केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River
Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

KASARAGOD DISTRICT, KERALA

केरल क्षेत्र, त्रत्रवेंद्रम

Kerala Region, Trivandrum

केंद्रीय भूजल बोर्ड, केरल क्षेत्र
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CENTRAL GROUND WATER BOARD, KERALA REGION
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
GOVERNMENT OF INDIA

AQUIFER MAPPING AND MANAGEMENT PLAN OF KASARAGOD DISTRICT, KERALA

(AAP: 2021-22)

SINGATHURAI S.
SCIENTIST- C

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. The target scale of investigation is 1:50,000 and envisages detailed study of the aquifer systems up to 200 m depth in hard rock and 300 m depth in sedimentary rock, to ascertain their resource, water quality, sustainability, and finally evolve an aquifer management plan. This report pertains to aquifer mapping and management plan of Kasaragod district.

The report titled "Aquifer Mapping and Management plan, Kasaragod district, Kerala" gives a complete and detailed scientific account of the various aspects of the hard rock and soft rock aquifers in the district including its vertical and horizontal dimensions, flow directions, quantum and quality of the resources, of both- the shallow and deeper zones in the aquifer systems. Voluminous data generated on ground water regime, ground water quality, ground water exploration, geophysical studies etc. for detailed analysis. The information is further supplemented by various data collected from Central and 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 holistic solution to the water security problems in Kasaragod district.

This document has been compiled by Shri. Singathurai S, Scientist C under the overall guidance of Dr. N. Vinayachandran, Scientist D & Nodal Officer and Smt. Rani V.R, Scientist D & Team leader. The painstaking efforts of field hydrogeologist Shri. Singathurai S. in carrying out the aquifer mapping and preparation of this report is well appreciated. Shri. Roopesh G Krishnan, Scientist C and Smt. Anu V, Scientist B deserves appreciation for the meticulous scrutiny of this report before printing. I am thankful to Shri. Sunil Kumar, Chairman and Dr. A. Subburaj, Member of CGWB, Faridabad for their valuable guidance in finalizing this report. I am also thankful to the officers of CGWB, Kerala Region, Thiruvananthapuram for their technical support in preparation of report. Thanks, are due to various organizations of Government of Kerala such as Ground Water Department, Irrigation Department, Agriculture Department, Land Use Board etc. and Central Government Departments such as GSI, IMD and Survey of India for providing data for aquifer mapping studies.

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.Pranab Jyoti Nath, IAS and is subject to approval of National Level Expert Committee (NLEC). The contribution of the committee in improvising the content of this report are acknowledged with gratitude.

I hope that this compilation will be of much help to the planners, administrators and stakeholders in the water sector for the optimal and sustainable management of ground water resources in Kasaragod district.

Thiruvananthapuram,
November 2022

(T.S. Anitha Shyam)
Regional Director

AQUIFER MAPPING AND MANAGEMENT PLAN OF KASARAGOD DISTRICT, KERALA (AAP- 2021-22)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXURES

AQUIFER MAPPING AND MANAGEMENT PLAN OF KASARAGOD DISTRICT, KERALA

1.0 INTRODUCTION

During the Annual action plan 2021-22, Aquifer mapping and Management Plan study was taken up in Kasaragod district, covering an area of 1992 sq.km, the study area is located in the northern tip of Kerala state. The

Aquifer mapping is a multi-disciplinary scientific process where data related to the aquifer system and groundwater regime are integrated to characterize the quantity, quality and movement of groundwater in aquifers. 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 aquifer system involves development of strategies for balancing the water extraction 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.

The hydrogeological environment of the study area has been conceptualized from the study of historical data (available data) on the groundwater regime and from the available technical reports and publications. The data gaps could be identified from the analysis of historical data which facilitated generation of new data in gap areas. The hydrogeological, hydrological, geophysical, hydro chemical and meteorological data were analyzed for data gaps. Groundwater draft from the aquifer systems has been evaluated from well inventory data and integrated use of lithological and geophysical data used to refine the aquifer geometry of the area.

1.1 Objectives

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. Thus, the main objective of aquifer mapping is to generate an aquifer map of the area in 1:50,000 scale so as to develop a management plan for aquifer sustainability.

1.2 Approach and Methodology:

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

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

ii. Define groundwater regime behavior.

iii. Identify the recharge characteristics and resource potential.

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

v. Arrive at an effective groundwater management plan.

1.3 Basic Geography and Administration:

The study area is situated in the northern part of Kerala state and is bounded on the north and east by Dakshin- Kannada district of Karnataka state, in the south by Kannur district of and in the west by Arabian sea. The area lies between North latitudes 12^0 05' 32" and 12^0 47' 43" and East longitudes 74^0 52' 59" and 75^0 25' 05", covering an geographical area of 1992 sq.km of which 307 Sq Km area is non mappable area, falls under hilly and forest category and the remaining 1685 Sq. Km is considered for aquifer mapping. The area falls in parts of Survey of India topo sheets 48L/14, 48P/02,03,04, and 07 and is served by a good network of roads and rail connecting important adjoining places in Kerala and Karnataka. Kasaragod town lies on the path of NH17. It is well connected by road to Cannonore (Kannur), Bangaluru, Mangalore, Kozhikode etc. Kasargod is well connected by rail to Trivandrum, Kochi, Kozhikode, Payyanur, Kannur, Mangalore etc.

Kasaragod district is divided into 4 taluks namely Kasaragod, Hosdurg, Manjeshwar and Vellarikundu and 75 villages. The district has 1 revenue division; 6 Block Panchayaths- Manjeshwar, Kasaragod, Kanhangad, Nileshwar, Karadka and Parappa; 38 Gram Panchayaths and 3 Municipalities (Kasaragod, Kanhangad and Nileshwar). The administrative map of Kasaragod district is given in **fig.1.1.**

As per census of India 2011, Kasaragod district has 273410 households, Population of the Kasaragod district is 13,07,375, which male and female were 6,28,613 and 6,78,762 respectively and the population is mainly concentrated in rural area, out of total population 77% living in rural area and only 23% in urban area, The Population growth rate is 8% only. The literacy rate of Kasaragod district is 79.36% out of which 82.16% males are literate and 76.76% females are literate with Population density of 657 per sq.km. The district wise population is given in **table 1.1.**

Table 1.1 Population of study area

Sl No	Block	Area (sq.km)	Population as on 2011	Rural Population	Urban Population
1	Kanhangad	24508	254979	176912	78067
2	Nileshwaram	19695	189415	66668	122747
3	Karadka	37247	146883	146883	0
4	Kasaragod	25876	312900	222168	90732
5	Parappa	54668	181247	181247	0
6	Manjeshwar	34136	221951	213209	8742
	Total	**196130**	**1307375**	**1007087**	**300288**

Source: Census of India, 2011

1.4 Data Availability:

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, Bore well data, Water quality, Water level data and Groundwater exploration data have been collected from Ground Water Department, Kasaragod. Cropping pattern, Minor irrigation data and Soil data has been collected from Agricultural and Soil Conservation Department. Thematic layers such as geology, soils, land use/land cover, geomorphology, etc., from various State Government agencies were collected, compiled, and validated for the study.

1.5 Data Adequacy:

In Kasaragod district, there are 35 exploratory bore wells and 2 tube wells were constructed during the ground water exploration by the CGWB. Water level monitoring data for 126 Observation wells and Water Quality monitoring data for 40 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.

1.6 Data collection, generation and integration:

The historical or available data on Geology, Geophysics, Hydrogeology and Hydrochemistry generated under various studies by the department (CGWB) such as Systematic Hydrogeological studies, Reappraisal Hydrogeological studies, Groundwater Management studies, Exploratory drilling, Microlevel hydrogeological studies and special studies have been utilized for data gap analysis in conjunction with the data collected from various State and Central government departments. The thematic layers on drainage, geomorphology, land use and land cover were reproduced from the data obtained from concerned State departments. The existing data on various themes analyzed for finding the data gaps is given in **table 1.2.**

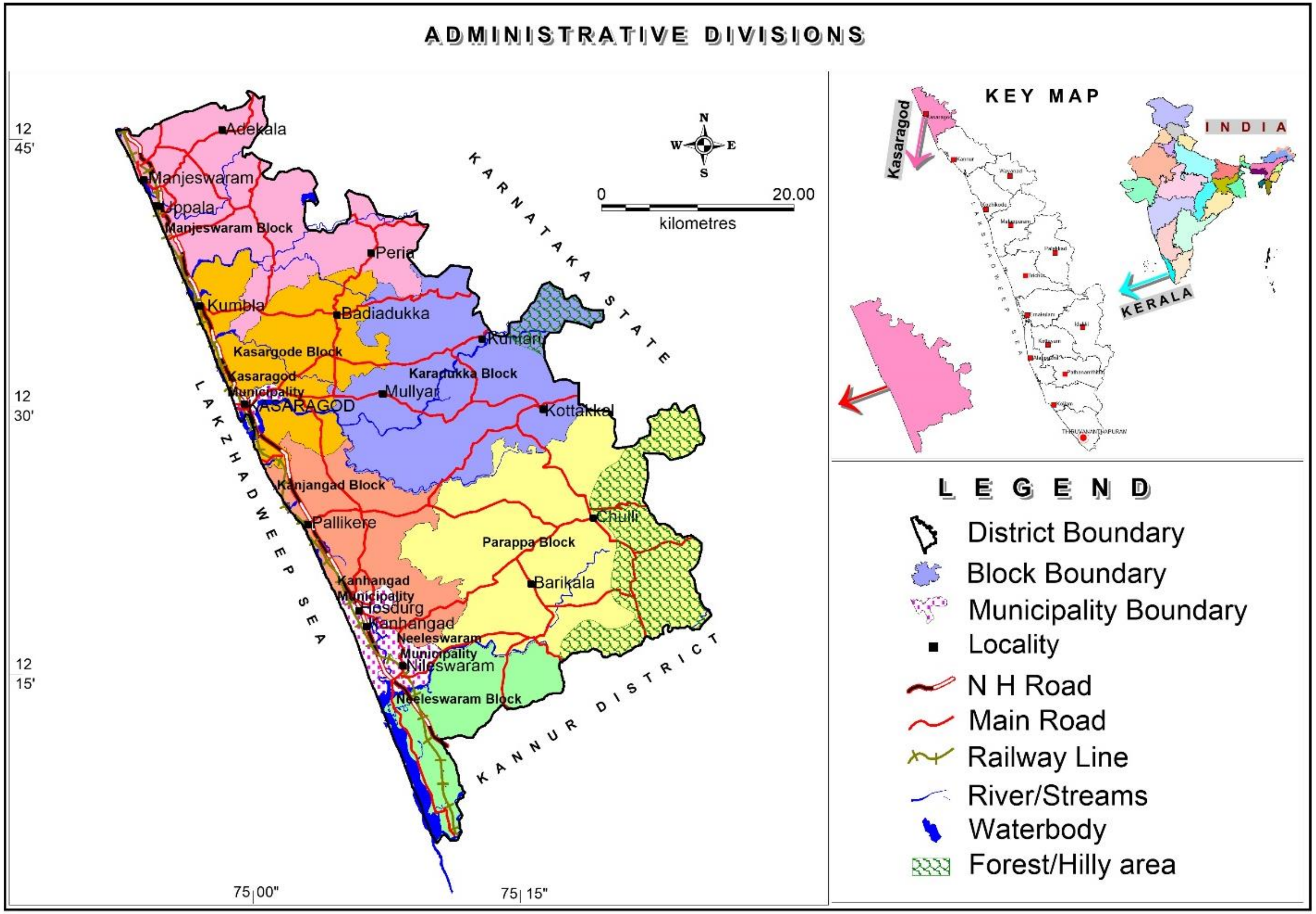

Fig 1.1 Administrative divisions of Kasaragod District

Table 1.2: Data gap analysis and data generation

#	Data Requirement	Data Availability with State	Data Availability with CGWB	Total	Additional data Generated
1	Ground water level data	20 DW 10 PZ	111 DW 22PZ	131 DW 32 PZ	15
2	Groundwater quality Data	-	30 DW 22 BW, 2 TW	30 DW 22 BW, 2 TW	10
3	Borehole Lithology Data	10 BW	35 BW 2 TW	45 BW 2 TW	
4	Geophysical Data (VES+ TEM)	-	15 VES	15 VES	
5	Pumping Test (EW/DW)		7	7	
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)			

1.7 Rainfall & Climate:

The district receives an average annual rainfall of about 3581 mm. The major source of rainfall is southwest monsoon from June to September which contributes nearly 85.3% of the total rainfall of the year. The northeast monsoon contributes nearly 8.9% and balance of 5.8% is received during the month of January to May as pre-monsoon showers. Out of the 106 rainy days in a year, 87 rainy days occur during south west monsoon season. The rainfall data of Hosdurg and Kudulu is given in **table 1.3 & 1.3(a)** and the rainfall patterns are represented in **Fig 1.2(a,b)** and annual normal rainfall map is represented in **Fig. 1.3.**

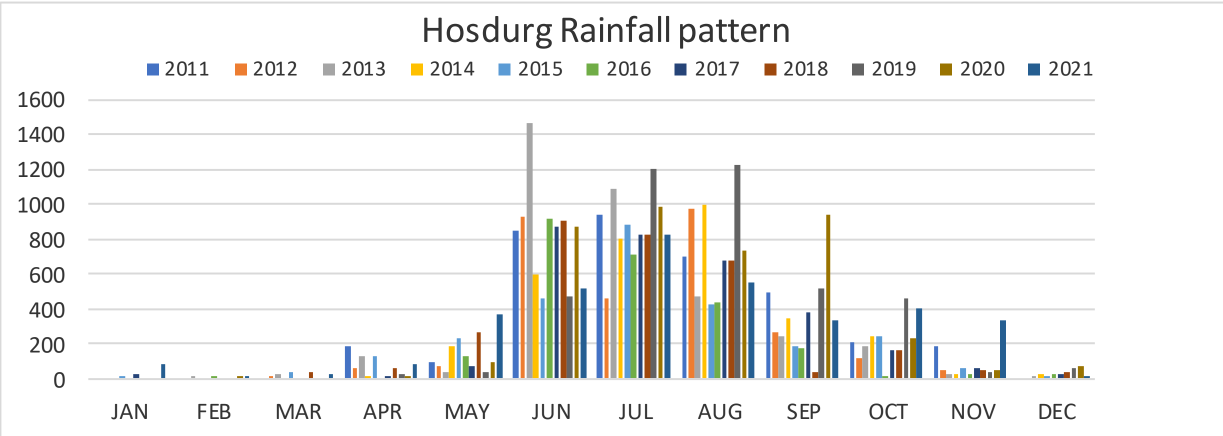

Fig 1.2 a Rainfall Pattern of Hosdurg, Kasaragod district

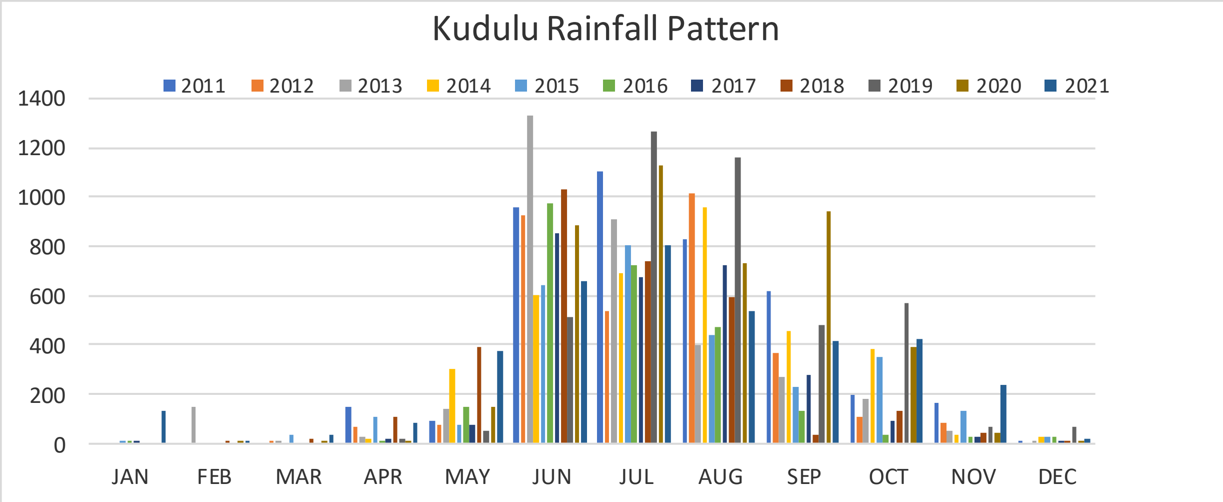

Fig 1.2(a) Rainfall Pattern of Kudulu, Kasaragod district

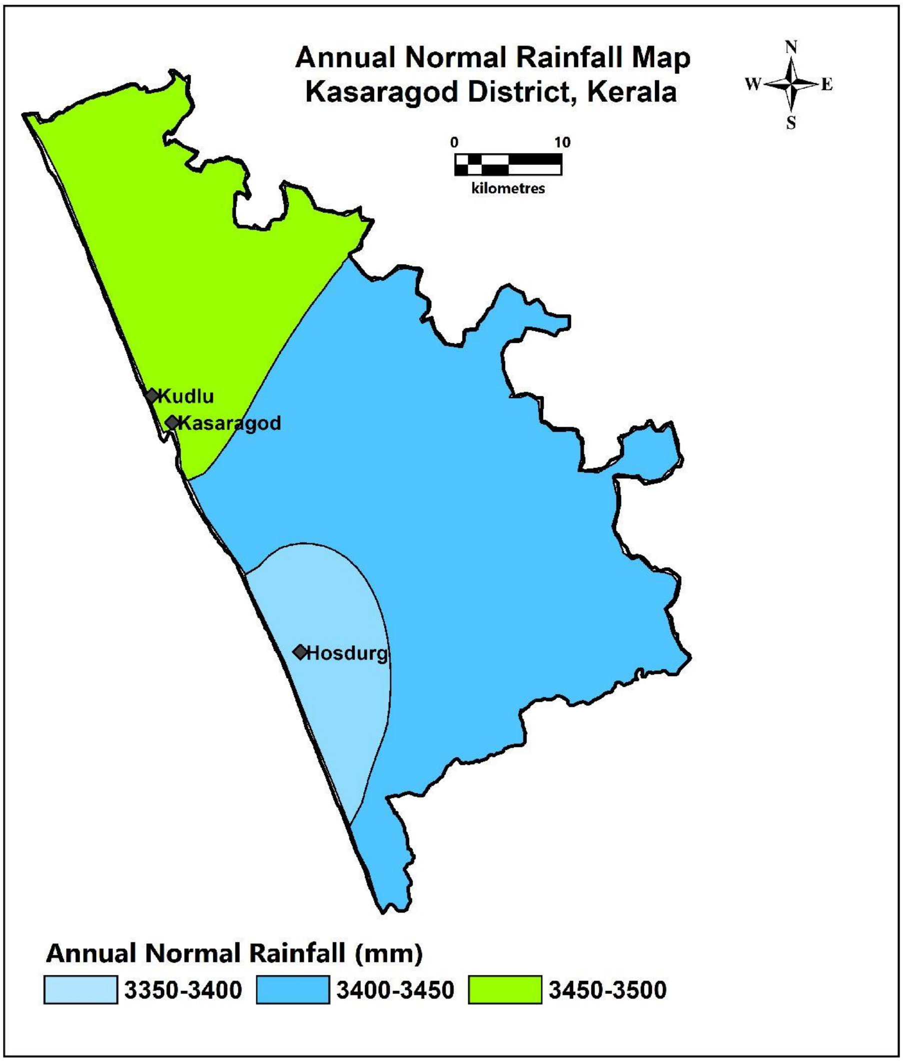

Fig 1.3. Annual Normal rainfall map, Kasaragod district

1.8 Geomorphology and Soil types:

Physiographically, the district can be divided into three district units viz. the low lands, the midlands and the eastern highland regions. The low lands with an elevation of less than 7.6 m occur as narrow belt of alluvial deposits parallel to the coast. To the east of coastal belt is the midland region with altitude ranging from 7.6 to 76 m amsl. The midland area is characterized by rugged topography formed by small hillocks separated by deep cut valleys. The midland regions show a general slope towards the western coast. To its east is the highland region. The midland and hill ranges of the district present a rugged and rolling topography with hills and valleys. Along the midlands the hills are mostly laterite and the valley are covered by valley fill deposits. The valley fill deposits are composed of colluvium and alluvium.

There are four major soil types encountered in the district. They are lateritic soil, brown hydromorphic soil, alluvial soil and forest loam.The lateritic soil is the most predominant soil type of the district and it occurs in the midland and hilly areas and is derived from laterites. The Brown hydromorphic soil is confined to the valleys between undulating topography in the midlands and in the low-lying areas of the coastal strip. They have been formed as a result of transportation and sedimentation of materials from adjoining hill slopes.

The alluvial soil is seen in the western coastal tract of the district. The coastal plain is characterized by secondary soils which are sandy and sterile with poor water holding capacity. The width of the zone increases towards the southern part of the district. The forest loamy soil is found in the eastern hilly areas of the district and are characterized by a surface layer rich in organic matter. The Geomorphology and Soil map is given in **Fig.1.4 & 1.5.**

