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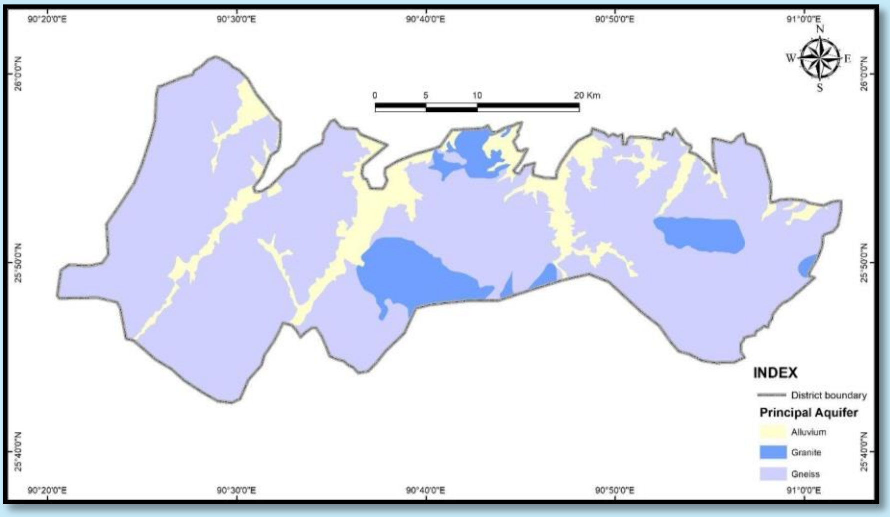
MINISTRY OF JAL SHAKTI
जल शक्ति मंत्रालय
DEPARTMENT OF WATER RESOURCES, RD & GR
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
CENTRAL GROUND WATER BOARD
केंद्रीय भूमि जल बोर्ड

AQUIFER MAPPING AND MANAGEMENT PLAN OF NORTH GARO HILLS DISTRICT, MEGHALAYA

ANNUAL ACTION PLAN, 2019-20



NORTH EASTERN REGION
उत्तरपूर्वी क्षेत्र
GUWAHATI
गुवाहाटी

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GOVERNMENT OF INDIA

MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

REPORT ON

"AQUIFER MAPPING AND MANAGEMENT PLAN OF NORTH GARO HILLS DISTRICT, MEGHALAYA"

(AAP 2019-20)

By
Shri Shasinlo Kent
Junior Hydrogeologist (Scientist-B)

Under the supervision of
Shri Tapan Chakraborty
Officer In Charge, SUO, Shillong &
Nodal Officer of NAQUIM, NER

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ABBREVIATION

AAP	Annual Action Plan
CGWB	Central Ground Water Board
NER	North Eastern Region
NAQUIM	National Aquifer Mapping and Management Plan
GL	Ground Level
GSI	Geological Survey of India
IMD	Indian Meteorological Department
LPM	Litres per minute
LPS	Litres per second
m	metre
mbgl	meters below ground level
MCM	Million Cubic Meter
Mm	Milli meter
mg/l	milligram/litre
m amsl	Metre above mean sea level
Sq.Km	Square Kilometre
µS/cm	Microsimens/centimetre
AMP	Aquifer Management Plan
AQM	Aquifer Mapping
BIS	Bureau of Indian Standards
BDL	Below detectable level
BCM	Billion Cubic Metres
DGM	Directorate of Geology and Mining
DTW	Depth to water table
DW	Dug Well
BW	Bore well
EC	Electrical Conductivity
EW	Exploratory Well
GEC	Ground water Estimation Committee
Ha	Hectare
Ham	Hectare meter
Km	Kilometer
MP	Measuring Point
OW	Observation Well
°C	Degree Celsius
Ppm	Parts per million equivalents to mg/l
Pz	Piezometer
SWL	Static water level
TDS	Total dissolved solid

EXECUTIVE SUMMARY

Aquifer Mapping Studies and Management Plan has been carried out in North Garo Hills district, Meghalaya under National Aquifer Mapping and Management Plan (NAQUIM) program with an objective to know the different aquifer system prevailing in the study area, to decipher the vertical and lateral extend of the aquifer down to the depth of 200 m, its characteristic, quantity as well as quality so as to bring a complete sustainable and effective aquifer management plan for ground water resources development in the study area.These studies has been done through multi-disciplinary approach so as to achieve the said objectives.

The total coverage area of aquifer mapping and management plan is 505 sq.km out of 1160 sq.km of the district and is underlain by alluvium and consolidated rocks of Granite and Gneiss.

Occurrence of ground water in the study area is mainly of weathered and fractured Granite and Gneiss and unconsolidated alluvium. The different hydrogeological data are generated through intensive field data collection and testing. The aquifers present in the district can be divided into a two aquifer system viz., first aquifer (shallow) and second aquifer (deeper).Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells as hand pump. The second aquifer is the deeper aquifer which tapped the fractured zone. Based on the study of litholog and analysis of depth of construction of dug wells and shallow bore wells, it is found that the first aquifer occur within 2 to 30 m bgl. Ground water in the second aquifer occurs under semi-confined condition in the fractures zone upto the maximum depth of 184.1 m bgl.

Ground water exploration has been carried out in different parts of the district to delineate the potential aquifers and their geometry and to determine the hydrogeological parameters of the aquifer systems. To know the different parameters of an aquifer, preliminary yield test were carried out during the course of study. Soil infiltration test was also conducted in different parts of the study area to know the infiltration rates at different soil conditions, topography, geology and environment and also to know its suitability and the amount of water recharging in the area and its rainfall infiltration factor.

Study of water level trend and its behavior both in phreatic and confined condition were carried out in the aquifer mapping area. Study of spring was also carried out in the study area.

In order to study the chemical quality of ground water in the district, water samples from first aquifer (dug wells and springs) and second aquifer (CGWB Bore well) were collected during the course of field work. The samples were analyzed and was found that all the elements are within permissible limit.

Dynamic Groundwater Resources of the study area has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). The net ground water availability was 14250.10 ham and the stage of ground water extraction was 0.52 % which comes under safe category.

Finally, the aquifer map of the study area is generated based on the inputs from geological, hydrogeological and hydrochemical studies and a management plan was made with an emphasis in providing irrigation facilities through ground water development as agriculture is the main means of livelihood of the people living in the district.

1. INTRODUCTION

Central Ground Water Board, North Eastern Region has carried out Aquifer mapping and management plan in North Garo Hills district, Meghalaya during AAP 2019-20 covering an entire area of 505 sq.km (total district area is 1160 sq.km). Under National Aquifer Mapping and Management (NAQUIM) program, combination of geologic, hydrologic and hydrochemical information is applied to characterize the quantity, quality and sustainability of ground water aquifers. Systematic aquifer mapping will improve our understanding of the geologic framework of aquifers, their hydrogeologic characteristics, quality and also quantifying the available ground water resources potential and proposing plans appropriate to the scale of demand and the institutional arrangements for management. Aquifer mapping at the appropriate scale can help to prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of our precious ground water resources, which, in turn, will help achieve drinking water security, improved irrigation facilities and sustainability in water resources development.

1.1 Objectives

The objectives of this project are to understand the aquifer systems up to 200 m depth, to define the aquifer geometry, type of aquifers, ground water regime behaviors, hydraulic characteristics and to establish groundwater quantity, quality, and sustainability, and to estimate the dynamic and static resources accurately through a multidisciplinary scientific approach on 1:50,000 scale and finally formulate a complete, sustainable and effective management plan for ground water development.

1.2 Scope of the Study: The activities of this Aquifer Mapping and management plan can be envisaged as follows:

1.2.1 Data Compilation & Data Gap Analysis: One of the important aspect of aquifer mapping program was the synthesis of the large volume of data already collected during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe an aquifer system. The data were assembled, analyzed, examined, synthesized and interpreted from available sources. These sources were predominantly non computerized data, which was converted into computer based GIS data sets. On the basis of available data, data gaps were identified.

1.2.2 Data Generation: There was also a strong need for generating additional data to fill the data gaps to achieve the task of aquifer mapping. This was achieved by multiple activities such as exploratory drilling, hydro-geochemical analysis, remote sensing, besides detailed hydrogeological surveys to delineate multi aquifer system; to bring out the efficacy of various geophysical techniques and a protocol for use of geophysical techniques for aquifer mapping in different hydrogeological environs.

1.2.3 Aquifer Map Preparation: On the basis of integration of data generated from various studies of hydrogeology, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical) in reference to aquifer extremities, quality, water level, potential and vulnerability (quality & quantity).

1.2.4. Aquifer Management Plan Formulation: Aquifer Maps and ground water regime scenario are being utilized to identify a suitable strategy for sustainable development of the aquifer in the area.

1.3 Approach and Methodology: Aquifer mapping has been carried out by adopting a multi-disciplinary approach:

(i) Geophysical Surveys through Vertical Electrical Sounding (VES)

(ii) Exploratory drilling and construction of bore wells tapping various groups of aquifers

(iii) Ground Water Regime monitoring by establishing monitoring wells tapping different aquifers at different depths for long term monitoring of water level and quality

(iv) Pumping test of bore wells, soil infiltration test for determination of ground water recharge scope, intensity and potentials and also to determine the characteristics and performances of existing aquifers at various depths.

(v) Collection of various relevant technical data from the field in aquifer mapping area and also from the concerned State Govt. Agencies and other Institutes dealing with ground water and incorporating these data along with CGWB data for final output.

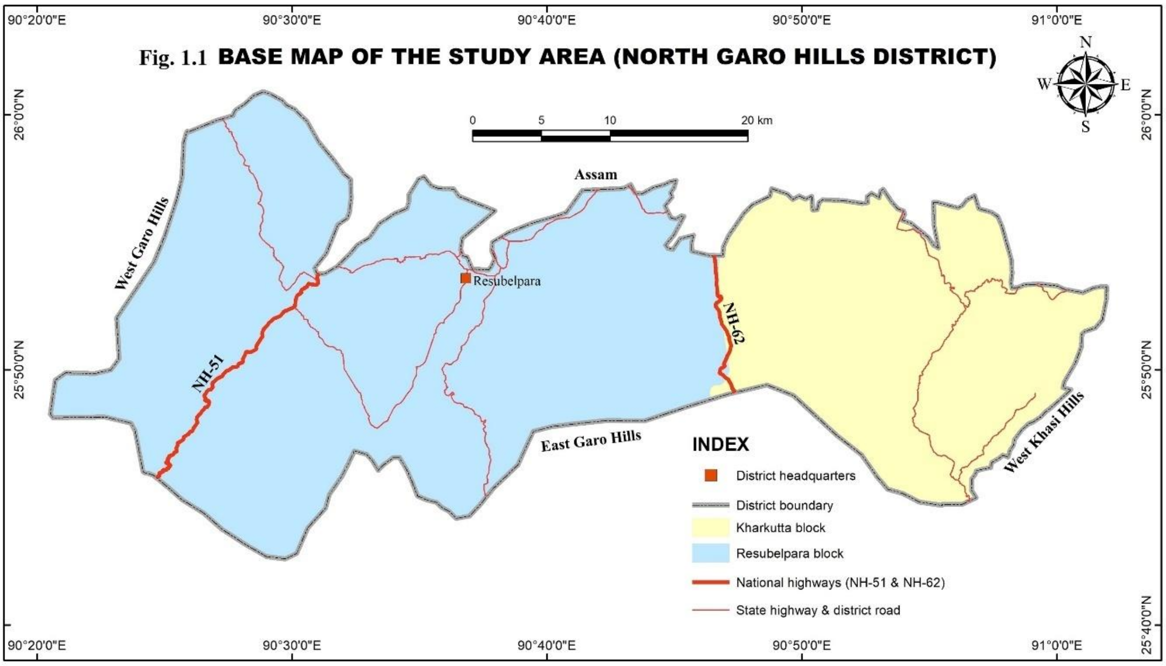
(vi) Preparations of a micro level mapping of existing aquifers, their potentials depth wise and sideways in 2D and 3D forms viewed from different angles by various GIS Layers.

(vii) Formulating a complete sustainable aquifer management plan for ground water development.

1.4 Area details: North Garo Hills district lies between E 90˚20’00” to E 91˚02’00” Longitude and N 25˚42’00” to N 26˚01’00” Latitude. The district is having an area of 1160 sq.km. Out of this, 505 sq.km of mapable area was covered under NAQUIM program. The district has three C &RD blocks viz. Resubelpara C & R.D. block, Kharkutta C & R.D. block and Bajengdoba C & R.D. block.

This area falls partly or fully in the quadrants of Survey of India Toposheets bearing nos. 78 J/8, 78 K/5, 78 K/6, 78 K/9, 78 K/13 and 78 O/1 and is bounded by West Khasi Hills district in the East, East Garo Hills district in the south, West Garo Hills district in the West and Assam in the North. The base map of the study area is shown in fig.1.1.

Fig. 1.1 BASE MAP OF THE STUDY AREA (NORTH GARO HILLS DISTRICT)



1.5 Data availability, data adequacy and data gap analysis:

Aquifer mapping and management plan is carried out through collaborative of different data. The required data on various attributes of the study are collected from the available literatures of Central Ground Water Board, State Water Resources Department of Meghalaya and various Central and State Government agencies. The Data Requirement, Data Availability and Data Gap Analysis are presented in Fig1.2,table 1.1 and annexure 8.

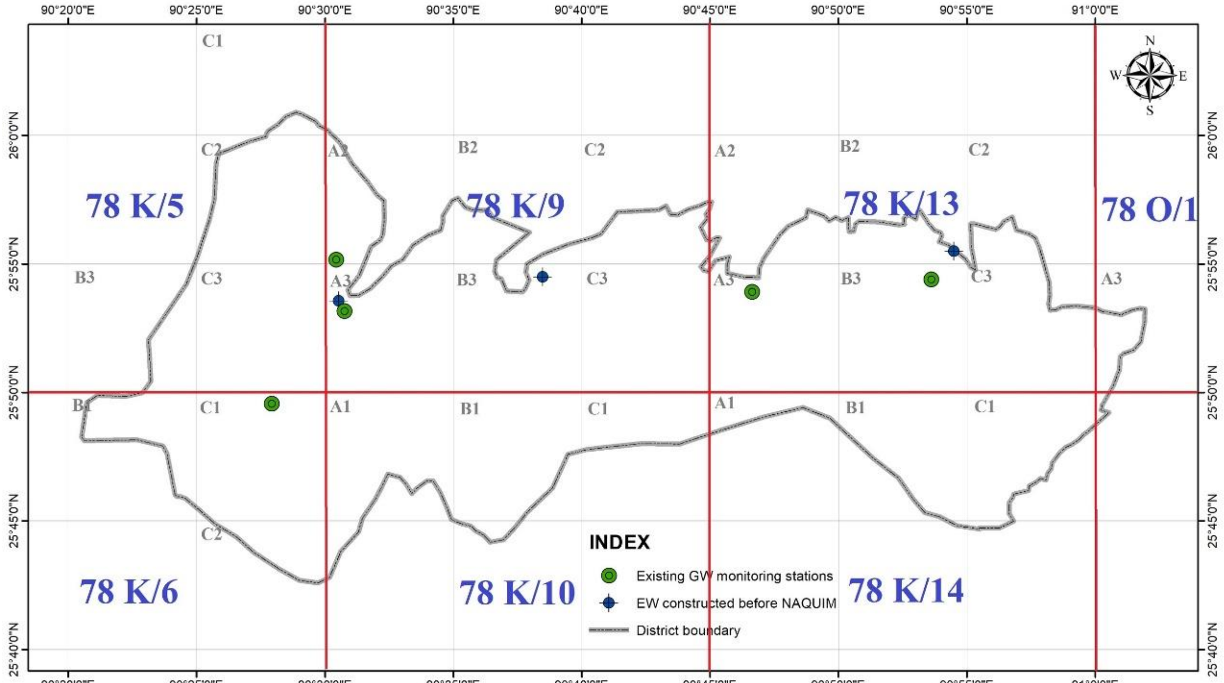


Fig. 1.2 Data gap map of North Garo Hills district

Table1.1 Data Availability and Data Gap Analysis in Aquifer Mapping Studies

Sl. No.	Items	Data Requirement	Data Availability	Data Gap
1	Ground Water Exploration Data	Both first aquifer and second aquifer	2 EW	I Aquifer : 13 nos. of EW &14 nos. of OW. II Aquifer : 12nos.of EW and 13 nos. of OW.
2	Geophysics	Geophysical data of the Study area	Nil	52 nos.
3	Ground Water Monitoring Regime	Representative Monitoring Wells well distributed over the Study Area for both first and second aquifers.	5 Monitoring Well (DW)	I Aquifer : 21 nos. II Aquifer :13 nos.
4	Ground Water Quality	Representative well distributed Monitoring Wells over the study area for both first and second aquifers.	Water quality data of 5 monitoring well	I Aquifer : 21 nos. II Aquifer : 13 nos.
5	Specific yield	Both aquifers	Nil	Entire study area
6	Climate	Season-wise Rainfall pattern	Nil	Monthly rainfall data for the past 10 years.
7	Soil	Soil map and Soil Infiltration Rate	Soil map	Soil Infiltration studies covering the entire study area
8	Land use	Latest Land Use pattern	Latest Land Use pattern	NA
9	Geomorphology	Detailed Information on Geomorphology of the area	District level information	NA
10	Recharge Parameters	Recharge parameters for different soil and aquifer types based on field studies	Recharge parameters given in Ground Water Resources Estimation	Entire study area

1.6 Demography: As per official web portal of Government of Meghalaya, North Garo Hills district has a population of 118325.

1.7 Communication: North Garo Hills district is well connected with two National Highways (NH-51 & NH-62) of the neighboring state Assam and lone railway station of Meghalaya which is also located at Mendipathar in North Garo Hills district. The headquarter of the district is at Resubelpara which is located at 230 km away from the state capital Shillong and 138 km from Guwahati.

1.8 Climate: The climate in the area is characterized by moderate temperature and is highly humid in nature. There are three prominent seasons - summer, rainy and winter. The summer season spans from March to May and is followed by SW monsoon lasting till September. Winter season starts from November and lasts till the end of February. The temperature in the area varies from 5.1°C to 35.6°C. Annual rainfall in North Garo Hills district is 2540 mm, out of which monsoon rainfall is 1670 mm.

1.9 Land use: Land utilization statistics provide detailed information of the land use pattern in the area. Based on the land utilization, the total area is divided into various types of landforms such as forest, cultivable land, fallows lands, crops area etc. which in turn reflects the degree of development of agricultural activities and cultivation potential. The land utilization statistics of the North Garo Hills district is shown in the following Table1.2.

