केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

WEST GARO DISTRICT, MEGHALAYA

उत्तर पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

GOVERNMENT OF INDIA

MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

REPORT
ON

"AQUIFER MAPPING AND MANAGEMENT PLAN OF WEST GARO DISTRICT, MEGHALAYA"

(AAP 2018-19)

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Preface

Under National Aquifer Mapping and Management Plan (NAQUIM) program, Central Ground Water Board, North Eastern Region, Guwahati, Assam has carried out aquifer mapping and management plan in West Garo Hills district of Meghalaya. The objective was to understand the aquifer system down to the depth of 200 meters, decipher the aquifer geometry, its characteristics, quantity, quality and formulate a complete sustainable and effective management plan for ground water development in the study area.

A multi disciplinary approach of geology, geophysics, hydrology and chemistry was adopted to achieve the objectives of the study. A management plan was made with emphasis on irrigation for agricultural.

This report elaborates the different aquifer system prevailing in the study area, its characteristics and also provides the different scientific data which will help in proposing plans to achieve drinking water security, irrigation facilities etc. through sustainable ground water development.

The groundwater 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 in the district. To use the groundwater for irrigation purpose, a cropping plan has been designed for the district by using CROPWAT model developed by FAO.

The study of this Aquifer mapping and management plan of West Garo Hills district was carried out under the guidance and supervision of Shri. G L Meena, Regional Director, CGWB, NER, Guwahati and Shri Tapan Chakraborty, Nodal officer of NAQUIM, NER who has helped in all the aspects of technical inputs and report preparation.

I hope this report will help the stake holders, planners, policy makers, professionals, academicians and researchers dealing with water resources or ground water resources management.

Acknowledgement

I would like to acknowledge all the below mentioned for their help and support in all aspects related to this work.

I would like to extend my heartfelt gratitude to Shri. G L Meena, Regional Director, CGWB, NER, Guwahati for his constant support and guidance during the course of this study.

I render my sincere thanks to my supervisor Shri Tapan Chakraborty, Officer In Charge, SUO, Shillong & Nodal officer of NAQUIM, NER and Shri Biplap Ray, Scientist-D and T.S to RD for their support, technical input, encouragement during the year.

Sincere thanks to Dr. D.J. Khound, Scientist-B and Shri. S.Kent, Scientist-B for all the technical inputs and support in preparation of report.

I would like to thank all the officers and staff of the Regional Chemical laboratory, NER, Guwahati for analysing the ground water samples and providing the data. I thank all the Engineers and Drilling staff of CGWB, Division VII, Guwahati for their contribution in ground water exploratory drilling activities in the study area.

I sincerely thank Geological Survey of India, North East Space Application Centre, Survey of India and Indian Meteorological Department for providing the valuable data and maps.

I would also like to thank Meghalaya State Government officials of Water Resource Department, Public Health Engineering Department, Statistical Department and Agricultural Department for providing all the necessary information of the study area.

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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
DTWL	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	Kilometre
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
TW	Tube Well

EXECUTIVE SUMMARY

Aquifer Mapping studies and Management Plan has been carried out in West Garo Hills district, Meghalaya under National Aquifer Mapping and Management Plan (NAQUIM) programme 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. This study 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 1830 sq.km out of 2811 sq.km of the district and is underlain by unconsolidated rock (alluvium), semi-consolidated rocks (sandstone and shale) and consolidated rocks (granite gneiss).

Geomorphologically, the district represents a remnant of an ancient plateau of Precambrian Indian shield block, uplifted to its present height due to tectonic activities in the past. The southern and northern parts form a platform on which Tertiaries were deposited in the post- cretaceous period. Agriculture is the main stays of livelihood of the people in the district. The importance of agriculture in the life of the people is reflected in the population which is predominantly rural. The main crop being paddy, the other crops cultivated in the district are mustard, sugarcane, jute, potato, tapioca, cotton etc.

Major part of the district is covered with hill and communication is poor. As such habitation is clustered in plain area and ground water abstraction structures are also clustered in the plain area. Occurrence of ground water in the study area is mainly of weathered and fractured Gneissic rocks, fractured Sandstone and granular zone of alluvium formation. 35 key dug wells and 7 nos. of springs are established to study the water level, quality, spring discharge and its behavior periodically. Besides there are 14 ground water monitoring station in the district and 8 Exploratory well and 4 observatory well (drilled during the AAP) were monitored throughout the year. Moreover, water samples were collected from monitoring wells for detailed, iron, heavy metals and arsenic.

The depth to water level in these dug well ranges from 0.95 to 4.95 m bgl during post monsoon and 1.66 to 6.89 m bgl during pre-monsoon season. These shallow aquifer occurs under unconfined condition and the depth of the dug well in the district ranges from 3 to 14 m bgl.To study the piezometric head, depth to water level were monitored in 9 bore wells drilled by CGWB. The piezometric head ranges from 3.2 m bgl at Dadenggre to 67.00 m bgl at Chasingre . A total of 7 springs were established and monitored periodically during the course of study. Most of these springs are depression and topographic or fractured springs. It

is observed that the discharge of springs ranges from dry to 7 litres per minute during pre-monsoon and 10 to 30 litres per minute during post-monsoon season

The aquifer system in this district can be divided as 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 40 m bgl. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures upto the maximum depth of 200 m bgl.

Aquifer I is the unconfined aquifer where the tapping of aquifer zone ranges within 2 to 40 m depth and generally exhibits unconfined nature of the aquifer. Aquifer IIis the deeper aquifer which occurs as semi confine to confine condition where ground water is found in granular zone of sand of alluvium formation and the fractured zone of consolidated Sandstone and granite gneiss. The number of fractures and granular zones varies widely which show the complexity of the hydrogeology of consolidated hard rock formation.

The ground water quality indicates that the concentration of iron is beyond permissible limit in one bore well. The concentration of fluoride is beyond permissible limit in 4 bore well. The other parameters are found to be within permissible limit.

Dynamic Groundwater Resources of the district has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC’2005). The net ground water availability was 29365 ham and the stage of ground water development was 1.41% which comes under safe category.

Finally, the aquifer map is generated based on the inputs from geological, hydrogeological, geophysical 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 West Garo Hills district, Meghalaya during AAP 2018-19 covering an entire area of 1830 sq.km. Under National Aquifer Mapping and Management (NAQUIM) program, combination of geologic, geophysical, hydrologic and hydro chemical 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/PYT of bore wells, soil infiltration test, slug tests 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 Location

West Garo Hills district is in the western part of Meghalaya State. The district is bounded by the East Garo Hills district on the east, the South Garo Hills on the south-east, the South west

Garo district in the south west, the North Garo and the Goalpara district of Assam on the north and north-west and Bangladesh on the south. It lies between longitude $89^0$50'00" and $90^0$27'30" and latitude $25^0$13'30" and $26^0$00'30" covered by survey of India toposheet No.78K and 78G.

1.5 Administrative set up

The district headquarters of West Garo Hill district is Tura, which is the second largest town in the State after Shillong. The district has one sub- divisions namely: Dadenggre and six development blocks. They are:- Rongram C & RD Block, Dadenggre C & RD Block, Selsella C & RD Block, Tikrikilla C & RD Block, Gambegre C & RD Block and Dalu C & RD Block. The administrative map of the district is given in Fig 1.1.

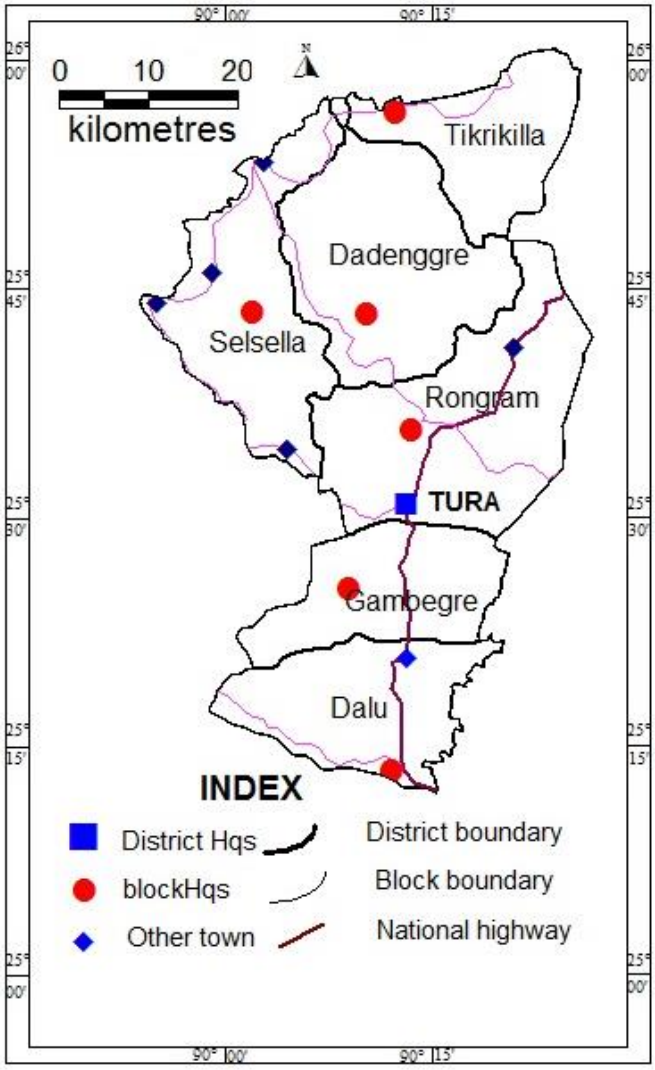


Fig 1.1: Administrative map of the district

1.6 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 district are collected from the available

literatures of Central Ground Water Board, Water Resources Department of Meghalaya and various Central and State Government agencies. The Data Requirement, Data Availability and Data Gap Analysis are presented in table 1.1.and annexure 6 respectively.

Table 1.1: Data Availability and Data Gap Analysis in the study area

Sl. No.	Items	Data Requirement	Data Availability	Data Gap
1	Ground Water Exploration Data	Both first aquifer and second aquifer	18 EW	I Aquifer : 16 nos. of EW & OW. II Aquifer : 23 nos. of EW and OW
2	Geophysics	Geophysical data of the Study area	10 VES	II Aquifer : 40 nos. of VES
3	Ground Water Monitoring Regime	Representative Monitoring Wells well distributed over the Study Area for both first and second aquifers.	14 Monitoring Well (DW)	I Aquifer : 26 nos. II Aquifer : 23 nos.
4	Ground Water Quality	Representative Monitoring Wells well distributed over the Study Area for both first and second aquifers.	Water quality data from monitoring well	I Aquifer : 26 nos. II Aquifer : 23 nos.
5	Specific yield (Shallow and deeper aquifer)	Both aquifers	Nil	Entire study area
6	Climate	Season-wise Rainfall pattern	Annual Rainfall data from one Meteorological Station	Time-series data on Rainfall
7	Soil	Soil map and Soil Infiltration Rate	Soil map	Latest data required
8	Land use	Latest Land Use pattern	Latest Land Use pattern	Latest data required
9	Geomorphology	Detailed Information on Geomorphology of the area	District level information	Entire study area
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

1.7 Demography:

West Garo Hills district is essentially a hilly and tribal area and as per 2011 census, the population of the district is 470796 with male population of 237024 and female population of

233772. The total population (urban/rural) of the district as per 2011 census is shown in table 1.2

Table 1.2: Rural/urban wise population according to 2011 census

total/urban/ rural	2011 census		
	Total	Male	Female
Rural	395938	199788	196150
Urban	74858	37236	37622
Total	**470796**	**237024**	**233772**

Source: District statistical office, Tura

1.8 Communication:

Tura, the district capital is well connected by road with other places in the district as well as with the rest of the Meghalaya and Assam. The National Highway 51 connects Paikan in Assam on National Highway 37 with Tura, which extends further to Dalu, near the Bangladesh border. Buses by Meghalaya Transport Corporation and other private transport services run regularly connecting Tura with all important places in the districts of Garo Hills and also to Shillong (323 km), the capital of the State and to Guwahati (220 km), the capital of Assam, which is also the nearest railhead.