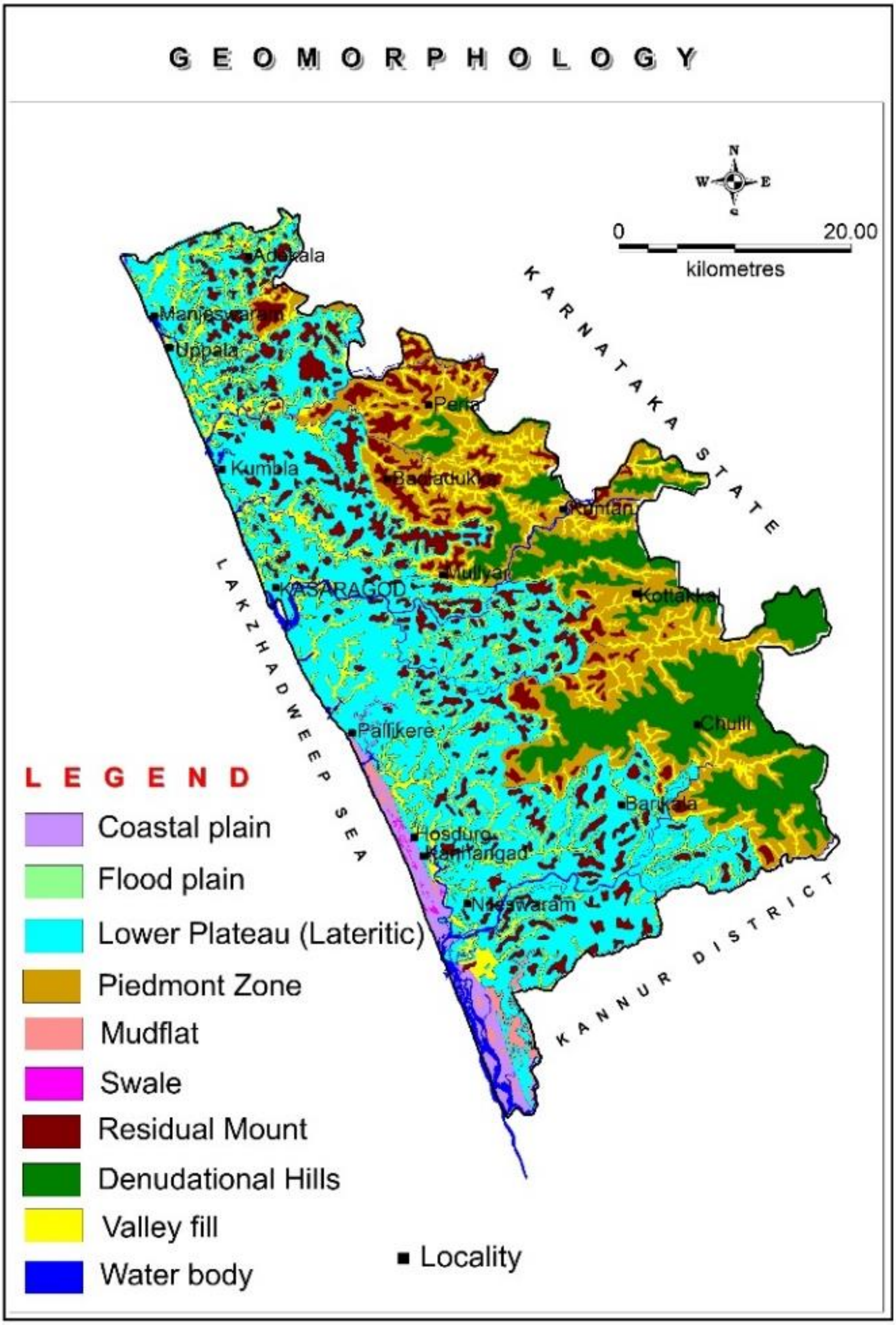

Fig. 1.4 Geomorphology map

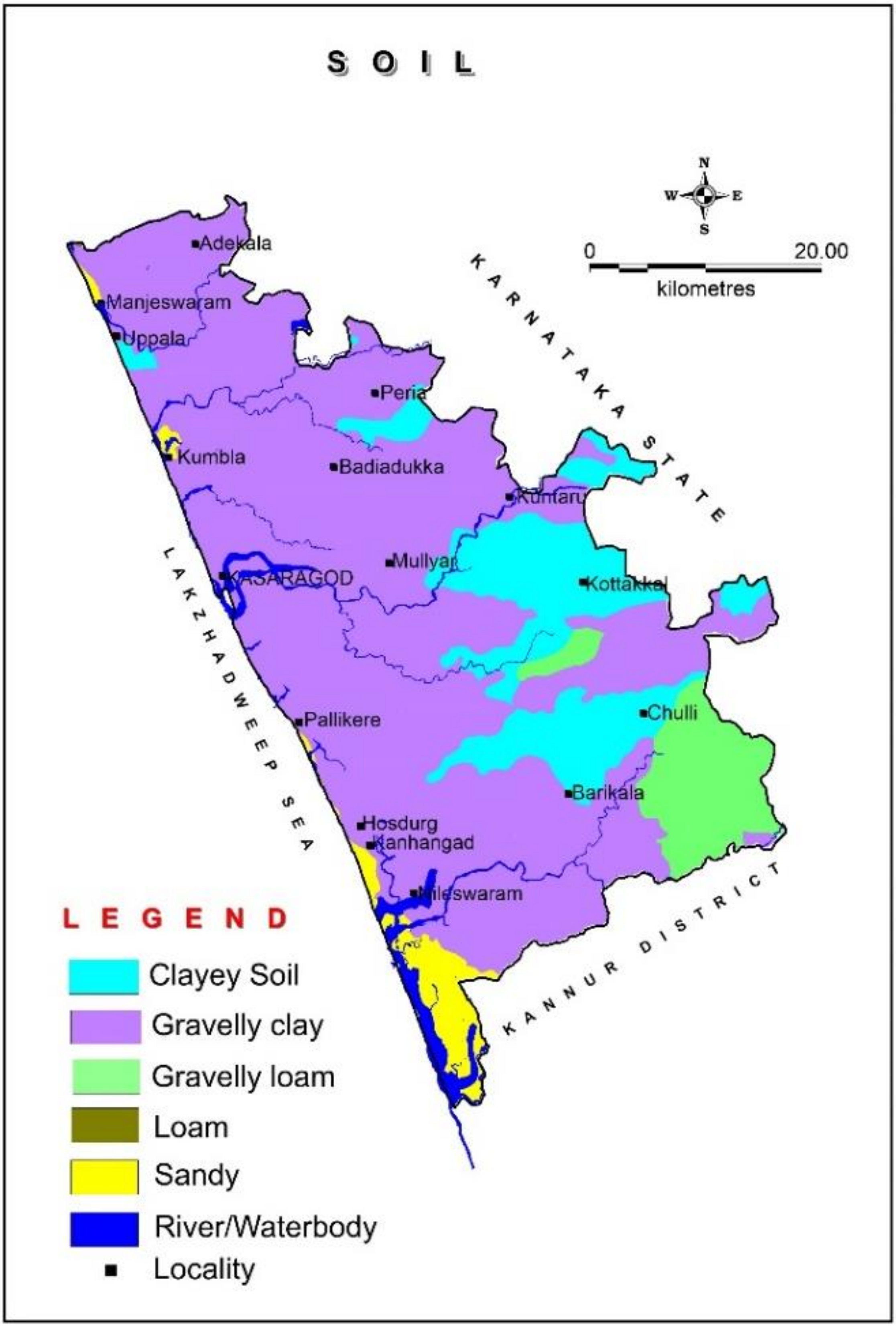

Fig. 1.5 Soil map

Table 1.3 Rainfall data of Hosdurg, Kasaragod district

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
2011	0	0	0	179.4	93	843.5	942.8	696	498.4	207	186	0	**3646**
2012	0	0	1	63.1	69.9	928.4	464	970	269	117	44.5	0	**2927**
2013	0	17	24.8	124.8	34	1468	1092.2	467.8	245.4	184.7	20.1	1	**3679**
2014	0	0	0	16	187.6	592	803.7	1002.5	342.5	244.2	24.5	26	**3239**
2015	1	0	38	131	230.5	455.5	887	427.7	182.7	244.7	57.1	16	**2671**
2016	0	1	0	0	126.1	914.3	713.6	440.7	176.4	11.3	19	24.5	**2427**
2017	25	0	0	12.2	66.6	866.3	831.2	681.1	384.2	164.8	57.2	21.2	**3109**
2018	0	0	31.6	58.5	268.5	910.8	826.7	681.9	38.1	161.4	46.6	38	**3062**
2019	0	0	0	26.1	37.3	474.2	1208.3	1231.3	513.5	454.7	35.2	60.2	**4041**
2020	0	1	0	2	94.6	874.1	984.1	729.4	944.1	233.2	52.2	68.2	**3983**
2021	83.9	4	20.5	82.1	365.6	517.6	821.6	554.2	331.4	397	332.9	9.3	**3520**

Table 1.3(a) Rainfall data of Kudulu, Kasaragod district

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
2011	0	0	0	147	87.6	957.2	1100.6	829.8	617.2	192.2	166.2	0.6	**4098**
2012	0	0	1	63.1	69.9	928.4	539.2	1018.2	361.5	104.1	79.6	0	**3165**
2013	0	149.6	10.6	28.8	137.7	1332	910.2	402	265	179.6	48	7	**3470**
2014	0	0	0	14.7	299.1	598.3	690.5	956.3	454.4	379.4	29.4	23.3	**3445**
2015	0.8	0	34.6	104.4	73	643.1	806	437.6	224.4	347.2	127.1	22.2	**2820**
2016	5.7	0	0	0.2	150.5	976.6	725.4	470.8	129	36.2	24.4	26.8	**2545**
2017	11.2	0	0	18.8	77	851	674.4	724.4	278.6	87.6	21.8	7.6	**2752**
2018	0	9.6	20.4	105.2	393.5	1034	735	591.8	34	130.4	38.2	2.4	**3094**
2019	0	0	0	16.6	48	511.8	1262.2	1157.7	476.2	565.6	61.6	67.7	**4167**
2020	0	3.2	3.2	3.2	150.4	883	1127.9	729.4	939.2	386	40.8	7.6	**4274**
2021	132.6	7.4	31.4	79	372	653.9	803.8	538	413	425.6	239	18.8	**3714**

1.9 Drainage & Irrigation practices

The district is drained by nine rivers, all are minor in nature except *Chandragiri* and *Karingote* which are originating from the eastern highland and flowing towards the west to join the Lakshadweep Sea. Most of the rivers have an east to west trend.

Even though the district is drained by 9 rivers which discharges about 4257 MCM of water to the ocean every year as surface run off, there is not a single major irrigation scheme to arrest this water for effective utilization for irrigation. At present out of the total cropped area of 1557.89 sq.km, only 558.69 sq.km, is being irrigated by different sources leaving major cropping as rain fed. Coconut is the principal crop irrigated which covers 40% of the total irrigated area followed by paddy which accounts for 20%. Arecanut cultivation in the district is now about 10% of the total irrigated area. Among source of irrigation, ground water is the principal source of irrigation accounting for about 53% of the area under irrigation and the rest by lift and other methods of irrigation.

In Kasaragod district, there is no major irrigation system, an area of 53981 Ha, is being irrigated using various irrigation schemes. Ground water irrigation is picking up well in the district and is confined to cash and garden land crops. The numbers of ground water abstraction structures especially private bore wells are in increasing trend and are extracting more ground water for irrigation purposes in Manjeshwar and Kasaragod district. The total irrigated area of the district is about 53981 Ha, in this about 74% of area is being irrigated by ground water, 24% of area is irrigated by Canal & Ponds ,and the remaining 1.3% of area is irrigated by other sources. The drainage map is given in **Fig.1.6.**

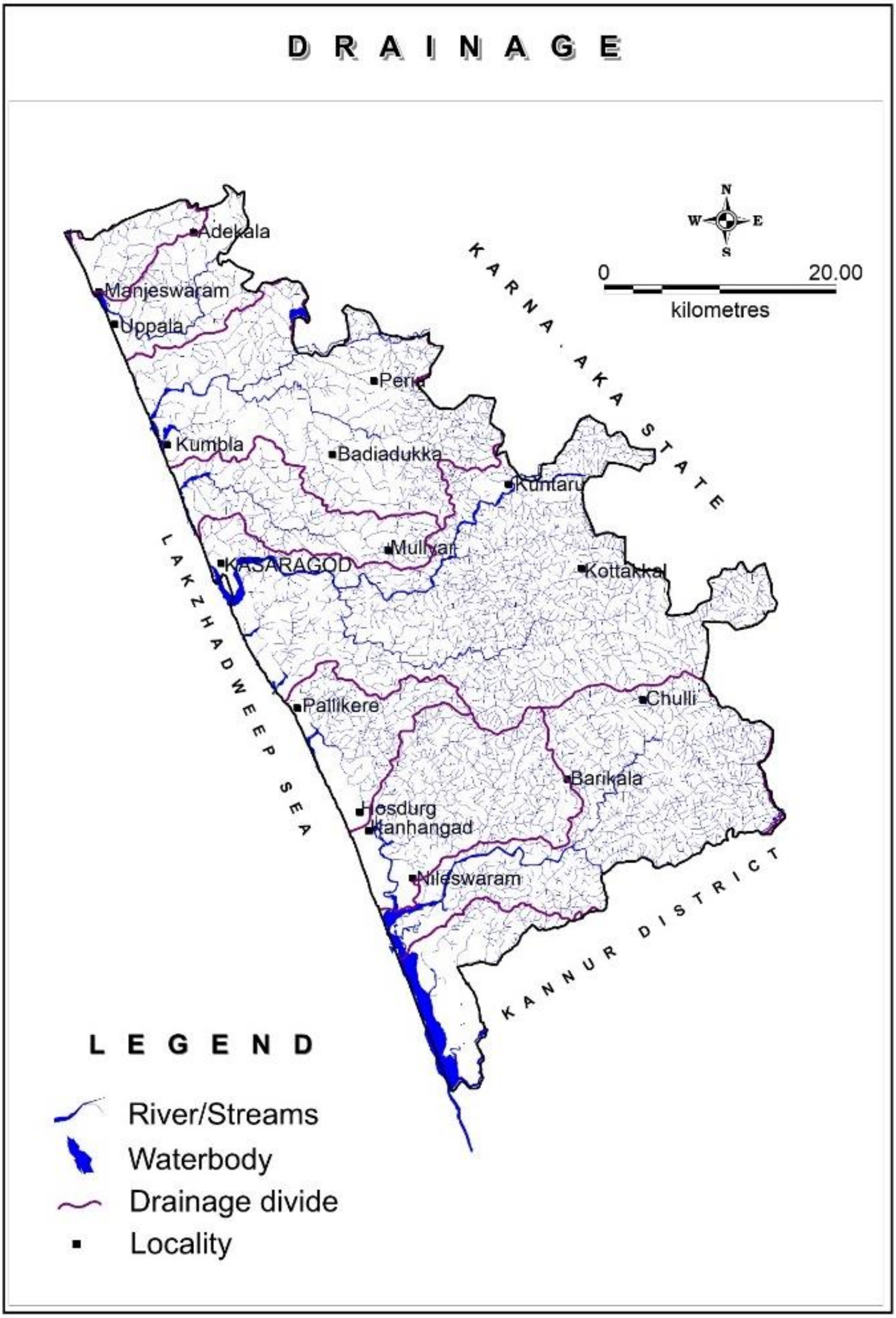

Fig 1.6 Drainage Map

1.10 Land Use/ Land cover:

Land use and land cover is an important aspect, as it has a direct relation with ground water resource availability and utilization. As per Agricultural Statistics 2019-20, the total cropped area is about 1562.81sq.km. which workout to be nearly 78 % of the total area, 56.25, sq.km area comes under forest cover, the major crops raised in the district are Coconut, pepper, rubber, banana, Arecanut, cashew etc. Based-on land use, the study area is divided into three units – arable, forest land and waste land. Summarized land use pattern and cropped area of the district is given in **table 1.4.** The land use map of the district is shown in **Fig.1.7**.The area under different crops is given in **table 1.5.** The pie chart showing the distribution of land use units is given in **Fig.1.8.**

Table 1.4 Land use and Land cover

Land Units	Area (Sq.Km)
Forest	56.25
Land put to non-agricultural use	265.08
Barren & uncultivable land	36.96
Land under misc. tree crops	21.43
Cultivable waste	103.61
Fallow other than current fallow	21.18
Current fallow	16.95
Still Water	43.36
Waterlogged Area	30.77
Social Forestry	0.63
Net area sown	1444.41
Area sown more than once	118.40
Total cropped area	1562.81

Table 1.5. Area under different crops

Crop	Area (Ha)	Percentage of total cropped area
Paddy	2269	1.45
Pepper	3360	2.15
Coconut	63303	40.51
Tapioca	439.58	0.28
Vegetables	1551	0.99
Areca nut	21074	13.48
Green manure plants	2134	1.37
Cashew	7027	4.50
Plantain	2095	1.34
Mango	2758	1.78
Jag fruit	3082	1.97

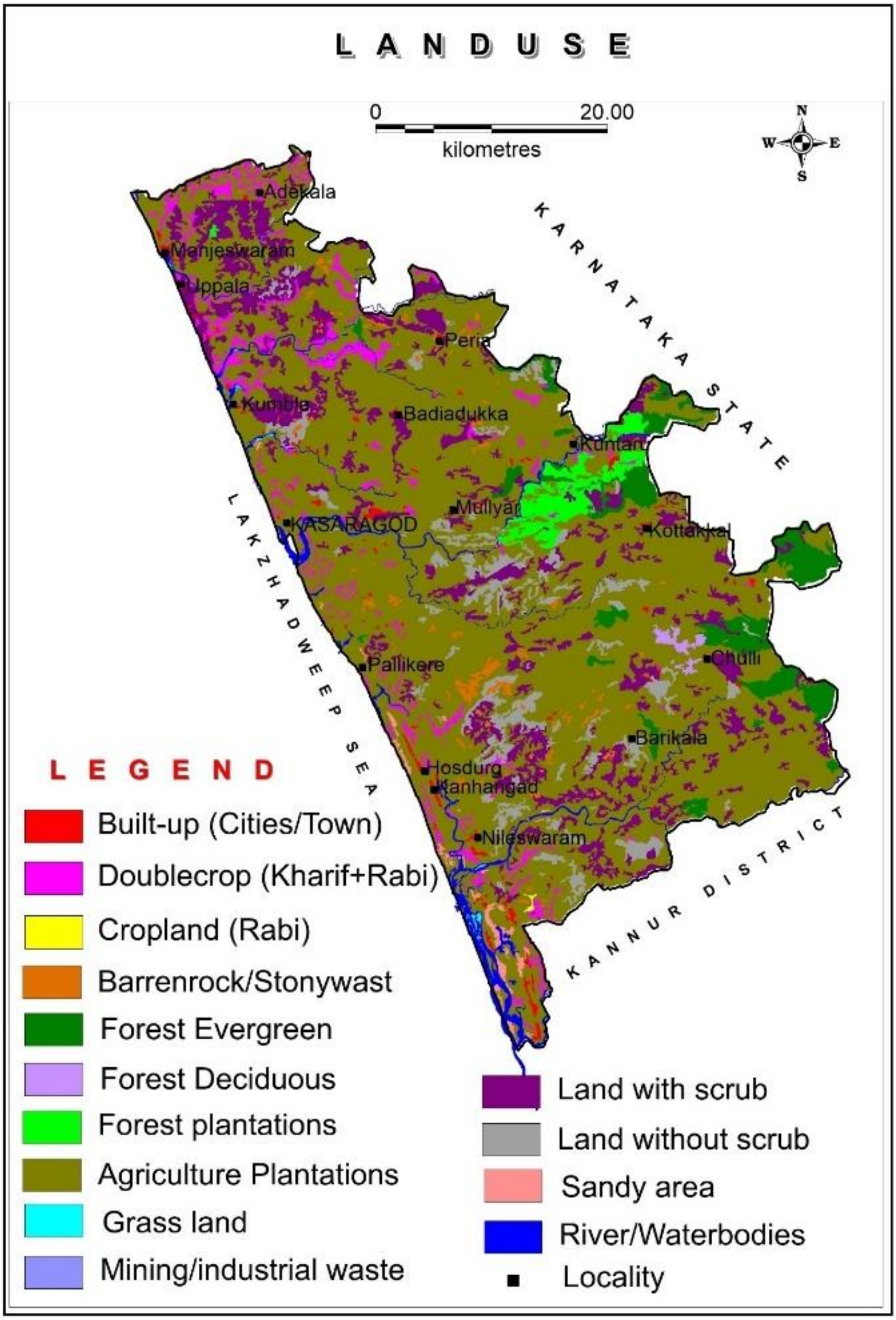

Fig. 1.7 Land use map

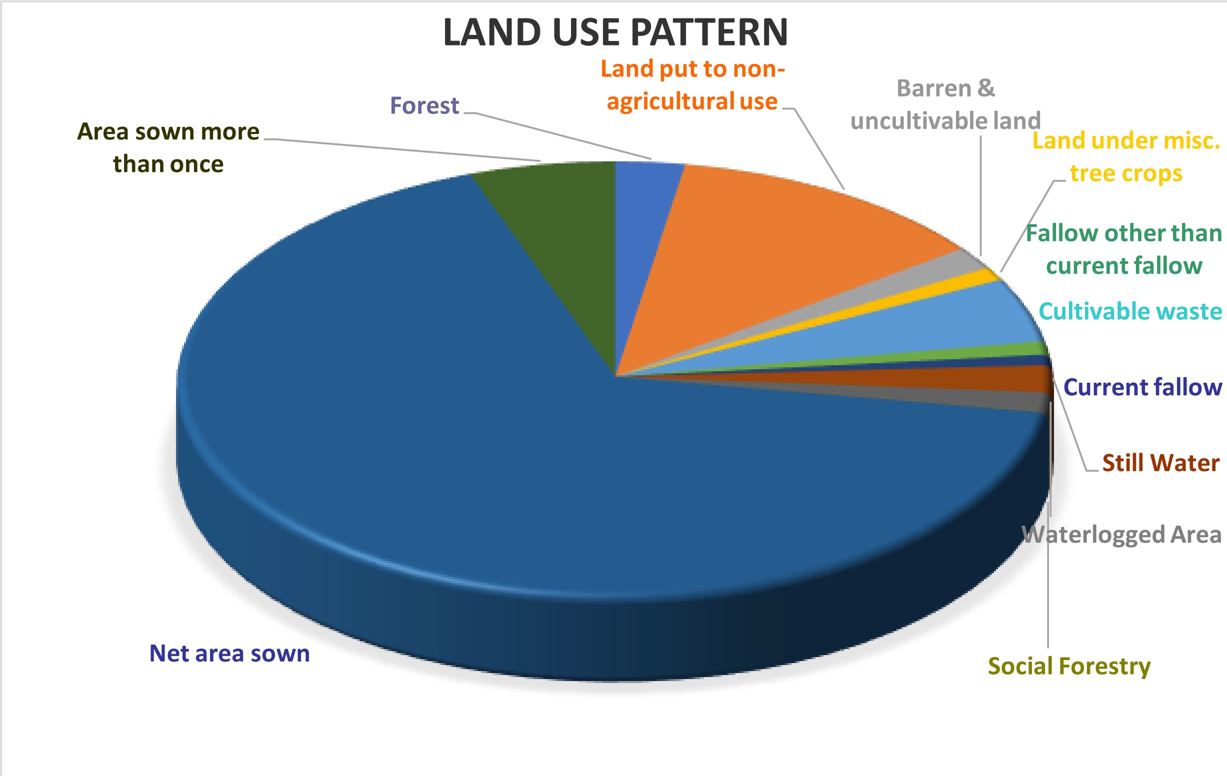

Fig 1.8 Pie chart showing the distribution of land use units in study area

1.11 Geology:

The district is broadly divided into five geological formations, they are Southern Charnockitic rocks which extends further south, the northern part is underlain by Gneissic rocks, the central part is consists of Syenite pluton and isolated patches of sedimentary rocks overlain by Alluvium formations are concentrated along the coastal plain. Intrusive rocks, basic rocks (Dolerite dyke), pegmatite and quartz veins, are common in the southern part of the area.

Laterite and Recent alluvium

Around 75% of the district area is covered by Laterite, its capping in Crystalline and sedimentary formation. In the eastern part of the district, the lateritic thickness is 5 to 10 m only, in central and western part the laterite thickness is 30 to 40 m. The geology map is given in **Fig.1.9.** Top soil and weathered mantle form the major recent lithounit as it covers almost the entire area. In the valley portion fill deposits of talus and scree are also observed. Alluvium composed of sand, silt, and clay is observed along the banks of river and their areal extent is very limited and insignificant as a geological unit from a hydrogeological point of view.

Archaean Crystalline rocks

The geological formations of the Kasaragod area belong chiefly to the Precambrian metamorphic complex, mainly composed of Peninsular gneisses. Charnockite, Khondalite, Peninsular gneiss, Acidic rocks and Syenites.

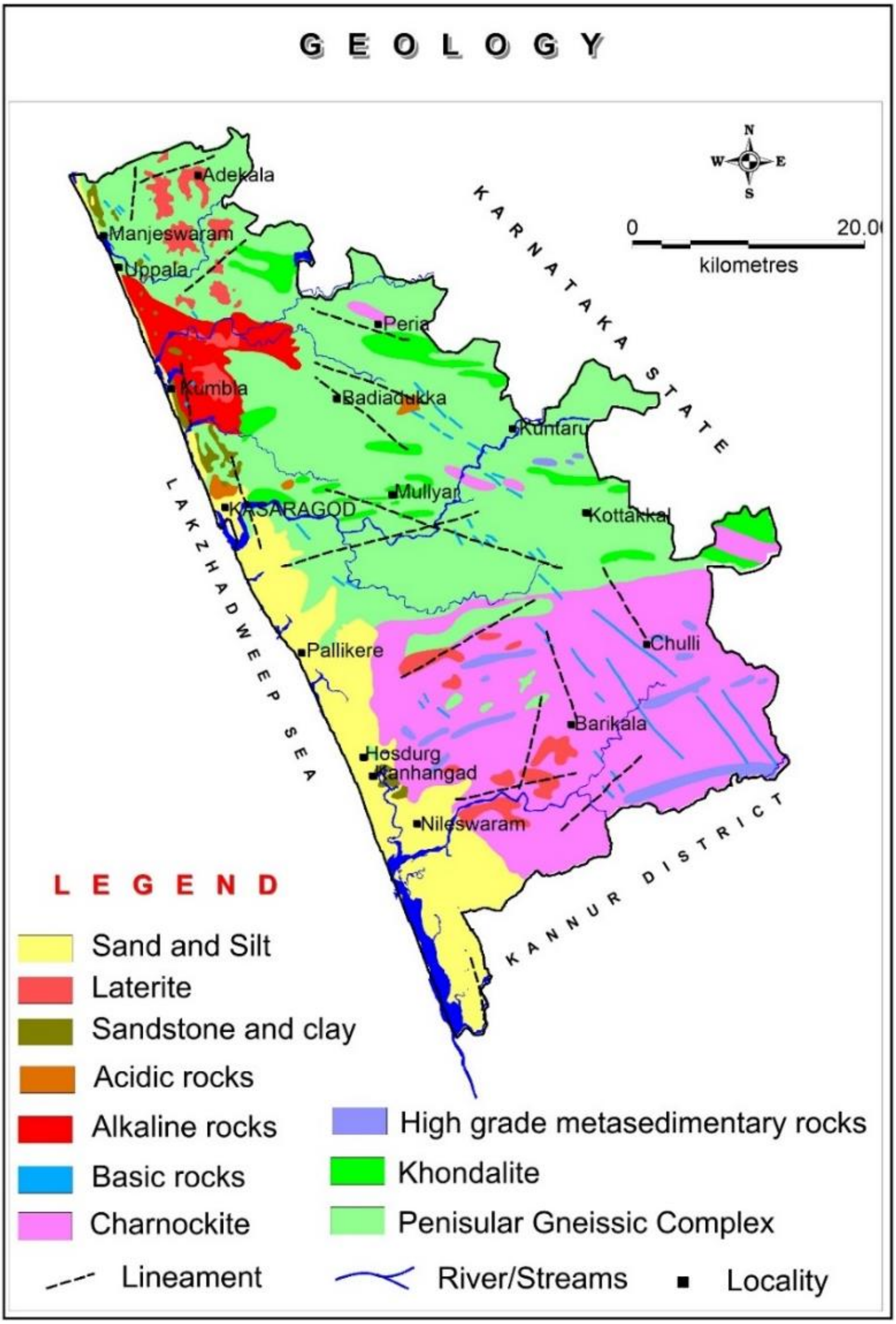

Fig.1.9 Geology Map

1.12 Previous work and Present Status of data

The report on ground water resources of Kasaragod district was compiled by Dr. K. Md. Najeeb (1987). Reappraisal survey was carried out by Sh. V. Dhingaran (1989-90), Shri V. Kunhambu and Sh. N.C. Nayak (1996-97) and Sh. K. Balakrishnan (2000-2001, 2007-08) Microlevel survey was carried out in Kasaragod block by Shri K. Balakrishnan (2002-03). Groundwater exploration was carried out in Kasaragod Taluk during 1982-85 upto the depth of 100 m. Groundwater exploration to the depth of 200 m was continued during the year 2002-03 and 2004-05 using DTH rig of 200 m capacity. Under hydrology project 15 piezometers were constructed in hard rock area in 1999 and again 10 piezometers were constructed in over-exploited and semi-critical blocks in 2004-05. Mass awareness programmes were conducted at Kasaragod (2000), Kanhangad (2004) and Manjeswar (2007) and water management training at Kasaragod during 2003 and 2007. Tier-II level training was conducted at Kasaragod in 2014 and Tier-III level trainings were conducted at Madikai in 2013 and at Kanhangad in 2016. Pamphlets depicting ground water scenario of the district were distributed to the public during each function.

The Central Ground Water Board has drilled, 35 borewells drilled up to depth ranging from 40 to 300 m bgl. The prominent lineament directions are NW-SE, NE-SW and E-W. The yield of the well's ranges from negligible to 12 lps and transmissivity values range from 8.5 to 124 m^2/day. The productive lineaments are NE-SW, N-S and E-W. The quality of water is generally good and potable. In Sedimentary terrain, two tube wells were drilled to a depth of 150 m bgl. Zones were encountered up to 30 mbgl. The yield of tube wells ranges from 120 to 600 lpm. The thickness of alluvium is about 30 m and occur as isolated patches.

To know the groundwater conditions in the study area, Central Ground Water Board has established 133 Ground Water Monitoring Wells which includes 111 dug wells and 22 piezometers tapping various formations. In addition to these monitoring wells, SGWD has established 30 wells in the study area which includes 20 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 pre-monsoon (April).