Table 1.2: Land use statistic in North Garo Hills, 2017-18

Land Classifications	Area in hectares
1. Geographical Area	116000
2. Reporting Area	115951
3. Forests (classed & unclassed)	55455
4. Area not available for cultivation	5250
5. Other uncultivable lands	25982
6. Fallow land	11243
7. Net area sown	18021
8. Area sown more than once	2602
9. Total cropped area	20623

Source: Directorate of Economics & Statistics, Shillong, Govt. of Meghalaya.

1.10 Soil: Soils in North Garo Hills are generally loamy, varying sometimes between clayey and sandy loam and rich in organic matter and nitrogen. Soil map of the area is given in Fig 1.3.

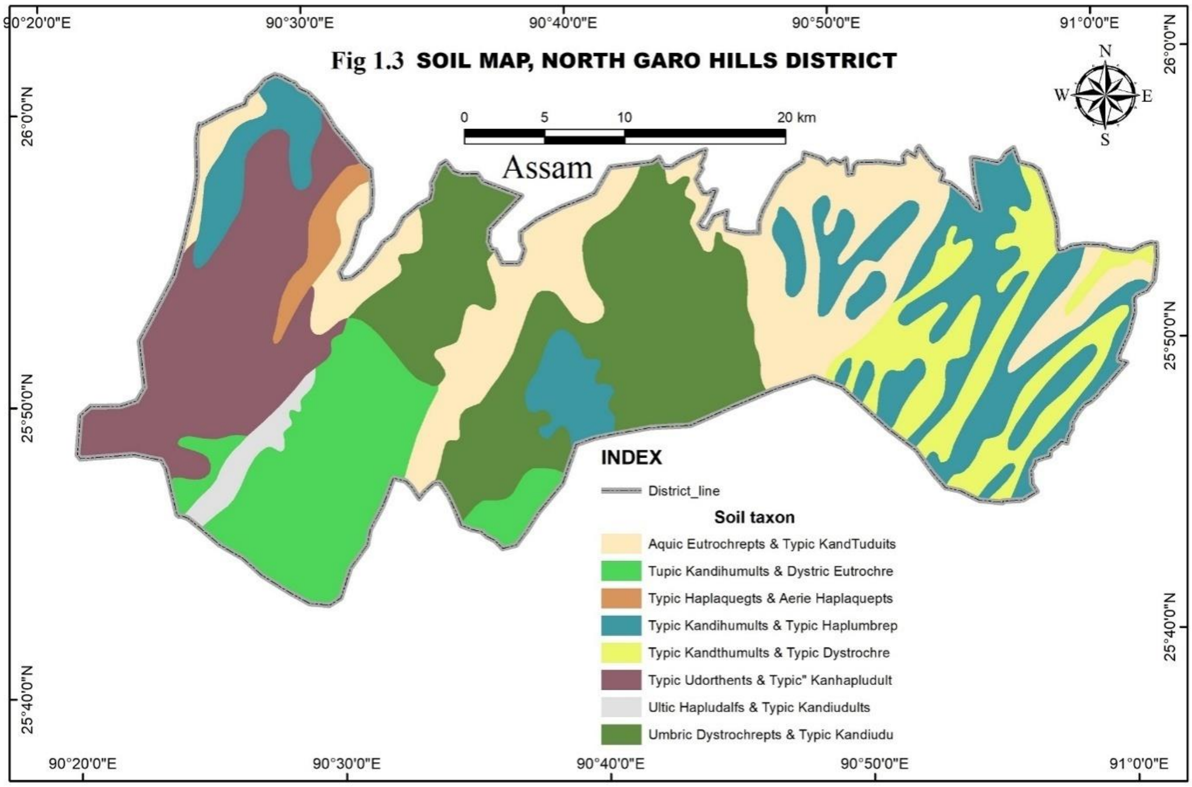


Fig 1.3 SOIL MAP, NORTH GARO HILLS DISTRICT

(*Source: Regional Center of National Bureau of Soil* Survey and Land *Use Planning*).

1.11 Agriculture: Agriculture is the main means of livelihood of the people in the district and about 90% of the population of North Garo Hills is dependent on agriculture and most earn their living directly or indirectly from agriculture. Rice is the most important food crop that is grown in the district, both in the plains and the hills. Other food crops that are widely grown in the district are tapioca, yam, maize, millet and pulses. Due to widespread practice of shifting cultivation and deforestation, the production of food crops is decreasing and Government has intervened to provide alternative measures of farming practices like terracing, contour farming etc. to the people. The area is endowed with diversified climatic condition thereby offering good scope for cultivation of temperate and subtropical crops. Broadly the low-lying areas were put under paddy during Kharif and with pulses, paddy, vegetables and oilseeds during the Rabi season depending on the availability of residual moisture and irrigation facilities. Gentle slopes up to 20% were put under other crops like wheat, paddy, maize, pulses, oilseeds, vegetables etc. Present area under different crops and their productivity is shown in table 1.3.

Table 1.3: Area under different crops and their productivity, North Garo Hills district (2017-18)

Sl. No.	Crops	Area (ha)	Production in MT	Avg.Yield (kg/ha)
1	Winter rice (Sali)	3706	7968	2150
2	Autumn rice (Ahu)	5090	15061	2479
3	Spring paddy	88	140	1591
4	Wheat	43	57	1326
5	Maize	296	506	1912
6	Millets	102	111	1090
7	Gram Pulses	418	442	1057
8	Tur (Ahar)	48	48	1000
9	Rabi pulses	247	270	1093
10	Potato	60	486	8100
11	Tapioca	721	4231	5868
12	Tobacco	137	130	949
13	Arecanut	1037	1369	1320
14	Cashewnut	125	138	1104
15	Tea leaf	11	59	5364
16	Strawberry	1	7	7000
17	Pineapple	531	11029	20770
18	Banana	1041	13983	13432
19	Papaya	83	763	9193
20	Citrius fruits (Khasi mandarin, Assam lemon, pomelon etc.)	265	915	3453
21	Black pepper	35	18	514
22	Ginger	1588	3242	2042
23	Turmeric	51	282	5529
24	Chillies	131	99	756
25	Soybean	108	114	1056
26	Rapeseed & Mustard	569	263	462
27	Sesame	79	81	1025
28	Castor	12	10	833
29	Sweet Potato	89	328	3685
30	Rubber	474	303	639
31	Coffee	8	30	3750
32	Total Vegetables	2086	22593	10831

Source: Agriculture Department, Govt. of Meghalaya

1.12 Irrigation: In the district there are no major irrigation projects, hence the agricultural development in the area is dependent on minor and medium irrigation schemes. The existing irrigation schemes are based only on surface water and the source is mainly through non-monsoon base flow. Piped water supply schemes and spot source water schemes are the main source of water supply schemes and play a major role for the water requirement of the people especially in the rural areas. Piped water supply schemes are categorized into (i) Gravity Feed Schemes and (ii) River Pumping Schemes. Spot source water supply scheme are classified into (i) Hand pump, (ii) Spring tapped chamber and (iii) Well (dug, ring) maintained by Public Health Engineering Department, Meghalaya (PHED). Present area under irrigation by different sources is shown in Table 1.4.

Table 1.4:Area under irrigation by different sources (up to2017-18) is as follows:

District	Net irrigated area (ha)			Gross irrigated area (ha)		
	Govt.	**Pvt.**	**Total**	**Govt.**	**Pvt.**	**Total**
North Garo Hills	4533	2356	6889	4763	2569	7332

Source: Directorate of Economics & Statistics, Shillong, Govt. of Meghalaya.

1.13 Industries: There are no major or minor industries in the district at present.

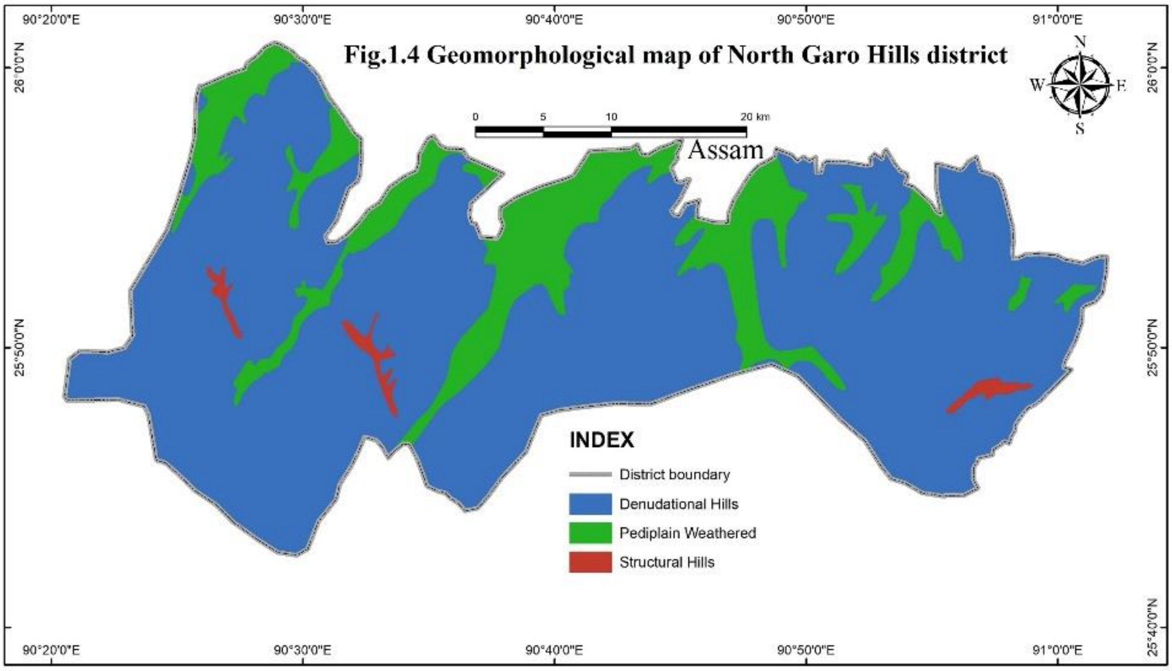
1.14 Forest: The District is very rich in natural resources. The forest types of the district comprise of east Himalayan moist mixed deciduous forest. As per Directorate of Economics and Statistics, the forest cover area is about 55455 ha (2017-18) which is about 48% of the total district area.

1.15 Geomorphology: Broadly, the district can be differentiated into the following geomorphic units,

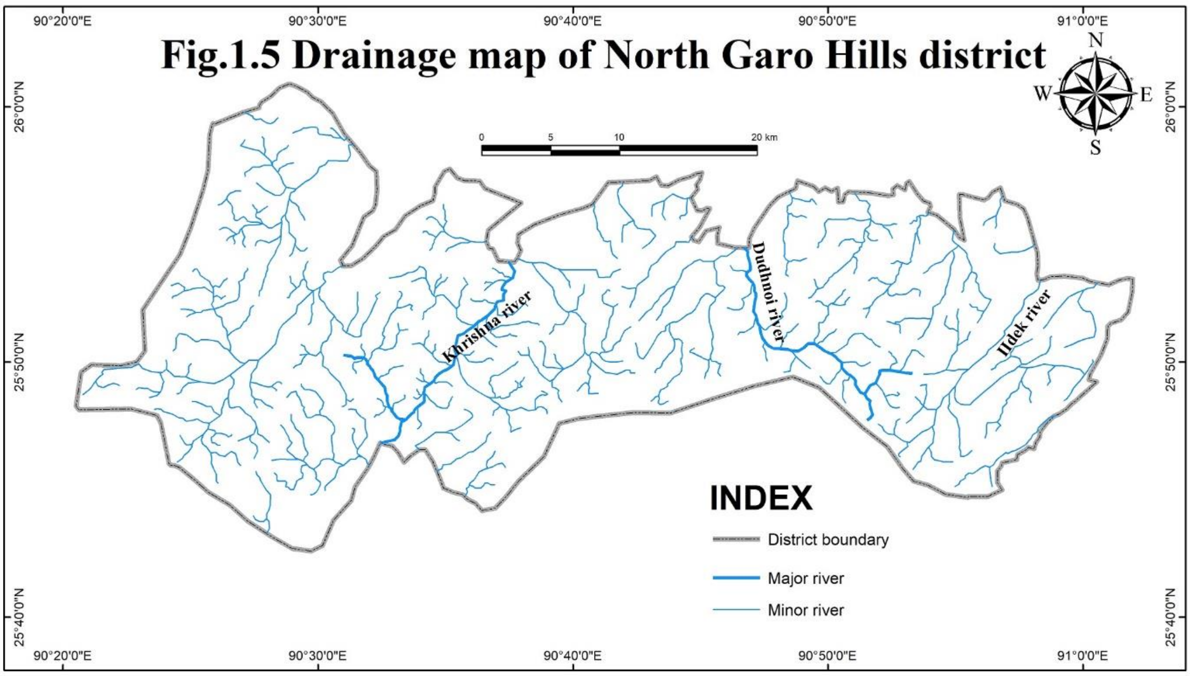
i. Denudational Hills: It occupies the major part of the district comprising of hard rock like granite and gneiss. These are the Archaean gneissic hills undergoing weathering and erosion. These have narrow to broad rounded crests. The elevation varies between 200 and 600 m above mean sea level. The hills have diverse orientations assuming isolated hummocky nature.

ii. Denudational weathered: These are intermontane valley existing between hills. They get widen towards the north merging into plains of Brahmaputra valley. Such valleys occur in areas of Dainadubi, Mendipathar, Resubelpara, Bajendoba, Kharkutta adjoining the Assam border in the northern part of the district. These valleys are structurally controlled by series of parallel lineaments found in the area as a result of tectonic disturbance in the past.

iii. Structural hills: It is the minor portion of the district as shown in the map.



1.15 Drainage: The drainage system of the district is controlled by topography. The drainage pattern of dendritic and rectangular types is found in the area which indicates both topographic and structural control. The important rivers of the district are Krishna/ Damring, Dudhnoi, the Manda, Didram, and Ildek river which are northbound flowing rivers joining the Brahmaputra. All these rivers emerges from the catchment and hills of the district having an average height of 600m above mean sea level as first order river, navigates down the undulating land with gentle to moderate slopes whose elevation ranges from 50 to 600 above MSL before meeting the Brahmaputra river. The drainage map is shown in Fig 1.5.



2. DATA COLLECTION AND GENERATION

One of the main objectives of the study was to collect various relevant technical data from the concerned State Government agencies and other Institutes dealing with ground water and incorporating these data along with CGWB data to generate strong data base. Based on the data availability and data gap analysis, the required sub-surface hydrogeological data, depth to groundwater level data and groundwater quality data were generated but the entire data required could not be generated due to unapproachable/inaccessible and difficult hilly terrain.

2.1 Hydrogeological: Occurrence of ground water in the study area is mainly of weathered and fractured Granite and Gneiss. The different hydrogeological data are generated through intensive field data collection and testing.

2.1.1 Water level monitoring: In the study area, only 16 dug well, 2 bore wells and 1 spring were established as key wells to study the water level, quality, spring discharge and its behavior periodically. There was huge data requirement, but due to lack of springs and bore wells structure in the study area only these could be established.

Phreatic aquifer: A total of 16 dug wells were established as key wells for periodical monitoring to know the water level trend and its behavior. The key observation wells details are presented in Annexure 2 and the pre- and post- monsoon Depth to Water Level map in Fig 3.4 and 3.5.

Semi-confined aquifer: Piezometric head was monitored from two newly constructed bore well. Details of this key observation well are presented in Annexure 2 and the pre-monsoon depth to water level map in Fig 3.6.

Springs: During the study only one spring at Resubelpara was found and monitored to know the type, discharge and its behavior. The location detail of this spring is given in table 2.1.

Table 2.1 Location of springs in North Garo Hills district

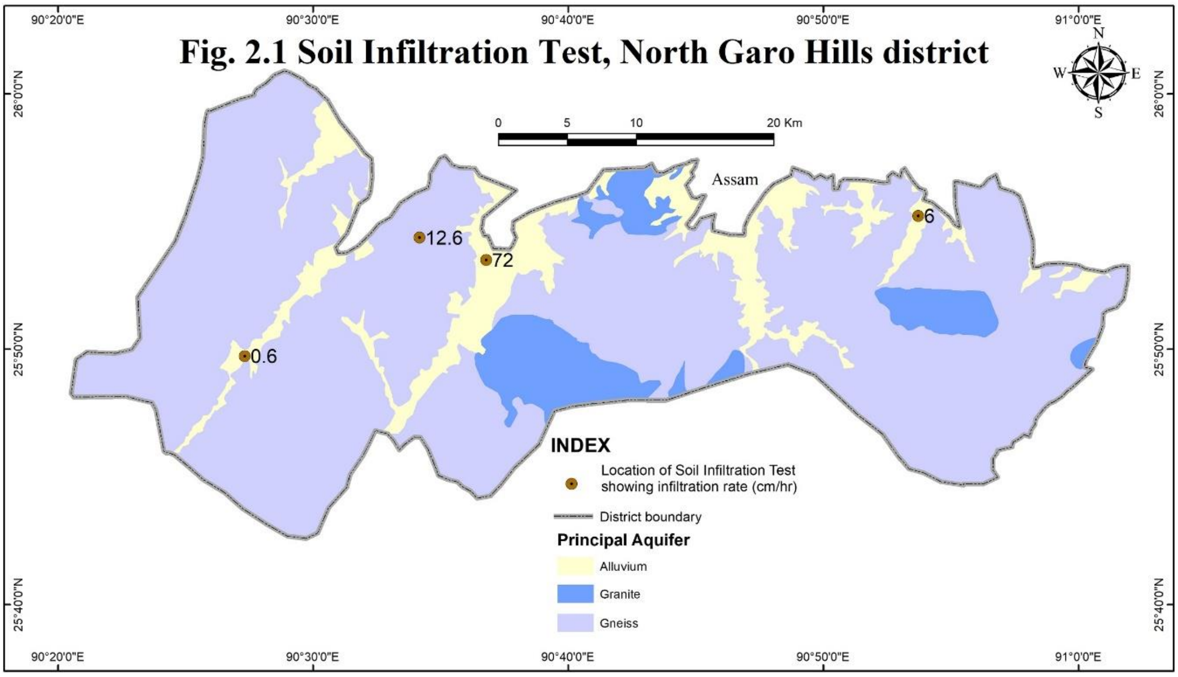
Sl. No.	Location	Block	Latitude	Longitude	RL (m)	Type	Lithology
1	Resubelpara hot spring	Resubelpara	25˚54’52.45”	90˚35’59.56”	76	Fractured	Gneiss

2.1.2 Preliminary Yield Test (PYT): A total of 2 preliminary yield tests were carried out during NAQUIM programme in the study area to know the aquifer parameters. The details are shown in Annexure 1.