1.9 Climate:

The climate of the district is largely controlled by South-West monsoon and seasonal winds. The West Garo Hills district being relatively lower in altitude to the rest of Meghalaya, experiences a fairly high temperature for most part of the year. The average annual rainfall is 2729 mm of which more than two-thirds occur during the monsoon, winter being practically dry. The rainfall data is given in table 1.3.

Table 1.3:Rainfall data in West Garo Hills District

Rainfall	**Normal RF (mm)**
SW monsoon (June-Sep):	1673
NE Monsoon(Oct-Dec):	299.2
Winter (Jan- March)	38.2
Summer (Apr-May)	719
Annual	2729.4

Source: District & Local Research Station & Laboratories, Tura

1.10Geomorphology

Geomorphologically, the district represents a remnant of an ancient plateau of Precambrian Indian shield block, uplifted to its present height due to tectonic activities in the past. The southern and northern parts form a platform on which Tertiaries were deposited in the post-cretaceous period.

In general, the district has a diversity of landscape such as hills, plateau, deep gorges and plain areas. The West Garo Hills district is mostly hilly with plains fringing the northern, western and the south-western borders. There are three important mountain ranges in the districts of Garo Hills namely, Tura range, Arbella range and Raggira range. Topography varies from gently rolling type to highly undulating type with the E-W trending Garo hill range of Central Upland zone and plains fringing the northern, western and the south-western borders. The altitude of the Garo Hills District ranges from 23 m amsl to 1631 m amsl. The Tura range is one of the most important mountain ranges in the West Garo Hills. The Tura range comprises of many peaks like Nokreh peak (1631 m), Megonggiri (1283 m), Meiminram (1196 m) and Gowangdar (1011 m) etc. The Arbella Peak lies on the eastern part of the district and the highest point is at Asananggre village (999 m). The Ranggira Hill (673 m) range lies on the western fringe of the Garo Hills and ends in Hallidayganj village. The DEM is shown in fig 1.2. Broadly, the district can be differentiated into the following geomorphic units.

- **Denudational Low and High Hills:** It occupies the major part of the state comprising of hard rocks like granite and gneiss. It is moderately dissected by fractures and joints forming a good number of narrow intermontane valleys.
- **Dissected Plateau:** It is found in the south portion of district comprising of soft and friable rocks such as shale and sandstone.
- **Deep Gorges:** It is found in the southern parts of the district and comprises mainly of tertiary group of rocks.
- **Alluvial Plain**: It is exposed in the northern, western and the south-western parts of the district comprising fluviatile sediments.

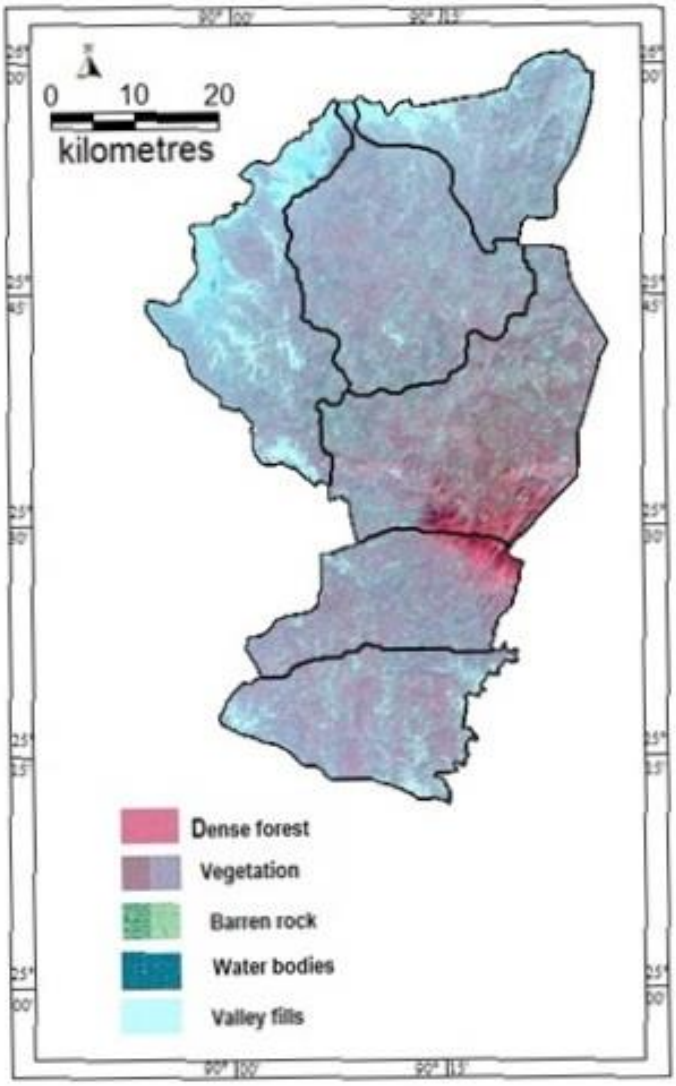


Fig 1.2: DEM of West Garo Hills District (*Source: NESAC*)

1.11 Land use

Land utilization statistics provide detailed information of the land use pattern in the district. 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 West Garo Hills district is shown in the following Table1.3 and land use map is shown in Fig. 1.3.

Table 1.3: Land use pattern in West Garo Hills District, 2015-16

Land Classifications	Area in hectares
A. Geographical Area	281100
B. Reporting Area	281090
1. Forests (classed & unclassed)	126265
2. Area not available for cultivation (i) Area under non-agricultural uses	
a. Barren and uncultivable lands	0

b. Water logged land	821
c. Social Forestry	2325
d. Land under still water	4702
e. Other land	2631
TOTAL (i) = (a to e)	10479
(ii) Barren and unculturable lands	5330
TOTAL = Col. i& ii	15809
3. Other uncultivable lands a. Permanent pastures and other grazing lands	0
b. Land under Misc. tree crops &	18420
grooves etc. c. Cultivable wastelands	11577
TOTAL = (a+b+c)	29997
4. Fallow lands	
a. Fallow lands other than current fallows	27666
b. Current fallows	8112
TOTAL = (a+b)	35778
5. Net area sown	73241
6. Area sown more than once	18668
7. Total Cropped area	91909

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

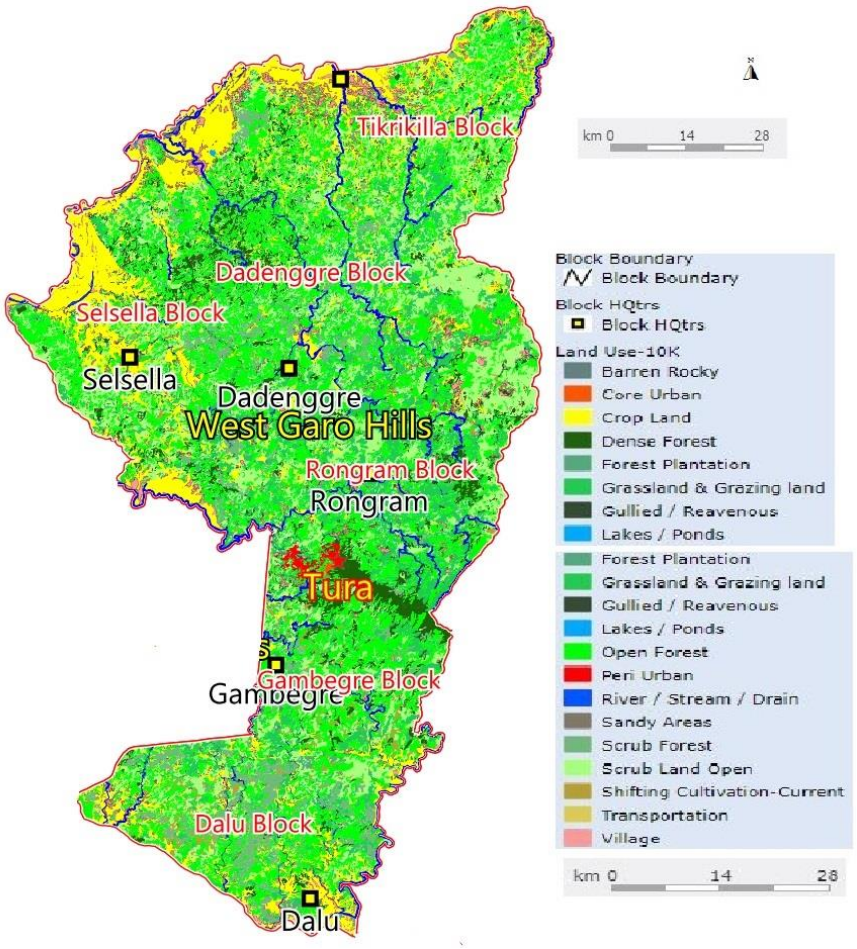


Fig 1.3: Land use map of West Garo Hills District (*Source: NESAC*)

1.12 Soil

High rainfall, humid subtropical climate and favorable topography have resulted in the formation of soil profile (1-10 m) in the district. The soil is mostly deep brown, black soil, red soil, alluvial soil, sandy soil and acidic soil. The acidic character is due to leaching of bases caused by high rainfall. The sandstone gave rise to sandy and permeable texture soil. The soil is mostly sandy, reddish brown to yellow brown in color, acidic in reaction with low water holding capacity and has poor contents of organic matter and nutrients. The soil classification has been conducted by the Regional Center of National Bureau of Soil Survey and Land Use Planning, for the State of Meghalaya. Soil map of the area is given in Fig 1.4.