2.0 DATA COLLECTION AND GENERATION

2.1 Data collection and data gap analysis

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

Table 2.1 The data availability for data gap analysis

#	Items	Total
1	Ground Water Monitoring stations – Dug Wells	146
2	Ground Water Monitoring stations – Piezometers.	32
3	Ground Water Exploration	47
4	Geophysical	15
5	Ground Water Quality Stations- Aquifer-I	40
6	Ground Water Quality Stations- Aquifer-II	22

2.2 Water Level Monitoring

Water level monitoring wells maintained by CGWB and SGWD in the area have been made part of the monitoring network for the present study. 111 dug wells and 22 Piezometers are presently monitored by CGWB; 20 dug wells and 10 Piezometers monitored by SGWD for water levels in the phreatic aquifer system. CGWB wells are being monitored four times (January, April, August and November) in a year whereas, the monitoring wells of State Ground Water Department (SGWD) are being monitored every month. The status of water level monitoring wells of CGWB and SGWD in the area is listed in **table 2.1**. The historical data from these stations have been used for data gap analysis. The water level monitoring well location of CGWB is given in **Fig.2.2.** Based on the data gap, additional 15 key observation wells were generated for water level monitoring in Phreatic Aquifer System. **(Annexure-I)**.

2.3 Exploration

Information on aquifer geometry, Groundwater potential of fracture systems and their characterization are primarily inferred from exploratory drilling data. The basic data from 35 exploratory bore wells and 2 tube wells in the area could be used for data gap analysis. Based on this study, data gaps were identified for 10 more exploratory wells and the data gaps are filled with Ground water department exploratory wells. Information on weathered thickness and depth of occurrence of fractures are also inferred from geophysical data such as Vertical Electrical Sounding (VES) and profiling. Geophysical methods are normally employed as a reconnaissance study before exploratory drilling. As the cost of geophysical investigation is much less when compared to exploratory drilling it is effectively used to extract subsurface information. The location of exploratory well is given in **Fig.2.3.**

2.4 Water Quality Monitoring

The historical data on water quality in the area is available from the water level monitoring stations maintained by CGWB. Water sampling is being done every year from these wells during pre-monsoon period (April). The water quality monitoring location map is given in **Fig.2.4.** The data gap analysis has been carried out to find out the adequacy of information on water quality and identified 10 new locations for additional sampling for Phreatic Aquifer System and for Fracture Aquifer system 22 bore wells and 2 tube wells water quality information's are available **(Annexure-II)**.

2.5 Vertical Electrical Sounding and Profiling

Geophysical data on VES and profiling are used to extract information on the weathered thickness, fracture depth, thickness of fracture etc. The aquifer geometry could be refined from the interpretation of geophysical data in conjunction with the available groundwater exploration data. Twenty-two VES were carried out for locating the sites for exploratory drillings. The VES were carried out by employing Schlumberger electrode configuration up to a maximum spread length (AB/2) of 200m. The obtained VES curves were of H, A, HA, AA, QH, KH and HAA type and were interpreted manually as well as by employing computer interpretational techniques. The interpreted results have given rise to 4 to 5- layered geoelectric sections. The VES locations are given in **Fig.2.5.**

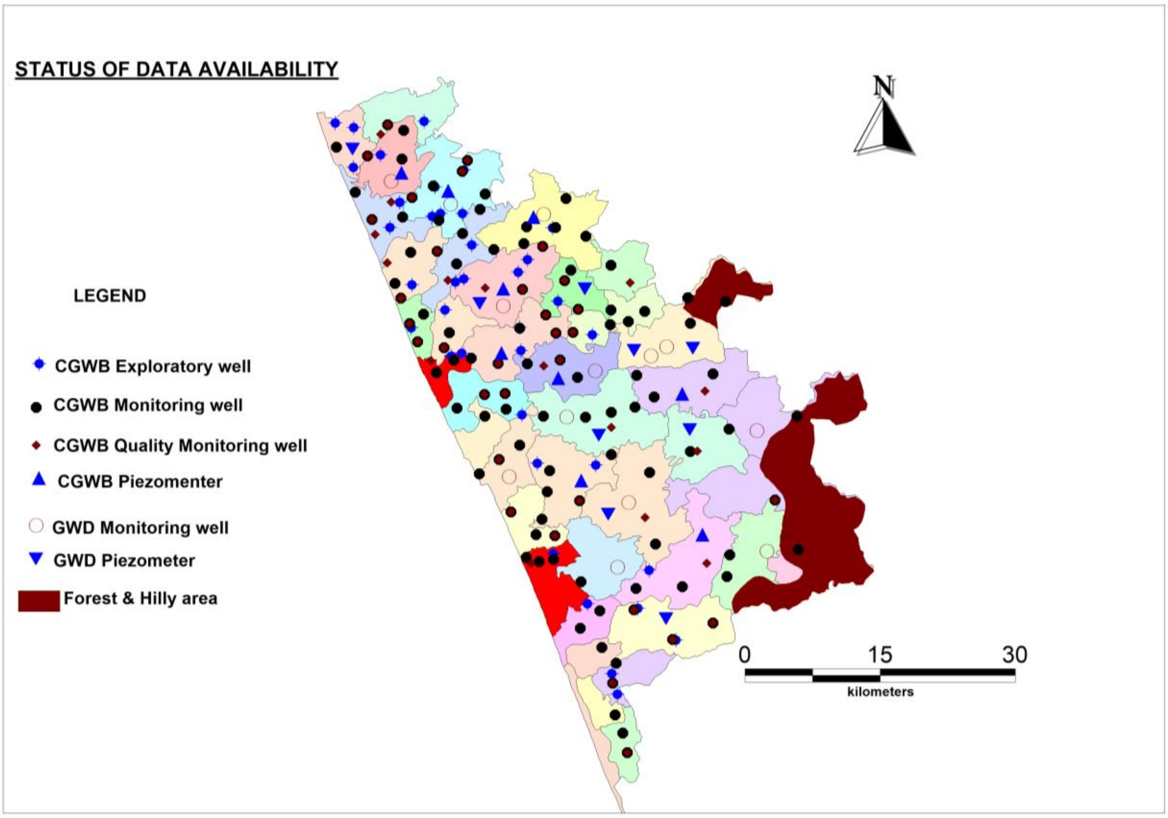

Fig. 2.1. Status of data availability map

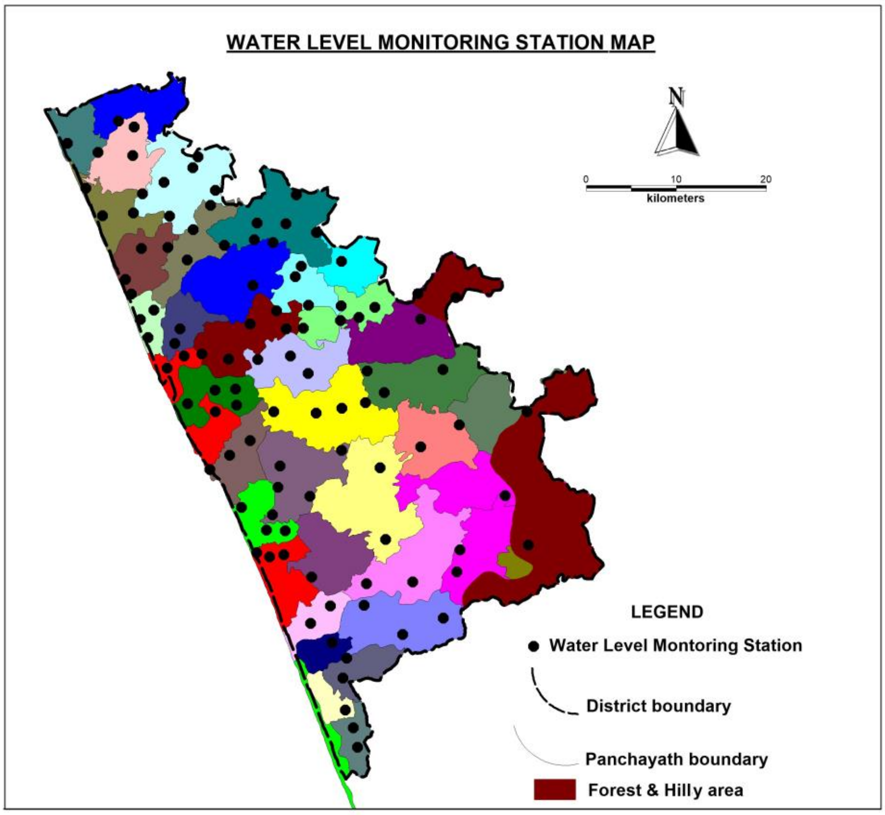

Fig. 2.2 CGWB Monitoring well Location map

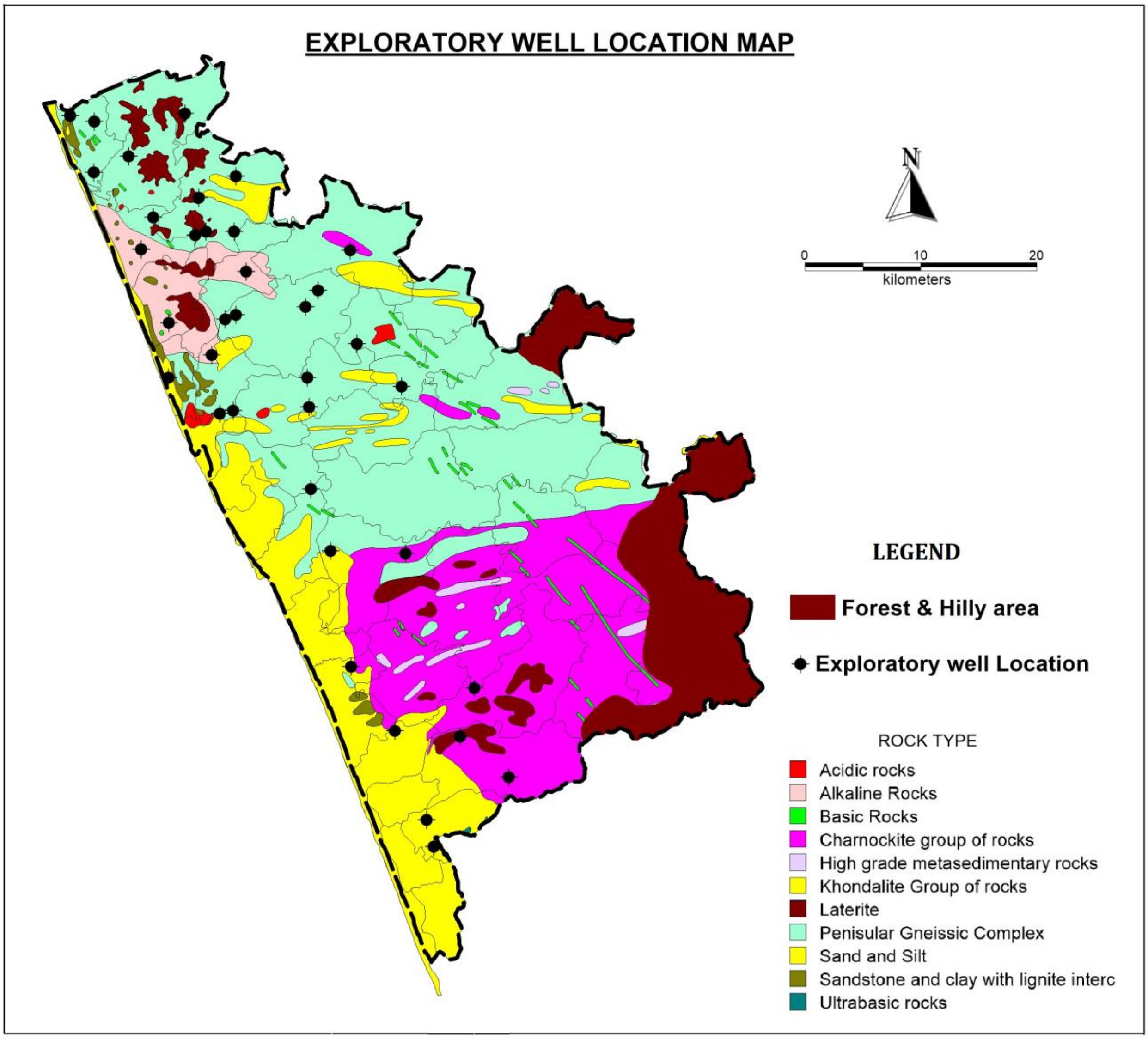

Fig. 2.3 Exploratory well location map

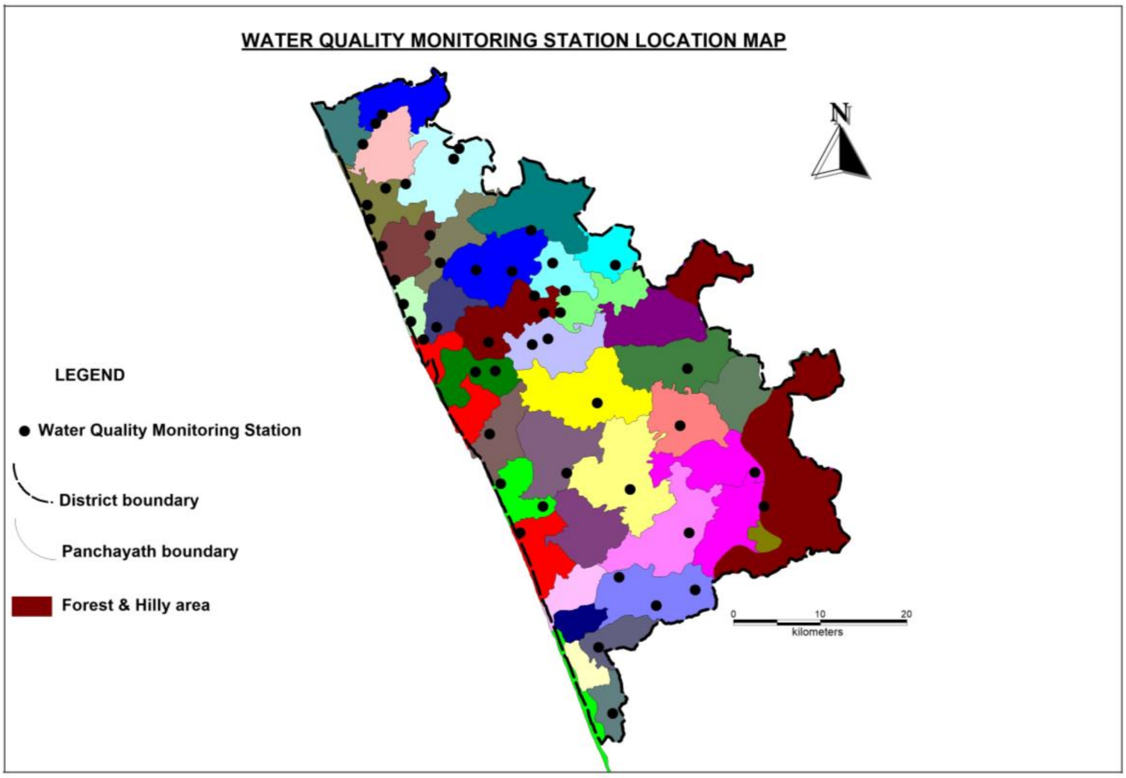

Fig. 2.4 Water Quality monitoring well Location map

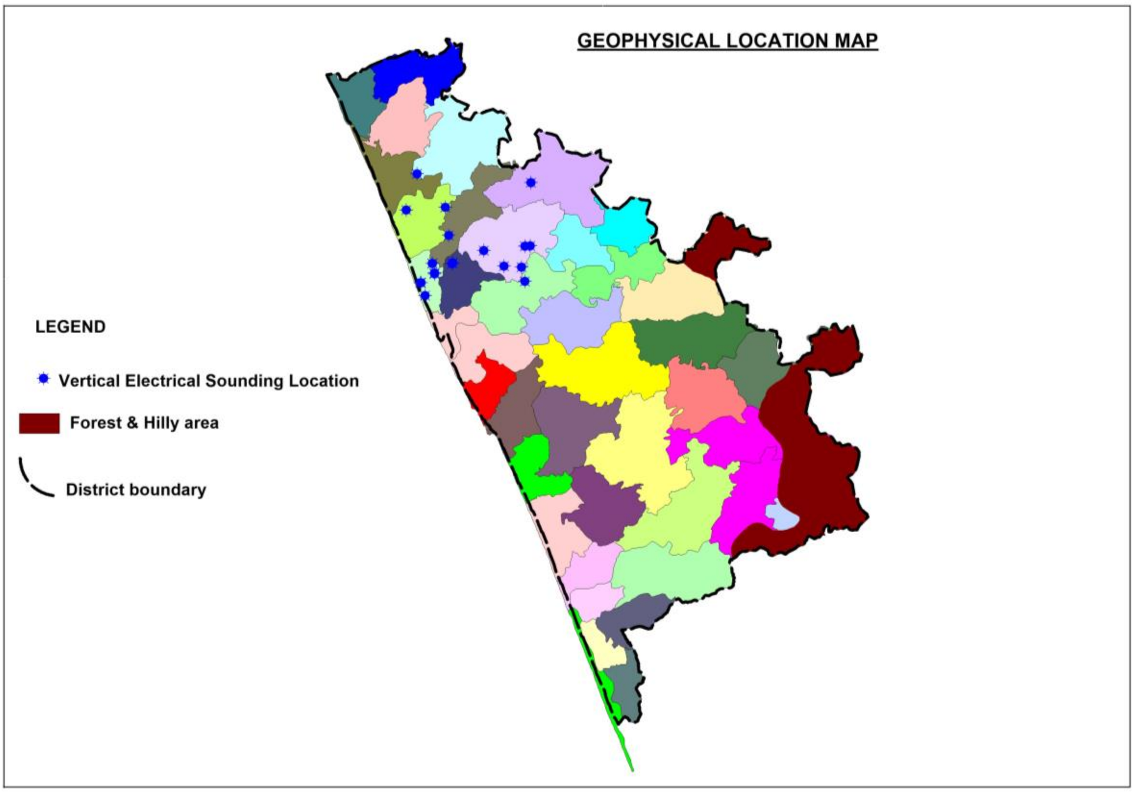

Fig. 2.5 VES Location Map

3.0 DATA INTERPRETATION AND AQUIFER MAPPING

The aquifer map of the area is generated based on the inputs generated from the synthesis and analysis of geological, geophysical, hydrological, hydrogeological, and hydro-chemical data. In the present study, the aquifer disposition and aquifer characterization has been brought out mainly by analyzing the data from 37 lithological logs, 22 electrical logs, 22 piezometric heads, hydro-chemical data from GWMW, previous literatures and inputs from the field investigations. Aquifer mapping involves extraction of information from the analysis of data and preparation of various thematic maps related to the groundwater regime so as to get any required information about the aquifer system from the thematic layer or from a suitable combination of thematic layers. Various aspects of the groundwater regime such as rainfall, soil, geomorphology, geology, aquifer geometry, aquifer characteristics, water levels, water resources and water quality were studied in detail and thematic maps prepared as part of the aquifer mapping.

3.1 Hydrogeological data interpretation

The Aquifer System in the district can be broadly divided into hard rock aquifers, sedimentary aquifers, and laterite aquifers. The hard rock and laterite aquifers constitute the major aquifer system of the district while the sedimentary aquifers are seen along the coast. The data generated, such as lithology, fracture depth, yield, water level, aquifer properties were and utilized to depict the prevailing aquifer systems of the study area. The aquifer mapping studies reveal that the presence of two distinct aquifer system. They are Phreatic Aquifer-I (Shallow Aquifer System) and Deeper Fracture Aquifer-II (Fracture Aquifer System).

3.1.1 Phreatic Aquifer – I (Shallow Aquifer System)

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, and it is hydraulically connected with deeper fracture zones. Weathered/Overburden thickness ranges from 2 to 40 mbgl and is increasing towards west to north western part. Maximum thickness upto 40 m is observed along coastal belt in Nileshwar and Kanhangad blocks. Overburden thickness map is prepared based on ground water exploration data and is shown in **Fig.3.1**. Depth of dug wells generally ranges from 4 to 28 mbgl. Depth to water level generally ranges from 2 to 24 m bgl in pre-monsoon and 2 to 22 mbgl in post-monsoon period. To understand the aquifer disposition, geological sections have been prepared by synthesizing the various sub-surface sections on the basis of study of the lithological logs, electrical logs of boreholes and VES data interpretation using the RockWorks 16 software, Fence diagram and 3D model are shown in **Fig. 3.2 & 3.3**. The cross section of the study area is shown in **3.4 (a) and 3.4 (b)** respectively.