2.1.3 Soil Infiltration Studies: Soil infiltration test were conducted using double ring infiltrometer and the constant infiltration rates of different soils were calculated by double ring infiltrometer method. The Horton’s equation method was used for calculation of infiltration rate. The infiltration factor was calculated by dividing infiltration rate with quantum of water applied and multiplied with specific yield into 100. These studies were carried out in different locations to know the infiltration rates at different soil conditions, topography, geology and environment. This will provide a scientific approach of groundwater recharge, its suitability and the amount of water recharging in that area, rainfall infiltration factor and will help in calculating ground water resource estimation. The details are shown in table 2.2 and fig. 2.1.

Table 2.2 Details of Soil Infiltration Test studies results

Sl. No.	Location	Latitude	Longitude	Soil type	Soil thickness (m)	Infiltration rate (cm/hr)	Rainfall Infiltration Factor
1	Mendal	25.828	90.455	Silty clay, brown	3 to 5	0.6	2.7
2	Rangmangre	25.906	90.569	Loamy, reddish	5 to 8	12.6	7.1
3	Resubelpara	25.891	90.613	Sandy-loam, reddish	2 to 3	72	11.9
4	Kharkutta	25.920	90.895	Clay, brown	10 to 20	6	7.02



2.2 Hydrochemistry: The quality of ground water is as important as that of the quantity. In order to study the chemical quality of ground water in the district, water samples from first aquifer (dug wells and springs) and second aquifer (CGWB Bore well) were collected during the course of field work. Ground water samples were analyzed in the regional chemical laboratory, Central Ground Water Board, North Eastern Region, Guwahati for 16 parameters. The analytical data are given in Annexure 4.

2.3 Ground water exploration studies: Ground water exploration has been carried out in different parts of the district to delineate the potential aquifers and their geometry and to determine the hydrogeological parameters of the aquifer systems. Before NAQUIM programme started in the district, 3 EWs were constructed and during NAQUIM study (as a part of data gap generation) 2 EWs were constructed during the course of study. Details of the exploratory wells are presented below in the table 2.3.

Table 2.3 Exploratory wells constructed in North Garo Hillsdistrict

Sl. No.	Village/ Location	Taluka/ Block	Toposheet No.	Longitude	Latitude	Type of well (DW/BW /TW)	Drilled Depth (m bgl)
1	Mendipathar	Resubelpara	78 K/9	90^{0}38’29”	25^{0}54’30”	BW	43
2	Bejengdoba	Resubelpara	78 K/9	90^{0}30’32”	25^{0}53’34”	BW	14.25
3	Kharkutta	Kharkutta	78 K/13	90^{0}54’30”	25^{0}55’30”	BW	214.7
4	Mendal EW	Bajengdoba	78 K/6	90˚27’19.59”	25˚49’42.87	BW	146.4
5	Mendal OW	Bajengdoba	78 K/6	90˚27’18.63”	25˚49’42.79”	BW	146.4
6	Bajengdoba EW	Bajengdoba	78 K/5	90˚29’35.59”	25˚53’18.20”	BW	201.4

The exploratory wells which were constructed before and during NAQUIM are shown in fig 2.2.

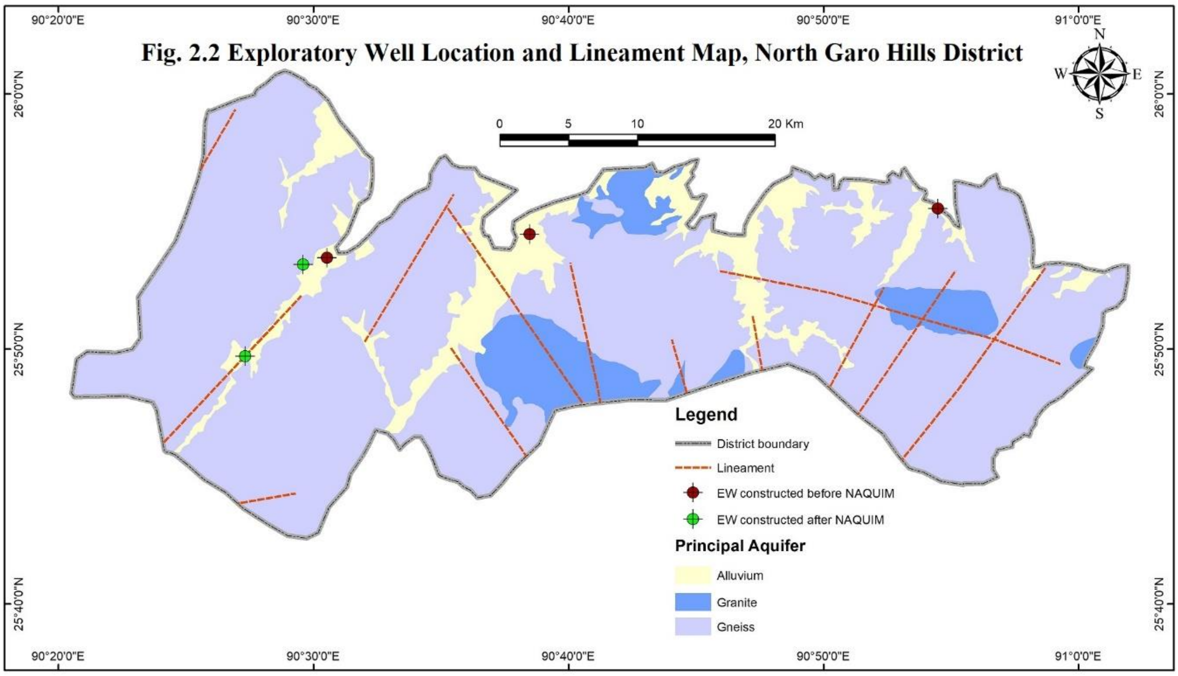


Fig. 2.2 Exploratory Well Location and Lineament Map, North Garo Hills District

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 General hydrogeology and occurrence of ground water: The hydrogeological formation of the study area comprised of Gneiss of Archean (?)- Proterozoic, Granite of Neo Proterozoic-early Proterozoic, Alluvium of Pleistocene-Holocene age. The presence of weak planes like fractures and joints in these hard rock formation forms the principal aquifer in the area. The ground water in the district occurs under unconfined and semi-confined conditions. Study of dug wells and exploration data reveals the presence of phreatic/shallow and deep fractured aquifers in the district. The principal aquifer of the study area is shown in fig 3.1.

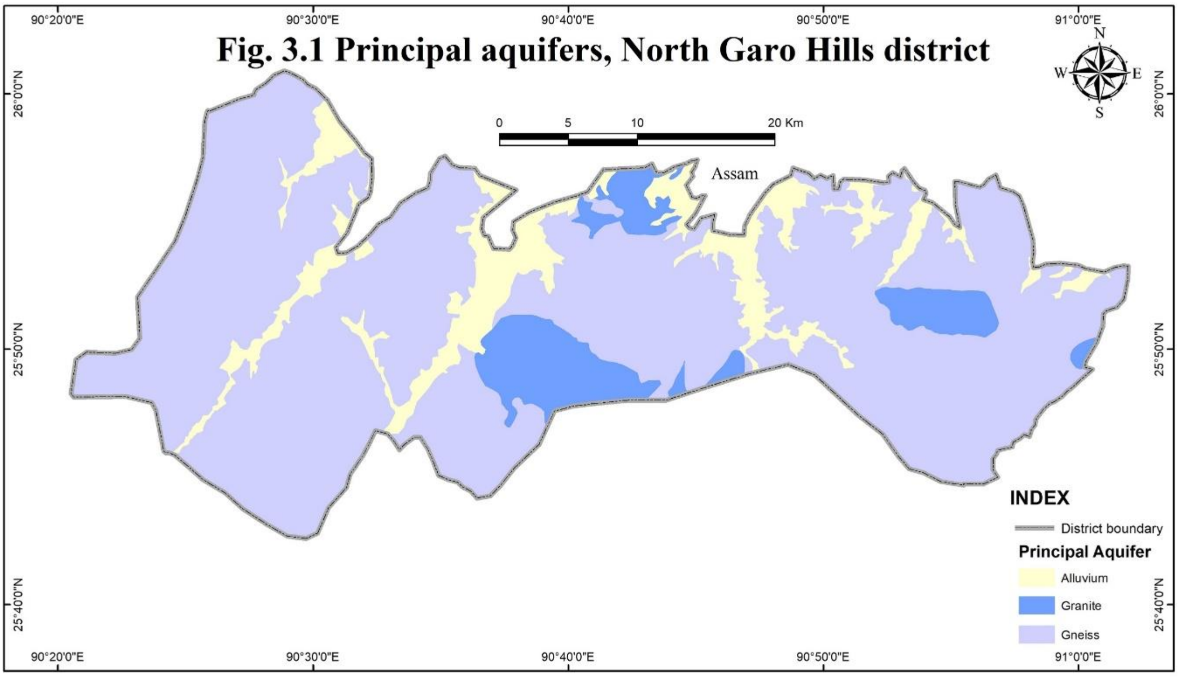
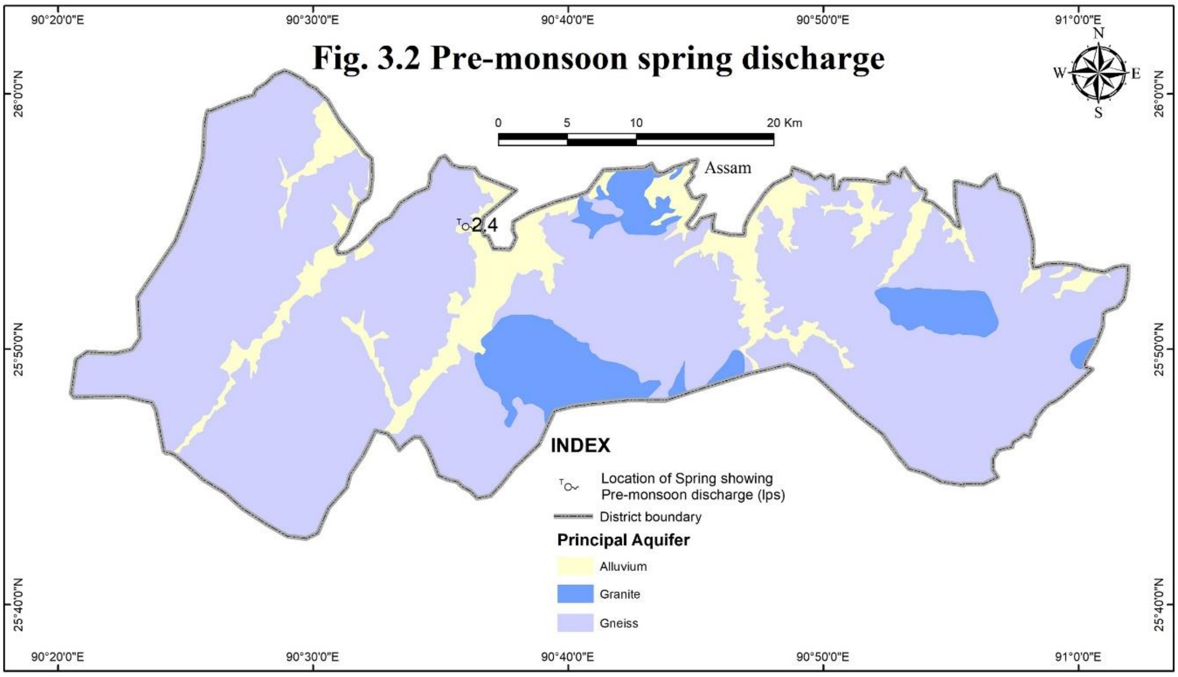


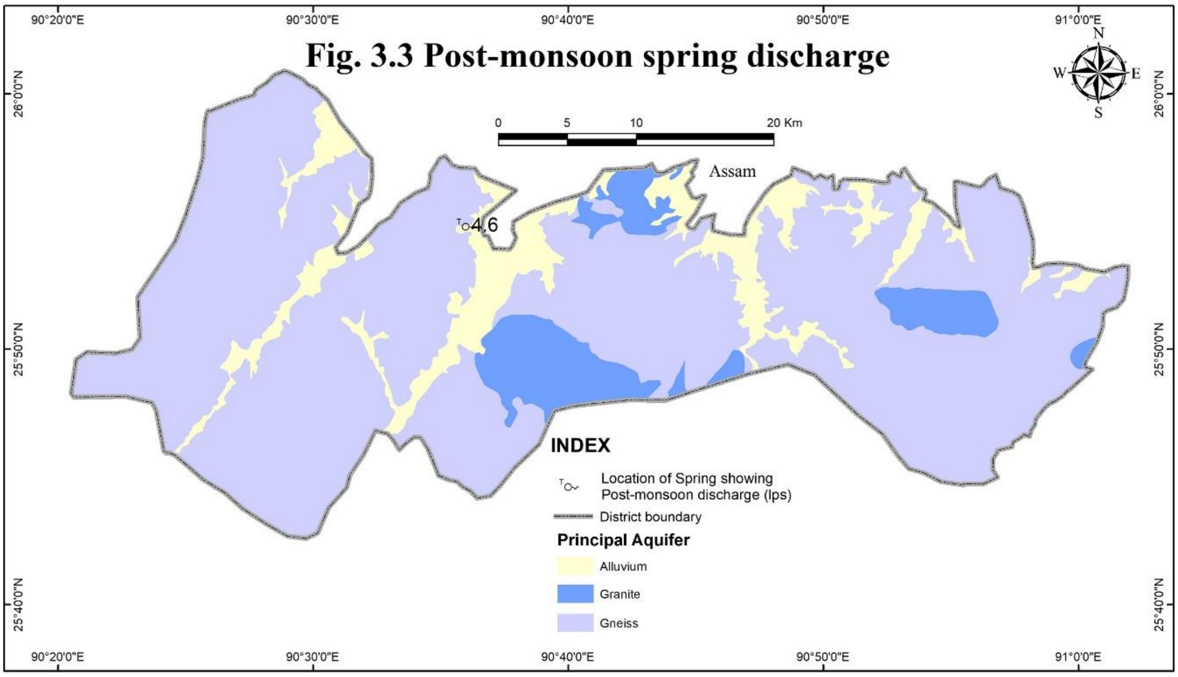
Fig. 3.1 Principal aquifers, North Garo Hills district

3.1.1 Occurrence of ground water in shallow aquifers: The depth of shallow aquifer in the district ranges from 2 to 30 meters. This shallow aquifer occurs under unconfined condition. Ground water from shallow aquifer is exploited through different types of ground water extraction structures such as dug wells (Kachha dug wells and ring well). This dug well tapped the unconfined aquifer generally down to 2 to 6 meters. This unconfined aquifer extends upto 30 meters which is the alluvium and weathered portion.

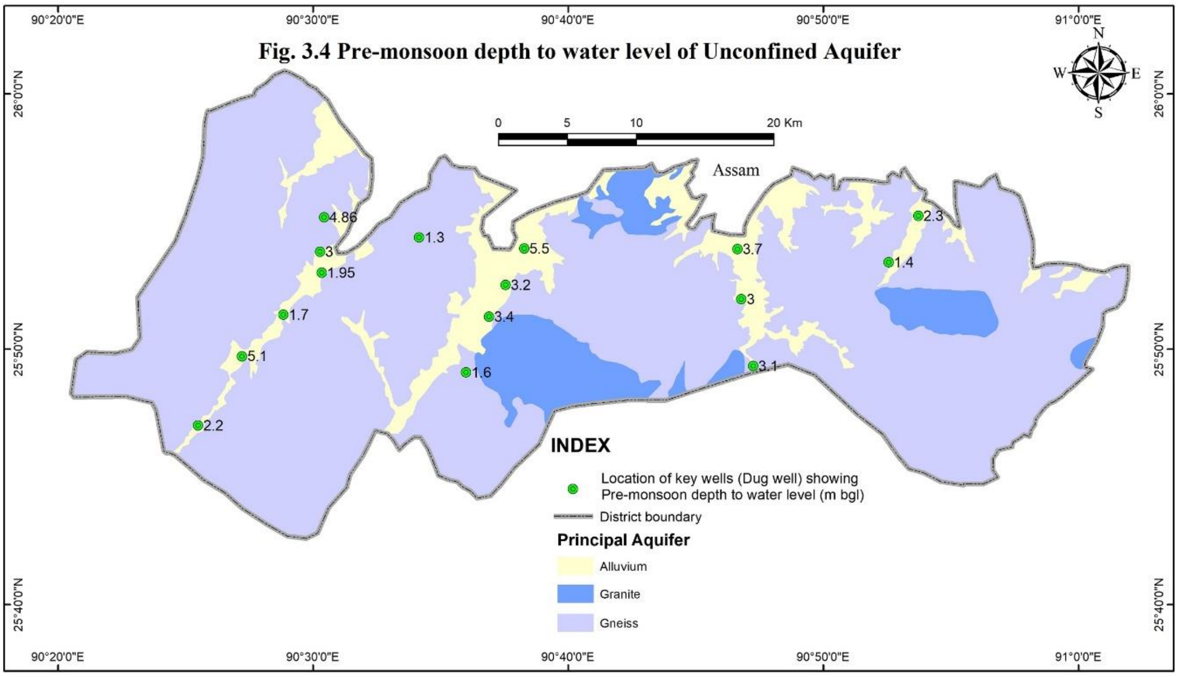
3.1.2 Occurrence of ground water in deeper aquifers: The deeper aquifer occurs as semi-confined condition where ground water is found in the fractured zone of consolidated Granite and Gneiss. The drilled depth of exploratory wells tapping this aquifer ranges from 146.4 to 201.2m bgl. The number of fractures encountered varies from place to place which show the complexity of the hydrogeology of consolidated hard rock formation.

3.1.3 Springs: Spring is defined as a localized natural discharge of ground water appearing at the ground surface as a current of flowing water through well-defined outlets. The discharge may vary from a trickle to a stream. Groundwater flow from springs is governed mainly by three inter-related factors: geology (type, distribution and permeability characteristics of geologic units), topography (landforms and relief), and climate (timing and amount of precipitation). Topography drives the groundwater flow downhill and largely dictates the occurrence of the spring itself. Climate would influence the timing and amount of recharge to the flow system and the volume and variability of discharge. Groundwater obtained from spring is similar to water pumped from shallow wells. The study of spring has been carried out in the aquifer mapping area and it was found that the location of the spring is mainly restricted to foothills and intermontane valleys. Only one spring was found, established and monitored periodically during the course of study. It is observed that the discharge of spring was 144litre/minute during pre-monsoon and 276 litre/minute during post-monsoon season which is shown in fig 3.2 and fig 3.3. It has also been observed that the discharge of springs has been increased during monsoon season and gradually decreases in post-monsoon and pre-monsoon.