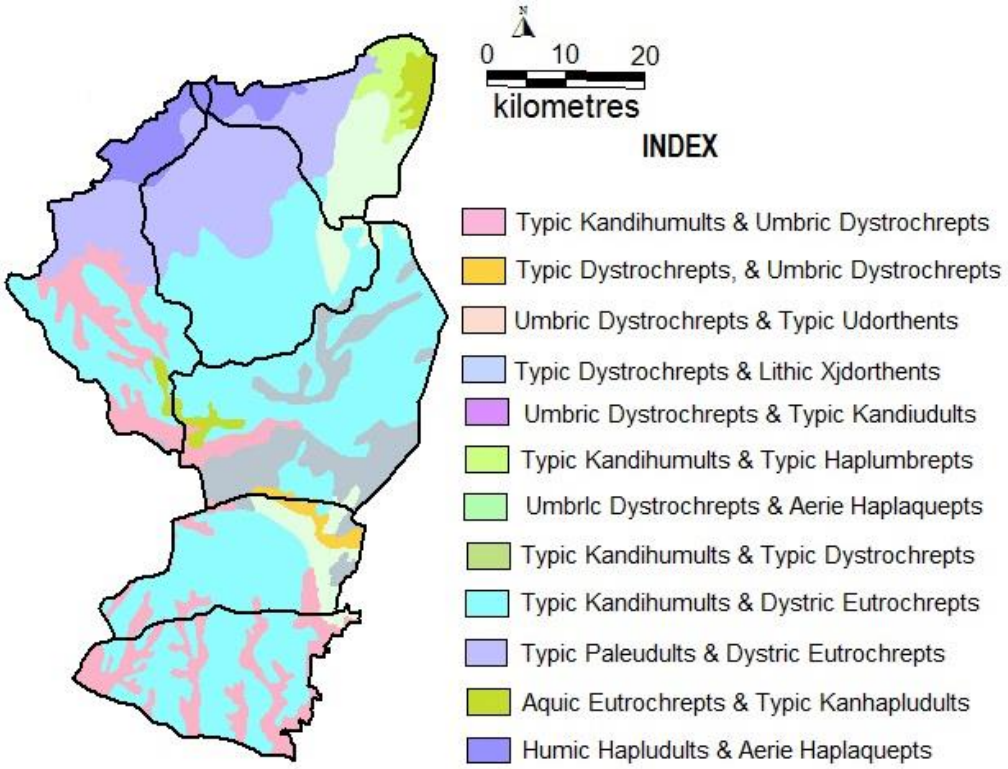


Fig. 1.4: Soil map of West Garo Hills District

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

1.13 Agriculture

Agriculture is the main stays of livelihood of the people in the district. The importance of agriculture in the life of the people is reflected in the population which is predominantly rural. The dominating role of agriculture has bearing even upon the socio-economic, cultural and religious life of the people and manifests itself in the form of festival, rites and beliefs. Agriculture and its activities are by and large confined to the valleys and slope. The main crop being paddy, the other crops cultivated in the district are mustard, sugarcane, jute, potato, tapioca, cotton etc. The sizeable crops with commercial potential are chilies, ginger,

pineapple, turmeric and also banana in the areas adjoining Assam. Tezpata leaf (Bay leaf) and leaf for Bidi making could have bright commercial prospects.

Wet rice cultivation is practiced in the plains areas while in the hills, the population practice *jhum* or shifting cultivation. With the passing of time, and the increasing pressure of population, the *jhum* cycle has been considerably reduced, averaging three years instead of the norm of seven. The practice has led to extensive denudation of forests and progressive destruction of the ecology. Government has taken several steps to wean the people away from this practice, either by taking up schemes of resettling the people of selected villages in new settlement, providing them with amenities like good roads and running water, or by encouraging them to adopt terrace cultivation. West Garo Hills with a wide variety of Agro-climatic conditions, soil and rainfall provide opportunities for growing varied range of Horticultural and plantation crops. The season wise cropping pattern of West Garo Hills District is shown in Table 1.4.

Table 1.4 Season wise cropping pattern of West Garo Hills district

Name of the Crop	Kharif (May to Oct)	Rabi (Nov to April)
Paddy	Ploughing, transplanting inter culture nursery operation, sowing	Harvesting
Maize	Sowing, harvesting	Land preparation, inter culture sowing operation,
Tomato, potato, beans etc	-----do----	-----do-----

Source: Department of Agriculture Office, Govt. of Meghalaya.

The important fruit crops of the district are oranges, pineapple, litchi, banana, jackfruit and other citrus fruits. Important plantation crops are arecanut, cashewnut, coconut, tea, black pepper, bayleaf, betel leaf and rubber. Spices like ginger; turmeric, chilies, large cardamom and cinnamon are also grown. Both kharif and rabi vegetables are grown. The district has a Tea Nursery at Rongram. The Rubber Board has a Regional office in Tura and has been promoting cultivation of rubber in the region. Present area under different crops and their productivity is shown in table 1.5 and table 1.6.

Table 1.5: Area of agricultural crop and their productivity, West Garo Hills district (2015-16)

Crops	**Area (ha)**	**Avg.Yield (kg/ha)**
Autumn rice	11318	2259
Winter rice	11361	2931
Spring rice	7850	4793
Total Rice	**30529**	**3161**
Wheat	**188**	**2059**
Maize	4667	2361
Small Millet (Finger millet,	1094	646

Foxtail millet, Pearl Millet)		
Pulses (pea, Lentil, cow pea, tur)	3529	1334
Oil seeds	6750	1068
Cotton	3976	238
Jute	3935	1900
Mesta	2216	1031
Sugarcane	28	3607
Tobacco	233	931
Total	57145	3161

Source: Department of Agriculture, Govt. of Meghalaya.

Table 1.6: Area of horticulture crop and their productivity, West Garo Hills district (2015-16)

Crops	Area (ha)	Avg.Yield (kg/ha)
Citrus fruits	1830	2607
Pineapple	2791	8802
Banana	1535	13061
Papaya	144	9729
Strawberry	66	2106
Potato	346	7821
Sweet potato	393	3349
Tapioca	1102	5775
Ginger	2405	4705
Turmeric	381	6100
Chillies	952	743
Black pepper	305	643
Tea	715	6705
Arecanut	4547	2103
Cashew nut	3643	2720
Rubber	717	145
Coffee	59	305
Total	**21931**	**4571**

Source: Department of Agriculture, Govt. of Meghalaya.

1.14 Irrigation

The district does not have any major or medium irrigation projects. There are 46 nos. of minor irrigation schemes available in the district as per 2015-16. All these minor irrigation schemes are based on surface water sources. The district wise area irrigation by different types of Minor Irrigation Scheme is given in Table1.7.

Table 1.7: Salient features of minor irrigation schemes/project in the district

Minor Irrigation Scheme	Particulars (2015-16)
A. Surface	
1. Flow Irrigation	
a. Numbers	46 nos
b. Command area (Ha)	6421.60 Ha
c. Gross area Irrigated (ha)	5242.40 Ha
2. Lift Irrigation	
a. Numbers	NIL
b. Command area (Ha)	
c. Gross area Irrigated (ha)	

B. Ground Water 1. Public shallow tube well (Govt) a. Numbers b. Gross area Irrigated (ha)	NIL
2. Public Deep tube well (Govt) a. Numbers b. Gross area Irrigated (ha)	 3 nos (CA 120 Ha) 55.00 ha
3. Others a. Canal b. Tanks c. Wells d. Other sources	 NIL
C. a. Net Irrigated area b. Gross irrigated area	3199.60 Ha 5297.40 Ha

Source: Department of Water Resources, Govt. of Meghalaya.

1.15: River Systems

The topography controls the drainage system as it divides the state into two watersheds namely the Brahmaputra system in the North and Meghna /Surma system in the South. The Tura range forms watershed, from which the rivers flows towards Bangladesh plains in the south and the Brahmaputra valley in the north and the west. River Simsang (Someswari), one of the major rivers of Meghalaya, whose valley is of the most important feature in the South Garo Hills. River Simsang starts from Nokrek mountains and runs towards the east, passing through Rongrenggre, Williamnagar the headquarters of East Garo Hills district, Nongalbibra, Siju, Rewak and lastly Baghmara the headquarters of South Garo Hills district. The chief tributaries are Chibok, Rongdik, Rompa and Ringdi rivers.

River Jinjiram starts from Derek village and its main tributary starts from Upot Lake. It runs towards the east connecting with Gagua river, then runs through the border of Goalpara towards Phulbari and reaches Hallidayganj where it enters the Goalpara district. It is the longest river in the Garo Hills districts.

River Ganol or Kalu starts from Tura peak and runs towards the west through Damalgre, Garobadha and Rangapani before it enters Goalpara district. Its chief tributaries are Dilni and Rongram rivers. River Didak stars from Anogre village and runs through Garo Hills district before it enters into Goalpara district. River Bugi or Bogai starts from the southern side of Nokrek mountains and runs through Dalu village and enters into Mymensingh district in Bangladesh. Rongairiver starts from Arabela peak and runs through Ringgegre village and then falls into Jinjiram river. Locally known as Ringge river. Dareng or Nitai river runs southwards through Silkigre and enters into Bangladesh. It has many famous deep pools like

Warima, Rong'ang, Bamon etc. where Bamon is the deepest. The chief tributaries are Kakija, Daji and Rompa. The drainage map is shown in fig 1.5.

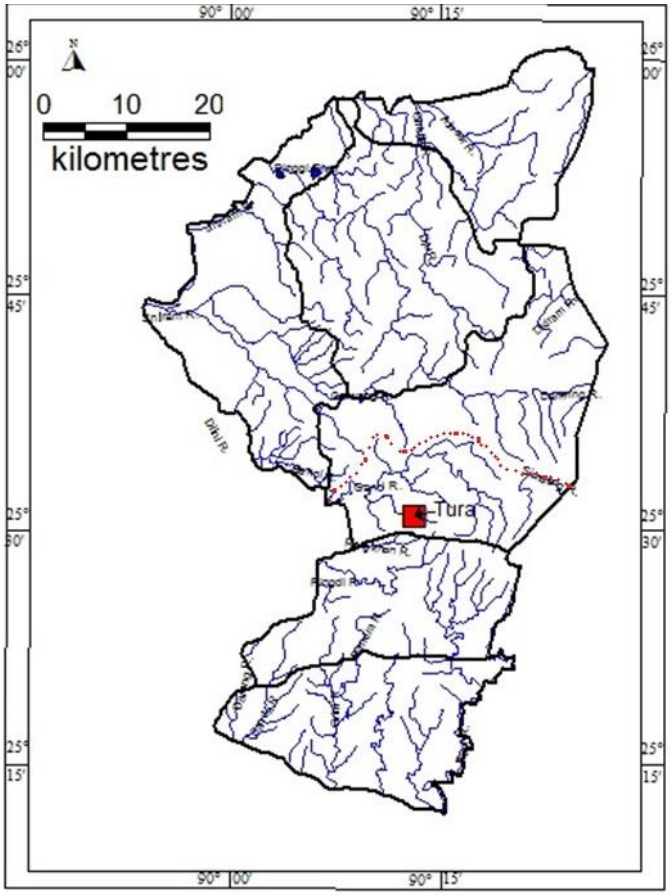


Fig:1.5:Drainage map of West Garo Hills District

1.16 Forest

The district has mostly dense tropical mixed forest, and a small patch of temperate forest in the higher parts of the Tura range. The forest area in the district falls in two categories viz., reserved forest and protected forest. The details of forest cover in West Garo Hills district is given in table 1.8.

Table 1.8: Details of forest area in West Garo Hills district

Reserved Forest	Area *(ha)*
Hollaidanga Beat - Dibru Hills	1930
Nokrek Biosphere reserved Protected Forest	4748
Tura Peak catchment area	3,95.691
Botanical Garden	4.95
Total	6781.641

Source: District Statistical Hand Book, 2015, Tura

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 Central Ground Water Board data to generate strong data base. Data collection includes collection of rainfall data from state government, litholog collection from state groundwater departments, compilation of CGWB's earlier survey data, chemical, exploration and geophysical data. Population data is collected from Census of India website. Agricultural data is collected from the website of Ministry of Agriculture, Govt. of India. Based on the data availability and data gap analysis, the required sub-surface hydrogeological data, groundwater level data, groundwater quality data and Geophysical data were generated but the entire data required could not be generated due to unapproachable/inaccessible and difficult hilly terrain.