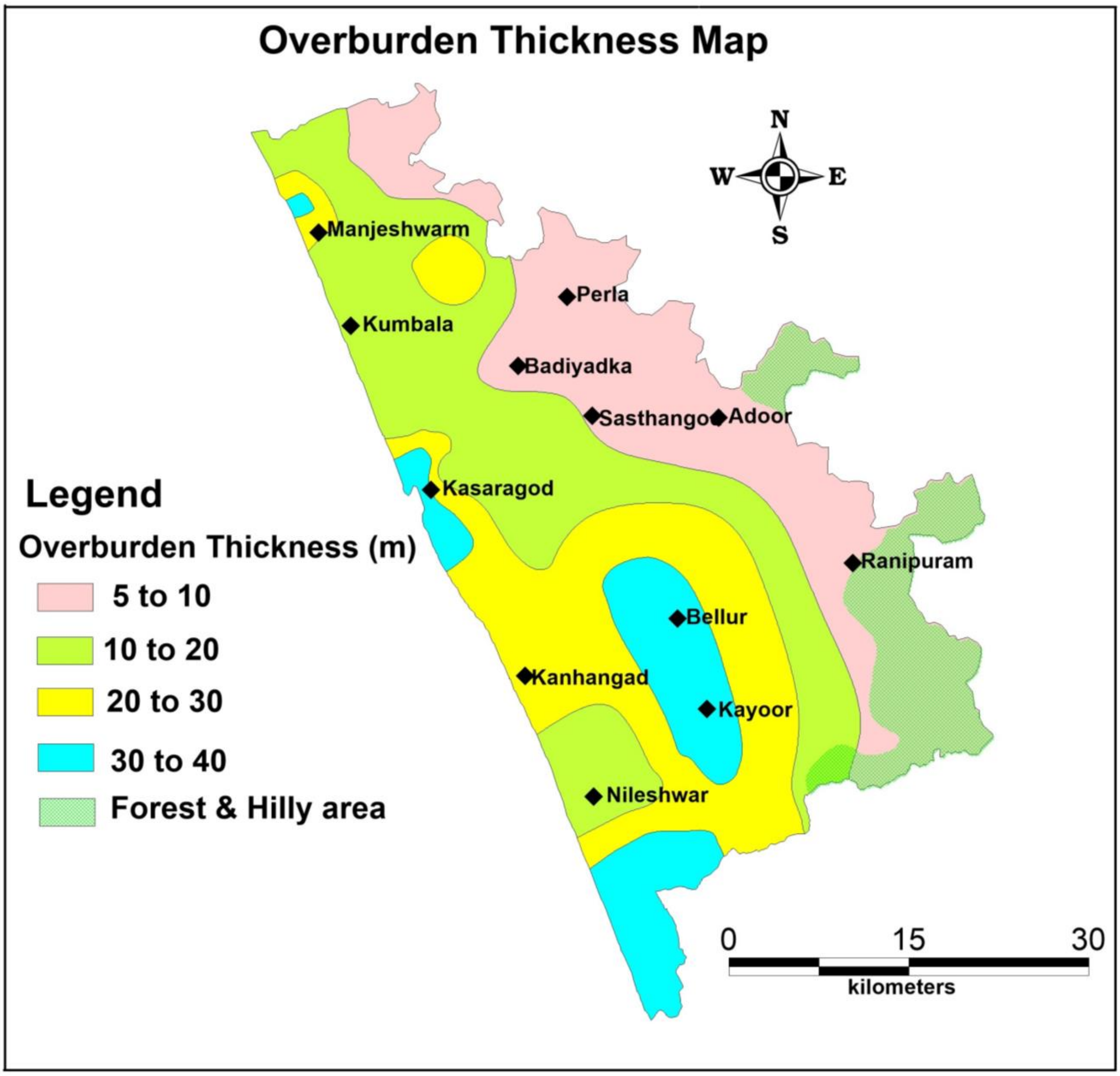

Fig.3.1 Overburden thickness Map

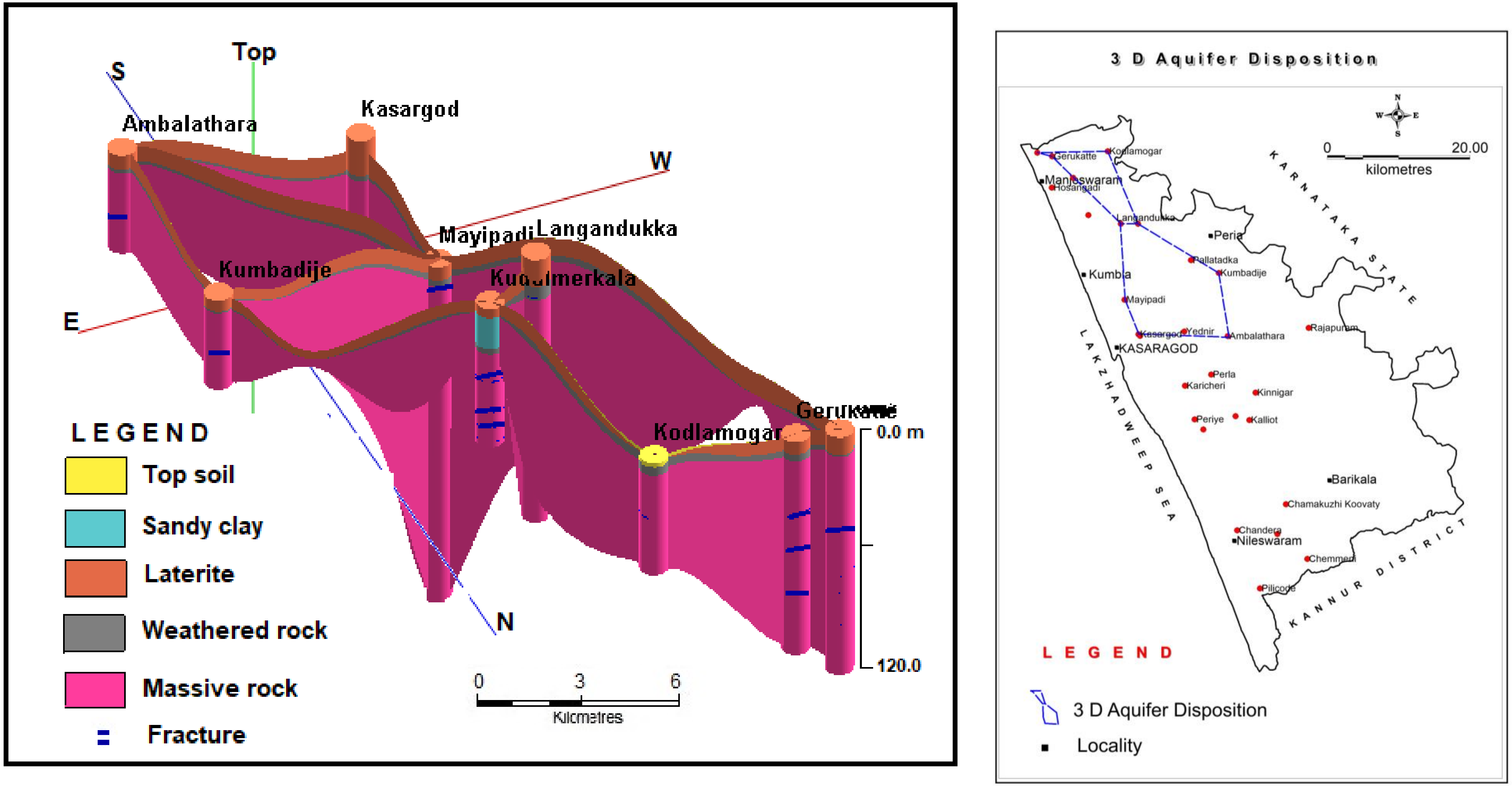

Fig.3.2 Fence diagram Showing Phreatic Aquifer

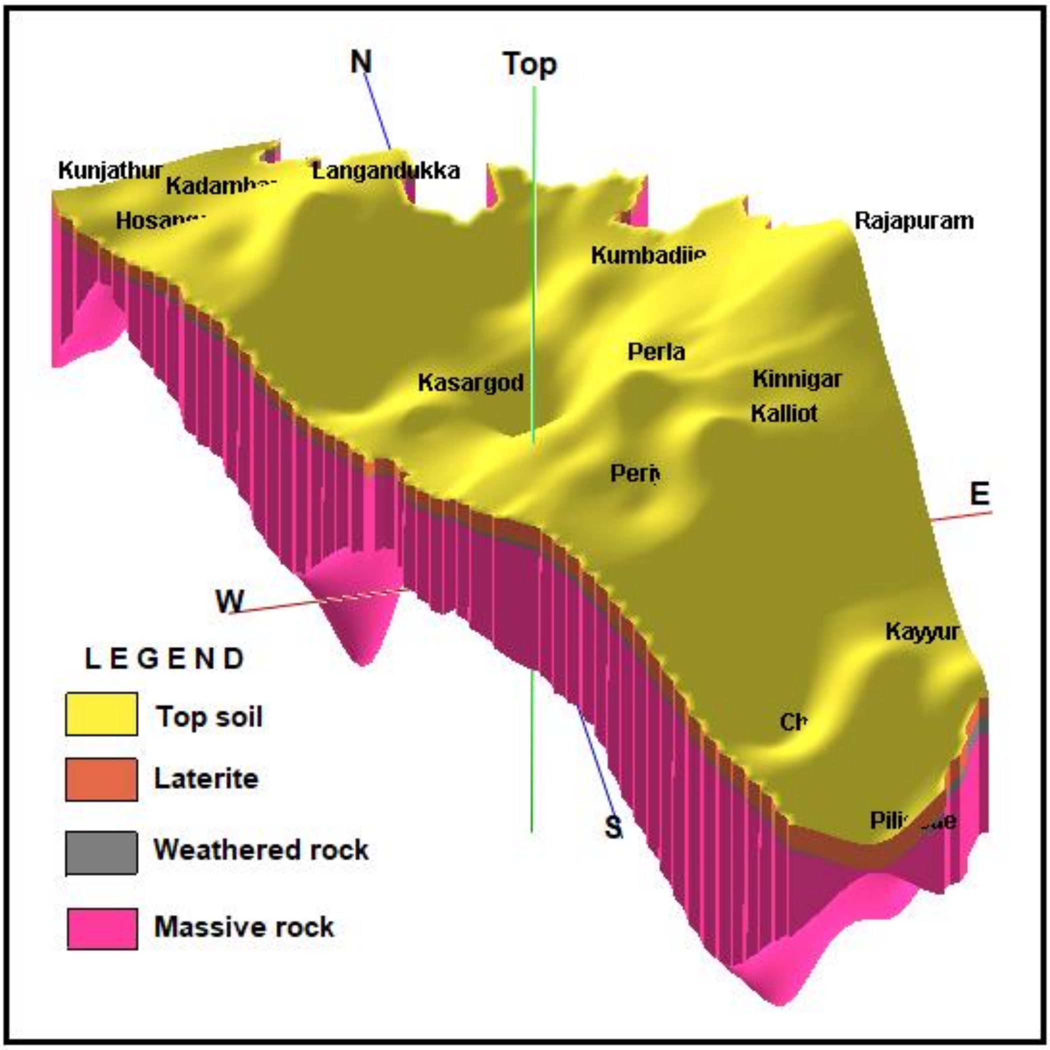

Fig.3.3 Three Dimension Model of the Study area

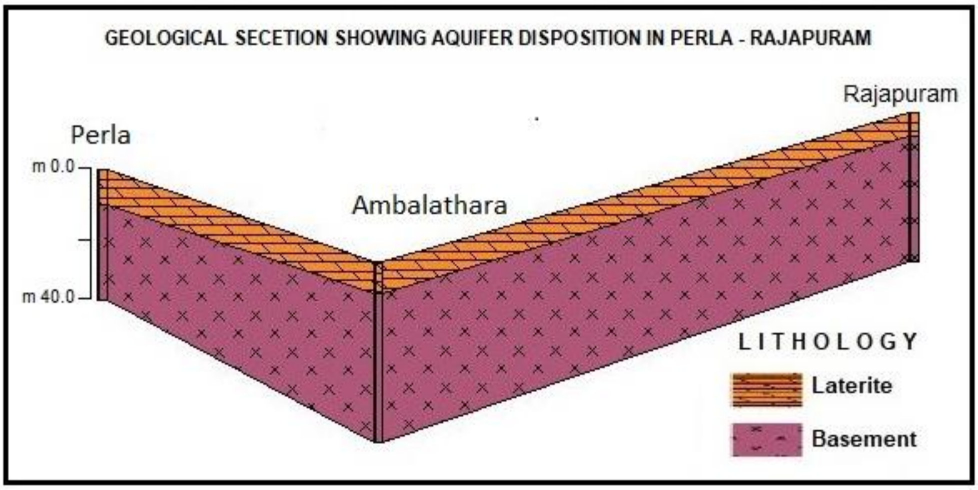

Fig. 3.4.a Cross-Section from Perla to Rajapuram

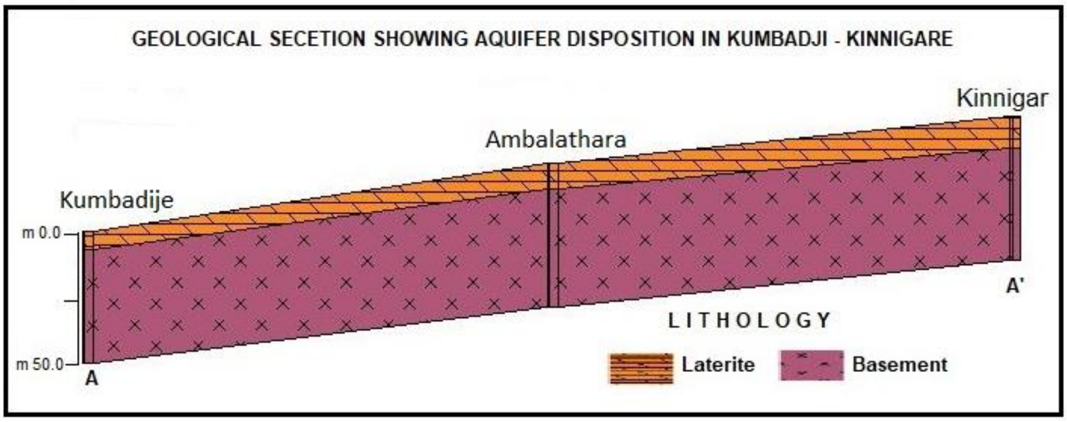

Fig. 3.4.b Cross-Section from Kumbadije to Kinnigar

Four hydrogeological units are encountered in the district - Alluvium (including valley fills), laterites, weathered crystallines and fractured crystallines. Coastal Alluvium occurs as narrow strips parallel to the coast south of Kasaragod. The width of alluvium increases to the south and attains about 5 km. around Trikaripur. North of Kasaragod (in Kasaragod and Manjeshwar blocks), the alluvium occurs as isolated patches close to the coast and have limited thickness. In the Kanhangad and Nileshwar blocks even though the width of alluvium is more, potential zones are seen in the top portion only followed by Tertiary sediments at deeper levels which do not contain potential granular zones. The valley fills occur in between laterite hills which are composed of colluvium and alluvium. The water level in Tertiary aquifer ranges from 2.95 to 5.60 m bgl in pre-monsoon period and 1.35 to 4.30 m bgl post monsoon period. The seasonal water level fluctuation is in the range of 0.30 to 2.37 m.

The laterite is the most widespread and extensively developed aquifer in the district. They widely vary in their physico-chemical characteristics. The laterite is generally underlain by thick lithomargic clay which is the preliminary lateralization front. The thickness of lithomargic clay varies from about 0.5 m to 5.0 m at places. Laterite is more ferruginous, porous and hard in northern parts of the district compared to those in the southern parts of the district. Due to its porous nature the dug wells tapping laterite get recharged fast and also the water escapes as sub-surface flow and water level falls quite fast especially in wells located on topographic highs and hill slopes.

In Laterite, the depth to water level (DTWL) in pre-monsoon period ranges from 2.95 to 25.75 m bgl and in post-monsoon period 1.35 to 22.90 m bgl. The DTWL is shallower in the valley portions and gentle slopes and deeper in laterite hillocks and lateritic ridges. The DTWL is comparatively deeper in eastern part of Chengala (Kasaragod block), Karadka and Delampady panchayaths (Karadka Block), where it is found to be more than 20 m. Similarly, deeper water level in laterite is seen in western part of Parappa block. Water level in laterite formation is found shallow in western part of Nileshwar block where the laterite is formed from the Tertiary formations. The water table fluctuation ranges from 0.30 to 4.05 meters. Maximum fluctuation is observed in wells located in topographic highs and slopes. In the northern part of the district, in midland areas a very common ground water abstraction structure are the Tunnel wells (locally known as *'SURANGAMS'*), which is a horizontal well (Adit) with a width of 50 cm to 75 cm and height of around 2 m. The length of tunnel well varies from few metres to 100 metres. Generally, the tunnel well starts at the foothills and cut across the slope horizontally to have the maximum yield. The yield of tunnel wells varies from 1 m^3/day to upto 50 m^3/day in summer. In peak summer, the yield of tunnel wells is generally less.

In the eastern part of the district (Karadka and Parappa blocks) the thickness of lateralization is comparatively low and weathered crystallines are encountered underlying the laterites in dug wells. The weathered crystallines form the aquifer of limited potential sustaining domestic dug wells. The depth to water level ranges from 2.75 m to 11.35 m bgl in pre- monsoon and 2.05 to 10.52 mbgl in post-monsoon. The water level fluctuation ranges from 0.60 to 2.45 meters.

In the fractured crystalline aquifers ground water occurs under semi-confined to confined conditions. They are tapped through borewells for domestic, irrigation and industrial purposes. Majority of the medium water supply schemes in the district are by bore wells. The yield of bore well in the district ranges from 500 to 72,000 lph. The data collected during NAQUIM studies in the year 2021-22 pertaining to the depth to water level in pre-monsoon and post monsoon period is compiled **Tables 3.1 (a) & 3 (b).** The Pre and Post-monsoon water level maps are shown in **Fig. 3.5 & 3.6** and the Water level Fluctuation map is shown in **Fig.3.7**

Table 3.1(a): DTWL Range- Pre-monsoon (April 2021)

Formation	Depth to Water Level (DTWL) Range			
	<5m	**5 to 10 m**	**10 to 20 m**	**>20 m**
Alluvium (24 wells)	4	5	15	-
Laterites (68 wells)	1	30	35	2
Crystallines(15wells)	2	4	9	2

Table 3.1 (b): DTWL Range – Post monsoon (November 2021)

Formation	Depth to Water Level (DTWL) Range			
	<5m	**5 to 10 m**	**10 to 20 m**	**>20 m**
Alluvium (26 wells)	6	14	5	1
Laterites (78 wells)	12	43	21	2
Crystallines(17wells)	3	11	1	2

Long term trend of pre-monsoon and post-monsoon water level of groundwater monitoring wells (NHS) between 2011 and 2021 are analyzed. Declining water level in the range of 0.0058 to 0.1648 m/year in pre-monsoon period is observed in the central and western part of Kasaragod, Manjeshwar and Kanhangad blocks. However, in majority of the area, the water level shows a rising trend in the range of 0.0017 to 0.1829 in pre-monsoon period and 0.0091 to 0.1717 in the post monsoon period. In the post-monsoon period, the water level showed a decline in a few wells only in the range of 0.0002 to 0.1498 m/year. The decadal water level trend of the area is shown in **Fig. 3.8.**

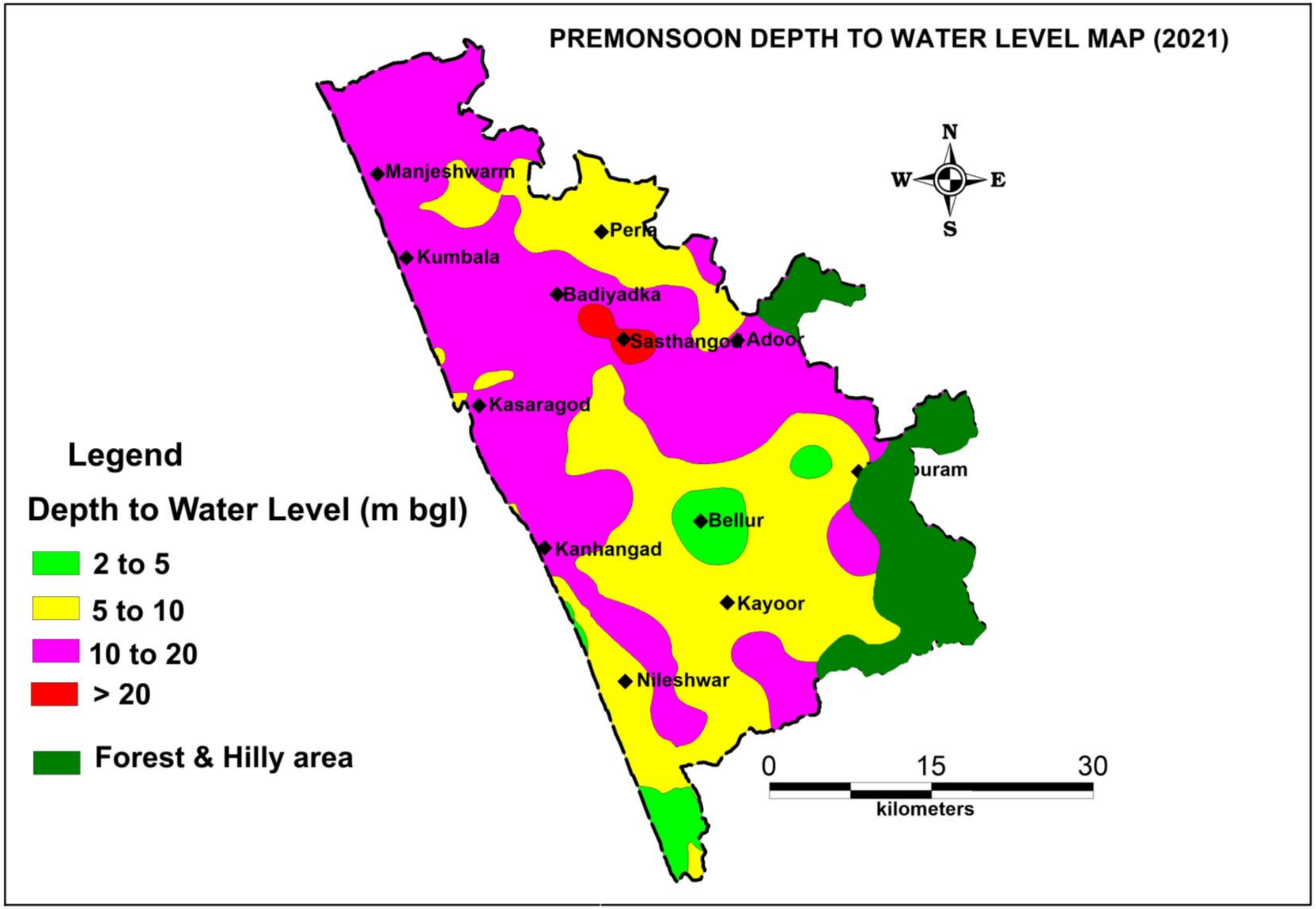

Fig.3.5 Pre monsoon Water Level Map

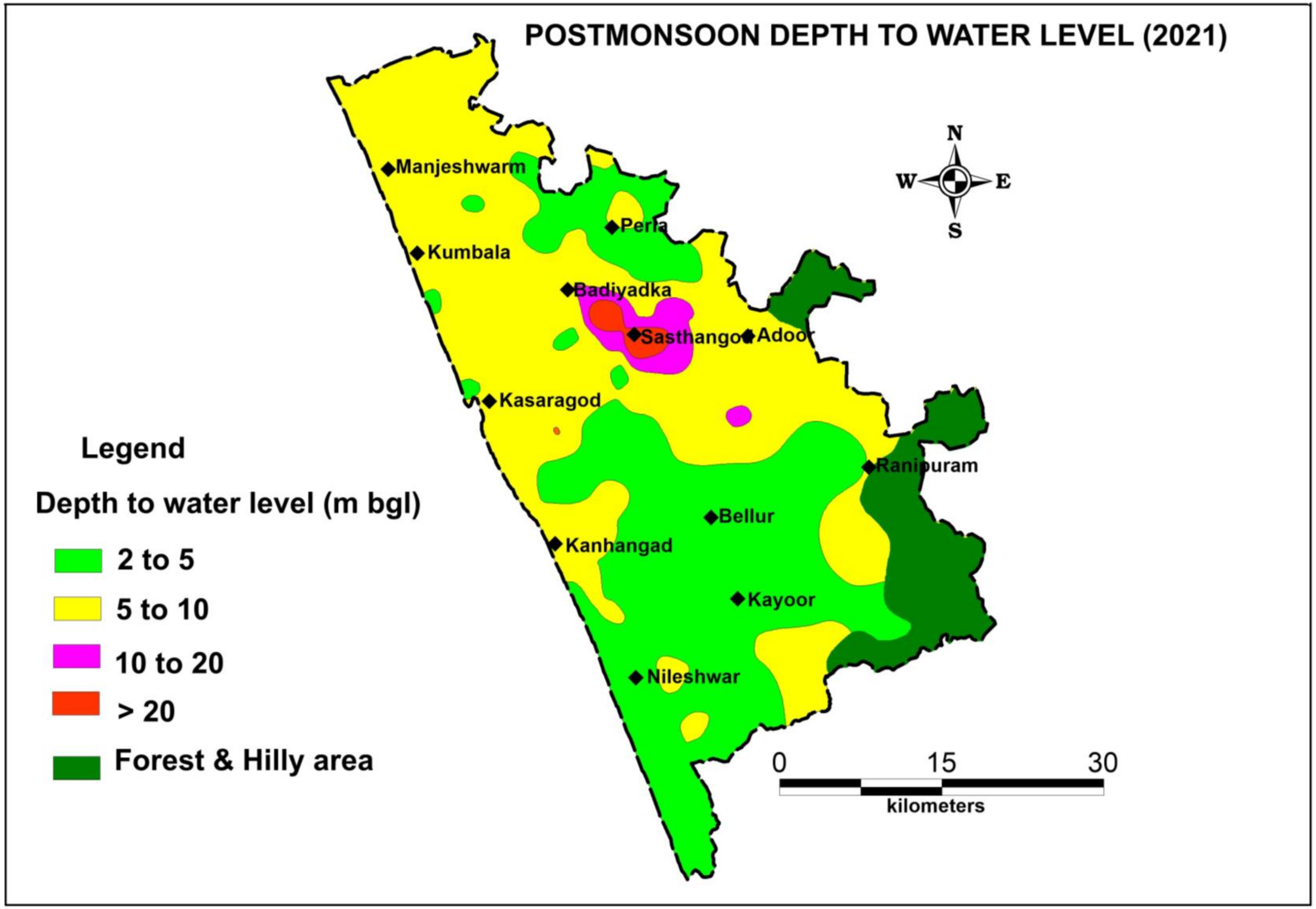

Fig3.6 Post monsoon Water Level Map

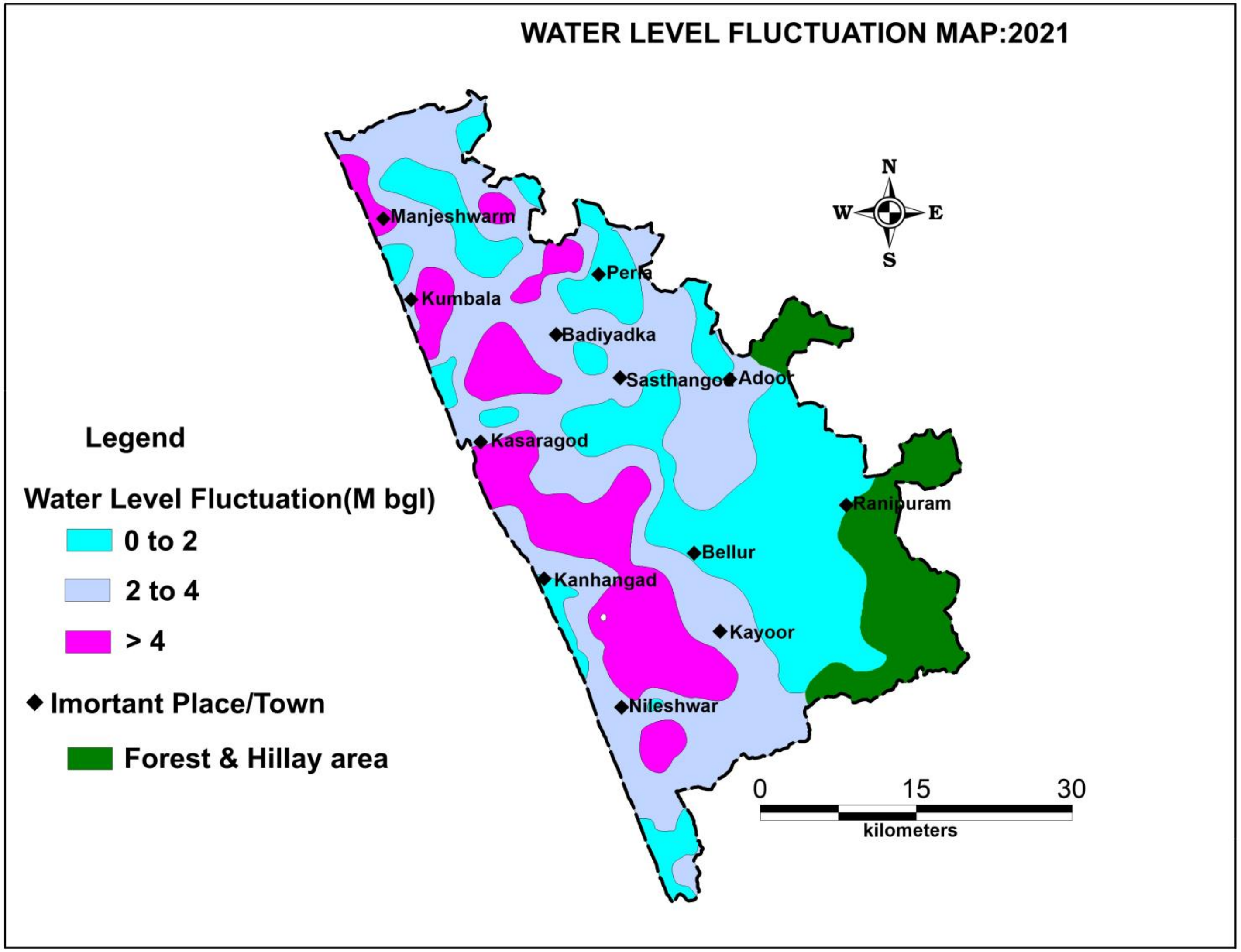

Fig.3.7 Water Level Fluctuation Map

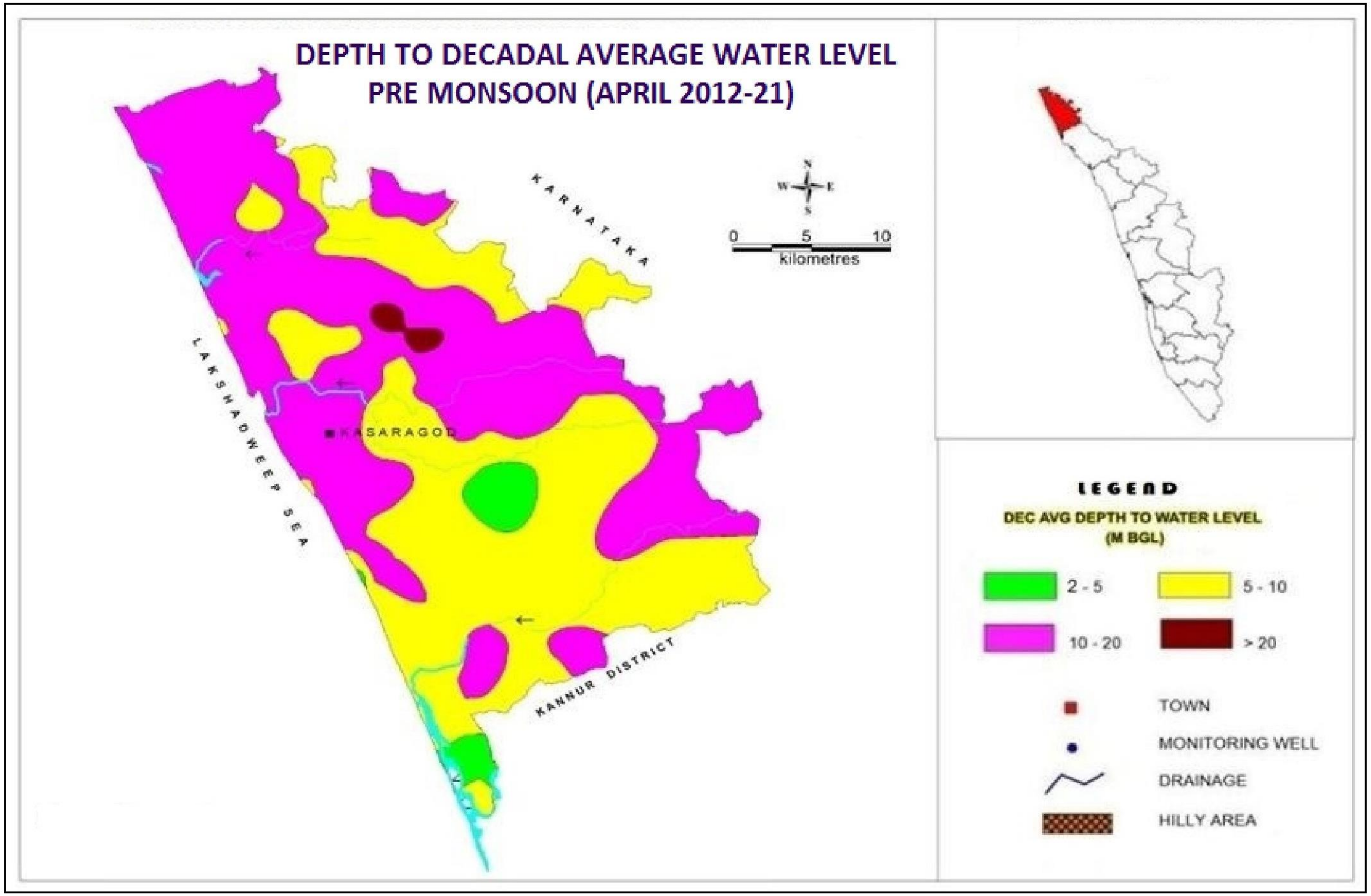

Fig.3.8 Decadal Water Level Map

3.1.1a Quality of water in Phreatic Aquifer

The existing water quality data from the dug wells have been analyzed for extracting information on regional distribution of water quality and their suitability for various uses. In a groundwater flow regime water chemistry constantly undergoes modification due to various processes such as dissolution of minerals, precipitation of dissolved ions under unstable conditions, cation exchange etc. The hydro chemical evolution along the flow paths are significantly altered under anthropogenic interferences and consequent pollution of aquifer systems (Drever, 1982; Langmuir, 1997; Abu-Jabeer, 2001; Singh et al, 2007). The effects of pollution in the flow system can easily be identified from a comparison of dissolved ions and ion ratio studies in simple terms (Hem, 1985).