3.2 Depth to Water Level: Study of water level and its behavior both in phreatic and semi-confined condition were carried out in the aquifer mapping area. A total of 16 dug well was established as key well for periodical monitoring to know the water level trend and its behavior in phreatic condition. The depth to water level in the phreatic aquifer vary from 1.3 to 5.5 m bgl during pre-monsoon and 1.05 to 4.6 m bgl during post-monsoon season and is shown in fig 3.4 and fig. 3.5 and the average water level fluctuation is 0.6 m.



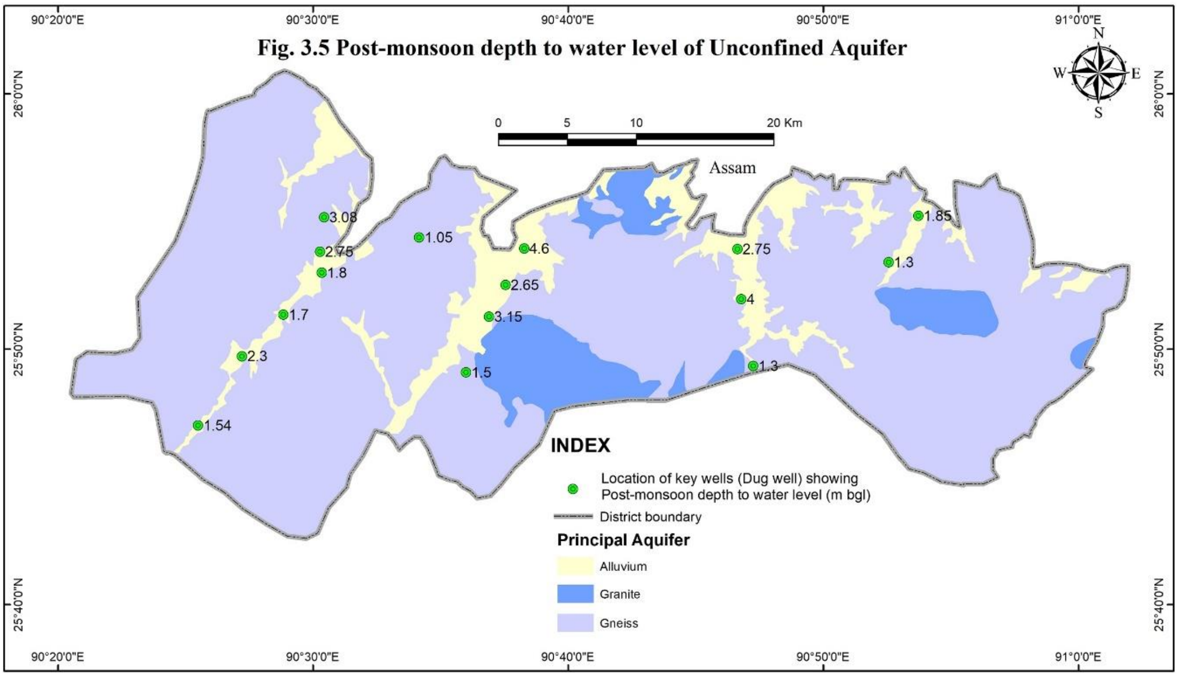


Fig. 3.5 Post-monsoon depth to water level of Unconfined Aquifer

To study the piezometric head, 2 newly constructed bore wells were monitored. The piezometric head ranges from 5.82 to 10.03 m bgl during pre-monsoon and is shown in fig 3.6.

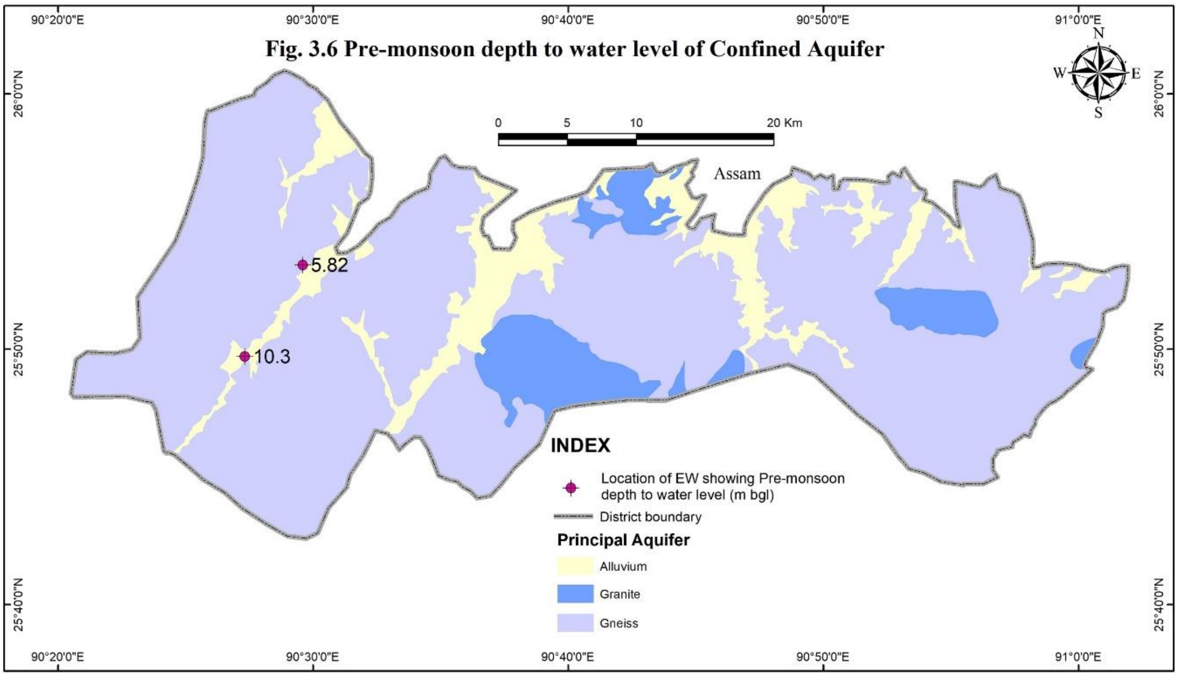


Fig. 3.6 Pre-monsoon depth to water level of Confined Aquifer

Further, long term water level data of 10 years were collected in one of the GWM stations to know the water level trend and its behavior over the years. Based on depth to water level data collected from this ground water monitoring station at Kharkutta, the hydrographs of this well shows no significant rise or fall in the water level trend and is shown in fig. 3.7.

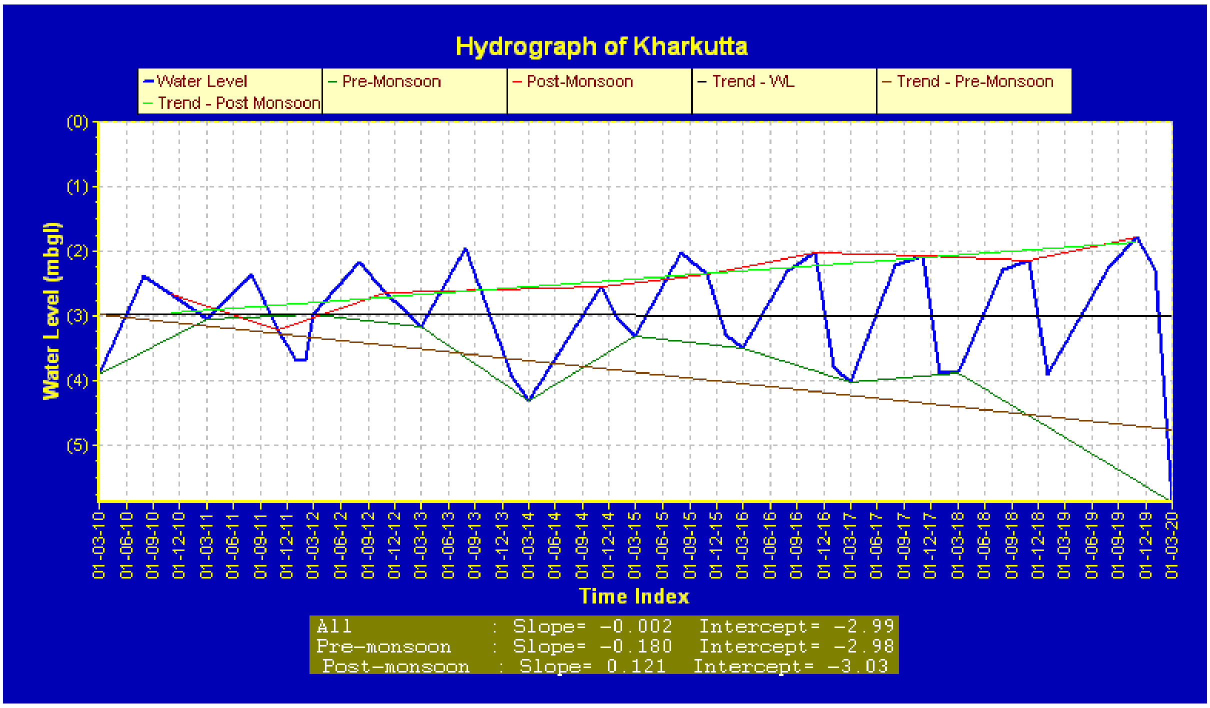


Fig.3.7 Hydrograph of Kharkutta from 2009-2019

3.3 Aquifer System: The study area is mainly underlain by consolidated rocks of Granite and Gneiss and a small area (valley portion) drained by rivers are under unconsolidated alluvium. The aquifer system exists in all the rock formations. It also exists in both weathered formation as well as fractured system down to the explored depth of 201.4 mbgl. The depth of weathered zone varies from 2 to as high as 30 m below ground level. Thus, hydrogeologically, the study area can be categorized into three groups i.e., (i) Granite aquifer, (ii) Gneiss aquifer, (iii) Alluvium aquifer. In fig.3.8, disposition of fractures were shown however lateral extension of these fractures cannot be established.

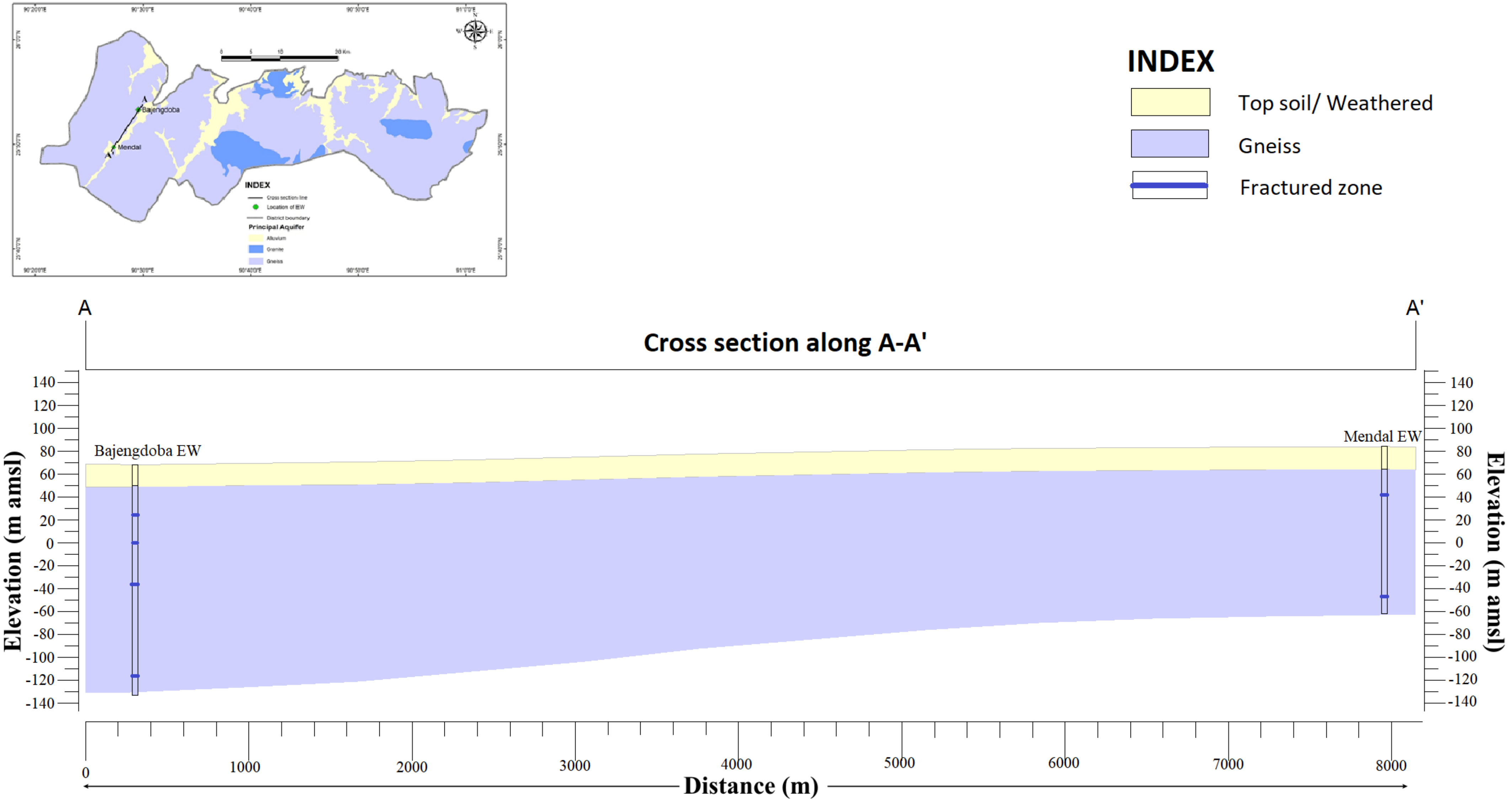


Fig 3.8 Hydrogeological cross section along A-A’

Formation wise hydrogeological behaviors in the district are discussed below:

3.3.1 Granite: The granite is exposed in the central northern and southern parts as well as in the eastern parts of the district. The occurrence of ground water in this formation is controlled by weathering and fractures/joints/weak planes patterns. Groundwater in these formations occurs under phreatic conditions in weathered mantle and under semi-confined conditions in the fractured rocks, which is governed by topography and drainage. CGWB has not constructed borewell in this formation in the district during the course of study but studies from other districts has shown different aquifer properties with Gneiss.

3.3.2 Gneiss: The major portion of the district is covered by Gneiss. The occurrence of ground water in this formation is also controlled either by weathering and or by fractures patterns. Groundwater in these formations occurs under phreatic conditions in weathered mantle and under semi-confined to confine conditions in the fractured rocks, which is governed by topography and drainage. In this formation, depth of first aquifer ranges from 3 to 30 m bgl and the second aquifer ranges beyond 30 m bgl. So far, CGWB has drilled only two bore well in this formation and the discharge of the exploratory well are about 3.2-3.3 lps and Transmissivity ranges from 3.61 to 14.45 m^2/day. Distribution of fractures at various depth and cumulative discharge is tabulated in table 3.1.

Table 3.1 Location wise details of fracture encountered in Gneiss

Location	**Depth drilled in m bgl**	**Number of fractures encountered**					**Discharge (in lps)**
		0 to 50 m	**50 to 100 m**	**100 to 150 m**	**150 to 200 m**	**200 to 250 m**	
Mendal	146.4	1	0	1	-	-	3.2
Bajengdoba	201.4	1	1	1	1	-	3.3

The above table reveals that 1 to 4 numbers of fractures were encountered within 200 m depth.

3.3.3 Alluvium: Unconsolidated alluvial aquifer consists of older and newer alluvium. The aquifer is characterized by coarse sand materials. However the thickness of alluvium is quite shallow (around 20-40 m bgl) based on the old drilling data.

3.4 Aquifer geometry: The aquifer system in this district can be divided into two aquifer system viz., first aquifer (shallow) and second aquifer (deeper). Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells as hand pump. The second aquifer is the deeper aquifer which tapped the fractured zone. Based on the study of litholog and analysis of depth of construction of dug wells and shallow bore wells, it is found that the first aquifer occur within 2 to 30 m bgl. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures upto the maximum depth of 183.1 m bgl.

3.5 Aquifer properties:

Aquifer I: It is the unconfined aquifer which occur between 2 to30 m depth. Tapping of this Aquifer by the villagers were done through ground water extraction structures like kachha dug well or ring well. The properties of Aquifer-I could not be established due to unavailability of pump for conducting dug well pump test.

Aquifer II: This is the deeper aquifer which occurs as semi confine to confined condition where ground water is found in the fractured zone of consolidated Granite and Gneiss. The drilled depth of exploratory wells tapping this aquifer ranges from 146.4 to201.4 m bgl. The number of fractures and zones of encountering fractures varies widely which show the complexity of the hydrogeology of consolidated hard rock formation. Through PYT, it was found that transmissivity values vary from 3.61 to 14.45 m^2/day and the discharge in these wells ranges from 3.2 to 3.3lps.

3.6 Hydrochemistry:

The quality of ground water is as important as that of the quantity. In order to study the chemical quality of ground water in the district, a total of 18 numbers of ground water samples were collected and analyzed during the course of study. Out of these, 16 water samples from dug well, 1 sample from springs and 1 sample from exploratory bore wells were analyzed for the parameters like pH, EC, Turbidity, TDS, CO_3, Cl, SO_4, Na, K, HCO_3, NO_3, F, Ca, Mg, TH and Fe. Table 3.2 summarizes the results of chemical analysis of groundwater samples from North Garo Hills district and the details of chemical analysis were given in the Annexure 2. EC, pH and Fe conc. maps are shown in fig. 3.9, fig. 3.10 and fig 3.11.