2.1 Hydrogeological data: Major part of the area is covered with hill and communication is very poor. As such habitation is clustered in plain area and ground water abstraction structures are also clustered in the plain area. Due to this reason entire study area could not be evenly covered by establishing new water level monitoring stations. Occurrence of ground water in the study area is mainly of weathered and fractured Gneissic rocks, fractured Sandstone and alluvium formation. The different hydrogeological data are generated through intensive field data collection and testing.

2.1.1 Water level monitoring: In the district, 35 key dug wells and 7 nos. of springs are established to study the water level, quality, spring discharge and its behavior periodically. Besides there are 14 ground water monitoring station in the district and 8 Exploratory well and 4 observatory well (drilled during the AAP) were monitored throughout the year.

Phreatic aquifer: A total of 35 dug wells and 14 existing GWMS were established as key wells for periodical water level monitoring to know the water level trend and its behavior. The key observation wells details are presented in annexure 2.

Confined/Semi-confined aquifer: To study the piezometric head in deeper aquifer, a total of 8 bore wells were monitored periodically. Details of exploratory wells are given in annexure 1.

Springs: A total of 7 springs were established and monitored to know the type, discharge and their behaviour. The locations of these springs are given in Annexure 3.

2.1.2 Preliminary Yield Test (PYT): A total of 5 preliminary yield tests were carried out during NAQUIM programme in the district to know the aquifer parameters. The details are shown in Annexure 1.

2.1.3 Dug Well Pump Test: A total of 1 dug well pump test were conducted in the study area to know the yield and specific capacity of shallow aquifers and its suitability for irrigation purposes.

2.2: 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 was started in the district, 18 EW were constructed and during the AAP 8 Exploratory Well and 4 Observation well were constructed during the course of study. The exploratory wells which were constructed in the district are shown in fig 2.1.

Table: 2.1:Exploratory wells drilled in the district

Location	Longitude	Latitude	Year of construction	Depth drilled (mbgl)	Aquifer type
Jugirjhar	90.172475	25.95266667	1984	28.39	Alluvium
Kadamsali	90.2083333	25.95833333	1984	28.5	Sandstone, clay
Lalmatighat	89.9013889	25.73333333	1995	64.65	Sandstone, shale
Phulbari	90.025	25.88944444	1978	37	Sandstone, gneiss
Shyamding	90.0375	25.87916667	1994	73.8	Alluvium, gneiss
Garobandha	90.0388889	25.57916667	1994	218.2	Sandstone
Gimigiri	90.0472222	25.81472222	1998	30.5	Alluvium
Harigaon	90.0638889	25.575	1983	192.23	Sandstone, clay
Kaimbhatpara	90.0736111	25.86666667	1984	37.2	Clay, sand,gravel
Chibinang	90.0861111	25.85138889	1995	35.75	S. stone &gneiss
Jewelgiri	90.1	25.55	1983	241.9	Clay, sand, gravel
Paham	90.1	25.91666667	1984	55.45	Alluvium
Williampur	90.1305556	25.94027778	1995	36.5	Alluvium
Romgiri	90.1472222	25.73222222	1995	31.7	Alluvium
Jagijhar	90.1813889	25.95277778	1983	28.4	Alluvium
Barengapara	90.2221111	25.22138889	1998	172	Sandstone, clay
Berengapara	90.2214	25.21633333	1998	155.5	Sandstone, clay
Damjongre	90.2402778	25.64916667	1995	85	Shale, gneiss
EW Sangsanggre1	90.2119444	25.495056	2018	19.57	Sandstone, shale
EW Sangsanggre	90.2119444	25.494444	2018	33.72	Sandstone, shale
EW Dakopgre	90.1894444	25.527222	2018	59.06	Sandstone, shale
EW Chasingre	90.2366667	25.575	2018	203.59	Gneiss
OW Chasingre	90.2363889	25.574861	2018	203.59	Gneiss

EW Rongram	90.2525	25.604167	2019	140.69	Gneiss
OW Rongram	90.2525	25.603889	2019	203.57	Gneiss
EW Jengjal	90.3369444	25.670556	2019	203.59	Gneiss
OWJengjal	90.3372222	25.670278	2019	203.59	Gneiss
EW Dadenggre	90.19075	25.724028	2019	118.77	Gneiss
OW Dadenggre	90.19075	25.724028	2019	117.77	Gneiss
EW Phulbari	90.0352778	25.99944444	2019	201.46	Sandstone, gneiss

2.3 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.

2.4 Geophysical studies: Surface Geophysical studies in the study area were carried out to delineate the subsurface geology as well as supplement the data gap under the assignment of Aquifer Mapping. A total of 10 VES were conducted and HAK, HK, HKH, HAK, KQ, QH, A, K type VES curves were obtained. The inferences drawn on the basis of interpreted results could not be obtained for deeper formation due to the limitations of unavailability of large and straight stretch for current electrode separation. However, taking into account the interpreted results as well as the apparent resistivity, inferences have been approximated to shallow to deeper depth at few places. The detail results are given in annexure 6. The locations of the survey carried out are tabulated below.

Table 2.2: Location of VES survey carried out in West Garo Hills district

Sl. No.	Village	VES No	Location	Coordinates	General Geology
1	Rongram1	322	40m due east of the road where the other side of the road is a nursery.	N 25°35'42.9" E 90°15'02.5"	Archaean Gneissic Complex/Sand stone
2	Rongram2	323	80m SE of VES-322.	N 25°35'40.5" E 90°15'02.3"	Archaean Gneissic Complex/Sand stone
3	Rongram3	324	In the Mushroom farm opposite to tea garden.	N 25°35'49" E 90°15'01.3"	Archaean Gneissic Complex/Sand stone
4	Rongram4	325	120m East of VES-324.	N 25°35'51.9" E 90°14'59.3"	Archaean Gneissic Complex/Sand stone
5	Rongram5	326	80m north of VES-325.	N 25°35'52.7" E 90°15'02.1"	Archaean Gneissic Complex/Sand stone
6	Sangsangre1	327	In the District Ag. Research station20m NW of Banian	N 25°29'41.2" E 90°12'40.5"	Archaean Gneissic Complex/Sand stone

			tree near Science building.		
7	Sangsangre2	328	80m south of eastern side of the green house near the straw godown and 70m N30°W of VES-327.	N 25°29'40.2" E 90°11'30.2"	Archaean Gneissic Complex/Sand stone
8	Sangsangre3	329	55m west of VES-328 and south of Bio fertiliser lab.	N 25°31'10" E 90°10'50"	Archaean Gneissic Complex/Sand stone
9	Sangsangre4	330	18.5m due N65E of ICAR Horticulture main gate.	N 25°29'44.5" E 90°12'17.8"	Archaean Gneissic Complex/Sand stone
10	Sangsangre5	331	82m S55°E of the main gate of ICAR Agro block farm.	N 25°29'44.3" E 90°12'14.1"	Archaean Gneissic Complex/Sand stone

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 General hydrogeology and occurrence of ground water:

The occurrence and behaviour of ground water is controlled by climate, topography, geology, structures of the rocks etc. Ground water occurs in permeable formation known as aquifers. The capacity to yield water is governed by storativity which indicates the amount that can be released or taken into storage per unit change in hydraulic head over unit area. Alluvium formation and medium to coarse grained sandstone forms good aquifers in which movement of ground water is controlled by intergranular porosity. Basic dykes and sills traversing the Achaean formation also play significant role in the sub-surface movement of groundwater. The principal aquifer system of the district is shown in fig 3.1 and lineament map in 3.2 respectively.

Fig 3.1:Principal aquifer system

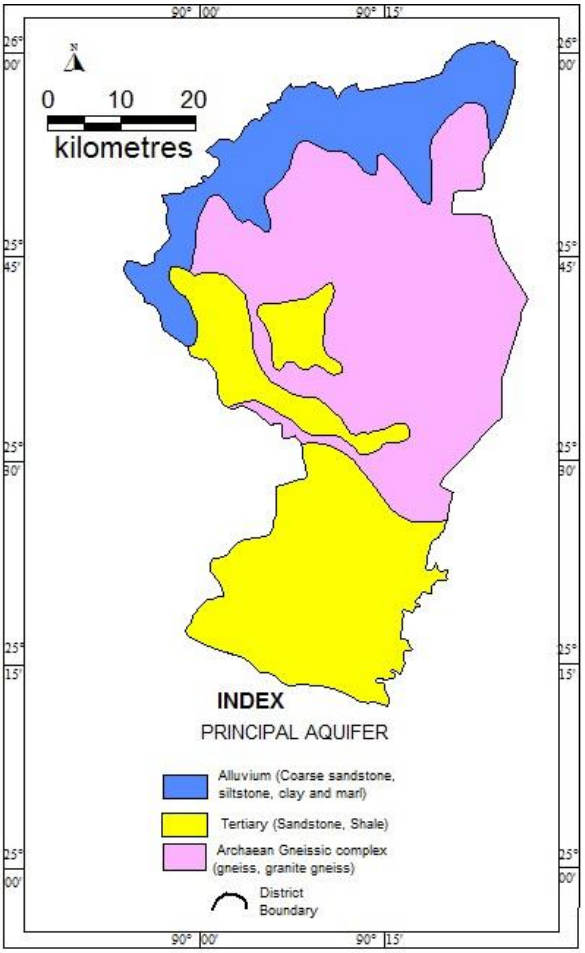
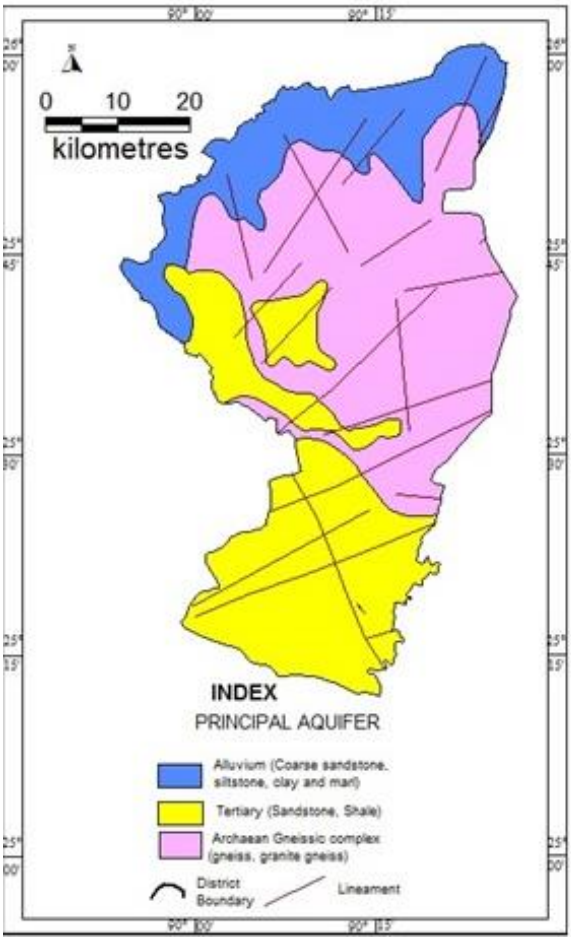


Fig 3.2: Lineament map



3.1.1 Occurrence of ground water in shallow aquifers: The 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 and ring well. The depth of the well ranges from 3 to 14 meters.