Hydro chemical facies

Plotting of the percentage of epm values of cations and anions in Hill-Piper diagram falls mostly either in the field where chemical properties are dominated by alkaline earths and weak acids (Ca-Mg-HCO_3 type) or in the field where chemical properties are dominated by alkalis and strong acids (Na-Cl type).The rest of the samples fall in the mixed cation-anion field where no single cation-anion pair exceeds 50% (mixed Ca-Na-HCO3 type or mixed Ca-Mg-Cl type). Influence of human intervention and soil salinity may be the causative factors for the samples with mixed cation-anion nature.

The water samples collected from shallow aquifer, the Electrical conductivity ranges between 34 (Kayoor) and 680 (Arikkad junction) microsiemens/cm at 25^0C with an average EC of 240 microsiemens/cm at 25^0C. The EC is a measure of mineralization in water and it depends on degree of weathering and mineralization. The pH value of water ranges from 5.6.00 to 8.17 with an average pH of 7.4 Total hardness of water samples ranges between 39 and 223 mg/l as $CaCO_3$.The water from the shallow aquifers is good and potable. As per the drinking water standards of Bureau of Indian Standards (BIS), all the major chemical constituents including fluoride in the groundwater of Kasaragode district is within the permissible limit and is suitable for all purposes in majority of samples. The water quality data are plotted in Hill Piper diagram and presented **Fig.3.9** and given in **Annexure-III**.

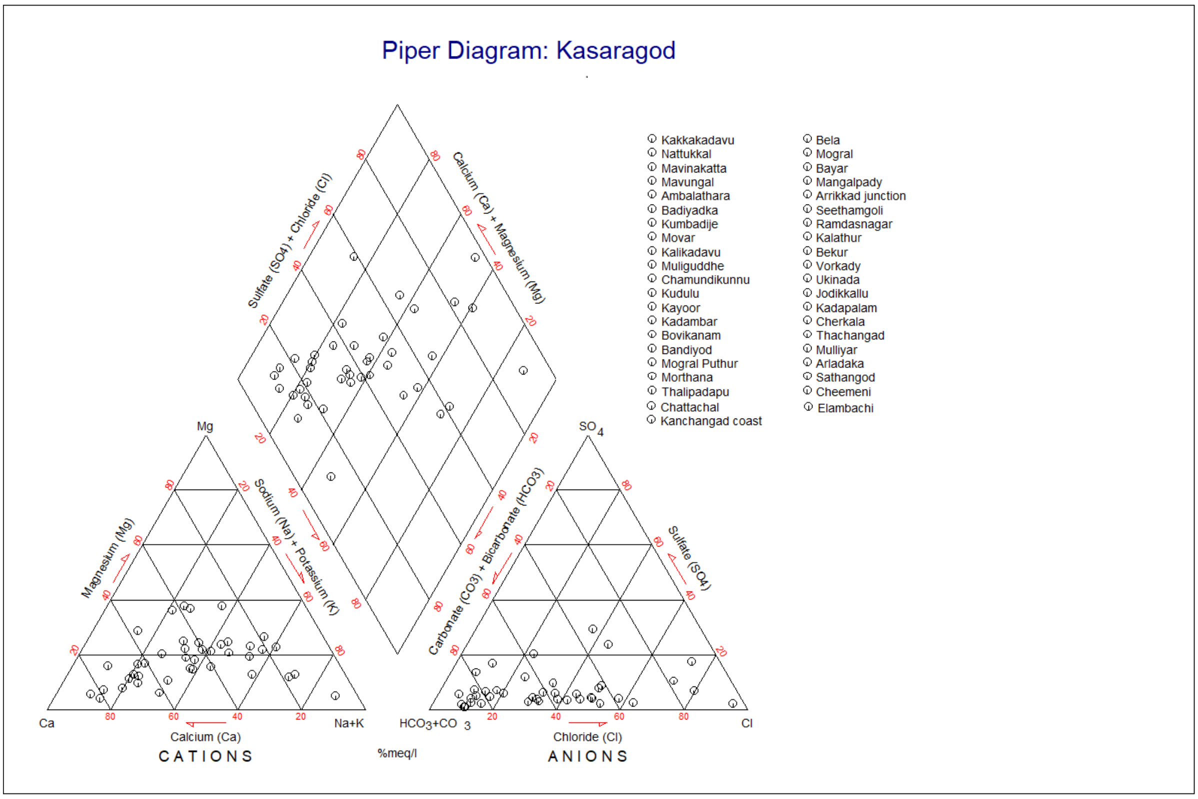

Fig 3.9 Hill-Piper diagram (Phreatic Aquifer)

3.1.2 Deeper Aquifer (Fracture Aquifer System)

The Deeper Fracture zone is potential as the area is tectonically disturbed and groundwater exists there under semi-confined conditions. Since the area experienced several episodes of tectonic deformations, a large number of interconnected fractures developed which offer very good conduits and storage space for groundwater. The Central Ground Water Board has drilled 35 numbers of exploratory wells and 2 numbers of Tube wells in the study area, the depth of the bore wells ranges from 40 m to 200 mbgl. The depth to fracture zones ranges from 20 m to 80 m bgl and the discharge ranges from 0.5 to 11 Lps. However, most of the potential fracture zones occur within the depth of 75 mbgl. Bore wells located along the lineaments are yielding high compared to the wells located away from the lineaments.

Aquifer disposition

Based on the validated lithology 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 and sedimentary rocks for a better perspective of the subsurface geology and the panel diagram are shown below.

Section along Kunjathur– Kudalmerkala direction tapped both Phreatic and deeper aquifers; Phreatic aquifer having thickness varying from 10 to 40 m. Deeper Aquifer is having maximum thickness up to 200m bgl depth. The shallow fractures are encountered at a depth of 25 m in Nellikatte have a discharge of 4 lps. The deeper aquifer cross-Section is given in **Fig.3.10.**

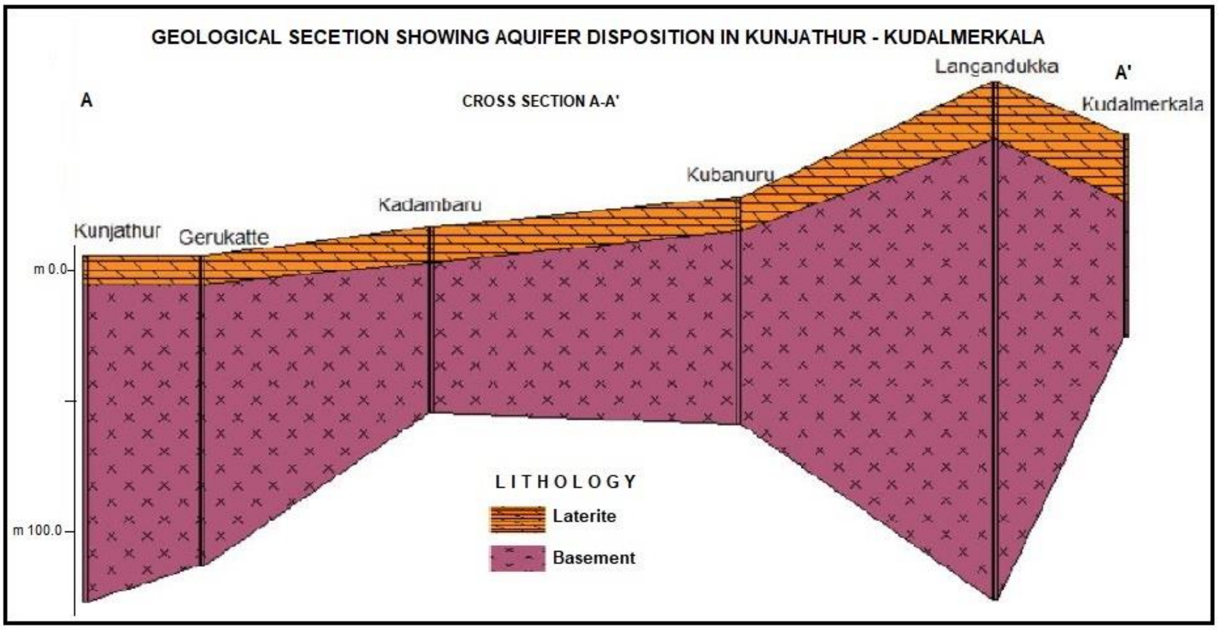

Fig. 3.10 Cross section showing aquifer disposition (Kunjathur-Kudalmerkala)

The fence diagram showing the vertical and lateral variation of aquifer along all directions and represents an undulating terrain with laterite formation at central to north western side and weathered formation on western side. Thickness of fractured aquifer is considerably high in north western & south eastern compare to east and west of the area and is shown in **Fig.3.11.** The rocks have undergone a series of brittle deformation at the later stage resulting in the formation of a number of lineaments and fractures. The prominent lineament directions are NW-SE, NE-SW and E-W. The productive lineaments are NE-SW, N-S and E-W.

Piezometric head

The data on piezometric head have been collected from 23 exploratory wells tapping the fracture systems in the area. The integrated data on water level and piezometric heads are ranges from 1.40 to 25 mbgl and with an average piezometric head of 15.00 m bgl.

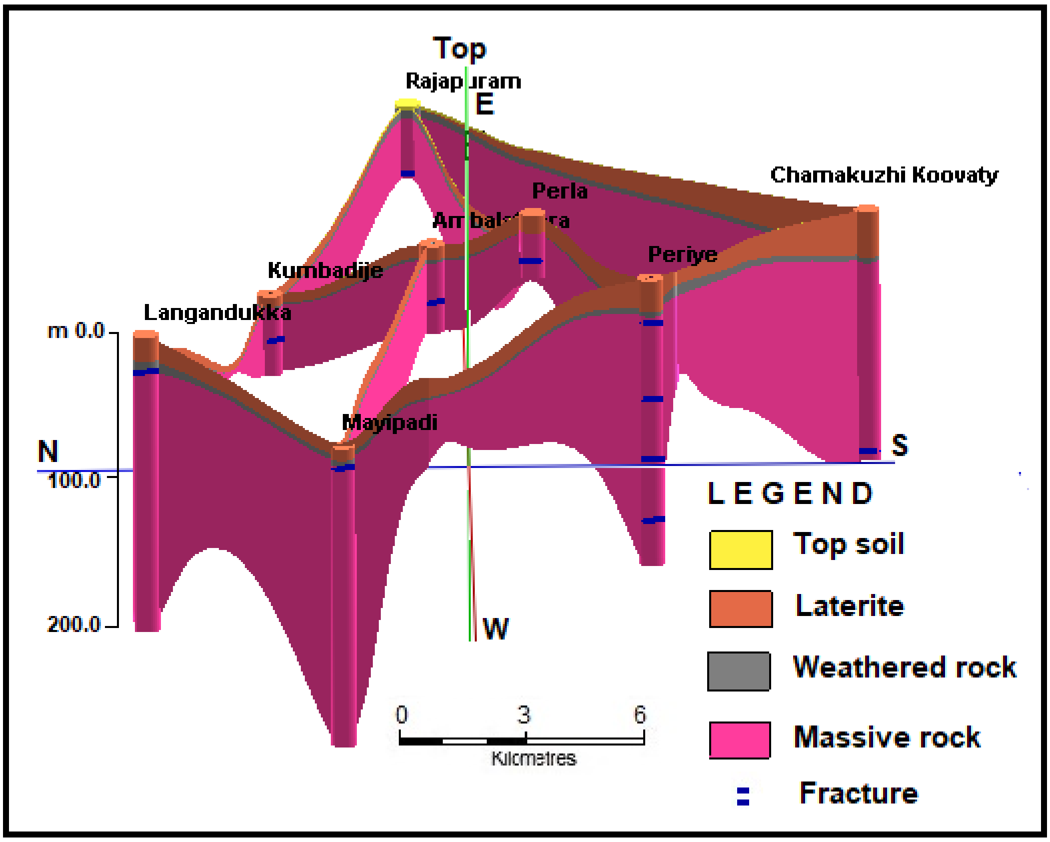

Fig.3.11. Fence diagram showing the deeper aquifer disposition

3.1.2a. Quality of water in Deeper Aquifer

The chemical quality of fractured aquifer system has been studied using the analytical data of water samples 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 at all locations except few locations.

For the deeper aquifer in hard rock terrains, the ground water quality is good and electrical conductivity ranges from 82 to 500(µs/cm at 25oC); higher values are also observed at Arikkad junction, but some pockets of area affected by iron, particularly in Karadka, Puthige, Bedadka and Karindalam, the iron content is >1 mg/Litre. The deeper aquifer tapping the coastal Tertiary formations and Recent formations are found to be brackish. The water samples from the tubewells drilled at Ajannur having Electrical conductivity of 3100 µs/cm at 25oC and is not potable and the water is Saline to brackish in nature.

The chemical quality data has been plotted in Hill-Piper diagram and given in **Fig.3.12.** The 2D Cross-Section of Aquifer disposition is given in **Fig.3.13.**

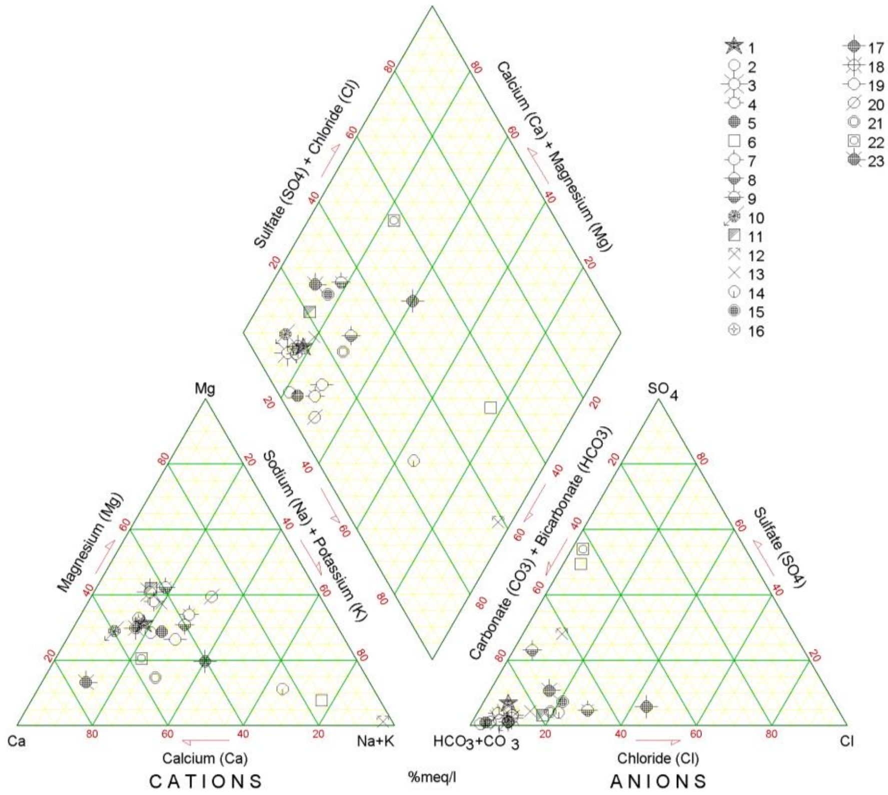

Fig. 3.12 Hill-Piper diagram (Deeper Aquifer)

3.1.3 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 were utilized to identify potential lineaments and fractures in the area. The lineaments identified in the basin trend various directions such as N-S, NNE-SSW, ENE-WSW, E-W, ESE-WNW, and NW-SE. The prominent lineaments in the area mainly trend in NW-SE, NE-SW and E-W direction and is shown as a rose diagram (**Fig.3.14)** based on the results of lineament analysis given in **table 3.2**

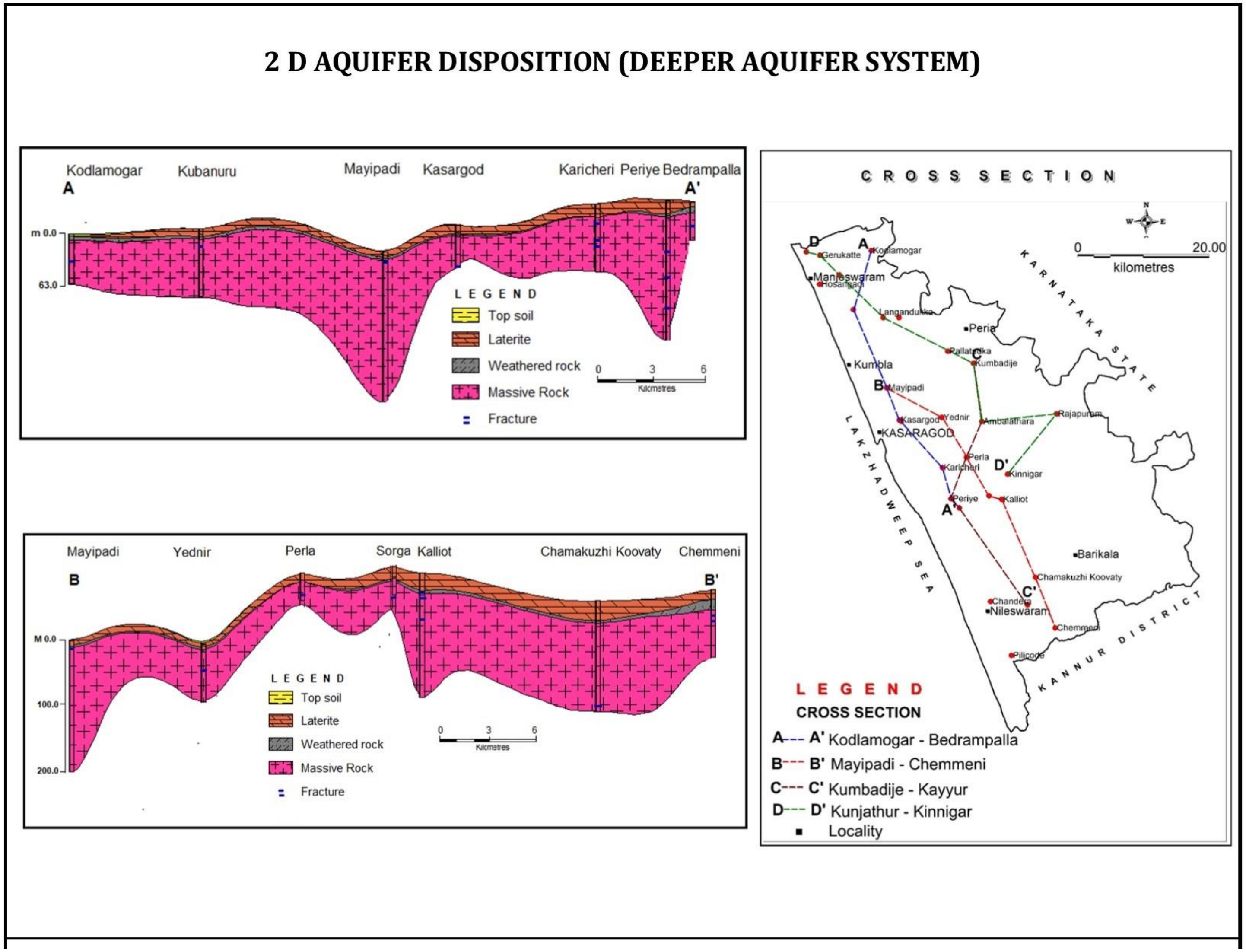

Fig.3.13 Cross-Section showing the Fracture Aquifer System

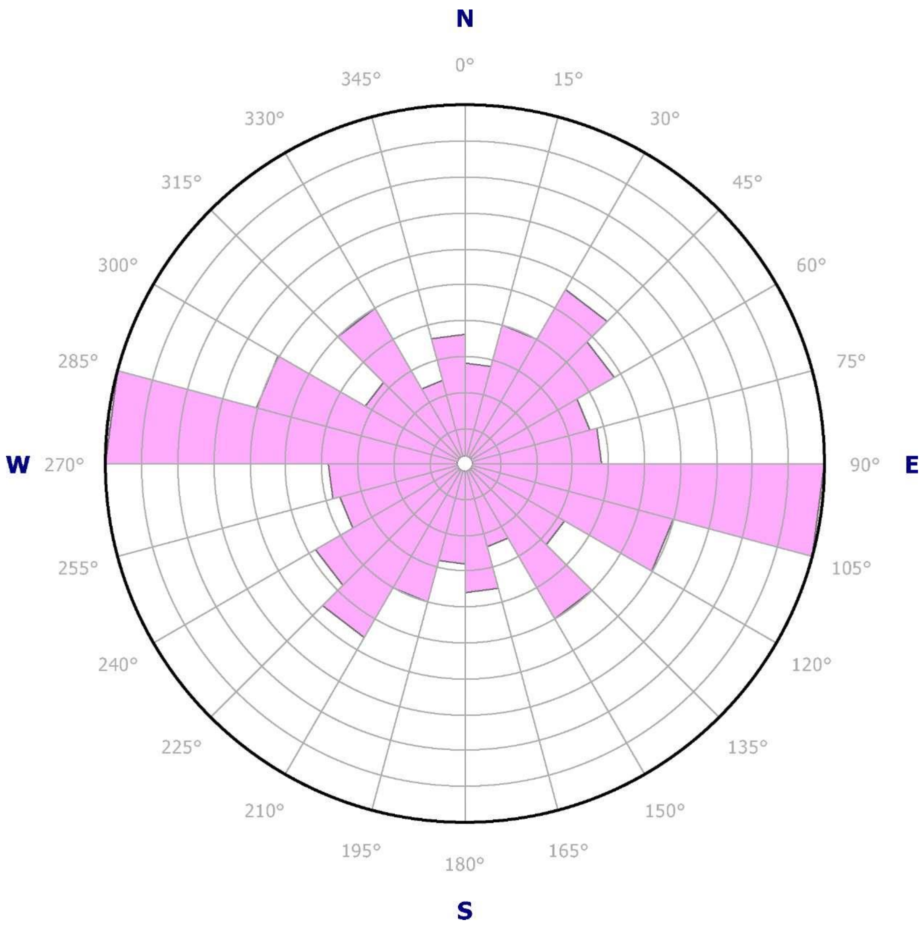

Fig.3.14 Rose diagram (Fracture direction)

Table 3.2 Lineament direction

#	Orientation	Lineament traces	
		Number	Percentage
1	N-S	15	11.68
2	NNE-SSW	12	17.88
3	ENE-WSW	6	14.96
4	E-W	6	10.50
5	ESE-WNW	7	16.79
6	NW-SE	22	13.50

3.2 Aquifer maps

Based on the data generated in the field, data integration and analysis the aquifer maps were prepared. Analysis of geological, geophysical, hydrological, hydrogeological, and hydro-chemical data has carried out. In the present study, the aquifer disposition and aquifer characterization has been brought out mainly by analyzing the data from 37 lithological logs, 22 electrical logs, 23 piezometric heads, hydro-chemical data etc. Aquifer mapping involves extraction of information from the analysis of data and preparation of various thematic maps related to the groundwater regime so as to get any required information about the aquifer system from the thematic layer or from a suitable combination of thematic layers. An aquifer map of the area is evolved out finally, based on various aspects of the groundwater regime such as aquifer geometry, aquifer characteristics, water levels, water resources, water quality and its yield potential **(Annexure-IV)**.