Table 3.2: Chemical quality of water samples from dug well, bore well and springs in North Garo Hills district

Sl. No.	**Chemical constituents (Concentrations in mg/l except pH & EC)**	**Dug well**	**Borewell**	**Spring**
		Range		
1	pH	6.42 to 7.86	7.03	7.86
2	EC µS/cm at 25°C	45.2 to 126.1	95.00	356.10
3	Turbidity(NTU)	BDL	BDL	0.10
4	TDS	26.78 to 74.53	51.80	211.50
5	CO_3	BDL	BDL	BDL
6	HCO_3	20.02 to 50.04	18.30	195.16
7	TA as $CaCO_3^*$	20.02 to 50.04	18.30	195.16
8	Cl	14.18 to 28.36	14.18	21.27
9	SO_4	2.05 to 1918	3.00	46.49
10	NO_3	BDL to 8.15	14.18	0.07
11	F^-	BDL to 0.18	0.11	1.70
12	Ca	4 to 16.01	12.00	58.05
13	Mg	2.42 to 8.49	4.86	8.47
14	TH	25 to 65	50.00	180.00
15	Na	4.16 to 14.57	1.38	21.00
16	K	1.37 to 7.81	0.88	7.08
17	Fe	BDL to 0.53	0.15	0.50

Fig. 3.9 EC values in Unconfined Aquifer, Semi-Confine Aquifer and Spring

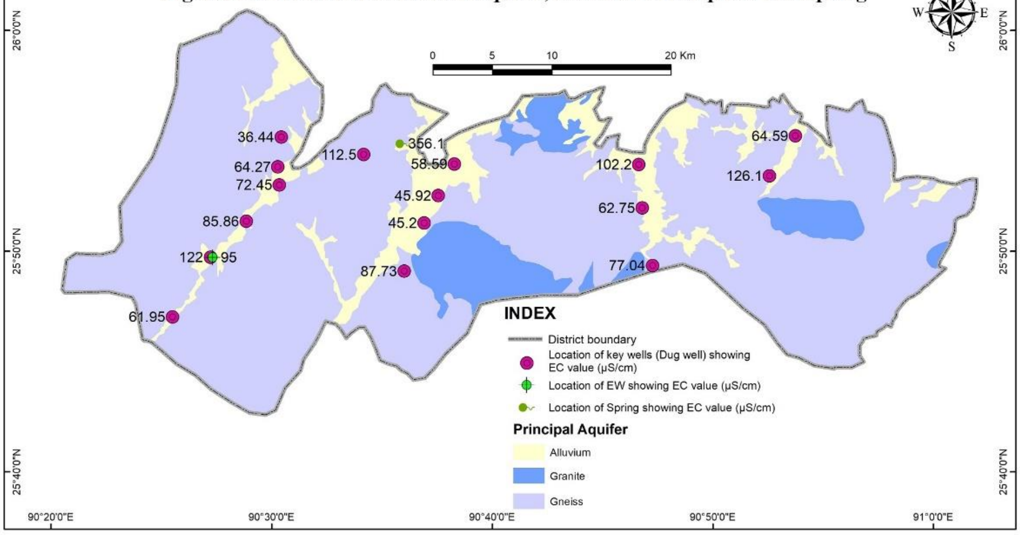


Fig. 3.10 pH values in Unconfined Aquifer, Semi-Confine Aquifer and Spring

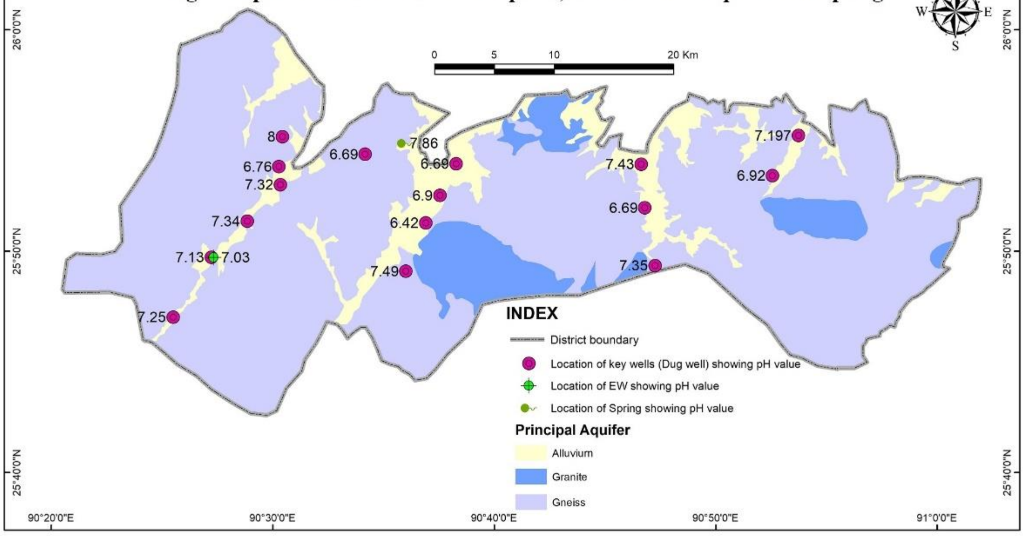
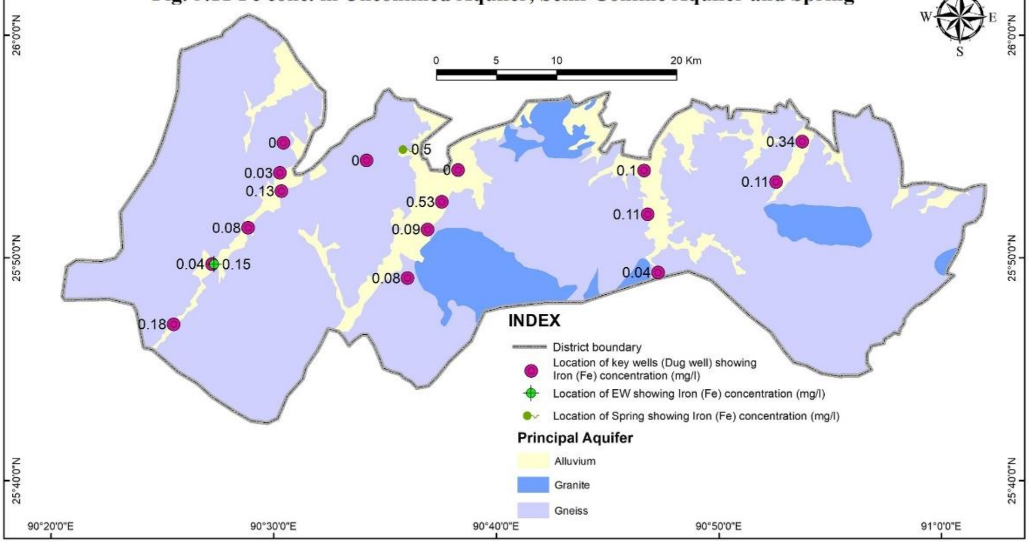


Fig. 3.11 Fe conc. in Unconfined Aquifer, Semi-Confine Aquifer and Spring



3.6.1 Ground water quality of unconfined aquifer:

A total of 16 ground water samples from dug well were collected during post-monsoon studies and the range of concentrations of different chemical constituents present in the ground water samples are given in table 3.2.

It is deciphered from table 3.2that all of the chemical parameters are within permissible limit for all uses. The EC values, pH and Fe conc. are shown in fig 3.9, fig. 3.10 and fig. 3.11.

3.6.2 Ground water quality in confined aquifer: Only one water samples was collected during exploratory drilling programme and monitoring during the course of study. Based on chemical analysis data the concentrations of different chemical constituents present in the deeper aquifer samples is given in table 3.2.

It is deciphered from table 3.2 that all of the chemical parameters are within permissible limit for all uses. The EC values, pH and Fe conc. are shown in fig 3.9, fig. 3.10 and fig. 3.11.

3.6.3 Water quality of springs: Only one water sample was collected from spring during post-monsoon monitoring and the concentrations of different chemical constituents present in the spring sample is shown in table 3.2.

It is deciphered from table 3.2 that all of the chemical parameters are within permissible limit for all uses. The EC values, pH and Fe conc. are shown in fig 3.9, fig. 3.10 and fig. 3.11.

4. GROUNDWATER RESOURCES

Dynamic Groundwater Resources of North Garo Hills district has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). The present methodology used for resources assessment is known as Ground Water Resource Estimation Methodology – 2015 (GEC'2015). The revised methodology GEC 2015 recommends aquifer wise ground water resource assessment. Ground water resources have two components – Replenishable ground water resources or Dynamic ground water resources and In-storage resources or Static resources. GEC 2015 recommends estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifers. In GEC'2015, two approaches are recommended – water level fluctuation method and norms of rainfall infiltration method. The resources computed for the groundwater year 2017-18. The following sub-units are recommended for the computation of various figures in the methodology and these are considered in details below:

Hilly Area: Area with more than 20% slope has been excluded for the recharge computation. As per NESAC, total recharge worthy area in the district is 505 sq.km.

Poor Groundwater Quality Area: In the district, there is no mappable area, which can be demarcated as poor groundwater quality and hence not considered.

Command and Non-Command Area: The methodology envisages computation of various figures separately for command & non-command area. In the district, there is no major or medium canal irrigation scheme and thus the entire rechargeable area has been considered as a non-command area.

Recharge from Rainfall has been computed separately for monsoon and non-monsoon periods for the entire district. The recharge from rainfall during monsoon season has not been computed using water level fluctuation method (WLFM) as Ground Water Monitoring Wells (GWMW) in the district is very few. The rainfall recharge estimated for non-command area of the entire district and the details are shown in annexure 8.

Recharge from All Sources: Total recharge to groundwater has several components, rainfall being the major one. The other components include seepage from canals, return flow from surface water irrigation, return flow from groundwater irrigation, seepage from tanks/ ponds etc. Recharge from various sources has been calculated for monsoon as well as non-monsoon periods and details have been shown in table 4.1.

Table 4.1: Groundwater recharge from various sources (ham).

Assessment Unit/ District	Command/ Non-Command/ Total	Recharge from rainfall during monsoon season	Recharge from other sources during monsoon season	Recharge from rainfall during non-monsoon season	Recharge from other sources during non-monsoon season	Total Annual Ground Water Recharge	Provision for Natural Discharges	Annual Extractable Ground Water
North Garo Hills	Non-command	12073.67	75.88	3773.95	20.61	15944.11	1594.41	14349.7
	Total	12073.67	75.88	3773.95	20.61	15944.11	1594.41	14349.7

4.2 Groundwater extraction for Various Purposes: Groundwater extraction for domestic use has been estimated based on number of households using groundwater (Census 2011 data) and number of tube wells used by PHED to supply water and existing dug wells. Groundwater draft for irrigation is nil. It was found that groundwater draft for all uses in the district is 59 ham.

4.3 Stage of Groundwater extraction & Categorization of the Blocks: The district falls under "**SAFE"** category. The stage of GW extraction is 0.52 %. Summary of groundwater resources, stages of development and categorization are given in annexure 8.

4.4 Comparison with earlier ground water resources estimate and reasons for significant departure from earlier estimates: A comparison is made between the previous estimate based on GEC'97 as on March 2013 and present estimate based on GEC'15 as on 2017, and presented in tabular statement given below.

Table 4.2:Comparison between ground water resources estimation for North Garo Hills for previous (based on GEC'97-2013) and present (based on GEC'2015-2017)

Sl. No.	ITEM	Year, 2012-13	Year, 2016-17	COMPARISON
	Methodology	**GEC'97**	**GEC 2015**	
1	Total Annual Ground Water Recharge (ham)	19330	15944.11	(-) 3385.89
2	Irrigation Draft (ham)	150	51	(-) 99
3	Domestic Draft (ham)	15.16	24.3	(+) 9.4
4	Stage of GW Development (%)	0.95%	0.52%	(-) 0.43%
5	Provision for Domestic, Industrial & Other uses (ham)	1125	48.6	(-) 1076.4
6	GW availability for future development (ham)	16122	14250.1	(-) 1871.9

The comparison depicts that there is a decrease in total annual ground water recharge by 3385.89 ham in the 2017 estimate. These differences in resource may be attributed to the changes in methodology and rainfall infiltration factor.

5. GROUND WATER RELATED ISSUES

There is one major ground water related issues found in the study area.

5.1 Low stage of ground water development: As per ground water resource estimation 2017, the stage of ground water extraction is just 0.52 % and there is not much utilization of ground water for irrigation in this area. All the irrigation schemes in the district are dependent upon the surface water resources. Therefore, there is enough scope for future development of ground water in the study area to bring more area under irrigation practice. At present the irrigation practice by utilizing ground water (constructing bore well) is not accepted by villagers due to small land holding, high cost for construction and running of a well compared to production outcome. Another major obstacle in accelerating ground water irrigation is the absence of power lines in most of the cultivated/cultivable area.

6. MANAGEMENT STRATEGIES

As per dynamic ground water resource estimation of North Garo Hills District for 2017, annual extractable ground water is 14349.70 ham and stage of ground water extraction is only 0.52%. The district is having balance net ground water availability for future irrigation use in the tune of 14250.1 ham. If an irrigation plan is made to develop 60% of the balance dynamic ground water resources available, then 8550 ham of groundwater resources is available in the district for the future irrigation uses. From this available resource (planned for future development), 8550 nos. of shallow tube wells (considering a unit draft of 1 ham/year) can be constructed in the aquifer mapping area. Therefore, there is enough scope for future development of ground water in the study area to bring more area under irrigation practice.

Present land under irrigation is 7332 ha. All the schemes which are used for irrigation is using surface water sources. Present irrigation from ground water source is almost nil. Hence, there is ample scope for ground water development for irrigation purpose which will bring prosperity to the society and help the district in achieving self-reliance on food grain. To use the groundwater for irrigation purpose a cropping plan has been designed for the district by using CROPWAT model developed by FAO. Cropping pattern data for the district is presented in table 6.1.

During 2017-18, net sown area in the district is 18021 ha, area sown more than once is 2602 ha. The net sown area included field crops as well as horticulture and plantation crops on slopes and hills. Cropping intensity is calculated generally from field crops, which are of short duration whereas horticulture (like citrus, banana, pineapple) and plantation crops like spices are long duration crops. Again crops grown on the hills like pineapple, turmeric and ginger are having negligible or nil irrigation requirements. During kharif season, paddy is cultivated in 8884 ha. After Kharif crops were grown major portion of this area remains fallow during Rabi season. The intention of this plan is to bring this fallow land of about 6300 ha under assured irrigation during Rabi season which will help to increase gross cropped area to 12600 ha and thereby increase cropping intensity up to 200%. In rice fallow, with the support of irrigation potato, mustard, pulses, millet and rabi vegetables can be grown. Present cropping pattern, proposed cropping pattern, intended increase in cropping intensity were shown in table 6.2a and 6.2b.

Crop-wise and month-wise irrigation water requirement (Precipitation deficit) has been taken from CROPWAT after giving necessary meteorological, soil, crop plan inputs and the same has been shown in table 6.3. Crop-wise and month-wise Irrigation water requirement in ham has been further calculated in table 6.4.

Table 6.1: CROPPING PATTERN DATA
(File: C:\ProgramData\CROPWAT\data\sessions\NGH.PAT)

Cropping pattern name: Resubelpara

No.	Crop file	Crop name	Planting date	Harvest date	Area %
1	...Data\CROPWAT\data	Rice	04/06	01/10	15
2	...Data\CROPWAT\data	Rice	11/06	08/10	15
3	...Data\CROPWAT\data	Rice	18/06	15/10	10
4	...Data\CROPWAT\data	Rice	25/06	22/10	10
5	rape___mustard.CRO	Mustard	15/10	26/02	10
6	...a\CROPWAT\data\cr	Pulses	25/10	11/02	10
7	...a\CROPWAT\data\cr	MILLET	05/01	19/04	10
8	...\CROPWAT\data\cro	Potato	05/02	14/06	10
9	...CROPWAT\data\crop	Small Vegetables	10/02	15/05	10

Table 6.2a. Cropping pattern, proposed cropping pattern, intended cropping intensity, North Garo Hills District.

Cropping pattern (s)				
Rice based cropping pattern				
1. Rice-Mustard 2. Rice-Pulses 3. Rice-Millets 4. Rice-Potato 5. Rice-Vegetables	Present Cultivated area (**ha**)	Area to be cultivated (**%**)	Area to be cultivated (**ha**)	Irrigation requirement (**ham**)
	1	2 (= % of 1)	3	4
Rice (main crop)	6300		6300	542.6
Mustard		20	1260	108.05
Pulses		20	1260	100.5
Millet		20	1260	84.4
Potato		20	1260	61.6
Small vegetables		20	1260	62.3
Net cultivated area	6300		**6300**	
Gross cultivated area (1+pulses/+Millet/+potato/+mustard/+Veg)			**12600**	
Total irrigation requirement				959.6
Cropping intensity	**100% (Present)**		**200% (Intended)**	
Total (North Garo Hills district)				959.6

Table 6.2b. Proposed cropping pattern with water deficit months and IWR, North Garo Hills district.

Rice based cropping pattern			
Crop	**Growing period (Months)**	**Periods/months of water deficit**	**Irrigation requirement (ha m)**
Rice	4	1-2	542.6
Mustard	4	4	108.05
Pulses	4	4	100.5
Millet	3	3	84.4
Potato	4	3	61.6
Small vegetables	3	3	62.3

Table 6.3: Crop-wise and month-wise precipitation deficit (IWR) from CROPWAT 8, North Garo Hills District.

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit (in mm)												
1. Rice	0	0	0	0	147.1	50	0	0	0	3	0	0
2. Rice	0	0	0	0	49.5	98	0	0	0	0	0	0
3. Rice	0	0	0	0	49.6	132.5	0	0	0	1.5	0	0
4. Rice	0	0	0	0	0	147.1	0	0	0	9.2	0	0
5. Mustard	46.6	29.3	0	0	0	0	0	0	0	0	46.5	49.1
6. Pulses	58.3	11.4	0	0	0	0	0	0	0	0	30.7	59.2
7. MILLET	15.1	49.8	69.1	0	0	0	0	0	0	0	0	0
8. Potato	0	22.1	60.7	15	0	0	0	0	0	0	0	0
9. Small Vegetables	0	25	65.6	8.3	0	0	0	0	0	0	0	0

Table 6.4: Irrigation Water Requirement (in ham),North Garo Hills District

Crops	% of total area of 6300 ha	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation deficit (ham)														
1. Rice	15	0	0	0	0	139.0	47.3	0	0	0	2.8	0	0	189.1
2. Rice	15	0	0	0	0	46.8	92.6	0	0	0	0	0	0	139.4
3. Rice	10	0.0	0.0	0.0	0.0	31.2	83.5	0.0	0.0	0.0	0.9	0.0	0.0	115.7
4. Rice	10	0.0	0.0	0.0	0.0	0.0	92.7	0.0	0.0	0.0	5.8	0.0	0.0	98.5
5. Mustard	10	29.4	18.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.3	30.9	108.05
6. Pulses	10	36.7	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.3	37.3	100.5
7.Millet	10	9.5	31.4	43.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.4
8.Potato	10	0.0	13.9	38.2	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.6
9.Small Vegetables	10	0.0	15.8	41.3	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.3
Total	100	75.6	86.7	123.1	14.7	217.0	316.0	0.0	0.0	0.0	9.6	48.6	68.2	959.6

Under ground water exploration programme, CGWB has constructed 5 bore wells in this area and has established that the aquifer in most part of the district is having moderate potentiality, having an average discharge of about 8.5 m^3/hr from Gneissic formation.