3.1.2 Occurrence of ground water in deeper aquifers: The deeper aquifer occurs as semi-confined to confined condition where ground water is found in the fractured zone of consolidated Sandstone and Achaean gneissic rock. The drilled depth of exploratory wells tapping this aquifer ranges from 19 to 203m bgl. The number of fractures and its zones encountered varies in all the places 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 springs 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. A total of 7 springs were established and monitored periodically during the course of study. Most of these springs are depression and topographic or fractured springs. It is observed that the discharge of springs ranges from dry to 7 litre per minute during pre-monsoon and 10 to 30 litre per minute during post-monsoon season and is show in fig 3.3 and fig 3.4. It has also been observed that most of the springs were dry in pre monsoon season.

Fig 3.3: Pre-monsoon spring water discharge

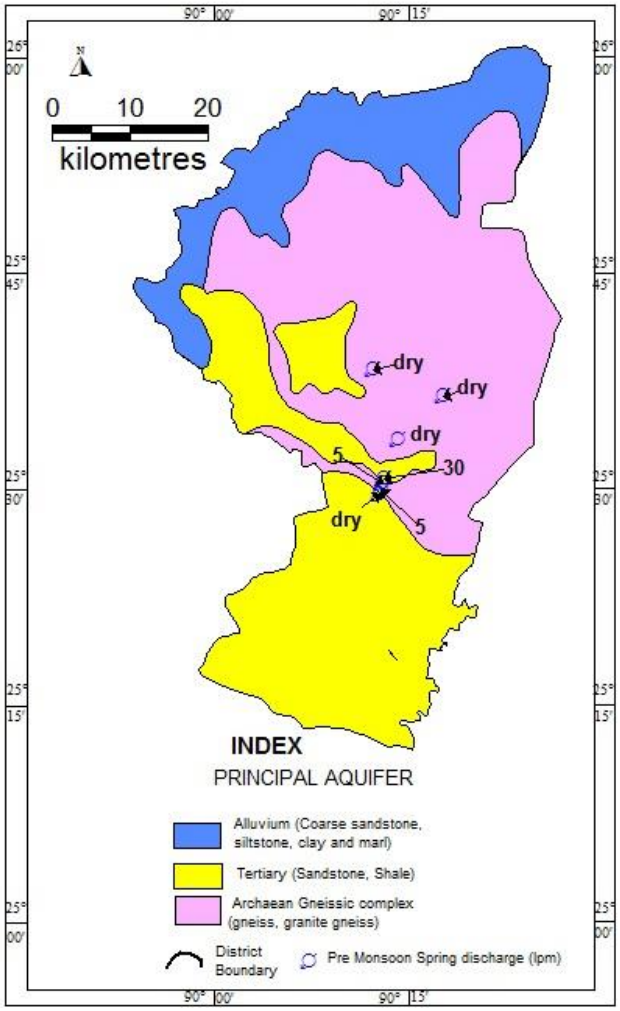
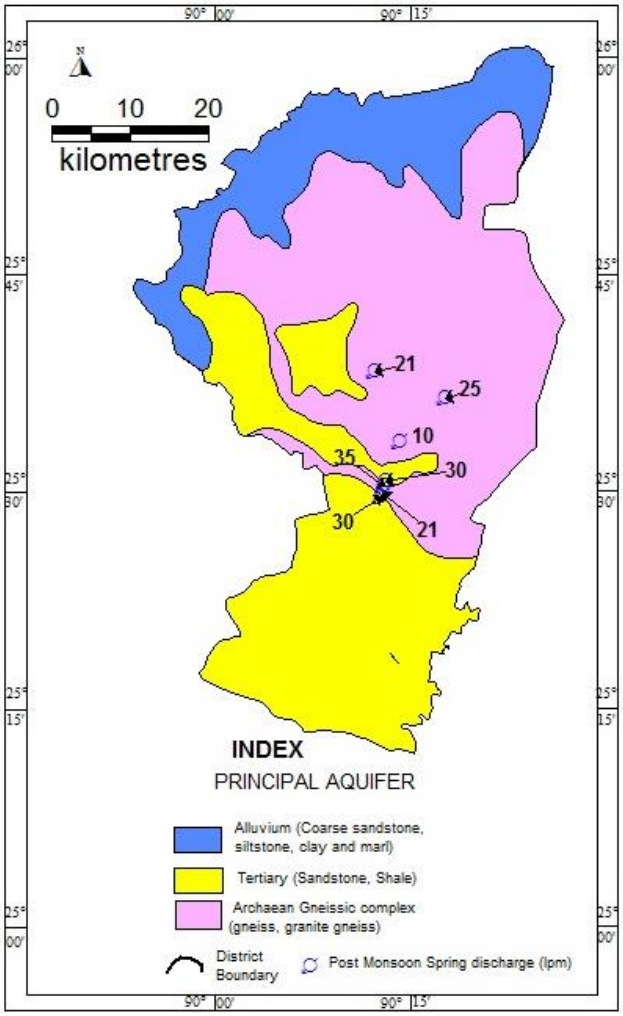


Fig 3.4: Post-monsoon spring water discharge



3.1.4 Depth to Water Level: A total of 35 dug well were established as key well for periodical monitoring to know the ground water level trend and its behavior in phreatic condition. The depth to water level in these dug well ranges from 0.95 to 4.95 m bgl during post monsoon and 1.66 to 6.89 m bgl during pre-monsoon season and is shown in fig 3.5 and fig. 3.6.

Fig: 3.5: Pre-monsoon Depth to Water Level

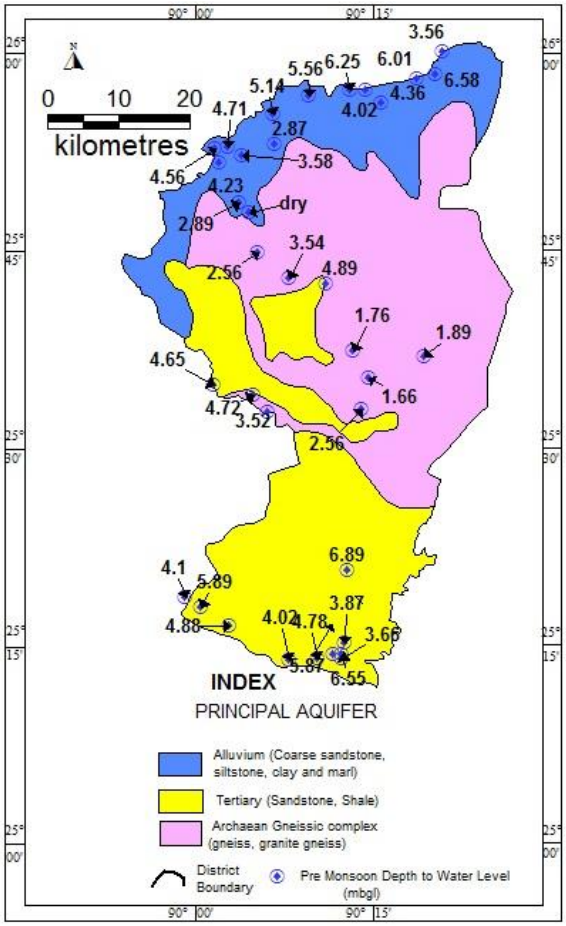
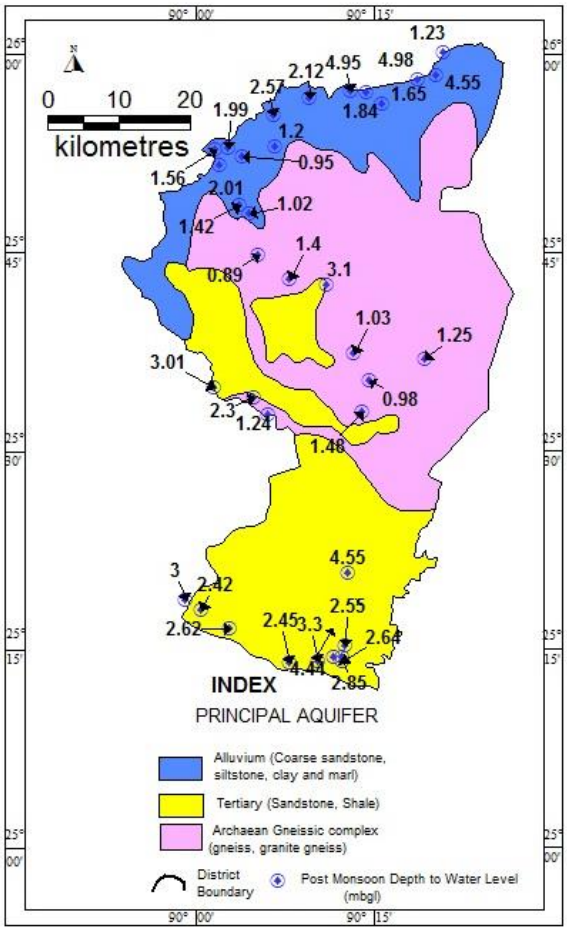


Fig: 3.6: Post-monsoon Depth to Water Level

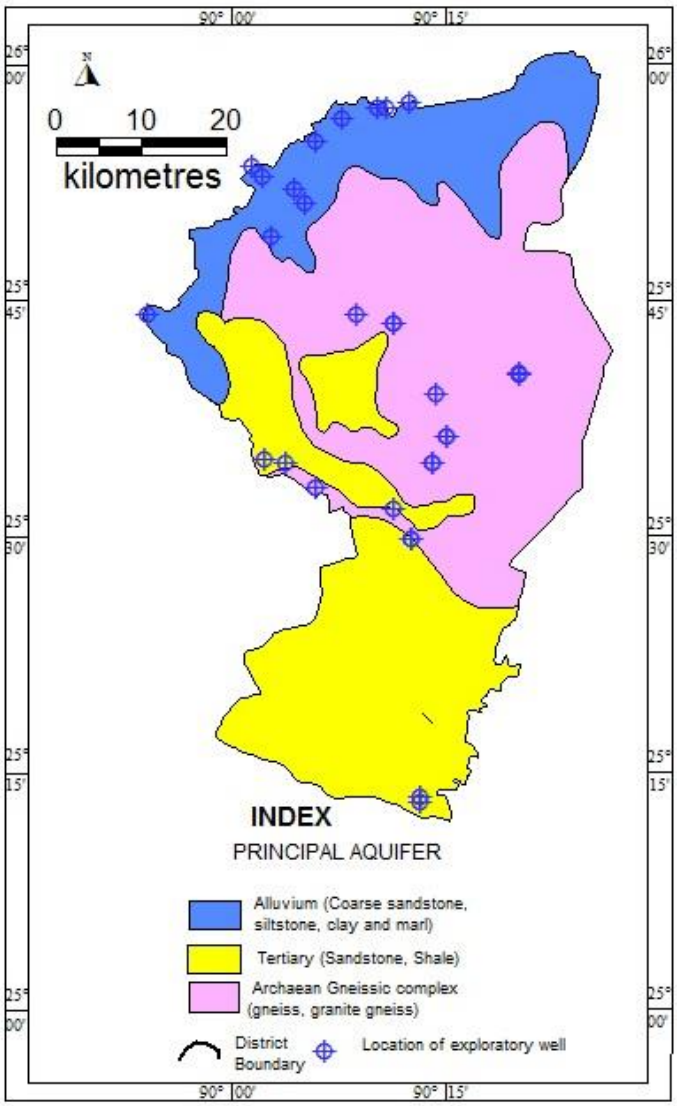


To study the piezometric head, 26 bore/tube wells drilled by Central Ground Water Board were monitored. The piezometric head ranges from 1 mbgl at Kadamsali to 67.00 mbgl at Chasingre. The formation wise of the bore/tube well drilled and peizometric head is given in table 3.1 and the location map of exploratory well drilled by CGWB is shown in fig 3.7.