3.2.1 Aquifer map of phreatic aquifer system

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. The aquifer with a thickness up to 40 m is noticed in the study area. The western part of the study area shows high ground water potential is up to 10 m^3/day and sustain with 3 to 4 hours of pumping, north, central, southern and western parts ground water potential is upto 5 to 10 m^3/day sustains 1 to 3 hours of pumping, south-eastern to eastern part ground water potential is upto 5 m^3/day sustains 1 to 2 hours of pumping and in north eastern to eastern part the weathered thickness is limited and the ground water potential is up to 3 m^3/day and sustains 1 hours of pumping. By integrating the available data along with aquifer mapping, an aquifer map of the phreatic aquifer system has been prepared and is shown in **Fig. 3.15.**

3.2.2 Aquifer map of fractured aquifer system

By integrating the exploration details, lithological cross sections and aquifer properties, water quality etc. an aquifer map for fractured aquifer is prepared and is depict in **Fig. 3.16.** 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 80 m bgl (upto 12 lps).

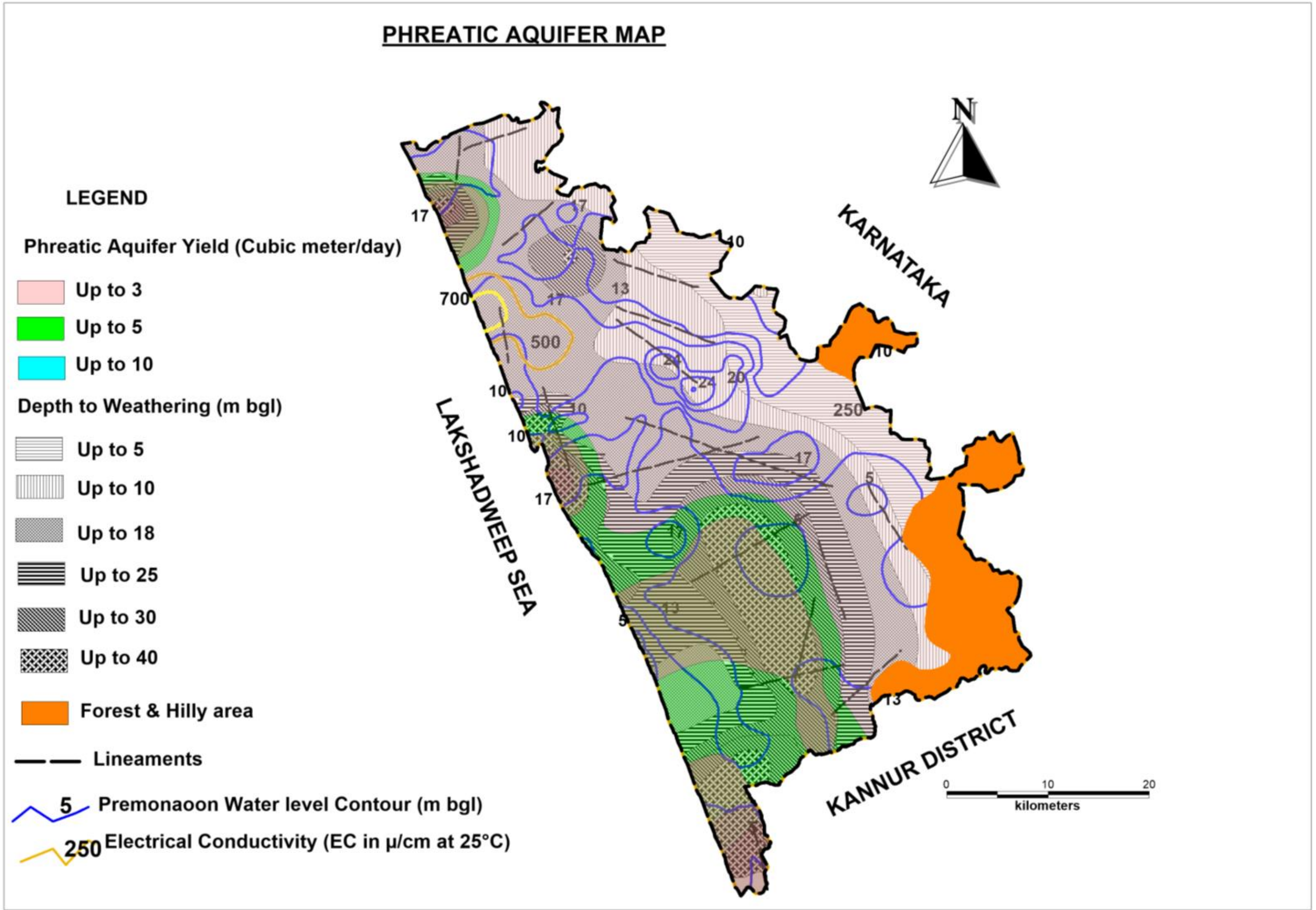

Fig.3.15 Phreatic Aquifer Map

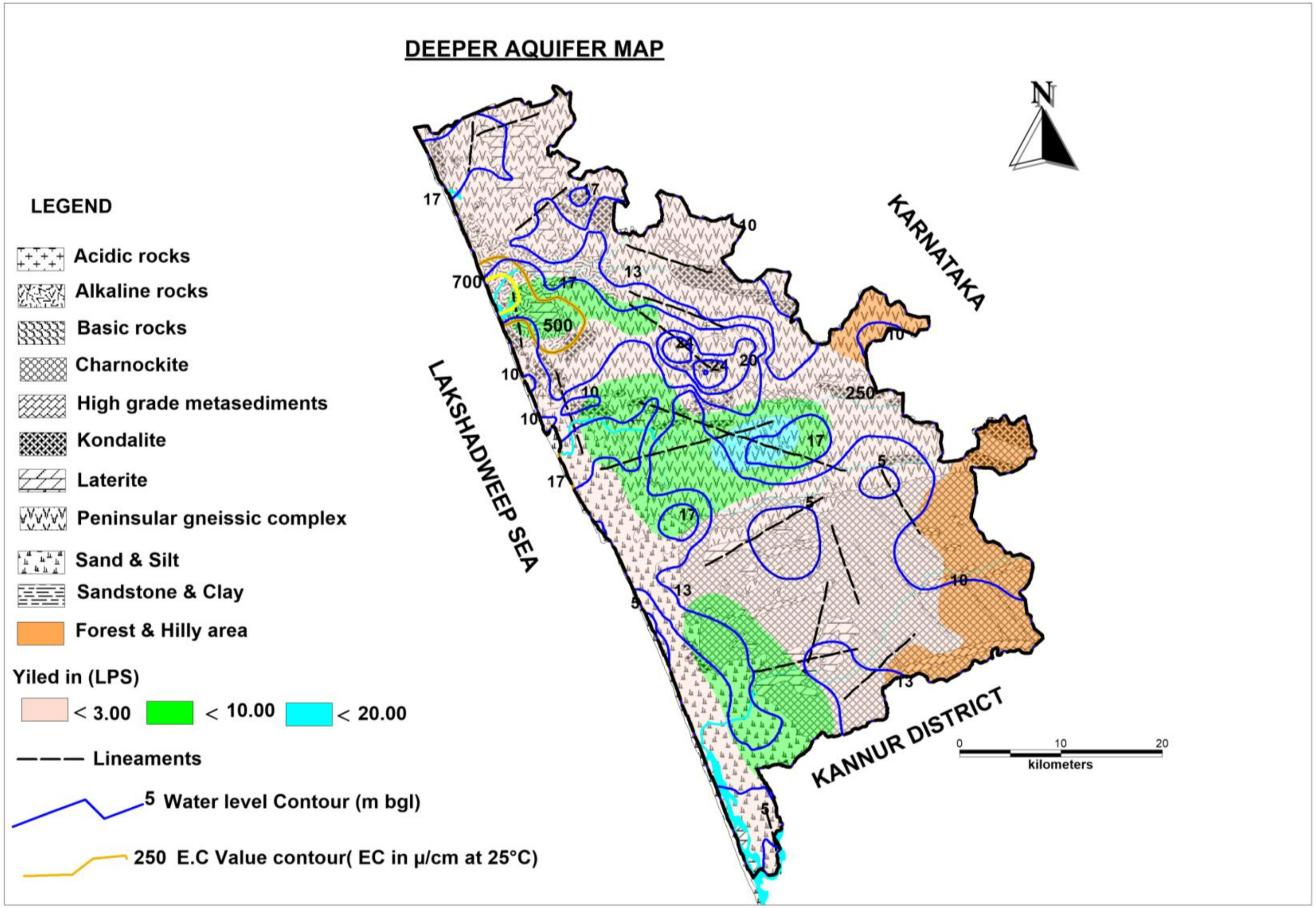

Fig.3.16 Deeper Aquifer Map

4.0 GROUND WATER RESOURCES

4.1 Groundwater resources in Aquifer-I

The water resources in the phreatic aquifers is the major sources for irrigation and drinking water in the area. In recent years, groundwater extraction for irrigated agriculture in the region has increased to a certain extent and depletion of the resource is observed over the years. Any decision about future utilizations depends on having a clear understanding of the status of the resource, the amount that has already been extracted, the amount remaining, and the impact of further depletion. The dynamic groundwater resources in the area are estimated based on the methodology proposed by Groundwater Estimation Committee (GEC 2015 methodology). In this study the area under command and non-command could not be separated mainly due to non-availability of data pertaining to canal command areas of the State. Further, the irrigation projects of Kerala are mostly planned for irrigating Coconut along the topographic lows. Hence in each unit there are large areas along the upstream side of the canal, which do not get benefits of surface water irrigation. Due to the highly undulating topography of the mid land area where most of the canals exist, it is quite difficult to accurately demarcate the areas under command and non-command. In view of the factors mentioned above, the computations have been made by taking all assessment units as non-canal command area. The recharge from canal segments and return seepage from irrigation due to surface water in the command area have, however, been incorporated into the computations. Annual extractable ground water recharge of unconfined aquifer of the district is estimated to be 291.52 mcm.

Ground water extraction in the study area is mainly for irrigation and domestic purposes. 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 block-wise on the basis of 2011 population, projected to the year of assessment (2020). Domestic requirement of water in the study area has been computed as the product of the population and the per-capita water requirement (assumed as 150 L/day/person). The share of ground water in the requirement has been computed as a percentage varying from 25 to 100%, arrived at on the basis of availability of surface water sources for domestic water supply.

The ground water extraction has been computed from the data on the block-wise number of irrigation wells collected by the State Ground Water Dept., Government of Kerala. The ground water extraction figures are arrived at by multiplying the number of wells with the corresponding unit draft. The Ground Water extraction for all uses in the study area is computed as 222.73 MCM. The stage of extraction of the district is 76.40 %. The block wise resource estimation data is given in **Table 4.1.** The in storage ground water resources of unconfined aquifer is calculated as 250.65 mcm. The ground water resources of the Aquifer- I is the sum of the annual extractable ground water resources and the in-storage resources of the Phreatic Aquifer is assessed as 542.62 mcm.

Table 4.1 Ground water resources estimated for Aquifer-I (Dynamic & In storage)

#	Block	(Non-Command area) (Sq.Km.)	Annual Extractable Ground Water Recharge of unconfined Aquifer/ Dynamic (mcm)	Existing Gross Ground Water Extraction for irrigation (mcm)	Existing Gross Ground Water Extraction for domestic and industrial water supply	Existing Gross Ground Water Extraction for All uses (5+6) (mcm)	Provision for domestic, and industrial use up to 2025 (mcm)	Net Ground Water Availability for future use (4-5-8) (mcm)	Stage of Ground Water Extraction {(7/4) * 100} (%)	Phreatic Instorage Aquifer Thickness (m)	In storage Ground Water Resources of Unconfined Aquifer (mcm)	Ground Water Resources Aquifer-I (mcm) (4+12)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	**Kanhangad**	245.08	40.59	17.83	11.49	29.32	20.24	2.5	72.25	23	33.82	74.41
2	**Karadka**	262.47	54.90	33.31	7.16	40.47	12.39	9.17	73.71	22	33.72	88.62
3	**Kasaragod**	258.76	45.97	29.55	13.99	43.55	24.32	2.42	94.73	24	36.54	82.51
4	**Manjeshwar**	331.36	57.81	35.72	11.83	47.55	20.55	1.52	82.26	26	51.69	109.95
5	**Nileshwaram**	196.95	32.09	12.91	9.22	22.13	15.97	3.16	68.99	30	35.45	67.54
6	**Parappa**	353.68	60.17	29.86	9.84	39.70	17.08	13.2	65.99	28	59.42	119.59
	TOTAL	**1648.30**	**291.52**	**159.19**	**63.53**	**222.73**	**110.55**	**31.97**	**76.40**		**250.65**	**542.62**

4.2 Groundwater resources in Aquifer-II

Assessment of groundwater resources of Aquifer-II (Fracture Aquifer System) assumes crucial importance since over-exploitation of these aquifers may lead to far more detrimental consequences than that of shallow unconfined aquifers. In view of the small amounts of water released from storage in the semi-confined aquifers, large scale pumpage from semi-confined to confined aquifers may cause decline in piezometric levels over a wide area and large-scale reduction in head over the years may lead to land subsidence. To assess the groundwater resources of the semi-confined aquifers, groundwater storage approach is recommended. Moreover, there is a need of more observation wells tapping exclusively deeper aquifers. The storativity for Aquifer-II (Semi confined to Confined In-storage) of the study area is 0.003 in fracture aquifer system.

It is assumed that groundwater developmental activity has not started from the fracture aquifer system of the study area. 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 of the fracture and associated matrix as about 10% of the storativity/ specific yield of the in-storage zone in Aquifer-1. The water resource in the fracture system thus computed is about 296.69MCM **(Table.4.2**). The Categorization of block is given in **Fig.4.1.**

Table 4.2 In-storage resources estimated for aquifer-II (Kasaragod District)

Sl. No.	Assessment Unit/ Block	Mapped Area in Sq.km.	Aquifer-II (Semi - confined) Thickness (m)	Storativity/ Specific Yield (%)	In storage Ground Water Resources of Semi-confined to Confined Aquifer (mcm)
1	2	3	5	6	7
1	Kanhangad	245.08	60	0.003	44.11
2	Karadka	280.47	60	0.003	47.24
3	Kasaragod	258.76	60	0.003	46.58
4	Manjeshwar	331.36	60	0.003	59.64
5	Nileshwaram	196.95	60	0.003	35.45
6	Parappa	372.38	60	0.003	63.66
	TOTAL	**1661.8**			**296.69**

The total ground water resources of the entire aquifer system (Aquifer-I and II) was estimated to about 839.31 mcm, out of which 542.62 mcm is from Aquifer-I and the remaining 296.69 mcm is accounted in Aquifer-II.

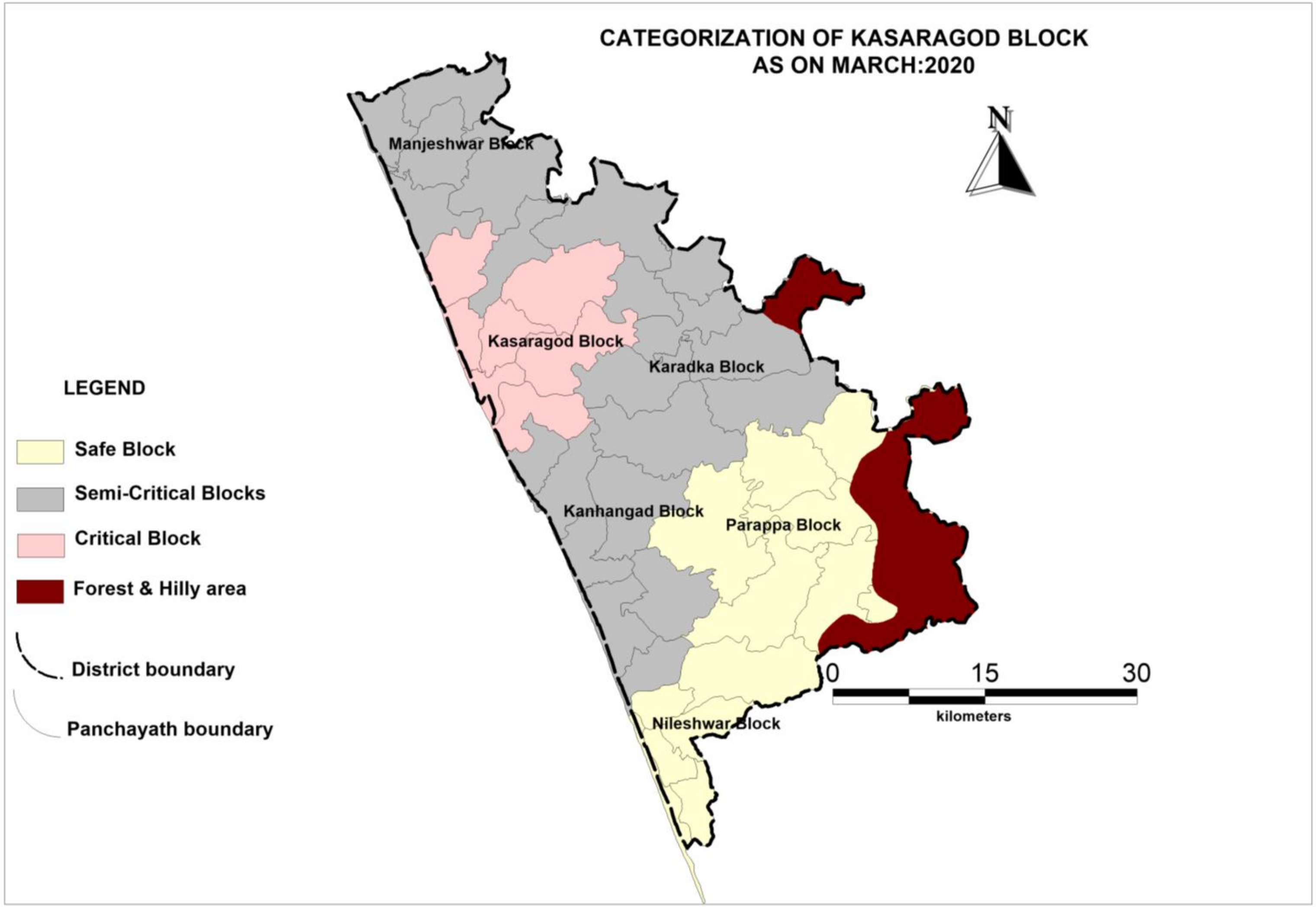

Fig.4.1 Categorization of Block (GEC-2020)

5.0 GROUND WATER RELATED ISSUES

The existing water quality data from the dug wells have been analyzed for extracting information on regional distribution of water quality and their suitability for various uses. In a groundwater flow regime water chemistry constantly undergoes modification due to various processes such as dissolution of minerals, precipitation of dissolved ions under unstable conditions, cation exchange etc. The hydro chemical evolution along the flow paths are significantly altered under anthropogenic interferences and consequent pollution of aquifer systems (Drever, 1982; Langmuir, 1997; Abu-Jabeer, 2001; Singh et al, 2007). The effects of pollution in the flow system can easily be identified from a comparison of dissolved ions and ion ratio studies in simple terms (Hem, 1985).

In the study area groundwater is utilized mostly through dug wells. In midland to high land area bore wells are also common as the dug wells in this area usually dries up during summer. In high land area springs are also a good source for drinking water. Except for iron above the permissible limits specified for drinking in certain locations, the water quality is generally good in the area. In Kasaragod district, although there are no major problems to be highlighted, experience minor issues that can be rectified by adopting site specific management practices.

Acute water scarcity is being faced in the hilly areas where the area is having steep slopes and isolated hillocks in summer period due to drying up of dug wells. Dug wells in midland region get dried up if monsoon is delayed or if there are no summer showers. The increased dependence on bore wells in midland areas leads to drying up of dug wells in lateritic mounds and slopes which affects the water needs of farmers and poor people. The construction of new bore wells by individuals near the existing water supply bore wells badly affecting the yield of many waters supply bore wells. Extensive depletion of aquifer in many panchayaths has been reported across the district. The panchayaths experiencing water scarcity problem are in parts of Karadka, Kuttikole, Balal, Paivalike, Dalampathy, Panarthody, Kallar,Maliyar and Badakha panchayaths. Also observed in certain parts of Manjeshwar taluk, Valiyaparamab, Trikaripur, Peelicode, Padanna, Cheruvathur, Kayyur-Cheemani, Kinanur, Karinthalam, East and West Eleri, Ajannur, Pallikara, Udumma, Pulloor, Periya, Kodambellur, Pananthadi, Madikaii panchayath, Neelashwar and Kanhanagd municipality.

Quarrying for laterite bricks and rocks in parts of eastern and midland area, causes localised ground water issues, like declining of water level and drying up of wells in shallow aquifers due to reduced recharge and discontinuity in groundwater flow resulting from the removal of overburden and drainage through exposed fractures.

The groundwater quality in the area is generally good for all purposes except for certain locations where high iron content and salinity problems are observed. Iron above permissible limit (>1 mg/l) are observed at certain pockets in panchayaths of Karadkha, Puthinge, Badadka and Karindalam. Coastal area is also affected by iron contamination. High salinity is noticed western part of coastal area. Higher Electeruical conductivity values are observed at Chemmanadu, Cheruvathur and Valiyaparamb panchayath. The ground water issues of Kasaragod district is given in **Fig 5.1.**

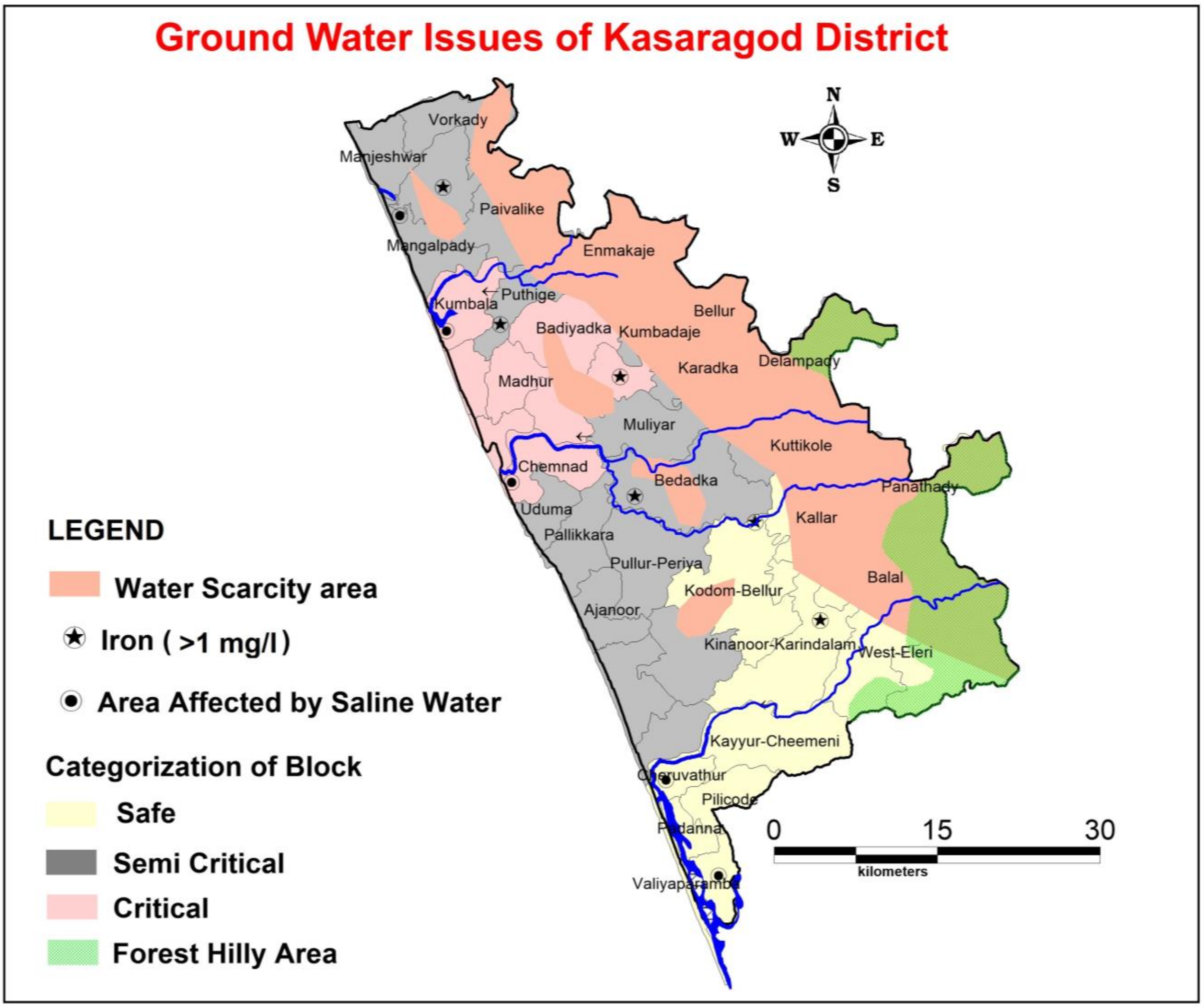

Fig.5.1 Groundwater Isuues of Kasaragod District

Participatory ground water management issues - Lack of scientific understanding of groundwater situation at grassroots level, lack of attention to demand management measures and near-absence of community participation in groundwater management have led to the concept of participatory groundwater management, under which efforts shall be made to train all the stakeholders including the farmers/youths in villages through para-hydrogeologists for sustainable management of water resources.