The ground water potentiality of the area is moderate, especially in the low-lying valley areas which are feasible for sustainable ground water development. Therefore, those areas can be brought under irrigation by developing ground water through bore wells or large diameter dug wells of size 2 to 3 m (dia) X 10 to 15 m (depth) can be constructed. This type of dug wells can be used to irrigate 0.2 ha of land especially under Rabi vegetables.

A bore well in the area is expected to yield 8.5 m^3/hr. If such a bore well runs for 10 hrs/day for 120 days, then it will create a draft of 1 ham. Bore wells can be designed within a depth of 100-150 m, expected to encounter 2 – 3 fractures. Bore wells can be constructed by using 8// or 7// dia. casing pipe down to 30 m.

In considered net sown area of 6300 ha, 1575 nos. of shallow bore wells can be constructed (considering 200m distance between any two shallow bore well). 1575 nos. of bore wells can extract 1575 ham of water annually.

Annual irrigation water requirement is 960 ham while irrigation water requirement during dry season spanning from October to March is 412 ham. Again proportionate dynamic groundwater resources available for future irrigation use in the considered area are 8550 ham. Hence, this area can be brought under assured irrigation from groundwater sources. The demand of 412 ham can be harnessed by constructing 100 nos. of large diameter dug well (which can irrigate 20 ha) and 409 nos. of bore wells (which can irrigate 6280 ha). At possible places water harvesting methods should be employed.

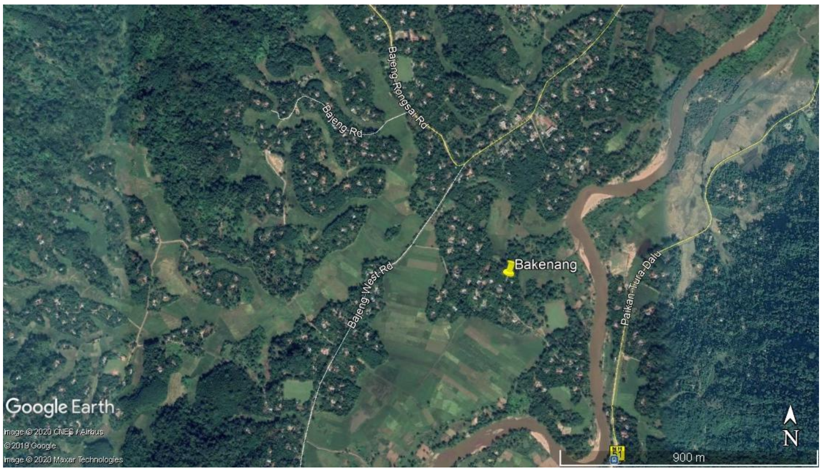
The groundwater quality in the springs, dug well and bore well are within the permissible limit and can be used for drinking, domestic and irrigation purposes.

7. MICRO LEVEL AQUIFER MANAGEMENT PLAN STUDIES

7.1 Bakenang (Rongbang) Village, North Garo Hills District

Bakenang (Rongbang) is a medium size village located in Bajengdoba Block of North Garo Hills district, Meghalaya with a total of about 48 families residing. Bakenang (Rongbang) village has population of 300. Annual rainfall in North Garo Hills district is 2540 mm, out of which monsoon rainfall is 1670 mm. The study area comprised of an intermontane valley and small mounds/ hills. Geologically, it is underlain by gneiss. The soil is of mainly loamy type with a thickness of about 2-4 meters.

The drainage system in this area is usually controlled by topography and the drainage pattern is mainly dendritic type. Didram river passes on the side village as shown in the map.



Water Supply

Drinking & domestic water demand in the village is 21 m^3/ day and annual water demand is 7665 cum. Dynamic Groundwater resources available in the village is 430,000 cum. There is a PHED water supply scheme in the village. The villagers are also dependent on ground water for domestic as well as drinking purpose, which is extracted mainly from dug wells. Almost every house is having a dug well.

Agriculture

The villagers grow mainly paddy during monsoon and the cultivated area is around 150 ha. There is no irrigation scheme being implemented in the village. Agriculture depends on rainfall. Apart from paddy cultivation, areca catechu and some rubber tree plantation are also being grown.

Hydrogeology

The hydrogeological formation of the study area comprised of gneiss. The presence of weak planes like fractures and joints in these hard rock formation forms the principal aquifer in the area. The ground water in the district occurs under unconfined, semi-confined to confined conditions. Study of dug wells reveals the presence of phreatic/shallow aquifers in the village. Ground water occurs in shallow weathered zone and the joints and fractures developed due to tectonic activities form the potential water bearing zones and suitable for development through construction of bore wells. The aquifer system in this village can be divided as a two aquifer system viz., first aquifer (shallow/ phreatic) and second aquifer (deeper).Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells as hand pump. The second aquifer is the deeper aquifer which tapped the fractured zone and is mainly in semi-confine to confine condition. During micro level studies in the area, the water level of phreatic aquifer ranges from 3-5 m bgl and the depth of dug well range from 5-7 m bgl. The details of the dug well are given below;

Village	Bakenang (Rongbang)
Latitude	25°52' 52.58"
Longitude	90°29' 52.16"
Source	Dug well
Depth (m bmp)	5.85
Measuring Point (m)	0.80
DTWL (m bmp)	4.8

Ground water quality of unconfined aquifer:

A total of 1 ground water sample from dug well was collected during micro level studies and the concentrations of different chemical constituents present in the ground water sample is given in the table below,

Table: Chemical quality of water sample from dug well

Sl. No.	**Chemical constituents (Concentrations in mg/l except pH & EC)**	**Range**
1	pH	6.217
2	EC (µs/cm) 25°C	63.35
3	TDS	34.6
4	CO_3^{-2}	BDL
5	HCO_3^{-1}	79.3
6	TA (as CaCO3)	79.3
7	Cl-	21.27
8	SO_4^{-2}	BDL
9	NO_3^{-1}	BDL
10	F-	0.07
11	Ca^{+2}	8
12	Mg^{+2}	2.43
13	TH (as CaCO3)	30
14	Na	22.72
15	K	8.98
16	Fe	0.1079

It is deciphered from the above table that all of the chemical parameters are within permissible limit for all uses.

Ground Water Issues

The major groundwater related issues found in the study area is low stage of development.

Management Plan

The hydrogeological studies carried out in the village indicate that the village is having good ground water potentiality and have a good scope for the development of ground water through construction of different ground water abstraction structures in a planned way. Total paddy cultivated area is about 150 ha in the area and is mainly rainfed and it remains fallow during rabi season. Present irrigation from ground water source is nil. The state government is planning for surface water irrigation in the area. If this area can be brought under assured irrigation, it will bring prosperity to the society and help the district in achieving self-reliance on food grain.

If it is planned to grow small vegetables and other crops with lesser crop water requirement then irrigation water demand is 300,000 cum (Area 150ha x CRW 0.2 m). In future, if the proposed surface irrigation schemes cover 50% of this area then rest of the area can easily be covered from ground water sources.

During the field visit, it has been observed that there is turbidity in some few dug wells. One of the reasons for turbid water in dug wells is improper construction. The well section should be either concrete or cemented lining and there should be proper cemented platform and parapet as well. In some cases, the water from the well becomes turbid due to siltation for which distillation from time to time is required from the dug well. Whenever there are water quality issues, it needs to be filter before consumption. A simple filter can be made by using sand, charcoal, gravel & pebble layers.

It has also been observed that the distance between dug well and septic tank are very less (some cases less than 10m) which can cause contamination in the well. When a dug well is too close to a septic system or other source of wastewater, varieties of contaminants can enter the well water, like bacteria, viruses, phosphates from detergents and soaps etc. Therefore, a septic tank should be at least 15 m away from a well that is used for drinking.

Keeping in view of the copious rainfall received in the district, rainwater harvesting structures like farm pond and roof top rainwater harvesting should be encouraged in the village.

7.2 Depagarat Village, North Garo Hills District

Depagarat is a medium size village located in Kharkutta Block of North Garo Hills district, Meghalaya with a total of 67 families residing. The Depagarat village has population of 355 out of which 192 are males while 163 are females as per Population Census 2011. Annual rainfall in North Garo Hills district is 2540 mm, out of which monsoon rainfall is 1670 mm. The study area comprised of an intermontane valley and small mounds/ hills. Geologically, it is underlain by alluvium which comprised of sand, silt and clay and gneiss (biotite). The soil is of mainly loamy type with a thickness of about 2-5 meters. The drainage system in this area is usually controlled by topography and the drainage pattern is mainly dendritic type. Dudhnoi river passes the village as shown in the map.

Water Demand & Availability

Daily drinking & domestic water demand in the village is 25 m^3/ day and annual water demand is about 9125 cum. Dynamic Groundwater resources available in the village is 510,000 cum. There is no PHED water supply scheme in the village. The villagers are mainly dependent on ground water for domestic as well as drinking purpose, which is extracted mainly from dug wells. Almost every house is having a dug well.

Agriculture

The villagers grow mainly paddy during monsoon and the cultivated area is around 250 ha. There is no irrigation scheme being implemented in the village. Agriculture depends on rainfall. Apart from paddy cultivation, areca catechu and some rubber tree plantation are also being grown.

Hydrogeology

The area consists of two hydrogeological units – 1) consolidated gneiss rocks and 2) alluvium consisting of unconsolidated sediments. Consolidated gneiss rocks are confined to hilly undulating areas, where ground water occurs in shallow weathered zone and the joints and fractures developed due to tectonic activities form the potential water bearing zones and suitable for development through construction of bore wells. In the alluvial plain, groundwater occurs in the sandy layer. The aquifers consist of sands of various grades with gravel and are suitable for construction of both shallow and deep tube wells. The aquifer system in this village can be divided as a two aquifer system viz., first aquifer (shallow/ phreatic) and second aquifer (deeper).Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells as hand pump. The second aquifer is the deeper aquifer which tapped the fractured zone or the second aquifer layer in alluvium and is mainly in semi-confine to confine condition. During micro level studies in the area, the water level of phreatic aquifer ranges from 4-7 m bgl and the depth of dug well range from 5-10 m bgl. The details of the dug well are given below;

Village	Depagarat
Latitude	25°52' 1.44"
Longitude	90°46' 48.39"
Source	Dug well
Depth (m bmp)	8.60
Measuring Point (m)	0.90
DTWL (m bmp)	7.30

Ground water quality of unconfined aquifer:

A total of 1 ground water sample from dug well was collected during micro level studies and the concentrations of different chemical constituents present in the ground water sample is given in the table below,

Table: Chemical quality of water sample from dug well

Sl. No.	Chemical constituents (Concentrations in mg/l except pH & EC)	Range
1	pH	6.476
2	EC (µs/cm) 25°C	138.7
3	TDS	76.33
4	CO_3^{-2}	BDL
5	HCO_3^{-1}	48.8
6	TA (as CaCO3)	48.8
7	Cl-	46.085
8	SO_4^{-2}	BDL
9	NO_3^{-1}	BDL
10	F-	0.15
11	Ca^{+2}	12
12	Mg^{+2}	3.645
13	TH (as CaCO3)	45
14	Na	19.66
15	K	5.75
16	Fe	0.711

It is deciphered from the above table that except Iron, all of the chemical parameters are within permissible limit for all uses. The iron conc. in this dug well is slightly above acceptable limit.

Ground Water Issues

The major groundwater related issues found in the study area are low stage of development and some of the dug wells get dried up during lean period and also high turbidity in some dug well. As per water quality analysis data of one dug well in the village, it was found that there is a moderately high concentration of iron in shallow aquifer.

Management Plan

The hydrogeological studies carried out in the village indicate that the village is having good ground water potentiality and have a good scope for the development of ground water through construction of different ground water abstraction structures in a planned way. Total paddy cultivated area is about 250 ha in the area and is mainly rainfed and it remains fallow during rabi season. Present irrigation from ground water source is nil. The state government is planning for surface water irrigation in the area. If this area can be brought under assured irrigation, it will bring prosperity to the society and help the district in achieving self-reliance on food grain.

If it is planned to grow small vegetables and other crops with lesser crop water requirement then irrigation water demand is 510,000 cum (Area 250ha x CRW 0.2 m). In future, if the proposed surface irrigation schemes cover 50% of this area then rest of the area can easily be covered from ground water sources.

During the field visit, villagers have complained about turbidity in water from a few dug wells. One of the reasons for turbid water in dug wells is improper construction. The well section should be either concrete or cemented lining and there should be proper cemented platform and parapet as well. In some cases, the water from the well becomes turbid due to siltation for which distillation from time to time is required from the dug well. Whenever there are water quality issues like this case of having moderately high concentration of Iron, it needs to be filtered before consumption. A simple filter can be made by using sand, charcoal, gravel & pebble layers.

It has also been observed that the distance between dug well and septic tank are very close (some cases less than 10m) which can cause contamination in the well. When a dug well is too close to a septic system or other source of wastewater, varieties of contaminants can enter the well water, like bacteria, viruses, phosphates from detergents and soaps etc. Therefore, a septic tank should be at least 15 m away from a well that is used for drinking.

Keeping in view of the copious rainfall received in the district, rainwater harvesting structures like farm pond and roof top rainwater harvesting should be encouraged in the village.

7.3 Rongdiping Village, North Garo Hills District

Rongdiping village is under Resubelpara municipal board which has a population of about 2500. Annual rainfall in North Garo Hills district is 2540 mm, out of which monsoon rainfall is 1670 mm. The study area comprised of an intermontane valley and small mounds/ hills. Geologically, it is underlain by alluvium which comprised of sand, silt and clay and Gneiss (biotite). The soil is of mainly sandy loam type with a thickness of about 2-5 meters.

The drainage system in this area is usually controlled by topography and the drainage pattern is mainly dendritic type.

Water Demand & Availability

Daily drinking & domestic water demand in the village is 175 cum and annual water demand is 63875 cum. Dynamic Groundwater resources available in the village is 500,000 cum. There is PHED water supply scheme in the study area. The people are also dependent on ground water for domestic as well as drinking purpose, which is extracted mainly from dug wells. Almost every house is having a dug well.

Agriculture

The people residing in the area grow mainly paddy during monsoon and the cultivated area is around 250 ha. There is no irrigation scheme being implemented in the area. Agriculture depends on rainfall. Apart from paddy cultivation, some vegetables like cabbage, cauliflower, tomato, potato, maize and chilli are grown during rabi season.

Hydrogeology

The area consists of two hydrogeological units – 1) consolidated gneiss rocks and 2) alluvium consisting of unconsolidated sediments. Consolidated gneiss rocks are confined to hilly undulating areas, where ground water occurs in shallow weathered zone and the joints and fractures developed due to tectonic activities form the potential water bearing zones and suitable for development through construction of bore wells. In the alluvial plain, groundwater occurs in the sandy layer. The aquifers consist of sands of various grades with gravel and are suitable for construction of both shallow and deep tube wells. The aquifer system in this area can be divided as a two aquifer system viz., first aquifer (shallow/ phreatic) and second aquifer (deeper).Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells as hand pump. The second aquifer is the deeper aquifer which tapped the fractured zone or the second aquifer layer in alluvium and is mainly in semi-confine to confine condition. During micro level studies in the area, the water level of phreatic aquifer ranges from 5-7 m bgl and the depth of dug well range from 5-10 m bgl. The details of the dug well are given below;

Village	Rongdiping
Latitude	25°53' 55.98"
Longitude	90°36' 19.16"
Source	Dug well
Depth (m bmp)	8.20
Measuring Point (m)	0.80
DTWL (m bmp)	5.9

Ground water quality of unconfined aquifer:

A total of 1 ground water sample from dug well was collected during micro level studies and the concentrations of different chemical constituents present in the ground water sample is given in the table below,

Table: Chemical quality of water sample from dug well

Sl. No.	Chemical constituents (Concentrations in mg/l except pH & EC)	Range
1	pH	6.05
2	EC (µs/cm) 25°C	97.81
3	TDS	53.88
4	CO_3^{-2}	BDL
5	HCO_3^{-1}	18.3
6	TA (as CaCO3)	18.3
7	Cl-	28.36
8	SO_4^{-2}	2.9491
9	NO_3^{-1}	BDL
10	F-	0.11
11	Ca^{+2}	8
12	Mg^{+2}	3.645
13	TH (as CaCO3)	35
14	Na	5.88
15	K	3.75
16	Fe	0.1278

It is deciphered from the above table that all of the chemical parameters are within permissible limit for all uses.

Ground Water Issues

The major groundwater related issues found in the study area are mainly of low stage of ground water development and improper construction of dug well.

Management Plan

The hydrogeological studies carried out in the village indicate that the village is having good ground water potentiality and have a good scope for the development of ground water through construction of different ground water abstraction structures in a planned way. Total paddy cultivated area is about 250 ha in the area and is mainly rainfed and most of it remains fallow during rabi season. Present irrigation from ground water source is nil. The state government is planning for surface water irrigation in the area. If this area can be brought under assured irrigation, it will bring prosperity to the society and help the district in achieving self-reliance on food grain.

If it is planned to grow small vegetables and other crops with lesser crop water requirement then irrigation water demand is 500,000 cum (Area 250ha x CRW 0.2 m). In future, if the proposed surface irrigation schemes cover 50% of this area then rest of the area can easily be covered from ground water sources.

During the field visit, it has been observed that there is turbidity in some few dug wells. One of the reasons for turbid water in dug wells is improper construction. The well section should be either concrete or cemented lining and there should be proper cemented platform and parapet as well. In some cases, the water from the well becomes turbid due to siltation for which distillation from time to time is required from the dug well. Whenever there are water quality issues, it needs to be filter before consumption. A simple filter can be made by using sand, charcoal, gravel & pebble layers.

It has also been observed that the distance between dug well and septic tank are very less (some cases less than 10m) which can cause contamination in the well. When a dug well is too close to a septic system or other source of wastewater, varieties of contaminants can enter the well water, like bacteria, viruses, phosphates from detergents and soaps etc. Therefore, a septic tank should be at least 15 m away from a well that is used for drinking.

Keeping in view of the copious rainfall received in the district, rainwater harvesting structures like farm pond and roof top rainwater harvesting should be encouraged in the village.

7.4 Rongmaklong Village, North Garo Hills District

Rongmaklong is a medium size village located in Resubelpara Block of North Garo Hills district, Meghalaya with a total of about 54 families residing. Rongmaklong village has population of 204 out of which 113 are males while 91 are females as per Population Census 2011. Annual rainfall in North Garo Hills district is 2540 mm, out of which monsoon rainfall is 1670 mm. The study area comprised of an intermontane valley and small mounds/ hills. Geologically, it is underlain by granite. The soil is of mainly loamy type with a thickness of about 2-4 meters.