Table 3.1: Peizometric head of the bore/tube well drilled in the district

Formation	No. of borewell/ tubewell drilled	Depth of the well (m)	Peizometric head (mbgl)
Alluvium	12	28 to 241	1 to 31.7
Tertiary	10	19 to 201	1.92 to 12.85
Achaean Gneissic complex	14	117 to 203	3.2 to 67

Fig 3.7 location map of exploratory well



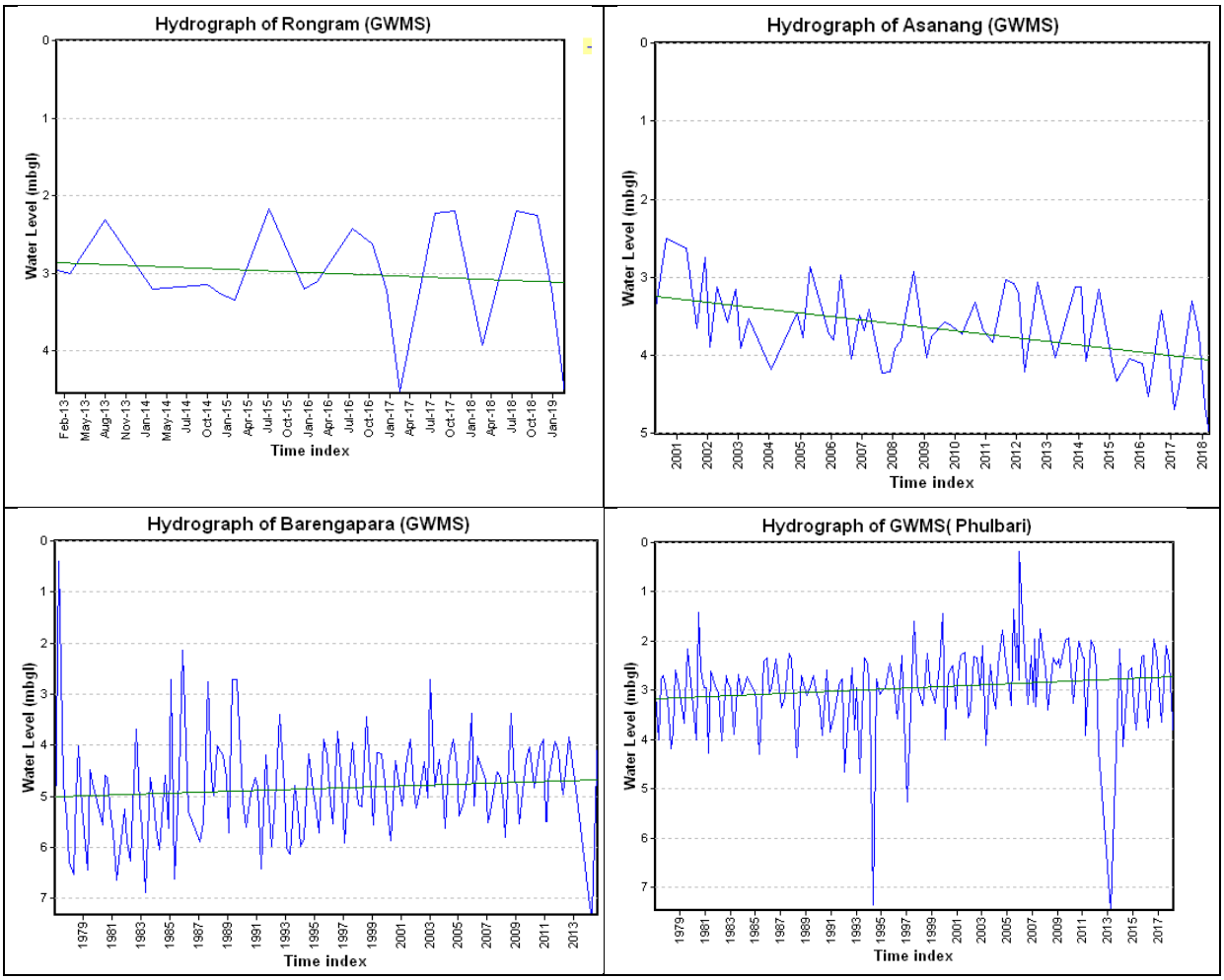
3.1.5 Water level trend: In the district, there are 14 Ground Water Monitoring Stations (GWMS). The depths to water level were monitored throughout the year and the detail result is given in table 3.2. Moreover, historical water level data of GWMS were analyzed and it was found that the water level maintain more or less a steady state except a few. It indicate rise of water level at Phulbari and Barengapara and fall in water level at Rongram and Asanang. The hydrograph is given in fig 3.8.

Table 3.2: Location and Depth to Water Level of GWMS

Village	MP	RL	Depth	Dia	Water Level (mbgl) August-18	Water Level (mbgl) Nov-18	Water Level (mbgl) Jan-19	Water Level (mbgl) March-19
Asanang	0.6	441	5.65	0.75	3.31	3.72	4.65	5.01

Baljek	0	315	1.8	0.7	0.91	0.78	1.29	dry
Belguri	0.7	79	12.6	0.7	3.39	3.98	5.89	8.35
Damjongre	0.8	140	5.7	0.8	2.21	2.29	3.13	4.56
Nidanpur	0.9	33	4.6	0.7	1.91	2.45	3.19	4.34
Phulbari	0.8	37	8.7	0.76	2.09	2.43	3.23	4.01
Phutamati	0.6	40	5.6	1.75	2.36	2.41	2.61	4.3
Rajabala	0.7	23	8.9	0.7	3.62	3.68	4.76	N/A
Rongram	0.9	334	4.6	0.9	2.19	2.25	3.21	4.55
Selsella	0.85	86	8.6	0.75	1.31	1.13	3.77	N/A
Tikrikilla	0.85	36	6.1	1.3	1.91	1.76	3.19	5.67
Snalgre	0.72	282	3.62	1.85	2.28	2.19	2.43	3.12
Purakhasia	0.8	31	8.7	0.75	2.56	2.59	3.92	4.67
Dalu	1	26	6.78	0.8	3.09	2.78	4.67	5.66

Fig.3.8 Hydrographs of GWMS



3.2 Aquifer system:

Broadly, the aquifer system in the district can be divided into three distinct hydrogeological units on the basis of their water bearing properties. They are i. Consolidated formation ii. Semi consolidated formation and iii. Unconsolidated formation. 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 200 m bgl. The details lithological log of the bore well/tube well drilled is given in Annexure 5.

3.2.1: C**onsolidated formation**

The crystalline and Gneissic rocks of the Achaean age are the oldest rocks in the district which form the basement for the deposition of latter semi-consolidated and unconsolidated formation. The crystalline formations consisting of granites, granitic gneiss and their variation besides intrusive rocks such as dolerites and occupy an area of about 1750 sq.km. in the central, eastern and northern parts of the district. These formations constitute the runoff zone due to high relief. The presence of substaintial-weathered mantle is confined to their secondary porosities, which form excellent repository of ground water. The storage and movement of ground water in consolidated formation is controlled by physiography, zone of weathering and interconnected places of weakness. These formations are of heterogeneous in nature as indicated by the variations in mineralogy, lithology, texture and structure within short distance. These rocks are devoid of primary porosity but are rendered porous and permeable with the development of secondary opening by means of fractures, joints, fault planes etc. Ground water potentials of these rocks depend upon topographic set up.

Occurrence of ground water is rather limited in this formation and is confines to topographic lows, valley and weathered residuum and its movement is controlled by the presence of fractures and fissures. Presence of a number of fractures has been noted during drillings from 13 to 142 mbgl. The depth to casing varies from place to place in the range of 12 to 43 m bgl. Depending on the intensity of fracture and hydrogeological set up, the discharge of wells ranges from $2m^3$/hr (Jengjal) to $29m^3$/hr (Dadenggre). The lithological section in Granite Gneiss formation is given in fig 3.9

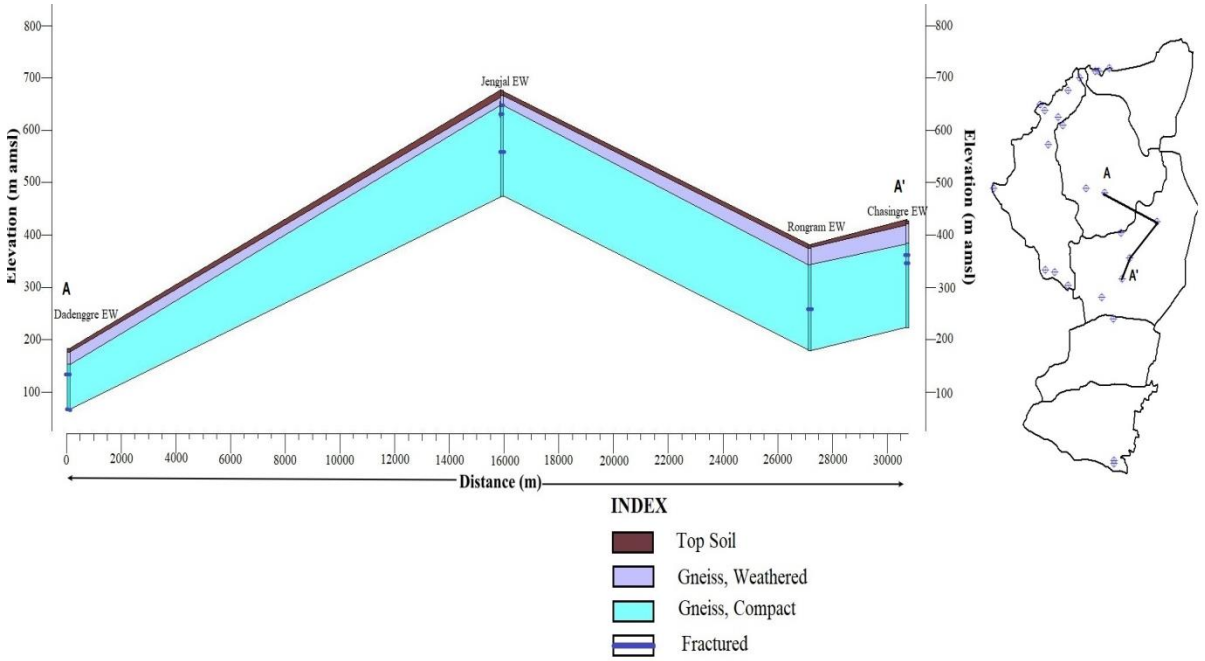


Fig.3.9: Lithological section in Granite Gneiss formation

3.2.2: Semi-consolidated formation

Tertiary sedimentary rocks represent the semi consolidated formation. They are exposed over a major part of south and western part of the district occupying an area of 660 sq.km mostly in Dalu block and partly in Rongram and Selsella blocks. This formation consists mainly of sandstone/siltstone and shale/claystone etc. However, at places conglomerate and limestone are also exposed. The thickness of the tertiary as reported by Geological Survey of India is more than 300m with tendency to thin out towards north and northwesterly directions. Drilling carried out as part of ground water exploration has shown the existence of sandy layers of varying grain size as potential aquifers. The shallow aquifers within 50 m are made up of coarse and gravelly sandstone and the deeper aquifers are made up of fine to medium grained micaceous sandstone, grayish in colour with silt/clay intercalations. In Bairagapara and Jewelgri occurrence of coarse sandstone and feldspar indicate presence of Baghmara formation at deeper level.