Periodical maintenance of the existing structures, checking of drinking water quality of wells and checking for leakage from drinking water and septic tank pipelines will ensure safe drinking water. 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 take an effort to sensitize and involve the community to work on the issue.

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, in Kasaragod district, the sustainable management plan for aquifer 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 of above 3000 mm, it has been experiencing increasing incidents of water scarcity in summer for meeting the irrigation as well as domestic requirements. This ironic situation is mainly attributed by natural reasons such as undulating topography with steep slopes and the limited thickness of aquifer material. Subsequently, these factors resulted in high run-off and low recharge. Besides this, the shallow depth to massive bed rock along hill slopes of the area limits groundwater storage in the aquifer system. Hence, development of water resources in this area demands a scientific management system co-ordinating the efforts of all concerned agencies for a swift development in the agricultural sector of the area. While formulating various ground water development and management strategies, geology of the area should be given importance.

6.1 Ground Water Development

Though there are 6 community development blocks in the district since 01.11.2010, the status of ground water development is described below:

The hydrogeological conditions in all the four coastal blocks viz, Manjeshwar, Kasaragod, Kanhangad and Nileshwar of the district are same. The aquifers are alluvium, laterites, weathered crystalline and deep fractured crystalline. The other two blocks-viz, Karadka and Parappa-the major aquifers are laterites and weathered and fractured crystallines. The yield of wells including filter point wells in alluvium ranges from 10 to 50 m^3/day. The dug wells have depth ranging from 3.59 to 6.74 mbgl. The diameters of wells are 1.5 to 2.5 m. Filter point wells with a depth of about 6 metres are constructed along the coastal areas especially along Kasaragod, Kanhangad and Padannakkad areas. The yield of wells in laterite ranges from 5 to 60 m^3/day in monsoon period and it reduces to the range of 2 to 20 m^3/day in summer. The depth ranges of wells are from 4.84 m to 26.85 mbgl. The diameters of wells are 2.0 to 4.0 m. Generally large diameter wells are constructed in laterite terrain. In the weathered crystallines, the yield of wells ranges from 1 to 10 m^3/day in summer period. The depth ranges of wells are 4.35 to 16.46 mbgl and the diameter of wells are 1.5 to 3.0 m. The depth ranges of wells in different formations are given in **Table 6.1(a).**

In the fractured crystalline rocks, the depth of the bore wells constructed ranges from 40 m to around 200 metres. The potential zones are generally encountered between 40 to 75 metres. Below 100 m depth only in limited areas high yielding zones encountered. 200 m deep wells were drilled by CGWB under groundwater exploration programme. The yield of borewell ranges from less than 500 to 72,000 lph. The data from exploratory drilling carried out by CGWB and borewell data from State Departments were analysed. The NE-SW lineaments followed by N-S and E-W lineaments are found to be potential. The borewells in the central and northern parts of the district yields comparatively higher discharges (Annexure 1). In Manjeshwar block, about 52% of the borewells are in the depth range of 70 to 90 mbgl and in Kasaragod block it is about 46%. In Kanhangad and Nileshwar blocks, more than 50% of the wells are in the depth range of less than 70 m. Generally, in the western part of the blocks, the depth of borewells is shallower. In Manjeshwar block the depth of bore wells is comparatively deeper. In Karadka and Parappa blocks, nearly two-third of bore wells are more than 70 m depth. Maximum shallow borewells are seen in Mangalapady, Manjeshwar panchayaths of Manjeshwar blocks, Kumbla Chengala, Chemnad, Mogral- Puthur panchayaths of Kasaragod block, Udma, Ajanur, Pallikkere and Pullur-Periye panchayaths of Kanhangad block. The borewells are generally shallower in valley areas, while deeper in the hillocks, slopes and ridges. The depths of borewells are generally deeper in the eastern parts of the blocks. The depth range of borewells is given in **Table 6.1(b).**

The yields of bore wells are generally up to 5000 lph in nearly 50% of the bore wells. About one -fourth of bore wells yields 5000 to 10000 lph in the district. About 24% of the bore wells yields 5000 to 10000 lph and 16% of the bore wells yields more than 10000 lph in the district. Most of these high yielding wells are utilizing for regional water supply. The high yielding wells are constructed in Bedadka, Chemnad, Mogral-puthur, Kumbla, Badiadka, Manjeshwar, Pullur-Periye, Pallikkere panchayaths. The failure percentage of borewells is generally less than 10%. The discharge range of bore wells block wise is given in **Table 6.1(c).**

Table 6.1 (a): Depth Range of Dug Wells (Formation wise)

Formation	Depth Range			
	<5m	5-10m	10-20m	>20m
Alluvium (24 wells)	18 75%	6 25%	-	-
Laterite (144 wells)	2 1.5%	27 18.5%	111 77%	4 3%
Crystallines (17 wells)	1 6%	14 82%	2 12%	-

Table 6.1 (b): Depth Range of Borewells (Block wise)

Name of Block	*No. of Borewells*	*Depth Range*			
		<50m	50-70m	70-90m	>90m
Manjeshwar	467	50 (10.7%)	102 (21.9%)	242 (51.8%)	73 (15.6%)
Kasaragod	416	81(19.5%)	113 (27.2%)	191 (45.9%)	31(7.4%)
Karadka	304	26 (8.6%)	54 (17.8%)	135 (44.4%)	89 (29.2%)
Kanhangad	292	67 (22.9%	81 (27.7%)	104 (35.6%)	40 (13.8%)
Nileshwar	98	26 (26.5%)	31 (31.7%)	25 (25.5%)	16 (16.3%)
Parappa	224	37 (16.5%)	51 (22.8%)	80 (35.7%)	56 (25%)
Total	**1801**	**287 (15.9%)**	**432 (24%)**	**777 (43.1%)**	**305 (17%)**

In the recent years, due to the fall in water level, the dug wells were deepened in laterites and the crystalline areas. The wells are deepened by 1 to 3 metres. Horizontal bores were constructed in crystalline areas to increase the yield. The lifting devices of water are through centrifugal pumps, jet pumps for dug wells and submersible pumps and compressor for borewells. Water is also being lifted by bucket and rope from dug wells for domestic purposes. The stage of groundwater development in the district as on 2017 was 79.64% leaving some scope for future development. Out of the six blocks in the district, one is critical, three semi critical and two blocks are safe. Future development can be possible in the two safe blocks and limited developments in Manjeshwar, Kanhangad & Karadka blocks (semi critical) and Kasaragod block (critical).

Table 6.1(c): Discharge Range of Bore wells (Block wise)

Name of Block	No. of Borewells	Discharge Range				
		<1000 lph	**1000-5000 lph**	**5000-10000 lph**	**10000-20000 lph**	**>20,000 lph**
Manjeshwar	467	50 10.7%	251 53.7%	103 22.1%	48 10.3%	15 3.2%
Kasaragod	416	40 9.6%	176 42.3%	100 24.0%	76 18.3%	24 5.8%
Karadka	304	30 9.9%	158 52.0%	71 23.3%	36 11.8%	9 3.0%
Kanhangad	292	29 10%	133 45.5%	79 27.1%	39 13.4%	12 4%
Nileshwar	98	10 10.2%	44 45%	24 24.4%	19 19.4%	1 1%
Parappa	224	32 14.3%	126 56.%	51 22.9%	13 5.8%	2 1%
Total	1801	191 10.6%	888 49.3%	428 23.8%	231 12.8%	63

For drinking water needs in the district, Kerala Water Authority (KWA) and Grama Panchayats are empowered with supply of protected water for domestic use. Open wells, borewells and rivers are the principal sources of water supply. The KWA has 496 borewells, 731 dug wells, 135 ponds/tanks for water supply. Kasaragod town is provided with piped water supply from Chandragiri River. The water supply to Kanhangad town is from infiltration galleries made at Kaniyachira Check weir in Kikankote Chal (stream). In addition to this, most of the houses have their own wells to meet the domestic requirements. Recently under sector reforms and swajaldhara-2 schemes of district panchayat, drinking water facilities were provided in 17 gram panchayaths. From the 431 rural water supply schemes of these projects, a total of 133275 persons were benefited. The Jalanidhi schemes for drinking water supply is further extended to 5 more gram panchayats.

6.2 Ground Water Management Strategy

Groundwater in the district is mostly developed through dug wells, dug cum borewells, filter point wells, borewells and tunnel wells mostly for domestic and irrigation purpose.

Most of the households have their own wells to meet the domestic requirements. Along the coastal areas groundwater development for irrigation is through filter point wells and dug wells. In the valley fill areas and laterites, groundwater is developed mostly through dug wells. Recently for irrigation and domestic needs in most of the areas in midlands and in eastern uplands groundwater is developed through borewells.

For the effective GW Resource management, ground water development studies should be coupled with management of rain water harvesting and surface water. The existing water resources and dug wells, ponds, tanks etc should be cleaned and protected. Artificial recharge schemes should be practiced in large scale along with rain water harvesting. The springs seen in the eastern part of the district can be developed.

There should be proper water budgeting in the district. Mass awareness programs should be carried out in panchayat level to make awareness among the people about the importance of conservation and protection of groundwater.

6.3 Sustainable plan

An effective ground water management practice must be preceded by an accurate assessment of the total available resources. Even though there exists scope for resource development, the main limitation in this district is the non-uniform distribution of the groundwater resources because of its typical undulating topography with steep slopes and limited thickness of aquifer. From the ground water resource estimation, out of 6 development blocks, three blocks (Manjeshwar, Karadkha and Kanhanagad) are categorised as semi-critical and Kasaragod as Critical and two blocks are as safe. So, there is limited scope for further ground water development for irrigation in these safe blocks, where the stage of extraction is near to 70%. Also, the usage of groundwater has to be reduced by 20 percent of the existing extraction for the sustainability of the resource in the 3 semi-critical and one critical blocks. Otherwise, the availability has to be augmented through artificial recharge methods to bridge the gap between extraction and availability. The dependence on groundwater can be reduced through application of water efficiency methods in irrigation sector like drip and or sprinkler irrigation especially in the semi-critical blocks to contrive the gap in availability and extraction.

The groundwater abstraction structures feasible in the safe blocks are dug wells in alluvium with depth of 3 to 5 metres and diameter of 1.5 to 2.25 metres. Filter point wells are feasible along the coast where thickness of alluvium is more than 6 metres. In the valley fill areas, the dug wells are feasible with depth range of 4 to 8 metres with a diameter of 2 to 3.0 metres. In the laterite terrain, dug wells are feasible in the valley portion with a depth range of 4 to 10 metres and diameter of 2.0 to 3.5 metres and on hillocks and ridges with a depth range of 10.0 to 23.0 metres and diameter of 2.0 to 3.5 metres. In the crystalline formations, dug wells are feasible with a depth range of 5.0 to 15.0 metres with a diameter of 2.0 to 2.5 metres. Borewells are feasible in favourable locations in crystallines (includes crystallines covered by laterite). The bore wells are generally feasible at a depth of about 40 to 80 metres bgl. The site has to be selected along lineaments, fractures, shear zones etc. For proper site selection for groundwater abstraction structures especially borewells farmers may make use of the technical knowhow of CGWB, GWD etc. There should be a mode for disseminating the technical knowledge through panchayaths. Farmers should also take support of GWD and reliable NGOs for Geophysical surveys for locating borewell sites. Additional groundwater abstraction structures can be recommended in the district with a feasibility study only in the critical and semi critical blocks. Since the data on actual number of groundwater abstraction structures are not available, the actual draft could not be calculated precisely. Indiscriminate construction of borewells in private sector is common in the district for the last ten to fifteen years. The census data on the number of groundwater abstraction structures is a must for computation of actual draft.

6.4 Water Conservation and Artificial Recharge

CGWB has implemented artificial recharge and rainwater harvesting schemes in Kasaragod and are compiled (**Table 6.2**).

Table 6.2 Artificial Recharge and Rainwater Harvesting Schemes

#	Location	Type of Structure	Year
1	Kadappallam	Percolation tank	2001
2	Bangalamkulam	Recharge pond	2001
3	Collectorate Kasargod	Roof top rainwater harvesting and recharge to groundwater	2002
4	Aninjha	Check dam	2003
5	Govinda Pai Memorial Govt. College,	Artificial recharge to ground water (Checkdams, Gabion structure	2010
6	Govt. UP School, Kolathur II	Recharge pond, Ferro cement tank	2010
7	Pallippara	Desiltation of pond	2010

Kadappallam is located on laterite upland. After the development of the percolation tank, it is observed that water level in the dug wells at downstream side of the structure has a risen to about 0.6 metres in summer compared to previous years and earlier dry dug wells also became perennial. At Bangalamkulam there is considerable rise in the water levels observed in the dug wells located in the downstream of the structure. At Aninjha, after the construction of check dam there is considerable rise in water level of dug well on both sides of the stream and upstream side. By construction of different artificial recharge structures at Govinda Pai Memorial Govt. College, Manjeshwar, there is an increase in yield of dug wells in downstream area and also find good changes in the flora of the surrounding areas.

The recharge pond constructed at Govt. UP School, Kolathur II of Bedadaka grama panchayat collects rainwater many times in a season and the recharge of the same is very well observed in the dug wells of the surrounding areas. The desiltation of pond at Pallippara also has shown positive effect in water level. Recently water conservation and artificial recharge works had been taken by the Kasargod district panchayat. Under sector reforms and Swajaldhara-2 schemes, the district panchayat had constructed 2288 rainwater harvesting structures in 17 grama panchayaths having a storage capacity of 266.92 lakhs litres. The schemes were extended in 5 panchayats subsequently. The rainwater harvesting structures became a boon for coastal panchayat Valiyaparamba which is surrounded all the sides by saline water. Groundwater development could be coupled with management of rainwater and surface water. More stress should be given for water shed management. The existing water resources and dug wells, tanks/ponds and streams should be cleaned and protected. Along with rainwater harvesting, artificial recharge schemes should also be practiced in large scale. The hydrogeological set up of the district very well suits for artificial recharge. Using rainwater, bore wells can be recharged especially in the critical and semi critical blocks.

The artificial recharge schemes proposed for all the six blocks are

1. Percolation tank by developing the abandoned laterite quarries
2. Vented cross bar (VCB)
3. Desiltation and deepening of pond/tank
4. Recharge of borewells with recharge pit
5. Recharge pit

The type of AR scheme and their intensity recommended for each block are compiled in **Table 6.3** and shown in **fig 6.1.**

Based on the water level monitoring in different seasons across the district, as well as after having better understanding of the disposition and extent of the aquifer system through exploratory drilling, pumping tests etc., recharge/ conservation structures suiting the area are suggested. It has been proposed to implement additional 26 check dams (CD) and 15 vented cross bars (VCB), 21 percolation ponds (PP) , 45 Desiltation and deepening of tanks, 20 Bore well recharge with recharge pits and 2 sub-surface dykes (SSD) at the identified placed in the district (with limited field check). Site selection for new water conservation/recharge structures should be dealt with utmost caution as the area is highly undulating and susceptible for landslides and other earthflows. Again, Nallah bunds and contour terracing may be attempted at suitable places considering the slope, geology and weathering thickness of the terrain. The expected recharge through these artificial recharge structures is in the order of 8.42 mcm. The details of feasible recharge/conservation structures in the district is given in figure 6.1.

Table 6.3: Artificial Recharge Schemes feasible in various blocks in Kasaragod

#	Name of Block	Proposed Artificial Recharge Structures (Feasible)						Quantum of water Recharged (MCM)
		CD	VCB	PP	NB	SSD	Desilting & Renovation of Pond/Tank	
1	Kanhangad	5	4	4	11	0	10	1.77
2	Karadka	4	5	4	9	1	5	1.11
3	Kasaragod	6	5	4	14	0	10	1.85
4	Manjesharam	5	4	4	16	0	10	1.79
5	Nileshwaram	4	3	3	13	0	5	1.02
6	Parappa	2	1	3	9	1	5	0.88
Total		**26**	**22**	**22**	**72**	**2**	**45**	**8.42**

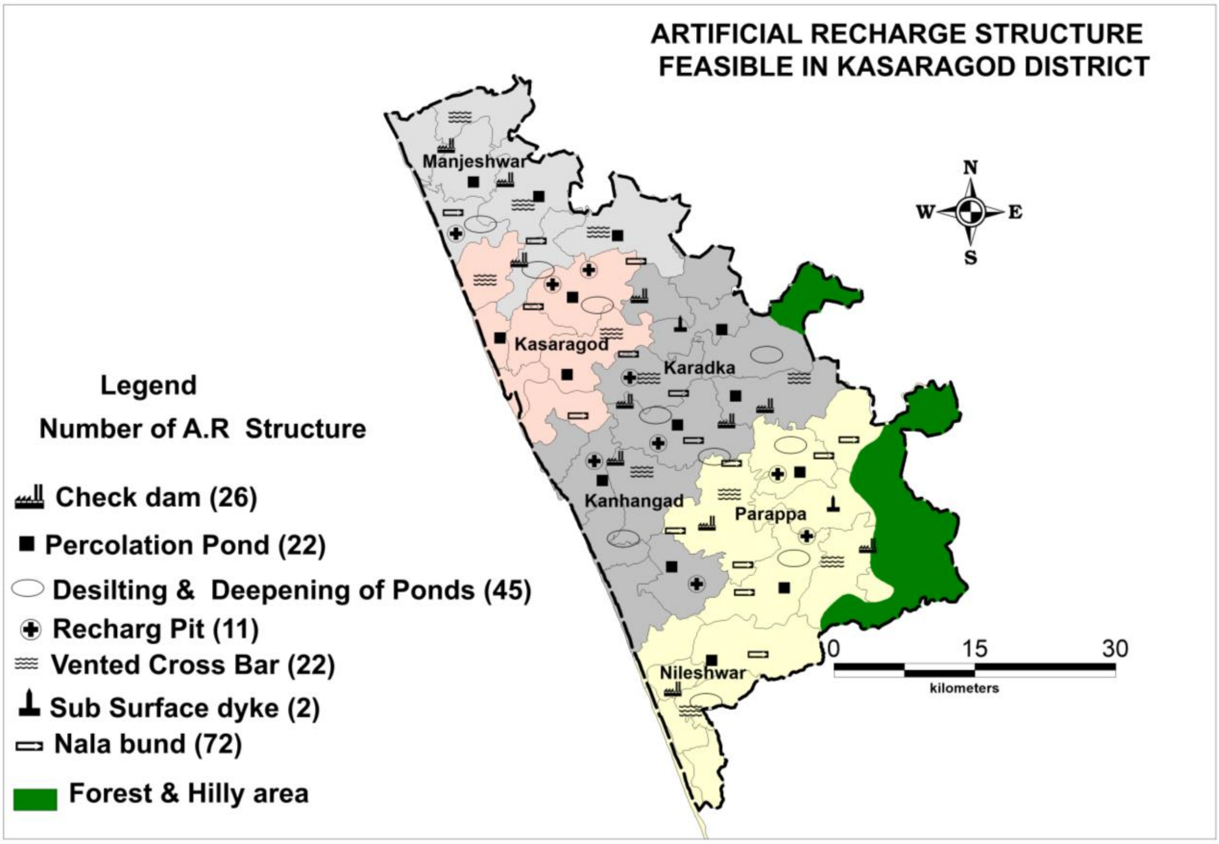

Fig.6.1. Artificial Recharge Schemes feasible in various blocks in Kasaragod

6.5. Demand Side Management

Demand side management can be accomplished through change in irrigation pattern. Farmers may be encouraged to adopt modern irrigation techniques like drip and micro irrigation to have optimal use of the available resources especially in semi-critical and critical blocks. An area of 1230 Ha can be brought for adopting drip/ sprinkler 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 up to 50% and productivity improvement in the range of 30-60% for different crops like coconut, arecanut, banana, vegetables under drip method of irrigation. Block wise details of area proposed under drip and Sprinkler irrigation area given in **table 6.4.**

Table 6.4 Block wise details of drip/Sprinkler irrigation feasible in Kasaragod

S.No	Name of Block	Drip Irrigation (Ha)	Sprinkler irrigation (Ha)	Total Area (Ha)
1	Kanhangad	100	200	300
2	Karadka	75	100	175
3	Kasaragod	60	70	130
4	Manjeshwar	150	250	400
5	Nileshwaram	50	75	125
6	Parappa	25	75	100
	Total	**460**	**770**	**1230**

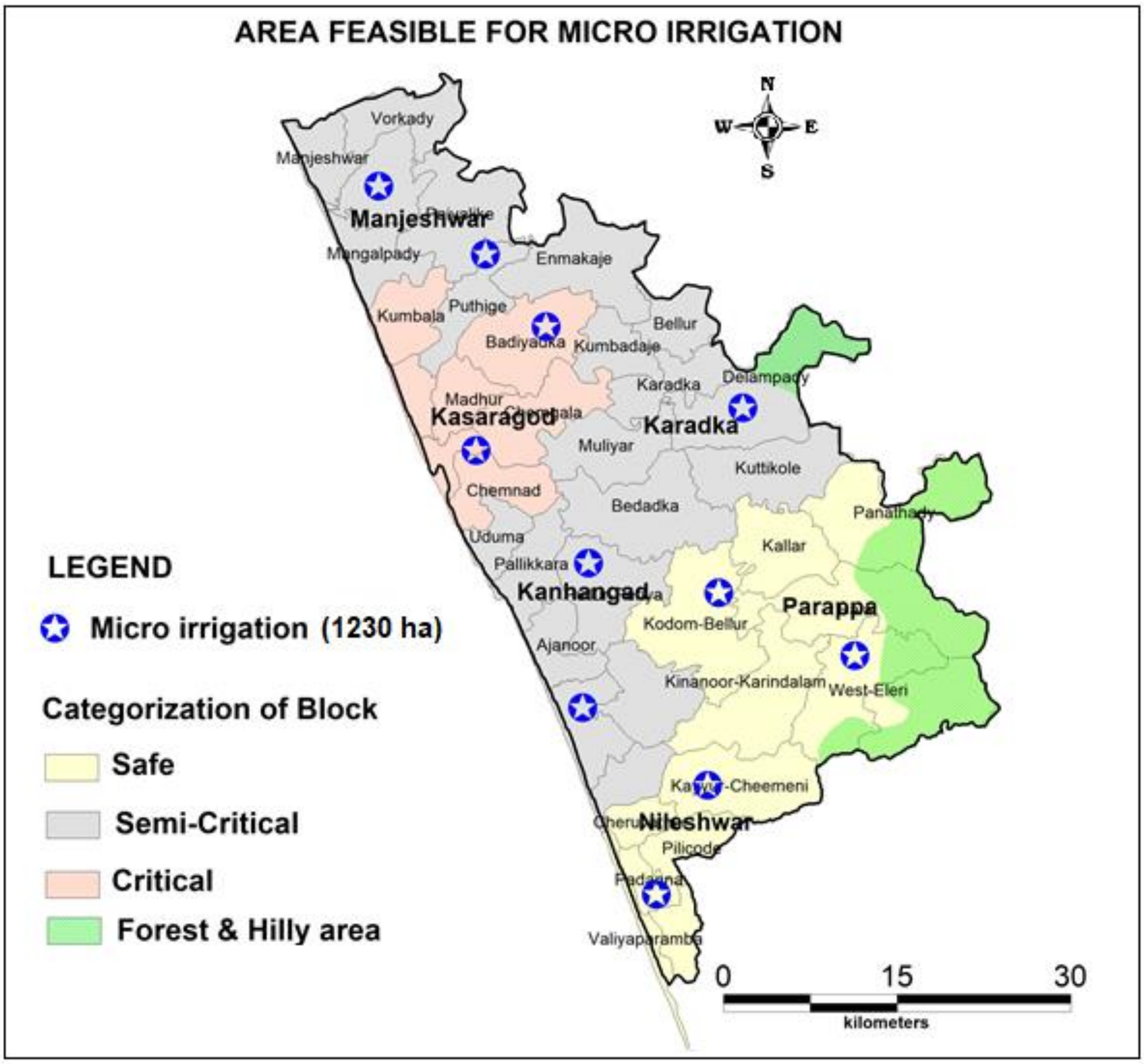

Fig.6.2. Area Feasible for Micro irrigation in various blocks of Kasaragod

6.6. Recommendations

- The stage of groundwater development in the district during 2020 was 76.40% leaving only limited scope for future development.
- The groundwater development in the central and western parts of the district are found to be more. The water level in these areas are showing falling trend in pre-monsoon period but no much change in post monsoon period. Hence future development is possible in Nileshwar, and Parappa blocks which are in safe category and limited groundwater development as per feasibility study in Manjeshwar, Kanhanghad and Karadka blocks. In Kasaragod block, the groundwater development should be restricted.
- The number of groundwater abstraction structures especially private borewells are on increasing trend, proper census of these structures are necessary for further development.
- There is an increasing trend for groundwater development through bore wells in the recent years. The studies indicate that the potential fracture zones are

encountered at shallower depths (40-80 m below ground level) and hence the farmers need not go beyond 100m depth.

- Committees to be formed to ensure the protection of water bodies at the village level by ensuring the participation of the public and farmers.
- Community based RTRWH (Storage) for drinking/domestic purpose is recommended for the High land and coastal areas.
- Groundwater development should be limited with conjunctive use of rainwater and surface water. More stress should be given for watershed management. The existing water resources, dug wells, ponds/tanks and streams should be cleaned and protected.
- Micro level survey is recommended in critical and semi critical blocks to get more realistic picture of groundwater development and to study the scope for future development.
- The springs seen in the hilly areas are to be developed and put to use.
- The use of tunnel well is to be reduced, since it drains large quantity of water from the wells and slopes.
- Priority should be given for small scale/micro water supply projects and proper maintenance of minor irrigation projects and water supply schemes.
- Mass awareness programs should be organized to bring awareness among the people about the importance of water conservation and protection at panchayath levels.
- Artificial recharge schemes should be taken up in large scale along with rainwater harvesting schemes.
- Removal of ‘Fe’ contamination in ground water by aeration and Filtration methods and the filtered water can be used for drinking purpose.