Water Demand & Availability

Daily drinking & domestic water demand in the village is 14 cum and annual water demand is 5110 cum. Dynamic Groundwater resources available in the village is 430,000 cum. There is no PHED water supply scheme in the village. The villagers are mainly dependent on ground water for domestic as well as drinking purpose, which is extracted mainly from dug wells. Almost every house is having a dug well.

Agriculture

The villagers grow mainly paddy during monsoon and the cultivated area is around 150 ha. There is no irrigation scheme being implemented in the village. Agriculture depends on rainfall. Apart from paddy cultivation, Areca catechu and some rubber tree plantation are also being grown.

Hydrogeology

The hydrogeological formation of the study area comprised of granite. The presence of weak planes like fractures and joints in these hard rock formation forms the principal aquifer in the area. The ground water in the district occurs under unconfined, semi-confined to confined conditions. Study of dug wells reveals the presence of phreatic/shallow aquifers in the village.

Ground water occurs in shallow weathered zone and the joints and fractures developed due to tectonic activities form the potential water bearing zones and suitable for development through construction of bore wells. The aquifer system in this village can be divided as a two aquifer system viz., first aquifer (shallow/ phreatic) and second aquifer (deeper).Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells as hand pump. The second aquifer is the deeper aquifer which tapped the fractured zone and is mainly in semi-confine to confine condition. During micro level studies in the area, the water level of phreatic aquifer ranges from 2-5 m bgl and the depth of dug well range from 5-10 m bgl. The details of the dug well are given below;

Village	Rongmaklong
Latitude	25°56' 54.49"
Longitude	90°43' 1.41"
Source	Dug well
Depth (m bmp)	5.30
Measuring Point (m)	0.90
DTWL (m bmp)	3.20

Ground water quality of unconfined aquifer:

A total of 1 ground water sample from dug well was collected during micro level studies and the concentrations of different chemical constituents present in the ground water sample is given in the table below,

Table: Chemical quality of water sample from dug well

Sl. No.	Chemical constituents (Concentrations in mg/l except pH & EC)	Range
1	pH	6.583
2	EC (µs/cm) 25°C	47.05
3	TDS	25.89
4	CO_3^{-2}	BDL
5	HCO_3^{-1}	12.2
6	TA (as CaCO3)	12.2
7	Cl-	10.635
8	SO_4^{-2}	4.6417
9	NO_3^{-1}	BDL
10	F-	0.2
11	Ca^{+2}	6
12	Mg^{+2}	3.645
13	TH (as CaCO3)	30
14	Na	0.74
15	K	0.68
16	Fe	0.1244

It is deciphered from the above table that all of the chemical parameters are within permissible limit for all uses.

Ground Water Issues

The major groundwater related issues found in the study area are low stage of development and some of the dug wells get dried up during lean period.

Management Plan

The hydrogeological studies carried out in the village indicate that the village is having good ground water potentiality and have a good scope for the development of ground water through construction of different ground water abstraction structures in a planned way. Total paddy cultivated area is about 150 ha in the area and is mainly rainfed and it remains fallow during rabi season. Present irrigation from ground water source is nil. The state government is planning for surface water irrigation in the area. If this area can be brought under assured irrigation, it will bring prosperity to the society and help the district in achieving self-reliance on food grain.

If it is planned to grow small vegetables and other crops with lesser crop water requirement then irrigation water demand is 300,000 cum (Area 150ha x CRW 0.2 m). In future, if the proposed surface irrigation schemes cover 50% of this area then rest of the area can easily be covered from ground water sources.

During the field visit, villagers have complained about turbidity in water from a few dug wells and some get dried up during lean period. One of the reasons for turbid water in dug wells is improper construction. The well section should be either concrete or cemented lining and there should be proper cemented platform and parapet as well. In some cases, the water from the well becomes turbid due to siltation for which distillation from time to time is required from the dug well. Whenever there are water quality issues, it needs to be filter before consumption. A simple filter can be made by using sand, charcoal, gravel & pebble layers.

It has also been observed that the distance between dug well and septic tank are very less (some cases less than 10m) which can cause contamination in the well. When a dug well is too close to a septic system or other source of wastewater, varieties of contaminants can enter the well water, like bacteria, viruses, phosphates from detergents and soaps etc. Therefore, a septic tank should be at least 15 m away from a well that is used for drinking.

Keeping in view of the copious rainfall received in the district, rainwater harvesting structures like farm pond and roof top rainwater harvesting should be encouraged in the village.

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Annexure 1: Hydrogeological details of bore wells constructed by CGWB in Aquifer mapping area.

Sl No	Rig No	Location	District	Lat	Long	Depth drilled	Depth of constuction	Aquifer tapped	swl	Discharge m^3/hr	Draw down (M)	Transmissibility m^2/hr	Hydrolic conductivity m/day	Specific capacity	Storage co efficient	Remarks
1	**DTH/IR-02/112**	Mendal EW	North Garo Hills	25°49'42.87	90°27'19.59"	146.4	146.4	Fractured Gneiss	10.3 m bgl	11.87	28.18	14.45				
2	**DTH/IR-02/112**	Mendal OW	North Garo Hills	25°49'42.79"	90°27'18.63"	146.4	146.4	Fractured Gneiss	10.03 m bgl	11.87						
3	**DTH/IR-02/112**	Bajengdoba EW	North Garo Hills	25°53'18.20"	90°29'35.59"	201.4	201.4	Fractured Gneiss	5.82 m bgl	11.87	22.03	3.61				

Annexure 2: Dynamic water level data of borewells and dug well during 2019-20

S.No	State*	District*	Block*	Village	Lat*	Long*	Well* Type	MP* (m)	RL* (m)	Depth* (mbgl)	Dia* (m)	Water Level (mbgl)June-2019*	Water Level (mbgl)Nov.-2019*	Water Level (mbgl)March-2020*
1	Meghalaya	North Garo Hills	Resubelpara	Kharkutta	25°55'12.97"	90°53'43.81"	Dug Well	0.9	67	4.4	0.9	1.22	1.85	2.3
2	Meghalaya	North Garo Hills	Kharkutta	Kosakgandim	25°53'24.35"	90°52'33.90"	Dug Well	0	83	2.38	0.9	1.07	1.3	1.4
3	Meghalaya	North Garo Hills	Resubelpara	Nogolpara	25°53'55.14"	90°46'38.33"	Dug Well	1	59	4.93	1	2.18	2.75	3.7
4	Meghalaya	North Garo Hills	Kharkutta	Depagarat	25°51'57.05"	90°46'47.64"	Dug Well	0.9	68	6.6	0.75	2.9	4	3
5	Meghalaya	North Garo Hills	Kharkutta	Wa-Geasi	25°49'20.60"	90°47'15.50"	Dug Well	0.8	79	4.9	0.9	3.6	1.3	3.1
6	Meghalaya	North Garo Hills	Resubelpara	Dajong Gate	25°49'05.14"	90°36'00.30"	Dug Well	0.9	69	2.4	1.5	1.48	1.5	1.6
7	Meghalaya	North Garo Hills	Resubelpara	Rongkaminchi	25°51'16.26"	90°36'54.22"	Dug Well	0.8	62	4.07	0.9	3.35	3.15	3.4
8	Meghalaya	North Garo Hills	Resubelpara	SeonangApal	25°52'30.52"	90°37'32.89"	Dug Well	0.9	62	5.1	1	2.45	2.65	3.2
9	Meghalaya	North Garo Hills	Resubelpara	Bajengdoba New	25°53'48.59"	90°30'16.57"	Dug Well	0.8	56	4.33	1	2.5	2.75	3
10	Meghalaya	North Garo Hills	Resubelpara	Dobakkol	25°52'59.60"	90°30'20.89"	Dug Well	0.8	62	3	1	1.8	1.8	1.95
11	Meghalaya	North Garo Hills	Resubelpara	Mikkasidam	25°51'20.64"	90°28'50.66"	Dug Well	0.5	59	3	1.1	1.71	1.7	1.7
12	Meghalaya	North Garo Hills	Resubelpara	Mendal	25°49'43.22"	90°27'13.37"	Dug Well	0.8	72	5.1	0.85	2.2	2.3	5.1
13	Meghalaya	North Garo Hills	Resubelpara	Rari	25°47'00.75"	90° 25'29.93"	Dug Well	0.7	86	2.8	1	1.75	1.54	2.2
14	Meghalaya	North Garo Hills	Resubelpara	Rangmangre	25°54'22.23"	90°34'09.98"	Dug Well	0.8	214	2.45	1.1	1.3	1.05	1.3
15	Meghalaya	North Garo Hills	Resubelpara	Soksan	25°53'56.60"	90° 38'16.68"	Dug Well	0.9	54	6.75	0.8	4.38	4.6	5.5
16	Meghalaya	North Garo Hills	Resubelpara	Mendipathar	25°55'10"	90°30'26"	Dug Well	0.72	52	5.6	0.8		3.08	4.86
17	Meghalaya	North Garo Hills	Resubelpara	Mendal OW	25°49'42.87"	90°27'19.59"	Bore well	0.6	84	146.4				10.03
18	Meghalaya	North Garo Hills	Resubelpara	Bajengdoba EW	25°53'18.20"	90°29'35.59"	Bore well	0.6	68	201.4				5.83

Annexure 3: Spring discharge data collected during 2019-20

S.No	State*	District*	Block*	Location	Lat*	Long*	Lithology	Spring* Type	RL* (m)	Discharge (lps)June-2019*	Discharge (lps)Nov.-2019*	Discharge (lps)March-2020*
1	Meghalaya	North Garo Hills	Resubelpara	Resubelperahotspring	25˚54’52.45”	90˚35’59.56”	Gneiss	Fractured	76	4.5	4.6	2.4

Annexure 4: Aquifer wise water quality data of Aquifer mapping area

Sl. No.	Village/ Location	Taluka/ Block	District	Toposheet No.	Lat	Long	RL (m)	Aquifer Type	Depth	pH*	EC* μS/cm at 25°C	Turbidity(NTU)	TDS	CO_3	HCO_3	TA as $CaCO_3$*	Cl*	SO_4	NO_3	F^-	Ca*	Mg*	TH*	Na*	K*	Fe
														mg/l												
Shallow Aquifer																										
1	Kharkutta	Kharkutta	North Garo Hills	78 K/13	25°55’12.97"	90°53’43.81”	67	Alluvium	4.4	7.20	64.59	BDL	38.10	BDL	40.0	40.0	14.2	6.0	BDL	0.2	10.0	2.4	35.0	6.8	4.8	0.3
2	Kosakgandim	Kharkutta	North Garo Hills	78 K/13	25°53’24.35”	90°52’33.90”	83	Gneiss	2.38	6.92	126.10	BDL	74.53	BDL	30.0	30.0	28.4	12.2	6.4	0.1	16.0	4.8	60.0	12.8	1.6	0.1
3	Dainadubi	Resubelpara	North Garo Hills	78 K/13	25°53’55.14”	90°46’38.33”	59	Alluvium	4.93	7.43	102.20	BDL	60.53	BDL	45.0	45.0	28.4	5.6	BDL	0.1	14.0	3.6	50.0	10.8	2.5	0.1
4	Depagarat	Kharkutta	North Garo Hills	78 K/13	25°51’57.05”	90°46’47.64”	68	Alluvium	6.6	6.69	62.75	BDL	37.16	BDL	25.0	25.0	17.7	2.0	BDL	0.2	4.0	3.6	25.0	6.3	5.8	0.1
5	Wa-Geasi	Kharkutta	North Garo Hills	78 K/13	25°49’20.60”	90°47’15.50”	79	Gneiss	4.9	7.35	77.04	BDL	45.53	BDL	45.0	45.0	17.7	4.1	BDL	0.1	8.0	6.1	45.0	7.0	1.4	0.0
6	Dajong Gate	Resubelpara	North Garo Hills	78 K/9	25°49’05.14”	90°36’00.30”	69	Gneiss	2.4	7.49	87.73	BDL	51.82	BDL	50.0	50.0	14.2	7.1	8.1	0.1	12.0	7.3	60.0	8.7	2.2	0.1
7	Rongkaminchi	Resubelpara	North Garo Hills	78 K/9	25°51’16.26"	90°36’54.22”	62	Alluvium	4.07	6.42	45.20	BDL	26.78	BDL	20.0	20.0	21.3	2.1	BDL	0.1	6.0	3.6	30.0	6.6	2.2	0.1
8	SeonangApal	Resubelpara	North Garo Hills	78 K/9	25˚52'30.52"	90˚37'32.89"	62	Alluvium	5.1	6.90	45.92	BDL	27.15	BDL	35.0	35.0	14.2	5.8	BDL	0.1	4.0	4.9	30.0	7.2	3.5	0.5
9	Bajengdoba New	Resubelpara	North Garo Hills	78 K/9	25°53’48.59"	90°30’16.57”	56	Gneiss	4.33	6.76	64.27	BDL	38.07	BDL	30.0	30.0	28.4	5.6	BDL	0.1	6.0	3.6	30.0	14.6	2.6	0.0
10	Dobakkol	Resubelpara	North Garo Hills	78 K/9	25°52’59.60”	90°30’20.89”	62	Gneiss	3	7.32	72.45	BDL	43.00	BDL	40.0	40.0	21.3	5.1	BDL	0.2	6.0	8.5	50.0	10.2	2.5	0.1
11	Mikkasidam	Resubelpara	North Garo Hills	78 K/5	25°51’20.64”	90°28’50.66”	59	Alluvium	3	7.34	85.86	BDL	51.03	BDL	45.0	45.0	14.2	6.7	BDL	0.1	10.0	6.1	50.0	8.0	1.7	0.1
12	Mendal	Resubelpara	North Garo Hills	78 K/5	25˚49’43.22”	90˚27’13.37”	72	Gneiss	5.1	7.13	122.00	BDL	72.63	BDL	35.0	35.0	28.4	16.9	1.1	0.0	14.0	6.1	60.0	12.0	7.8	0.0
13	Rari	Resubelpara	North Garo Hills	78 K/5	25˚47'00.75"	90˚ 25'29.93"	86	Gneiss	2.8	7.25	61.95	BDL	36.78	BDL	40.0	40.0	17.7	5.8	BDL	0.1	4.0	3.6	25.0	13.6	3.1	0.2
14	Rangmangre	Resubelpara	North Garo Hills	78 K/9	25°54’22.23”	90°34’09.98”	214	Gneiss	2.45	6.69	112.5	BDL	66.95	BDL	25.0	25.0	24.8	19.2	4.8	BDL	12.0	8.5	65.0	7.0	4.6	BDL
15	Soksan	Resubelpara	North Garo Hills	78 K/9	25˚53'56.60"	90˚ 38'16.68"	54	Alluvium	6.75	6.69	58.59	BDL	34.8	BDL	20.0	20.0	17.7	4.6	BDL	0.1	4.0	6.1	35.0	4.2	3.8	BDL
16	Mendipathar	Resubelpara	North Garo Hills	78 K/9	25°55'10"	90°30'26"	52	Gneiss	5.6	8	36.44	0	17.96	0	40.0		16.0	1.7	1.7	0.5	4.8	1.6	16.0	4.7	2.4	0.0
Deeper Aquifer																										
1	Mendal EW	Resubelpara	North Garo Hills	78 K/5	25°49'42.87"	90°27'19.59"	84	Gneiss	146.4	7.028	95	BDL	51.8	BDL	18.3	18.3	14.2	3.0	14.2	0.1	12.0	4.9	50.0	1.4	0.9	0.2
Spring																										
1	Resuhotspring	Resubelpara	North Garo Hills	78 K/9	25˚54’52.45”	90˚35’59.56”	76	Gneiss		7.86	356.1	0.1	211.5	BDL	195.16	195.16	21.27	46.49	0.07	1.7	58.05	8.47	180	21	7.1	0.5

Annexure 5: Litholog of exploratory wells

Unique ID	
Village	Mendal EW
Taluka/Block	Bajengdoba
District	North Garo Hills
Toposheet No	78K/6
Latitude	25°49'42.87"
Longitude	90°27'19.59"
RL (m amsl)	84
Drilled Depth	146.40
Casing	19
SWL (mbgl)	10.3
Discharge (lps)	3.2
Date/year	07.02.2020

Depth range (mbgl)		Thickness (m)	Litholog
From	To		
0	7.30	7.30	Top Soil, brown in colour
7.30	40.95	33.65	Gneiss, compact, sample cuttings are fine grained size, brown in colour.
40.95	41.95	1	Gneiss, fractured, sample cuttings are fine to medium grained size, brown in colour.
41.95	129.90	87.95	Gneiss, compact, sample cuttings are medium to coarse grained size, brown grey in colour.
129.90	130.90	1	Gneiss, fractured, sample cuttings are coarse grained size, brown in colour.
130.90	146.40	15.45	Gneiss, compact, sample cuttings are medium to coarse grained size, grayish brown in colour.

Unique ID	
Village	Mendal OW
Taluka/Block	Bajengdoba
District	North Garo Hills
Toposheet No	78K/6
Latitude	25°49'42.79"
Longitude	90°27'18.63"
RL (m amsl)	84
Drilled Depth	146.40
Casing	20
SWL (mbgl)	10.03
Discharge (lps)	3.2
Date/year	07.02.2020

Depth range (mbgl)		Thickness (m)	Litholog
From	To		
G.L	7.30	7.30	Top Soil, brown in colour
7.30 l	13.43	6.13	Gneiss, weathered, sample cuttings are medium to coarse grained size, brown in colour.
13.43	40.95	27.52	Gneiss, compact, sample cuttings are fine grained size, brown in colour.
40.95	41.95	1	Gneiss, fractured, sample cuttings are fine to medium grained size, brown in colour.
41.95	129.90	87.95	Gneiss, compact, sample cuttings are medium to coarse grained size, brown grey in colour.
129.90	130.90	1	Gneiss, fractured, sample cuttings are coarse grained size, brown in colour.
130.95	146.40	15.45	Gneiss, compact, sample cuttings are medium to coarse grained size, grayish brown in colour.