In Shallow aquifers the ground water occurs both under water table and semi-confined conditions. The depth to water level varies from ground level to 4.00 mbgl. Ground Water in deeper aquifer is found to occur under confined condition. The Peizometric head varies from 4 to 13.0 mbgl. Discharge of these wells was found to vary from 2.6 to 52.0 m^3/hr. The lithological section in Tertiary formation is given in fig 3.10

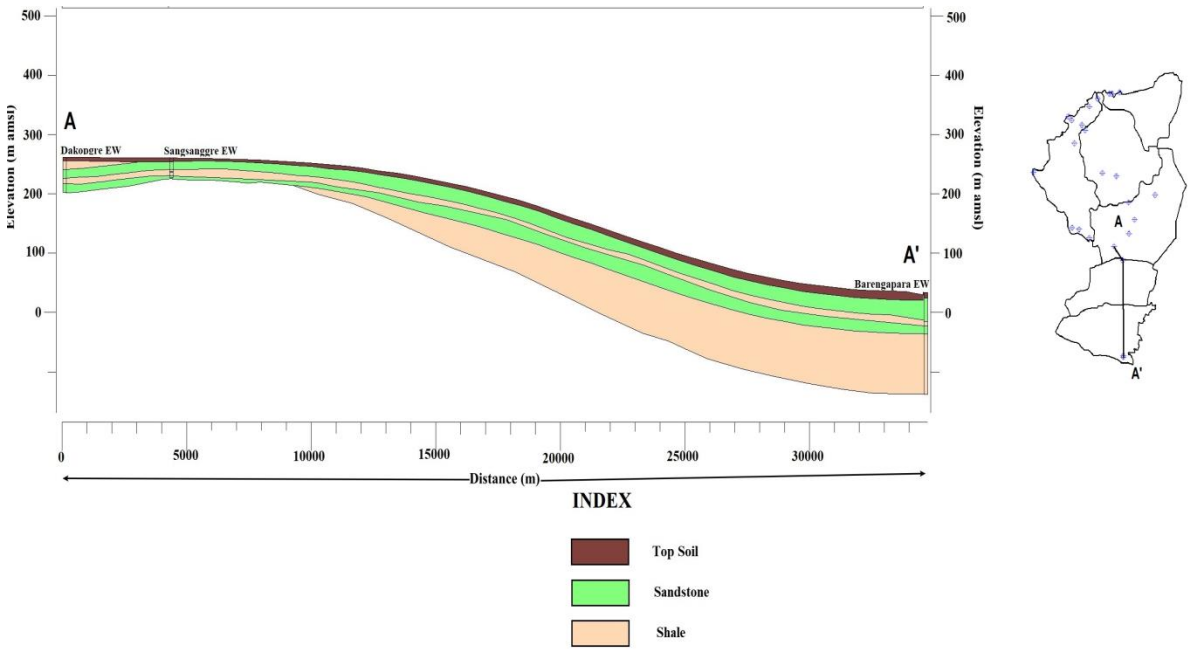


Fig.3.10 Lithological section in Tertiary formation

3.2.3 Unconsolidated formation

This formation consists of sand and clay deposits occupying an area of 400 sq.km in the northern and southern part of the district in consanguinity with the Brahmaputra plains and sylhet plain. The thickness of these unconsolidated formations varies widely but within 50 m depending upon the basement topography. Prolific aquifers made up of medium sand and gravel occurs between the depth ranges of 3 and 35 metres. The thickness of the aquifer increases towards axis of the valley in northern direction.

Ground water occur under water table condition with depth to water level within the range of 5m bgl. Tube wells constructed by the Govt. of Meghalaya revealed 9 to 13.5 m of cumulative thickness of granular horizon within 102 m depth. The wells constructed to a depth of 50 m tapping about 20 m of saturated zone yield between 1 m^3/h and 66m^3/h. Transmissivity varies from 4to 833 m^2/day. The lithological section in alluvium formation is given in fig 3.11.

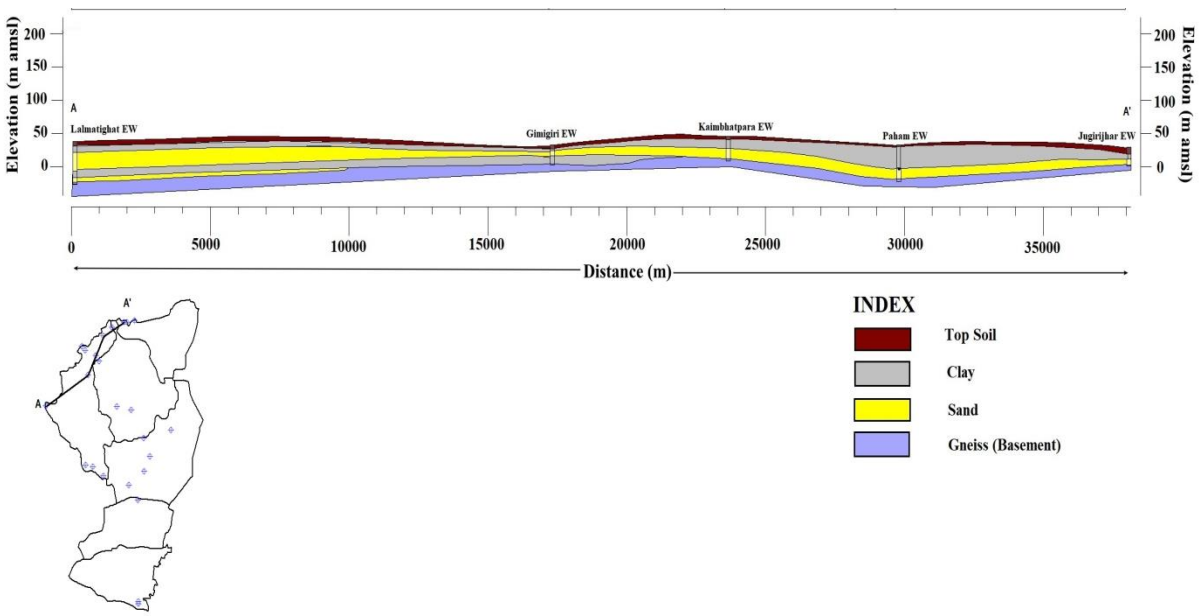


Fig.3.11: Lithological section in Alluvium formation

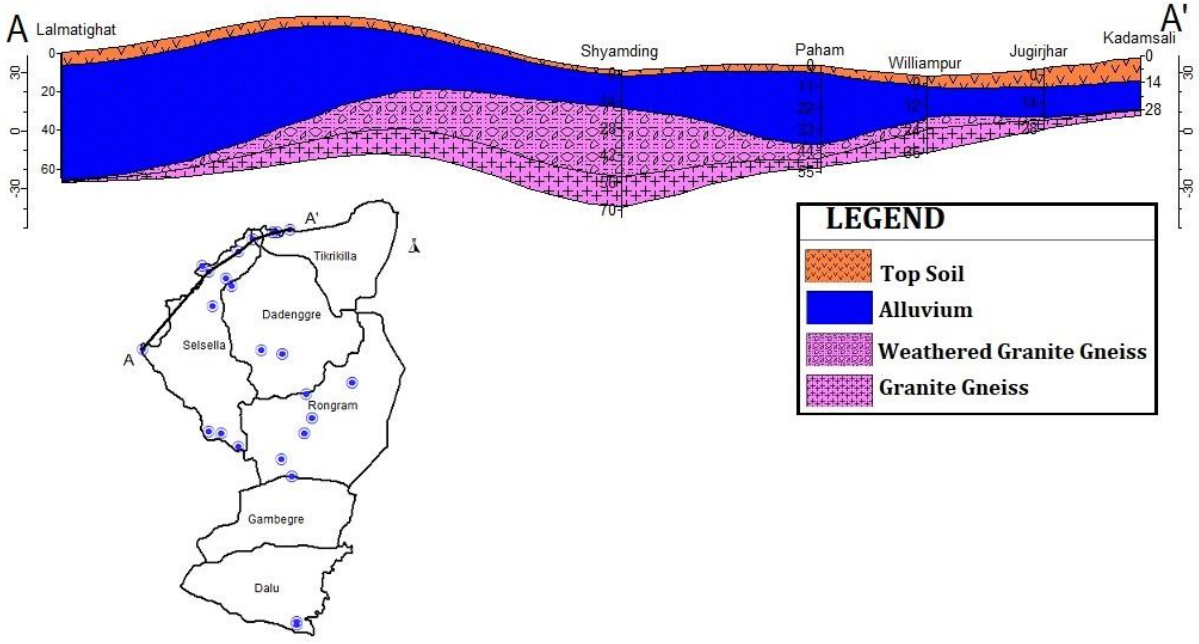


Fig.3.12: Stratigraphical section along A…A' line

3.3 Aquifer geometry

The aquifer system can be divided as 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 bore/tube wells, it is found that the first aquifer occur within 2 to 40 m bgl. Ground water in the second aquifer occurs under semi-confined to confined condition down to the maximum depth of 200 m bgl. The disposition of these aquifers is shown in fig.3.13.

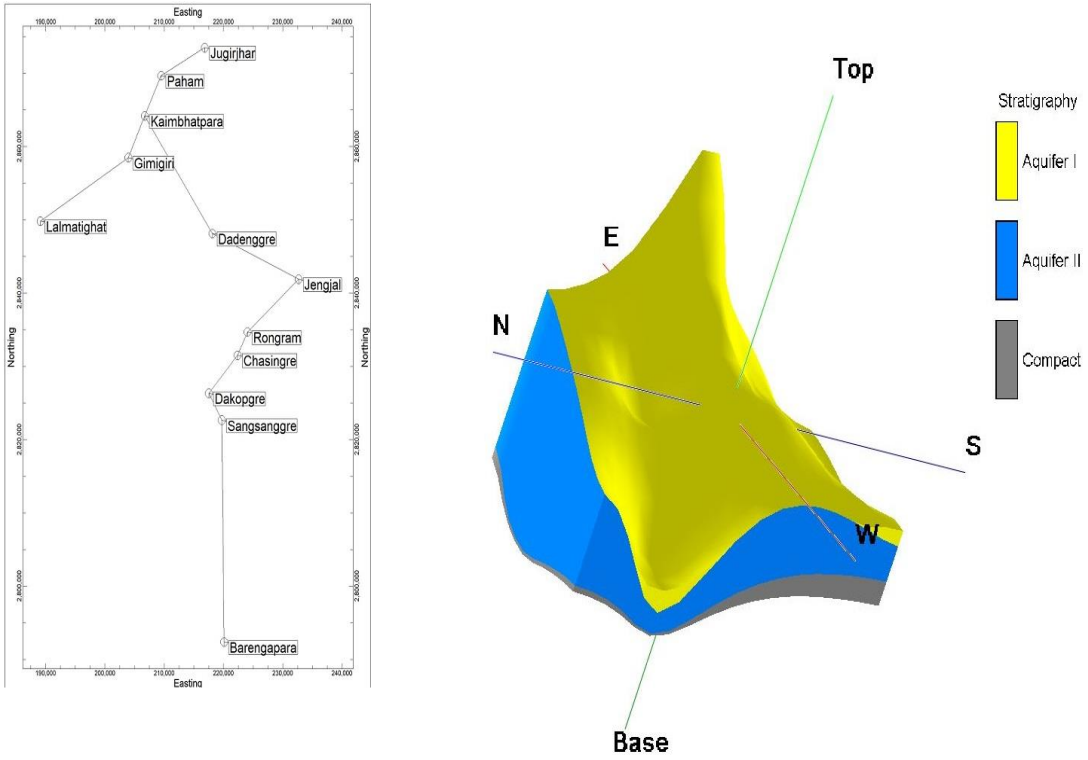


Fig. 3.13 Disposition of aquifers zone inWest Garo Hills district, Meghalaya (I)

3.4 Aquifer properties

Aquifer I: It is the unconfined aquifer where the tapping of aquifer zone ranges within 2 to 40 m depth and generally exhibits unconfined nature of the aquifer. The district is highly undulating terrain and tapping of Aquifer I in hilly terrain is not suitable.

