	Charnockite, Weathered
6.00	175.00	169	Charnockite, Hard and Massive
175.00	178.10	3.1	Charnockite, slightly Fractured
178.10	200.00	21.9	Charnockite, Hard and Massive

Unique ID	NAQERN 50
Village	Thirumaradi
Taluka/Block	Pampakuda
District	Ernakulam
Toposheet No.	58 C/9
Latitude	9.889
Longitude	76.555
RL (m amsl)	29.0
Drilled Depth	60
Casing	6
SWL (mbgl)	
Discharge (lps)	
Date/Year	2012

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	1.00	1	Top Soil with Laterite
4.00	6.00	2	Charnockite, Weathered
6.00	21.00	15	Charnockite, Hard and Massive
21.00	60.00	39	Charnockite Gneiss, slightly Fractured

Unique ID	NAQERN 51
Village	Kodussery
Taluka/Block	Parakkadav
District	Ernakulam
Toposheet No.	58B/8
Latitude	10.194
Longitude	76.349
RL (m amsl)	20.0
Drilled Depth	40
Casing	20
SWL (mbgl)	
Discharge (lps)	
Date/Year	2012

Depth Range (mbgl)		Thickness (m)	Litholog
From	To		
0.00	2.00	2	Top Soil

2.00	7.00	5	Laterite
7.00	18.00	11	Clay, micaceous
18.00	20.00	2	Charnockite, Weathered
20.00	38.00	18	Biotite Granite Gneiss
38.00	40.00	2	Granite Gneiss

Unique ID	NAQERN 52
Village	Aikaranad1 (Kadayiruppu)
Taluka/Block	Vadavucode
District	Ernakulam
Toposheet No.	58 C/5
Latitude	9.9997
Longitude	76.459
RL (m amsl)	37.0
Drilled Depth	30
Casing	11
SWL (mbgl)	
Discharge (lps)	
Date/Year	2012

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0.00	2.00	2	Top Soil
2.00	6.00	4	Laterite
6.00	9.00	3	Clay, Lithomarge
9.00	11.00	2	Charnockite, Weathered
11.00	30.00	19	Charnockite, Hard and Massive

Unique ID	NAQERN 53
Village	Mullankunnu
Taluka/Block	Vazhakulam
District	Ernakulam
Toposheet No.	58B/8
Latitude	10.0953
Longitude	76.433
RL (m amsl)	23.0
Drilled Depth	40
Casing	11
SWL (mbgl)	9
Discharge (lps)	nil
Date/Year	2012

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0.00	1.00	1	Top Soil
1.00	6.00	5	Laterite
6.00	9.00	3	Clay, Lithomarge
9.00	11.00	2	Charnockite, Weathered

11.00	40.00	29	Charnockite, Hard and Massive

Unique ID	NAQERN 54
Village	Poothrikka Pz
Taluka/Block	Vadavucode
District	Ernakulam
Toposheet No.	58 C/5
Latitude	9.9481
Longitude	76.456
RL (m amsl)	29.0
Drilled Depth	40
Casing	18
SWL (mbgl)	
Discharge (lps)	
Date/Year	2012

Depth Range (mbgl)		**Thickness (m)**	**Litholog**
From	**To**		
0.00	2.00	2	Top Soil
2.00	12.00	10	Laterite
12.00	18.00	6	Clay, Lithomarge
18.00	20.00	2	Charnockite, Weathered
20.00	40.00	20	Charnockite, Hard and Massive

Annexure-VIII: Analytical Results of Ground water quality monitoring wells (NHNS) April 2018