ANNEXURES

Annexure-I: Details of Phreatic water level monitoring stations of Kasaragod District (2021)

Sl.no	Location	Longitude	Latitude	Type of Well	Well depth (m bmp)	Pre-monsoon Water level (m bgl)	Post-monsoon Water level (m bgl)	Water Level Fluctuation(m)
1	Adhuru	75.183	12.552	Dug well	19.65	09.85	06.85	3.00
2	Adkasthala	75.119	12.674	Dug well	13.60	08.60	06.60	2.00
3	Adoor	75.246	12.550	Dug well	14.37	12.45	10.25	2.20
4	Ajannur DW	75.089	12.340	Dug well	14.87	12.40	09.40	3.00
5	Ambalathara	75.133	12.374	Dug well	07.75	06.10	01.80	4.30
6	Anangoor	75.005	12.513	Dug well	17.10	09.50	07.90	1.60
7	Angadimogar	75.014	12.639	Dug well	12.80	10.35	08.45	1.90
8	Arladka	75.109	12.540	Dug well	19.00	16.80	13.80	3.00
9	Badiyadka	75.075	12.584	Dug well	18.18	14.07	11.87	2.20
10	Bandadka	75.269	12.500	Dug well	14.40	11.15	09.65	1.50
11	Bangathadka	75.165	12.563	Dug well	19.50	17.90	14.10	3.80
12	Banputhadka	75.077	12.629	Dug well	11.32	09.20	07.80	1.40
13	Bayar	75.014	12.701	Dug well	14.60	14.40	07.50	6.90
14	Bedadka	75.166	12.461	Dug well	15.30	13.05	11.25	1.80
15	Bedradka	74.974	12.559	Dug well	16.25	13.00	11.20	1.80
16	bedrampalla	75.079	12.646	Dug well	12.00	08.40	03.20	5.20
17	Bekal	75.031	12.400	Dug well	11.40	09.90	07.40	2.50
18	Bethoorpara	75.192	12.498	Dug well	12.60	12.35	09.85	2.50
19	Bhimanady-I	75.287	12.320	Dug well	12.80	06.25	05.35	0.90
20	Bhimanady-II	75.284	12.298	Dug well	07.60	07.90	07.40	0.50
21	Chalingal	75.101	12.383	Dug well	12.12	11.70	08.70	3.00
22	Chamundikkunnu	75.063	12.363	Dug well	14.00	10.90	09.10	1.80
23	Chattanchal	75.058	12.480	Dug well	14.62	14.40	11.00	3.40
24	Cheemeni	75.228	12.236	Dug well	12.80	08.50	04.50	4.00
25	Cherkala	75.050	12.510	Dug well	12.50	11.60	08.10	3.50

Sl.no	Location	Longitude	Latitude	Type of Well	Well depth (m bmp)	Pre-monsoon Water level (m bgl)	Post-monsoon Water level (m bgl)	Water Level Fluctuation(m)
26	Chittarikkal	75.357	12.325	Dug well	11.65	06.40	05.00	1.40
27	Choyankode	75.191	12.287	Dug well	10.30	08.60	01.70	6.90
28	Dharmathadka	75.032	12.663	Dug well	11.00	10.10	08.30	1.80
29	Elambachi	75.182	12.124	Dug well	06.27	05.05	02.35	2.70
30	Iriyanni	75.131	12.496	Dug well	12.84	10.80	09.00	1.80
31	Jodakallu	74.962	12.675	Dug well	14.00	10.90	08.10	2.80
32	Kadambar	74.917	12.716	Dug well	15.00	12.90	11.34	1.56
33	Kadappallam	75.036	12.479	Dug well	15.09	16.60	10.14	6.46
34	Kakkadavu	75.270	12.252	Dug well	15.22	11.70	08.55	3.15
35	Kalathur	74.988	12.621	Dug well	14.50	12.30	10.00	2.30
36	Kalichanadukkam	75.211	12.331	Dug well	07.50	05.55	02.60	2.95
37	Kalikkadavu	75.167	12.192	Dug well	07.70	06.40	03.65	2.75
38	Kanhangad Coast	75.076	12.312	Dug well	08.50	02.90	01.90	1.00
39	Kanhangad Town	75.092	12.313	Dug well	13.50	09.15	06.55	2.60
40	Kaniyala	75.037	12.678	Dug well	08.65	05.80	02.90	2.90
41	Kannadippara	75.171	12.213	Dug well	14.52	12.00	08.10	3.90
42	Karinthalam	75.238	12.288	Dug well	12.65	11.00	07.20	3.80
43	Kasaragod	74.987	12.501	Dug well	11.60	10.00	06.50	3.50
44	Kayyoor	75.189	12.265	Dug well	11.30	07.90	04.30	3.60
45	Kinningar	75.166	12.607	Dug well	09.30	07.25	04.40	2.85
46	Kolichal	75.286	12.445	Dug well	09.50	04.10	02.90	1.20
47	Koliyarpadavu	74.954	12.741	Dug well	16.00	12.00	09.60	2.40
48	Koolom road	75.135	12.293	Dug well	10.95	11.10	04.20	6.90
49	Kottiyadi	75.244	12.575	Dug well	11.60	11.00	08.10	2.90
50	Kovval	75.156	12.228	Dug well	09.20	12.20	05.40	6.80
51	Kudlu	74.968	12.532	Dug well	12.44	09.80	08.30	1.50
52	Kumbadaje	75.118	12.592	Dug well	12.00	11.20	08.20	3.00

Sl.no	Location	Longitude	Latitude	Type of Well	Well depth (m bmp)	Pre-monsoon Water level (m bgl)	Post-monsoon Water level (m bgl)	Water Level Fluctuation(m)
53	Kumbala	74.945	12.590	Dug well	15.23	13.40	09.50	3.90
54	kundamkuzhy	75.140	12.457	Dug well	12.51	07.60	02.40	5.20
55	Kuttikkol	75.210	12.477	Dug well	16.50	15.05	12.25	2.80
56	Madhur	75.001	12.540	Dug well	16.55	15.30	09.30	6.00
57	Mandecappu	74.990	12.653	Dug well	10.06	08.40	06.60	1.80
58	Mangad	75.037	12.458	Dug well	13.00	11.70	07.20	4.50
59	mangalpady	74.922	12.653	Dug well	17.50	12.10	11.10	1.00
60	Manjeswaram	74.886	12.725	Dug well	18.00	14.70	09.20	5.50
61	Mavinakkatta	75.099	12.558	Dug well	26.75	23.00	22.00	1.00
62	Mavungal	75.108	12.339	Dug well	10.10	09.20	02.10	7.10
63	Melparamba	75.008	12.466	Dug well	16.48	15.25	10.20	5.05
64	Miyapadavu	74.952	12.713	Dug well	17.50	13.00	11.50	1.50
65	Mogral	74.951	12.575	Dug well	12.80	11.00	04.80	6.20
66	Mogral-puthur	74.960	12.550	Dug well	13.92	10.50	09.40	1.10
67	Movvar	75.132	12.564	Dug well	20.50	14.95	11.15	3.80
68	Muligadhe	75.019	12.712	Dug well	12.30	10.55	08.35	2.20
69	Muliyar	75.113	12.513	Dug well	09.00	07.00	05.80	1.20
70	Mulleriya	75.165	12.549	Dug well	20.80	17.20	15.80	1.40
71	Munnad	75.190	12.467	Dug well	15.08	13.50	09.90	3.60
72	Naimarmoola	75.023	12.515	Dug well	15.00	09.70	08.30	1.40
73	Nattakkal	75.333	12.374	Dug well	15.10	12.50	11.30	1.20
74	Neeleswaram	75.134	12.247	Dug well	07.95	05.80	03.00	2.80
75	Nellikkatta	75.072	12.545	Dug well	11.22	10.40	06.40	4.00
76	Odayanchal	75.205	12.402	Dug well	05.10	03.55	02.15	1.40
77	Pachambla	74.953	12.656	Dug well	13.00	09.90	07.20	2.70
78	Padiyathadka	75.200	12.562	Dug well	12.00	08.60	07.00	1.60
79	Paivalige	74.984	12.686	Dug well	12.90	09.30	07.90	1.40

Sl.no	Location	Longitude	Latitude	Type of Well	Well depth (m bmp)	Pre-monsoon Water level (m bgl)	Post-monsoon Water level (m bgl)	Water Level Fluctuation(m)
80	Pallam	75.046	12.623	Dug well	12.90	09.70	05.40	4.30
81	Panathur	75.355	12.458	Dug well	13.40	11.25	09.75	1.50
82	Parappa N	75.282	12.571	Dug well	12.70	09.20	07.30	1.90
83	Periya	75.103	12.404	Dug well	16.20	14.60	07.80	6.80
84	Periyattadukkam	75.072	12.429	Dug well	12.52	10.20	04.50	5.70
85	Perla	75.109	12.645	Dug well	16.20	08.10	07.50	0.60
86	Perladakkam	75.096	12.458	Dug well	09.55	06.95	04.60	2.35
87	Poinachi	75.059	12.464	Dug well	16.10	14.10	11.95	2.15
88	Pookkatta	74.961	12.620	Dug well	13.40	16.50	10.00	6.50
89	Povval	75.080	12.510	Dug well	16.70	13.20	11.50	1.70
90	Pullur	75.095	12.355	Dug well	10.50	08.90	06.70	2.20
91	Putheriyadukkam	75.154	12.264	Dug well	12.60	10.75	09.00	1.75
92	Puthige	75.008	12.609	Dug well	19.70	15.25	11.45	3.80
93	Rajapuram	75.246	12.423	Dug well	09.78	06.05	05.05	1.00
94	Ramdas nagar	74.995	12.526	Dug well	16.16	14.50	11.35	3.15
95	Sasthangod	75.127	12.541	Dug well	26.00	24.10	21.40	2.70
96	Sorga	75.140	12.636	Dug well	12.90	08.65	06.65	2.00
97	Thachangad	75.051	12.414	Dug well	12.30	11.40	06.55	4.85
98	Thaniyadi	75.166	12.420	Dug well	08.36	05.40	04.65	0.75
99	Thoyammal	75.107	12.315	Dug well	13.80	12.55	08.80	3.75
100	Thrikkarippur	75.178	12.143	Dug well	05.62	04.10	03.10	1.00
101	Udinur	75.170	12.161	Dug well	04.85	04.55	02.15	2.40
102	Ukkinadka	75.096	12.626	Dug well	10.20	06.60	05.00	1.60
103	Uppala	74.905	12.680	Dug well	18.00	12.50	07.20	5.30
104	Vorkady	74.938	12.747	Dug well	17.00	13.80	11.70	2.10
105	Yethadka	75.125	12.603	Dug well	09.20	05.80	04.60	1.20

Annexure-II: Details of Piezometric water level monitoring stations of Kasaragod District

#	Location	Longitude	Lattitude	Well Type	M.P (m agl)	Premonsoon Water Level (m bgl)	Postmonsoon Water Level (m bgl)
1	Ajannur	75.071	12.328	Tube well	0.80	02.40	01.60
2	Ajannur	75.071	12.328	Tube well	0.65	01.10	00.75
3	Bella	75.094	12.324	Bore well	0.60	13.80	07.80
4	Bovikkanam	75.091	12.506	Bore well	0.80	16.30	11.40
5	Chalingal	75.101	12.383	Bore well	0.60	11.60	05.10
6	Chattanchal	75.058	12.480	Bore well	0.70	15.75	13.30
7	Cherkala	75.053	12.510	Bore well	0.75	14.25	00.05
8	CPCRI	74.962	12.544	Bore well	0.70	09.70	22.75
9	Karinthalam	75.247	12.287	Bore well	0.70	24.80	08.80
10	Kumbala	74.949	12.590	Bore well	0.60	21.00	07.40
11	Kundamkuzhy	75.141	12.456	Bore well	0.70	11.70	06.30
12	Kuniya	75.082	12.421	Bore well	0.60	13.80	04.05
13	Madhur	75.001	12.540	Bore well	0.70	09.40	04.30
14	Mangad	75.037	12.458	Bore well	0.60	17.60	04.05
15	Manjeswaram	74.886	12.725	Bore well	0.75	11.05	08.25
16	Melparamba	75.008	12.466	Bore well	0.75	16.35	10.35
17	Mylatti	75.059	12.450	Bore well	0.60	09.50	02.15
18	Nellikkatta	75.072	12.545	Bore well	0.60	19.40	11.80
19	Pallikkare	75.043	12.389	Bore well	0.70	08.20	05.98
20	periya	75.102	12.404	Bore well	0.70	11.95	06.15
21	Seethangoli	75.000	12.588	Bore well	0.90	08.20	06.90
22	Vidyanagar	75.017	12.520	Bore well	0.60	10.30	18.40

Annexure III: Chemical Quality data of Phreatic Aquifer, Kasaragod district

#	Location	pH	EC in µs/cm at 25^{0}C	TH as $CaCO_3$	Ca*	Mg*	Na*	K*	CO_3*	HCO_3*	SO_4*	Cl*	NO_3*	F*
1	Kakkakadavu	6.6	101	32.2	11.6	0.78	3.16	0.77	0	38.5	7.2	3.6	3.49	0.0
2	Nattukkal	6.71	101	31.0	6.7	3.48	3.57	0.48	0	38.5	0.9	4.1	1.8	0.02
3	Mavinakatta	6.77	91	29.6	8.6	1.97	4.26	0.81	0	43.6	0.46	3.05	1.23	0.03
4	Mavungal	6.64	56	15.8	4.50	1.11	3.43	0.56	0	12.8	0.5	3.8	1.78	0.0
5	Ambalathara	6.68	126	32.1	8.2	2.81	5.97	0.71	0	28.2	2.39	10.4	1	0.013
6	Badiyadka	6.69	136	42.4	15.5	0.90	2.78	0.67	0	53.9	7.45	3.11	1.04	0.06
7	Kumbadije	7.04	130	35.7	9.6	2.87	7.17	1.06	0	48.7	2.37	6.0	2	0.03
8	Movar	7.06	67	23.8	7.6	1.21	2.5	0.51	0	25.7	0.64	2.05	0.47	0.01
9	Kalikadavu	6.91	66	13.1	3.8	0.9	4.3	0.6	0	10.3	0.8	6.2	0.81	0.0
10	Muliguddhe	6.69	69	13.8	3.6	1.19	3.4	0.81	0	7.7	0.56	4.7	5.39	0.14
11	Chamundikunnu	6.74	100	21.0	5.4	1.86	6.3	0.61	0	20.5	1.1	7.9	1.17	0.004
12	Kudulu	6.34	103	14.7	3.4	1.50	7.03	1.46	0	5.1	2.4	11.9	4.6	0.0
13	Kayoor	6.41	34	7.9	2.4	0.46	2	0.43	0	7.7	0.65	2.4	2.2	0.0
14	Kadambar	6.32	60	20.7	6.5	1.10	2.2	0.89	0	22.8	1.56	2.4	0.63	0.05
15	Bovikanam	6.64	220	45.8	15.4	1.80	8.58	2.6	0	57.0	2.1	14.50	1.3	0.05
16	Bandiyod	7.47	250	51.3	12.5	4.90	19.6	1.91	0	127.0	1.2	8.67	0.09	0.1
17	Mogral Puthur	7.34	120	24.8	6.2	2.30	5.58	1.27	0	12.8	8.8	8.02	2.83	0.02
18	Morthana	7.03	140	35.5	12.4	1.10	4.4	1.12	0	25.7	3.78	5.64	9.03	0.01
19	Thalipadapu	7.02	85	17.1	4.0	1.73	5.65	0.34	0	7.7	4.58	6.24	5.7	0.01
20	Bela	6.87	67	24.1	8.06	0.96	2.6	0.5	0	23.1	1.75	3.16	1.91	0
21	Mogral	6.89	158	16.7	2.81	2.36	11.56	0.45	0	5.19	2.14	17.97	3.87	0
22	Bayar	6.71	67	18.7	6.3	0.729	1.9	1.03	0	10.3	2.9	2.39	5.54	0.02
23	Mangalpady	6.73	98	19.4	5.9	1.13	4.88	0.73	0	15.4	0.83	6.8	2.58	0
24	Arrikkad	6.49	680	223.9	51	23.5	750	4.38	0	31.7	50.1	154.7	1.6	0.03
26	Seethamgoli	8.05	460	159.8	32.9	18.9	77.9	4.2	0	31.7	17.23	505	17.23	0.03
27	Ramdasnagar	8.16	107	23.0	5.1	2.5	7.9	0.9	0	18	1.1	9.4	5.2	0.02

#	Location	pH	EC in µs/cm at 25^0C	TH as $CaCO_3$	Ca*	Mg*	Na*	K*	CO_3*	HCO_3*	SO_4*	Cl*	NO_3*	F*
28	Kalathur	8.17	100	37.9	14.2	0.6	1.78	0.53	0	46.2	2.4	1.94	1.24	0.03
29	Bekur	8.10	108	14.8	4.1	1.1	9.03	0.5	0	12.8	0.53	8.66	6.74	0
30	Vorkady	7.70	93	32.1	12.2	0.4	2.26	0.4	0	41.1	0.79	2.47	1.34	0.02
31	Ukinada	5.62	42	5.5	1.2	0.6	6	0.46	0	7.7	0.66	6.7	0	0
32	Jodikkallu	6.64	151	50.7	8.3	7.3	12.41	1.17	0	51.4	2.87	13.78	6.9	0.4
33	Kadapalam	6.95	109	48.7	9.8	5.9	6.23	1.52	0	51.4	3.7	3.78	1.02	0.07
34	Cherkala	7.00	119	50.7	10.1	6.2	7.15	2.18	0	56.4	2.82	4.84	2.56	0.1
35	Thachangad	7.00	103	20.8	3.4	3.00	10.64	1.68	0	25.7	2.32	12.7	3.71	0.03
36	Mulliyar	7.15	99	13.3	3.2	1.3	13.18	1.83	0	18	2.63	12.05	9.01	0.03
37	Arladaka	7.27	95	58.6	19.2	2.59	3.34		0	59.1	2.34	4.46	1.52	0.02
38	Sathangod	7.38	42	12.7	3.6	0.9	3.2	0.44	0	10.3	1.41	3.62	3.6	0.02
39	Cheemeni	7.38	38	8.1	1.6	1.00	4.47	0.68	0	5.14	0.3	5.4	4.78	0
40	Chattachal	7.09	100	39.4	10.5	3.2	1.2	3	0	12.04	2.04	8.41	21.64	0.02
41	Kanchangad coast	7.27	230	105.5	36.2	3.68	11.36	1.26	0	97.5	6.27	15.61	0.09	0.03
42	Elambachi	7.4	160	61.6	22.4	1.39	13.04	0.73	0	51.36	2.58	14.81	11.7	0.02

*All parameter values are in mg/l

Annexure IV: Exploratory well details of Kasaragod district

#	Location	Year of construction	Co ordi-nates	Lineament Direction	Depth drilled	Depth of casing mbgl	Fracture zones	Discharge lpm	SWL mbgl	T m²/day	EC µs/cm at 25⁰C	Cl ppm	Rock type
1	Vidyanagar	1982-83	12.5167 75.0028	EW	68.00	6.15	17-18,68-69	378	4.85	14.03	110	14	Garnetifuous Garnite Gneiss
2	Yednir	1982-83	12.5222 75.0736	NW-SE	88.00	4.85	6.55, 19.00, 29.00	52	5.11	4.584	185	14	Charnockite
3	Santipalla	1982-83	12.5875 74.9625	N-S	50.50	5.71	13.5-13.8, 13.8-50.5	600	3.20	98.23	135	14	Charnockite
4	Sitamguli	1982-83	12.5903 75.0069	E-W	63.00	3.95	3, 4-5, 15-16, 30, 63	261	2.29	13.752	1100	298	Charnockites Calc-G
5	Karambila	1982-83	12.6000 75.0708	NW-SE	94.00	4.83	5.5, 30, 44.7, 53.5, 69.15	72	5.33	1.31	120	14	Charnockite
6	Pallathadka	1982-83	12.6125 75.0806	NW-SE	69.00	NA	32-33.6, 36.1	375	7.90	13.4	340	14	Charnockite
7	Ichlangodu	1982-83	12.6444 74.9403	N-S	81.50	4.14	13.5, 22-24, 32-33, 36-37, 68-69	88	4.29	9.024	80	21	Granite Gneiss
8	Kokkechal	1982-83	12.6556 74.9833	N-S	73.00	4.13	6-7, 13-14, 69-70, 73	76	4.13	0.86	NA	NA	Charnockite
9	Kundalmarkala	1982-83	12.6583 75.0139	N-S	78.50	5.88	4-5, 21-22, 56-57, 61-62, 70-71, 75-76	200	5.80	12.38	58	14	Gneiss with Pegmitite veins & bands of Dolerite dyke
10	Kubanuru	1982-83	12.6694 74.9500	NW-SE	87.60	9.20	13-14, 16-17, 34, 38.9, 51-52	50	9.70	3.58	51	14	Pyroxene Granulite
11	Paivalike	1982-83	12.6847 74.9861	N-S	81.50	4.37	27.5, 69.5	66	4.57	3.438	110	18	Garnite Gneiss

#	Location	Year of construction	Co ordi-nates	Lineament Direction	Depth drilled	Depth of casing mbgl	Fracture zones	Discharge lpm	SWL mbgl	T m²/day	EC µs/cm at 25⁰C	Cl ppm	Rock type
12	Kadambaru	1982-83	12.7167 74.9306	NW-SE	72.00	5.45	8, 34-35, 35-36, 60-61, 66-67, 68-69	102	4.12	8.778	120	11	Horneblende Biotite Gneiss
13	Kodlamogar	1982-83	12.7500 74.9750	N-S	63.00	2.14	4.5, 8-9, 14-15, 35-36	30	2.60	1.528	NA	NA	Charnockite Gneiss
14	Langanaduka	2002-03	12.6583 74.9917	E-W	200.00	20.50	21.5-28.0, 108.0-110.0 148.0-150.0	30	8.32		199	5.7	Granite Gneiss
15	Hosangadi	2002-03	12.7042 74.9028	NE-SW	62.30	30.20	53 - 55	180		2.38		349	Hornblende Gneiss
16	Gerukatte	2002-03	12.7436 74.9033	NE-SW	120.20	11.60	61-62 86-88	660	10.79	43.51	261	5.7	Syenite
17	Kunjathur	2002-03	12.7483 74.8842	NE-SW	122.50	11.20	11-14 88-89 105-108 122-122.5	600	11.07	161.4	312	9.9	Hornblende Gneiss
18	Mayippadi	2002-03	12.5625 74.9964	NE-SW	200.00	11.25	10.0-14.0	30	1.35	0.65	231	7.1	Hornblende Gneiss
19	Chemmattam-vayal	2004-05	12.3203 75.1069		199.5	13.4	53.10-54.10	30	5.87		423	9.9	Charnockite
20	Periye	2004-05	12.4103 75.0906		200.4	23.6	27.70-28.70 76.50-77.50 113.0-114.0	90	11.5	2.96	154	5.7	Charnockite
21	Kalliot	2004-05	12.4083 75.1500		112.5	21.0	24.60-25.60 64.20-65.20 70.30-71.30 111-112.50	510	4.25	15.82	169	5.7	Granite Gneiss
22	Chirapuram	2004-05	12.2708 75.1417		200	31.7	37.0-38.0 128.0-129.0 198.0-199.0	120	3.93	9.8	167	4.2	Granite Gneiss

#	Location	Year of construction	Co ordi-nates	Lineament Direction	Depth drilled	Depth of casing mbgl	Fracture zones	Discharge lpm	SWL mbgl	T m²/day	EC µs/cm at 25⁰C	Cl ppm	Rock type
23	Chamakuzhy (Koovatty)	2004-05	12.3039 75.2044		72.3	28.5	38.30-39.80 54.0-55.0 60.10-61.10	420	36.05	60.0	268	7.1	Hornblende Biotite Gneiss
24	Kayyur	2004-05	12.2661 75.1933		200	22.9	25.60-28.60	120	10.3	7.9	184	4.3	Charnockite
25	Cheemeni	2004-05	12.2347 75.2319		98	20.4	28.60-29.60 40.8-41.8	660	5.8	27.0	242	5.7	Charnockite
26	Chandera	2004-05	12.1806 75.1722		200	31.7	34.7-35.7	96	9.25	6.66	268	11	Charnockite
27	Pilicode	2004-05	12.2014 75.1667		135	38.2	41.2-42.2 126.2-127.0 132.3-1333.3	420	19.35		232	8.5	Charnockite & Granitic Gneiss
28	Karicherri	2004-05	12.4583 75.0750		86.6	18.4	23.0-23.5 43.5-44.0 48.5-49.0	600	16		204	4.3	Charnockite
29	Kasaragod	2004-05	12.5194 75.0133		90	23.3	34.7-35.7 40.8-41.50	555	12.3		179	5.7	Quartzo Feldspathic Gneiss
30	Kumbadaje	2012-13	12.5710 75.1113		101	34.0	34.00-38.00	30	17.1	6.38	160		Hornblende Granulite
31	CPCRI Kasaragod	2012-13	12.5447 74.9619		101	10	45.00-46.00 90.00-92.00	180	10.15	16.57	960		Hornblende Granulite
32	Karadka	2012-13	12.5378 75.1467		101	29.4	30.00-31.00	30 30	12.5	4.33			Hornblende Granulite
33	Nellikatte	2012-13	12.5450 75.0722		100	19.0	28.00-29.00 98.00-99.00	240	13.2	12.34	220		Hornblende Biotite Gneiss
34	Vidhyagiri	2012-13	12.5935 75.0155		61	38.0	54.00-55.00	30	19.9				Quartzo Felspathic Gneiss

#	Location	Year of construction	Co ordi-nates	Lineament Direction	Depth drilled	Depth of casing mbgl	Fracture zones	Discharge lpm	SWL mbgl	T m²/day	EC µs/cm at 25⁰C	Cl ppm	Rock type
35	Perla	2012-13	12.6439 75.1061		58	22.0	30.00-31.00 56.00-58.00	60	18.15	10.42	280		Hornblende Biotite Gneiss
36	Bayar	2012-13	12.7012 75.0155		85	35.0	55.00-56.00 80.00-81.00	174	43.07	18.98	130	5.7	Hornblende Biotite Gneiss
37	Angadimogar	2012-13	12.6274 75.0236		100	12.0	16.00-17.00 72.00-74.00	12	41.6		190		Syenites