Unique ID	
Village	Bajengdoba EW
Taluka/Block	Bajengdoba
District	North Garo Hills
Toposheet No	78 K/5
Latitude	25˚53’18.20”
Longitude	90˚29’35.59”
RL (m amsl)	68
Drilled Depth	201.4
Casing	20.8
SWL (mbgl)	5.82
Discharge (lps)	3.3
Date/year	18.03.2020

Depth range (mbgl)		**Thickness (m)**	**Litholog**
From	To		
GL	6.2	6.2	Top Soil, reddish brown in colour
6.2	18.4	12.2	Gneiss, highly weathered, sample cuttings are very fine to medium grained size, brown in colour.
18.4	42.8	24.4	Gneiss, compact, sample cuttings are fine to coarse grained size, brownish grey in colour.
42.8	43.8	1	Gneiss, fractured, sample cuttings are fine to coarse grained size, dark grey in colour.
43.8	67.2	23.4	Gneiss, compact, sample cuttings are fine to coarse grained size, grey in colour.
67.2	68.2	1	Gneiss, fractured, sample cuttings are fine to coarse grained size, grey in colour.
68.2	103.8	35.6	Gneiss, compact, sample cuttings are fine to very coarse grained size, grey in colour.
103.8	104.8	1	Gneiss, fractured, sample cuttings are medium to very coarse grained size, grey in colour.
104.8	183.1	78.3	Gneiss, compact, sample cuttings are fine to coarse grained size, grey to dark grey in colour.
183.1	184.1	1	Gneiss, fractured, sample cuttings are fine to very coarse grained size, grey in colour.
184.1	201.4	17.3	Gneiss, compact, sample cuttings are fine to coarse grained size, grey in colour.

Annexure 6: Soil Infiltration Test data

a. Location – Mendal

Time (t)	Time difference	After filling	Before filling	Depth of Infiltration	Cummulative Infiltration	Infiltration rate	f-fc	Remarks
min	**min**	**cm**	**cm**	**cm**	**cm**	**cm/hr**	**f0**	
0		**21**		**0**	**0**	**f0 = 0.6 from the curve**	**ft**	
1	1		20.3	0.7	0.7	42	41.4	
2	1		19.9	0.4	1.1	24	23.4	
3	1		19.6	0.3	1.4	18	17.4	
4	1		19.5	0.1	1.5	6	5.4	
5	1		19.4	0.1	1.6	6	5.4	
6	1		19.3	0.1	1.7	6	5.4	
7	1		19.2	0.1	1.8	6	5.4	
8	1		19.1	0.1	1.9	6	5.4	
9	1		19	0.1	2	6	5.4	
10	1		18.9	0.1	2.1	6	5.4	
15	5	21	20.7	0.3	2.4	3.6	3	Refilled
20	5		20.5	0.2	2.6	2.4	1.8	
25	5		20.4	0.1	2.7	1.2	0.6	
30	5		20.3	0.1	2.8	1.2	0.6	
35	5		20.2	0.1	2.9	1.2	0.6	
40	5		20.1	0.1	3	1.2	0.6	
50	10	21	20.8	0.2	3.2	1.2	0.6	Refilled
60	10		20.6	0.2	3.4	1.2	0.6	
70	10		20.5	0.1	3.5	0.6	0	
80	10		20.4	0.1	3.6	0.6	0	
90	10		20.3	0.1	3.7	0.6	0	
110	20	21	20.8	0.2	3.9	0.6	0	Refilled
130	20		20.6	0.2	4.1	0.6	0	
150	20		20.4	0.2	4.3	0.6	0	
170	20		20.2	0.2	4.5	0.6	0	

b. Location – Rangmangre

Time (t)	Time difference	After filling	Before filling	Depth of Infiltration	Cummulative Infiltration	Infiltration rate	f-fc	Remarks
min	**min**	**cm**	**cm**	**cm**	**cm**	**cm/hr**	**f0**	
0		**21.5**		**0**	**0**	**f0 = 12.6 from the curve**	**ft**	
1	1	21.5	20.5	1	1	60	47.4	
2	1	20.5	19.9	0.6	1.6	36	23.4	
3	1	19.9	19.4	0.5	2.1	30	17.4	
4	1	19.4	18.9	0.5	2.6	30	17.4	
5	1	18.9	18.5	0.4	3	24	11.4	
6	1	18.5	18.1	0.4	3.4	24	11.4	
7	1	18.1	17.7	0.4	3.8	24	11.4	
8	1	17.7	17.4	0.3	4.1	18	5.4	
9	1	17.4	17.1	0.3	4.4	18	5.4	
10	1	17.1	16.8	0.3	4.7	18	5.4	
15	5	22	20.2	1.8	6.5	21.6	9	Refilled
20	5	20.2	18.6	1.6	8.1	19.2	6.6	
25	5	18.6	17	1.6	9.7	19.2	6.6	
30	5	17	15.8	1.2	10.9	14.4	1.8	
35	5	15.8	14.6	1.2	12.1	14.4	1.8	
40	5	14.6	13.4	1.2	13.3	14.4	1.8	
50	10	22	19.6	2.4	15.7	14.4	1.8	Refilled
60	10	19.6	17.3	2.3	18	13.8	1.2	
70	10	17.3	15.1	2.2	20.2	13.2	0.6	
80	10	15.1	12.9	2.2	22.4	13.2	0.6	
100	20	22	17.6	4.4	26.8	13.2	0.6	Refilled
120	20	22	17.8	4.2	31	12.6	0	Refilled
140	20	22	17.8	4.2	35.2	12.6	0	Refilled

c. Location – Resubelpara

Time (t)	Time difference	After filling	Before filling	Depth of Infiltration	Cummulative Infiltration	Infiltration rate	f-fc	Remarks
min	min	cm	cm	cm	cm	cm/hr	f0	
0		**21.5**		**0**	**0**	**f0 = 72 from the curve**	**ft**	
1	1	25	21.5	3.5	3.5	210	138	
2	1	21.5	19.2	2.3	5.8	138	66	
3	1	19.2	17	2.2	8	132	60	
4	1	17	14.8	2.2	10.2	132	60	
5	1	14.8	13.6	1.2	11.4	72	0	
6	1	13.6	12.2	1.4	12.8	84	12	
7	1	25	23.2	1.8	14.6	108	36	Refilled
8	1	23.2	21	2.2	16.8	132	60	
9	1	21	19.2	1.8	18.6	108	36	
10	1	19.2	17.5	1.7	20.3	102	30	
15	5	25	17.5	7.5	27.8	90	18	Refilled
20	5	17.5	11	6.5	34.3	78	6	
25	5	25	17.8	7.2	41.5	86.4	14.4	Refilled
30	5	17.8	11.5	6.3	47.8	75.6	3.6	
35	5	25	18.7	6.3	54.1	75.6	3.6	Refilled
40	5	25	18.8	6.2	60.3	74.4	2.4	Refilled
45	5	25	18.9	6.1	66.4	73.2	1.2	Refilled
50	5	25	18.9	6.1	72.5	73.2	1.2	Refilled
60	10	25	12.9	12.1	84.6	72.6	0.6	Refilled
70	10	25	13	12	96.6	72	0	Refilled
80	10	25	13	12	108.6	72	0	Refilled
90	10	25	13	12	120.6	72	0	Refilled

d. Location – Kharkutta

Time (t)	Time difference	After filling	Before filling	Depth of Infiltration	Cummulative Infiltration	Infiltration rate	f-fc	Remarks
min	**min**	**cm**	**cm**	**cm**	**cm**	**cm/hr**	**f0**	
0		**23**		**0**	**0**	**f0 = 6 from the curve**	**ft**	
1	1	23	22.4	0.6	0.6	36	30	
2	1	22.4	21.9	0.5	1.1	30	24	
3	1	21.9	21.5	0.4	1.5	24	18	
4	1	21.5	21.3	0.2	1.7	12	6	
5	1	21.3	21	0.3	2	18	12	
6	1	21	20.8	0.2	2.2	12	6	
7	1	20.8	20.6	0.2	2.4	12	6	
8	1	20.6	20.4	0.2	2.6	12	6	
9	1	20.4	20.2	0.2	2.8	12	6	
10	1	20.2	20	0.2	3	12	6	
15	5	23	22.3	0.7	3.7	8.4	2.4	Refilled
20	5	22.3	21.6	0.7	4.4	8.4	2.4	
25	5	21.6	20.9	0.7	5.1	8.4	2.4	
30	5	20.9	20.3	0.6	5.7	7.2	1.2	
35	5	20.3	19.7	0.6	6.3	7.2	1.2	
40	5	19.7	19.1	0.6	6.9	7.2	1.2	
50	10	23	21.9	1.1	8	6.6	0.6	Refilled
60	10	21.9	20.8	1.1	9.1	6.6	0.6	
70	10	20.8	19.8	1	10.1	6	0	
80	10	19.8	18.8	1	11.1	6	0	
100	20	23	21	2	13.1	6	0	Refilled
120	20	21	19	2	15.1	6	0	
140	20	23	21	2	17.1	6	0	Refilled

Annexure 7: Ground water resource

a) General Description of Ground Water Assessment in North Garo Hillsdistrict for 2017-18 (area in ha)

Name of Ground Water Assessment Unit	North Garo Hills
Type of Ground Water Assessment Unit	District
Type of rock formation	Granite, Gneiss and alluvium
Total area of Groundwater Assessment Unit	116000
Hilly area	65472
Command area	0
Non-command area	50528
Poor ground water quality area	0
Area considered for groundwater recharge	50528

b) Ground Water Resource Potential in North Garo Hillsdistrict during 2017-18

Assessment Unit / District	North Garo Hills
Command/ Non-Command/ Total	Total
Recharge from rainfall during monsoon season	12073.67ham
Recharge from other sources during monsoon season	75.88ham
Recharge from rainfall during non-monsoon season	3773.95ham
Recharge from other sources during non-monsoon season	20.61ham
Total Ground Water Recharge	15944.11 ham
Annual extractable Ground Water	14349.70ham

c) Ground Water extraction for All Uses in North Garo Hillsdistrict

District	North Garo Hills
Total extraction for domestic and industrial purpose (as per households)	24.30 ham
Total extraction for irrigation	51 ham
Total groundwater extraction	75.30 ham

d) Balance Ground Water Resources Available and Stage of Groundwater extraction in the Study Area as On 31st March 2017

Assessment Unit / District	North Garo Hills
Command/ Non-Command/ Total	Total
Net Annual Ground Water Availability	14250.10ham
Existing Gross Ground Water extraction for Irrigation	51 ham
Existing Gross Ground Water extraction for domestic and industrial water supply	24.3 ham
Existing Gross Ground Water extraction for All Uses	75.3 ham
Provision for domestic, and industrial requirement supply to 2025	48.60ham
Net Annual Ground Water Availability for future irrigation extraction	14250.10ham
Stage of ground water extraction	0.52%

e) Categorization for Ground Water Development of North Garo Hillsdistrict during 2017-18

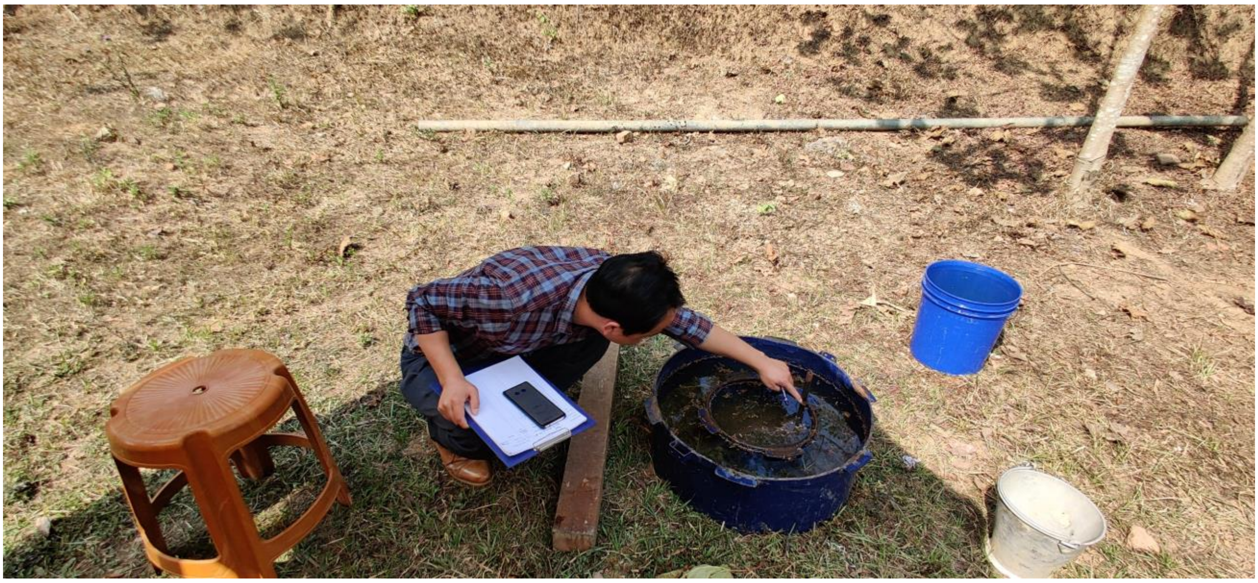
Assessment/Administrative Uint	Stage of Ground Water Development %	Quantity Categorization (Safe/Semi-Critical/ Critical/ Over Exploited)	Quality Tagging	Validation of Assessment using GW Level Trends (Valid/To be Re-assessed)
North Garo Hills	0.52	Safe	Fresh	Could not validate , WL data not sufficient/ representative

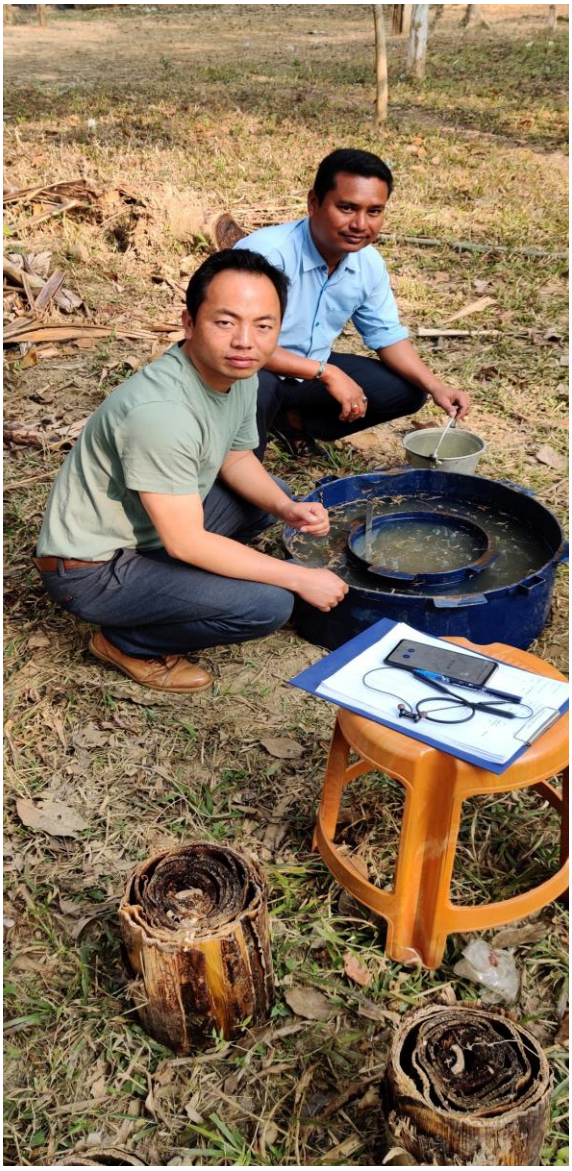
Annexure 8: Data gap and data requirement in North Garo Hills district

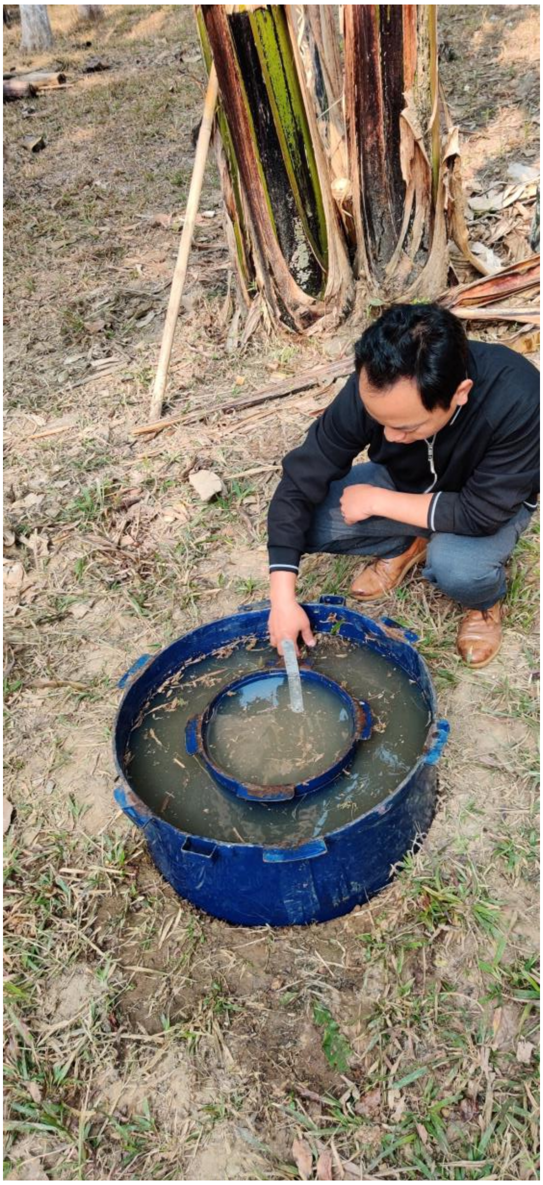
Toposheet No.	Grid	Data Existing										Data required									
		Aquifer I					Aquifer II					Aquifer I					Aquifer II				
		EW	OW	VES	CHE	WL	EW	OW	VES	CHE	WL	EW	OW	VES	CHE	WL	EW	OW	VES	CHE	WL
78 K/5	B3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/5	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/5	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/5	C3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/6	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/6	C1	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	1	1	2	1	1
78 K/6	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/9	A2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
78 K/9	A3	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	1	2	1	1
78 K/9	B2	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	2	0	0
78 K/9	B3	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/9	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/9	C3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/10	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/10	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/10	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/13	A2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/13	B2	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1	0	1	2	1	1
78 K/13	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/13	A3	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	1	1	2	1	1
78 K/13	B3	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
78 K/13	C3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/14	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/14	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
78 K/14	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/1	A3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
	TOTAL	2	0	0	5	5	1	0	0	0	0	13	14	0	21	21	12	13	52	13	13

FIELD PHOTOGRAPHS

Ground Water exploration studies in North Garo Hills district during 2019-20







Soil Infiltration Test Studies in North Garo Hills during 2019-20

Water level monitoring, water sample collection and monitoring of spring discharge in North Garo Hills district during 2019-20

Interacting with villagers during micro level aquifer management plan studies in North Garo Hills district during 2019-20