Location	Date of collection	pH	EC in µs/cm at 25^0C	TH as $CaCO_3$	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3	Aquifer Type
				<----------Conc.in mg/L---------->											
Elur North	12.4.18	7.34	2900	565	154	44	314	9.7	0	110	88	764	0.16	43	Phreatic Aquifer
Thaikattukara	13.4.18	7.27	580	120	28	12	60	11	0	61	142	53	0.11	9	Phreatic Aquifer
Kunnukara	13.4.18	7.16	122	14	4	1	17	2	0	4.9	0	23	0.05	12	Phreatic Aquifer
Parakadavu	13.4.18	6.84	330	78	18	8.3	19	12	0	61	16	50	0.04	1.7	Phreatic Aquifer
Chengamanad	13.4.18	6.83	119	24	6.4	1.9	14	3.1	0	12	0	18	0	18	Phreatic Aquifer
Mallussery	13.4.18	6.77	122	14	3.2	1.5	17	4	0	4.9	0	24	0.16	16	Phreatic Aquifer
Karukutty	13.4.18	6.17	105	26	5.6	2.9	8.9	1.3	0	27	0.58	11	0.02	12	Phreatic Aquifer
Kottapuram	13.4.18	6.18	158	36	10	2.4	16	5.3	0	37	16	16	0	4.1	Phreatic Aquifer
Aluva	13.4.18	6.11	195	28	8	1.9	17	17	0	9.8	16	26	0	24	Phreatic Aquifer
Trikkakkara	13.4.18	6.5	300	72	26	1.5	30	3.3	0	78	4.2	50	0	7.6	Phreatic Aquifer
Angamali	13.4.18	6.7	240	50	17	1.9	20	8.6	0	44	18	34	0	10	Phreatic Aquifer
Chulli	13.4.18	6.63	142	42	11	3.4	14	1.4	0	27	0	17	0.05	24	Phreatic Aquifer
Malayattur	14.4.18	6.69	106	28	7.2	2.4	6.2	3.5	0	27	6.7	9.9	0	8.1	Phreatic Aquifer
Aikaranad	14.4.18	5.9	40	6	1.6	0.49	3.1	1.3	0	7.3	0.38	7.1	0	0.38	Phreatic Aquifer
Perumbadavam	16.4.18	6.03	73	18	3.2	2.4	4.1	1.7	0	15	0.19	11	0	1.9	Phreatic Aquifer
Mulanthuruthi	16.4.18	6.49	152	24	8.8	0.49	17	2.2	0	7.3	0.29	24	0	24	Phreatic Aquifer
Anchalpetty	16.4.18	6.56	77	18	5.6	0.97	4.9	1.6	0	12	3.3	11	0	3.1	Phreatic Aquifer
Vallom	17.4.18	6.41	117	22	6.4	1.5	15	3.5	0	22	0.29	16	0	9.8	Phreatic Aquifer
Vazhakulam North	17.4.18	6.45	116	38	9.6	3.4	8	2.7	0	32	5.3	11	0	9.9	Phreatic Aquifer
Neriyamangalam	18.4.18	7.01	91	22	4.8	2.4	6.6	2.3	0	15	3	16	0	5.7	Phreatic Aquifer
Pothanikad	18.4.18	6.68	176	40	15	0.49	12	12	0	41	12	16	0	19	Phreatic Aquifer
Kottapadi	18.4.18	6.66	76	24	6.4	1.9	5.1	0.48	0	27	1.9	8.5	0	2.4	Phreatic Aquifer

Kothamangalam	18.4.18	6.56	200	62	18	3.9	12	5.1	0	27	14	20	0	32	Phreatic Aquifer
Muvattupuzha	18.4.18	6.62	181	62	17	4.9	5.7	8.6	0	56	28	9.9	0	9.3	Phreatic Aquifer
Koothattukulam	18.4.18	6.75	290	70	21	4.4	18	21	0	61	9.4	31	0	44	Phreatic Aquifer
Vazhakulam (Nadukkara)	31.10.18	7.41	430	16	3.8	1.6	87	4.5	0	250	21	7.1	0	26	Deeper Aquifer
Kakkad, Piravom	15.11.18	7.57	300	115	31	9	14	4.7	0	177	3.3	5.7	0.05	1	Deeper Aquifer
District Agricultural Farm, Neriyamangalam-EW 1	07.01.19	6.72	178	74	24	3.4	4.2	1.1	0	112	2.2	4.3	0	0.54	Deeper Aquifer
Neriyamangalam-EW 1	11.01.19	7.4	210	93	28	5.6	4.7	1.1	0	146	1.7	4.3	0	0.56	Deeper Aquifer
Neriyamangalam	19.01.19	7.3	220	110	31	7.7	5.4	1.1	0	156	4.5	5.7	0	0.25	Deeper Aquifer
Neriyamangalam-EW 1	31.01.19	7.13	187	87	24	6.7	4.6	1	0	124	1.4	5.7	0	0.16	Deeper Aquifer
District Agricultural Farm, Neriyamangalam-EW 1	31.01.19	7.19	260	116	33	8.1	5.2	1	0	159	1.4	5.7	0	0	Deeper Aquifer

Annexure-IX: Interpreted Results of VES for Hard Rock Terrains of Ernakulam District

Location	Longitude	Latitude	Interpreted Results											Depth to Massive Rock (m.)
			Resistivity (Ohm.m.)						Thickness (m.)					
			r_1	r_2	r_3	r_4	r_5	r_6	h_1	h_2	h_3	h_4	h_5	
Alamuttom	76.30	10.18	209	44	15	46	7	314	0.88	2.63	11.98	11.16	28.44	55.1
Alwaye	76.36	10.15	61	480	58	255			0.37	4.88	8.94			14.2
Arakunnam	76.43	9.88	6217	817	59	1758			0.65	14.06	31.51			46.21
Ayiroor	76.31	10.18	350	38	5	7977			0.63	2.23	17.83			20.69
Boothathankettu [forest station (FS)] 1	76.67	10.16	2625	191	2956				2	13.1				15.1
Boothathankettu (FS) 2	76.67	10.16	7198	735	208	1596	193	VH	0.8	2.5	3.3	6.2	12.2	25
Boothathankettu (FS) 3	76.66	10.14	1690	270	2161	594	2028		3.6	4.8	9.3	18.5		36.2
Chembankuzhy-1	76.81	10.03	1523	4951	823	8352	1223		0.477	7.95	5.83	17.1		31.36
Chembankuzhy-2	76.81	10.03	2785	1674	2549				2.383	12.19				14.57
Chembankuzhy-3	76.81	10.03	3153	1764	2495				1.386	7.879				9.27
Chembankuzhy-4	76.81	10.04	471	5575	185	1547	5739		0.546	0.889	1.34	35.5		38.28
Chengamanod	76.34	10.15	205	93	290	58	197		0.52	2.85	3.73	13.78		20.87
Edattala	76.39	10.07	312	1103	131	306			1.31	1.67	19.8			22.78
Eddayapuram	76.37	10.10	74	21	829	45			1.68	10.89	37.96			50.54
Elambra (Kothamangalam)	76.61	10.06	461	194	117	773			0.5	5.2	8.5			14.2
Govt. LP School, Namakuzhi	76.52	9.85	812	445	921				0.723	4.72				5.44
Govt. UP School, Chembankuzhy	76.81	10.04	2432	6481	169				12.7	13.3				26
Govt.HSS, Neriamangalam	76.78	10.05	697	197	492	1728	22.1		1.07	0.567	15.2	18.7		35.54
Illanji	76.54	9.83	437	200	-	-			23	38.1	-			-
Inchathotty-1	76.74	10.09	423	1978	69	866	163		0.587	1.12	1.96	4.05		7.717
Inchathotty-2	76.74	10.09	2762	6269	704	348			2.17	2.4	41.9			46.47
Inchathotty-3	76.74	10.09	2116	VH	817	6458	1779		1.099	1.395	5.256	2.45		10.2

Inchathotty-4	76.75	10.08	VH	2847	1195	654.1			0.371	4.691	16.06			21.12
Inchathotty-5	76.76	10.07	4109	720	5387	490	4613	52	2.58	1.61	3.74	8.47	20.5	36.9
JNV, Neriamangalam	76.78	10.05	1105	3180	521	1383	441		0.947	0.976	14.6	6.56		23.08
Kadalikad	76.68	9.92	387	230	High	-			6.1	94	-			100.1
Kakkanad	76.34	10.02	231	1558	426	54	359		0.54	1	10.78	22.93		35.25
Karakutty	76.37	10.23	899	3462	208	34	1378		0.44	0.72	3.46	9		13.63
Karimannur			320	140	230	High			1.8	23.2	25			80
Kodanad	76.52	10.18	220	7377	161				4.8	7.3				12.1
Kodanad	76.52	10.18	106	644	4325	113			0.5	6.6	8.6			15.7
Koothattukulam	76.59	9.86	395	110	200	-			3.1	76.3	22.3			101
Koothattukulam, Govt. UP School	76.59	9.86	135	2252	369				1.28	1.13				2.41
Kothamangalam	76.61	10.04	944	12140	3602	598	982		0.7	1.6	8.5	19.3		30.1
Kothamangalam	76.61	10.05	4567	11197	1134	2126			1.4	5	16.6			23
Kothamangalam bypass	76.61	10.07	337	65	681	1850			0.8	5.5	5			11.3
Kottapuram	76.30	10.13	70	9	68	3	210		2.8	2.68	5.79	18.75		30.03
Kottayattupara	76.38	9.93	616	60	225				3.05	20.04				23.09
Kozhipalli	76.61	9.87	510	183	230	High			1.3	58.1	60.8			120.2
Kunnara	76.29	10.16	1248	207	78	210			1.38	4.93	49.49			55.8
Kunnatheri	76.35	10.08	990	6	0.2				2.02	50.49				52.51
Kuzhuvilapady	76.37	10.05	143	662	91	168			0.42	1.06	25.07			26.55
Makkad	76.35	10.18	666	37	372				3.8	8.78				12.58
Muppattadam	76.32	10.08	794	419	702	67	177		0.41	6.76	4.92	11		23.09
Muppattadam®	76.32	10.08	768	349	941	48	187		0.58	3.03	3.04	9.5		16.14
Nayathode	76.39	10.17	29	89	11	365	12295		2.78	2.63	7.98	14.62		28.01
Nellimattom 1	76.68	10.06	1632	622	180	5054			2.4	4.4	17.9			24.7
Nellimattom 2	76.68	10.06	2222	347	1627	557	3362	643	0.6	1.6	2.4	3.8	8.9	17.3
Neriamangalam	76.77	10.05	1635	858	1539				0.9	14.5				15.4
Neriamangalam	76.77	10.06	1090	739	3031	51	8080		2.7	4.3	5	11		23

Neriamangalam	76.77	10.05	410	986	383	7318	135		0.5	3.7	10.7	18.7		33.6
Neriamangalam	76.77	10.05	210	697	82	1079	184	1345	0.4	3.8	6.1	11.9	29	51.2
Oliyapuram	76.38	9.96	180	153	230	High			0.8	80.6	61			142.4
Onakkur	76.52	9.89	310	180	220	High			1.1	57.3	62.2			120.6
Oonukkal 1	76.71	10.05	1144	59	217	1629			0.7	6.1	14.7			21.5
Oonukkal 2	76.71	10.05	830	113	VH	-			0.7	15.4				16.1
Palamattam 1	76.70	10.11	382	216	879	2820	820		0.9	1.5	12.6	17.7		32.7
Palamattam 2	76.70	10.11	431	82	5053	192	6817		1	2.1	7.7	16.2		27
Palamattam 3	76.72	10.10	1986	216	1084	514	1117		1.8	1.6	13.9	15.6		32.9
Parabiyam	76.35	10.14	109	17	34	235			1.51	9.02	20.63			31.15
Pattimattom	76.44	10.02	200	1106	432				1.2	5.7				6.9
Pattimattom	76.45	10.02	2674	224	3867	164	VH		0.5	0.9	2.3	6.6		10.3
Pattimattom	76.45	10.02	1107	570	3973	529	VH		2.1	2	4.1	9.3		17.5
Puthenkurussi	76.42	9.96	6542	542	196	1623			0.65	5.86	26.99			33.5
School of medical Education, Manimalakunnu	76.57	9.89	3215	2229	1001				1.24	13.8				15.04
SreeDharmasastha, Neriamangalam	76.79	10.05	1065	181.3	268	VH			1.696	8.989	31.28			41.97
Sreemulangaram	76.40	10.13	9081	1175	275	2602			1.16	3.97	21.49			26.61
Thadikulam	76.72	10.06	188	3158	115	VH			1.8	7.8	11.5			21.1
Thaikattukara	76.34	10.09	98	46	128	21	148		0.49	0.93	1.45	25.34		28.2
Thalakkod ground	76.75	10.05	4944	2084	3763	4731	3452	VH	1.1	1.4	6.3	8.5	22.9	40.2
Thiruvaniyoor	76.43	9.93	4667	970	213	939			0.32	3.32	39.51			43.15
Thrikkakara	76.33	10.04	66	225	2	14			0.8	1.38	44.08			46.26
Tiruvalur	76.31	10.12	193	54	5	13			1.1	6.49	6.66			14.24
Udyogmandal	76.31	10.07	55	261					19.59					19.59
Vadattupara (Poika ground) 1	76.71	10.18	13927	4073	1036	5526	2156	4707	1.3	4.3	9.4	16.5	18.4	49.9
Vadattupara (Poika ground) 2	76.71	10.18	15160	4638	721	265	VH		0.8	3.4	6.2	9.9		20.3
Vallamakuthu	76.73	10.05	279	156	233	2434			1.1	3.1	12.4		-	16.6

Vattapambu	76.34	10.20	349	23	751				1.54	6.82				8.36
Vazhakkulam-1	76.60	9.94	243	13	260				3.1	3				6.1
Vazhakkulam-2	76.60	9.94	1308	542	300	1198	50		0.6	5.8	4.5	8.7		19.6
Vazhakkulam-3	76.60	9.94	717	1240	719	1147	389		1.1	1.5	3.4	6.2		12.2
Vazhakkulam-4	76.60	9.94	75	170	112	385			0.5	2.9	6.7			10.1
Velienchal 1	76.69	10.10	981	385	2176	349	695		1.3	2	7.7	8.6		19.6
Velienchal 2	76.69	10.10	1052	1753	4786	669	982		0.4	5	4.5	8.2		18.1
Vettickal	76.42	9.91	10408	1239	172	849			1.24	4.74	7.05			13.03

State Level coordination Committee for NAQUIM

File No.GW1/181/2019-WRD

GOVERNMENT OF KERALA

Water Resources(Ground Water)Department

No.GW1/181/2019-WRD 02/08/2019,Thiruvananthapuram

From
Secretary to Government

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

Sir,

Sub: Water Resources(Ground Water) Department-Meeting of the State Level Coordination Committee for National Aquifer Mapping & Management -minutes forwarding Reg

Ref: -------

I am to forward herewith the approved minutes of the meeting of the State Level Coordination Committee for National Aquifer Mapping & Managementheld on 03.07.2019 in the chamber of secretay,Water Resources Department for necessary action.

Yours Faithfully,
DR.B.ASHOK IAS
SECRETARY
For Secretary to Government.

Approved for Issue,

Section Officer.

e—3645103—

MINUTES OF THE 7TH MEETING OF THE STATE LEVEL COORDINATION COMMITTEE(SLCC) FOR NATIONAL AQUIFER MAPPING & MANAGEMENT (NAQUIM), KERALA, HELD ON 03.07.2019

The 7th meeting of the State Level Coordination Committee of National Aquifer Mapping Programme of GGWB was held on 03.07.2019 at 16.00 hours in chamber of Shri. B. Ashok, IAS, Secretary, Water Resources, Power & Industries, Govt. of Kerala and Chairman, SLCC of NAQUIM chaired the meeting. The following Members attended the meeting.

1.	Shri. K. Biju, IAS, Director of Industries & Commerce, Government of Kerala	Member
2.	Shri. K. H. Shamsudeen, Chief Engineer (I&A)	Member
3.	Shri.V.Kunhambu, Regional Director, CGWB, Kerala Region, Thiruvananthapuram	Member Secretary
4.	Smt. Thresiamma Antony, Administrative Assistant, Panchayath Directorate	Member
5.	Shri. K. Rajan, Hydrogeologist, GWD	Member
6.	Dr. N. Vinayachandran, Scientist D	Invitee
7.	Smt. Rani V. R., Scientist – C	Invitee

At the outset, the Chairman welcomed the members and invited Regional Director, CGWB to appraise the members about the developments and progress of NAQUIM as per agenda set up for the meeting. Shri. V. Kunhambu, Regional Director, CGWB, Kerala Region informed that Report on Aquifer Mapping & Management plan of the entire sedimentary area of Kerala along with hard rock areas of Thiruvananthapuram, Kollam, Pathanamthitta & Palakkad districts have already been issued. Followed by this item, a power point presentation on Aquifer Mapping and Management plan of Kottayam and Ernakulam district (2966 sq.km) were presented by Dr. N. Vinayachandran, Sc- D and Nodal Officer (NAQUIM), CGWB. During the course of presentation, provision was given for clarifications and interaction. After listening to the presentation, Chairman expressed satisfaction on the contents of the report and commented that artificial recharge should not be promoted everywhere since the thickness of unsaturated aquifer is minimum in both districts. Dr. N. Vinayachandran informed the possibility and stressed that instead of constructing widespread recharge structures it should be site specific, considering the thickness of the phreatic aquifer. After interactions, Secretary(WR) approved the aquifer management plan presented and advised CGWB to circulate an executive

summary of the report to all the departments which RD, CGWB readily agreed. Chairman also pointed out that the details of mapped aquifer could become a powerful management tool especially for the ensuing Jal Sakthi Abhiyan activities. He also suggested the full-hearted involvement of all line departments in this mission and advised RD, CGWB to extend all support to the team.

The meeting ended with thanks to the Chair.

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