Aquifer II: It is the deeper aquifer which occurs under semi confined to confined condition where ground water is found in granular zone of sand of alluvium formation and the fractured zone of consolidated sandstone and granite gneiss. The drilled depth of exploratory well tapping this aquifer ranges from 28 to203 m bgl. The number of fractures and granular zones of encountering fractures varies widely which show the complexity of the hydrogeology of consolidated hard rock formation. The piezometric head ranges from 1 to 67 m bgl. The transmissivity value varies from 1 to 833 m^2/day. The formation wise discharge and transmissivity is given in table 3.3 and the details of the productive zone are in table 3.4. Fig 3.14 shows the disposition of aquifer zone in the district.

Table 3.3: formation wise discharge and transmissivity in deeper aquifer

Formation	Depth of the well (m)	Peizometric head (mbgl)	Discharge (m^3/hr)	T (m^2/day)
Alluvium	28 to 241	1 to 31.7	1.5 to 150	4 to 833
Tertiary	19 to 201	1.92 to 12.	2.10 to 18	11 to 95
Archean Gneissic complex	117 to 203	3.2 to 67	1.5 to 29.50	1 to 253

Table 3.4:details of the productive zone in deeper aquifer

Productive zones (fractures and granular zone encountered)					Discharge
0 to 50	50 to 100	100 to 150	150 to 200	200 to 250	(in m^3/hr)
m bgl	m bgl	m bgl	m bgl	m bgl	
Granite Gneiss					
2	2	6	0	Not Explored	1.5 to 29.52
Tertiary (Sandstone and Shale)					
2	2	0	1	Not Explored	2.10 to 18
Alluvium					
6	2	1	1	1	1.5 to 150

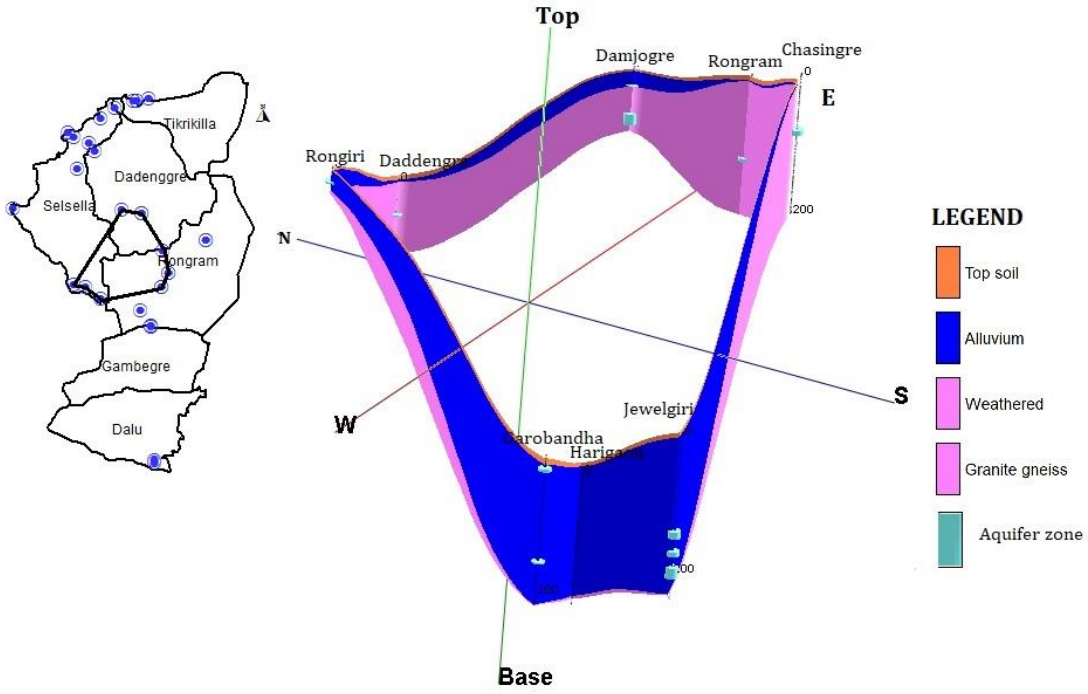


Fig. 3.14 Disposition of aquifers zone in West Garo Hills District (II)

3.5 Hydrochemistry

The quality of ground water is as important as that of the quantity. Mineralogical composition and soluble products of rock weathering affect the chemical quality of ground water. Therefore in order to study the chemical quality, water samples from representative dug well, stream, surface water and spring were collected during the course of field work during pre monsoon and post monsoon studies. The parameters analyzed are pH, EC, Turbidity, TDS, CO_3, Cl, SO_4, Na, K, HCO_3, NO_3, F, Ca, Mg, TH and Fe. The details of chemical analysis were given in the Annexure 2.

3.5.1 Suitability of ground water for drinking purposes

Depending on the impact of concentration of various ion in water on human health and plants, various standard had been laid down by different agencies such as BIS, ICMR, WHO etc. The BIS standard for drinking water is shown in table 3.5

Table 3.5: Drinking Water standard by BIS (IS 10500-91)

Sl. No	Parameters	BIS (IS 10500-91)	
		Desired Limit	Max Permissible Limit
1	pH	6.5 to 8.5	No relaxation
2	TDS	500	2000
3	Total hardness as $CaCO_3$	300	600
4	Magnesium as Mg	30	100
5	Chlorine asCl	250	1000
6	Nitrate as NO_3	45	100
7	Sulphate as SO_4	200	400

8	Fluorine as F	1.00	1.5
9	Iron as Fe	0.3	1.0
10	Calcium as Ca	75	200

3.5.2 Water quality of spring: A total of 2 number of water samples from spring were collected during the course of study and the range of concentration of different chemical constituent present in the spring water are shown in table 3.6.

Table 3.6: Chemical quality of spring water

Sl. No.	Chemical constituents (Concentrations in mg/l except pH & EC)	Range	
		Min	Max
1	pH	6.97	7.61
2	EC (µs/cm) 25°C	144.8	163
3	TDS	BDL	BDL
4	CO3-2	79.74	89.79
5	HCO3-1	BDL	BDL
6	TA (as CaCO3)	40.03	65.05
7	Cl-	35.45	35.45
8	SO4-2	14.82	22.21
9	NO3-1	0.6	1.52
10	F-	0.09	0.19
11	Ca+2	16.01	24.02
12	Mg+2	7.27	8.48
13	TH (as CaCO3)	70	95
14	Na	7.84	10.65
15	K	4.42	5.17
16	Fe	BDL	BDL

It can be inferred from table 3.6that all parameters are within the permissible limit in spring water in the district.

3.5.3 Ground water quality of unconfined aquifer

A total of 29 number of ground water samples from dug well were collected during pre and post-monsoon studies and the range of concentration of different chemical constituent present in the dug wells are given in table 3.7

Table 3.7: Chemical quality of water samples from dug well

Sl. No.	Chemical constituents (Concentrations in mg/l except pH & EC)	Range	
		Min	Max
1	pH	6.88	8.48
2	EC (µs/cm) 25°C	29.39	328.9
3	TDS	BDL	0.5
4	CO3-2	16	172.3
5	HCO3-1	BDL	40
6	TA (as CaCO3)	10.01	95.1
7	Cl-	21	63.81
8	SO4-2	1.98	69.12
9	NO3-1	BDL	10.52

10	F-	0.05	0.54
11	Ca+2	2	22.02
12	Mg+2	2.42	26.69
13	TH (as CaCO3)	35	155
14	Na	3.19	30.4
15	K	0.48	17.24
16	Fe	BDL	0.79

It is deciphered from table 3.7 that all of the chemical parameters are within permissible limit for all uses.

3.5.4 Ground water quality in confined aquifer

A total of 8 number of water samples were collected during exploratory drilling of CGWB in the district. Based on chemical analysis data the range of concentration of different chemical constituent present in the deeper aquifer are given in table 3.8.

Table 3.8: Chemical quality of ground water in deeper aquifer

Sl. No.	Chemical constituents (Concentrations in mg/l except pH & EC)	Range	
		Min	Max
1	pH	6.58	10.51
2	EC (µs/cm) 25°C	58.89	458.7
3	TDS	BDL	1.4
4	CO3-2	38.87	240.6
5	HCO3-1	BDL	30
6	TA (as CaCO3)	10.03	135.13
7	Cl-	35.03	165.13
8	SO4-2	10.64	67.35
9	NO3-1	7.46	79.81
10	F-	BDL	3.47
11	Ca+2	0.22	19.1
12	Mg+2	6	24.02
13	TH (as CaCO3)	1.2	12.13
14	Na	35	100
15	K	8.7	86.26
16	Fe	1.54	39.65

It can be inferred from table 3.8 that except fluoride, iron and pH, the other parameters are within the permissible limit. Table 3.9 and table 3.10 shows the concentration of Iron and Fluoride in Ground water respectively.

Table 3.9: Concentration of Iron in Ground Water

Type of Structure	No. of Sample analysed	Conc. of Iron (mg/ lit)		
		< 0.3	0.3 to 1	> 1

Dug well	29	27	2	Nil
Bore well	8	7	1	1
Springs	2	2	2	Nil

Table 3.10: Concentration of Fluoride in Ground Water

Type of Structure	No. of Sample analysed	Conc. of Fluoride (mg/ lit)		
		< 1	1 to 1.5	> 1.5
Dug well	29	29	0	Nil
Bore well	8	2	2	4
Springs	2	2	0	Nil

From the above table, the concentration of iron beyond permissible limit is found only in one bore well. The concentration of fluoride beyond permissible limit is found in 4 bore wells. Table 3.11 shows the location of bore well having high fluoride content and the location of bore well with high fluoride is shown in fig 3.15

Table 3.11: Location of bore well having high flouride content in Ground Water

Location	Depth drilled (mbgl)	Aquifer type	pH	Aquifer tap/zone (m)
EW Chasingre	203.59	Granite Gneiss	7.97	80 to 87
EW Rongram	140.69	Granite Gneiss	8.9	122-125
EW Jengjal	203.59	Granite Gneiss	8.3	28-31,
				45-46,
				117-119
EW Dadenggre	118.77	Granite Gneiss	10.5	49-50,
				116-118

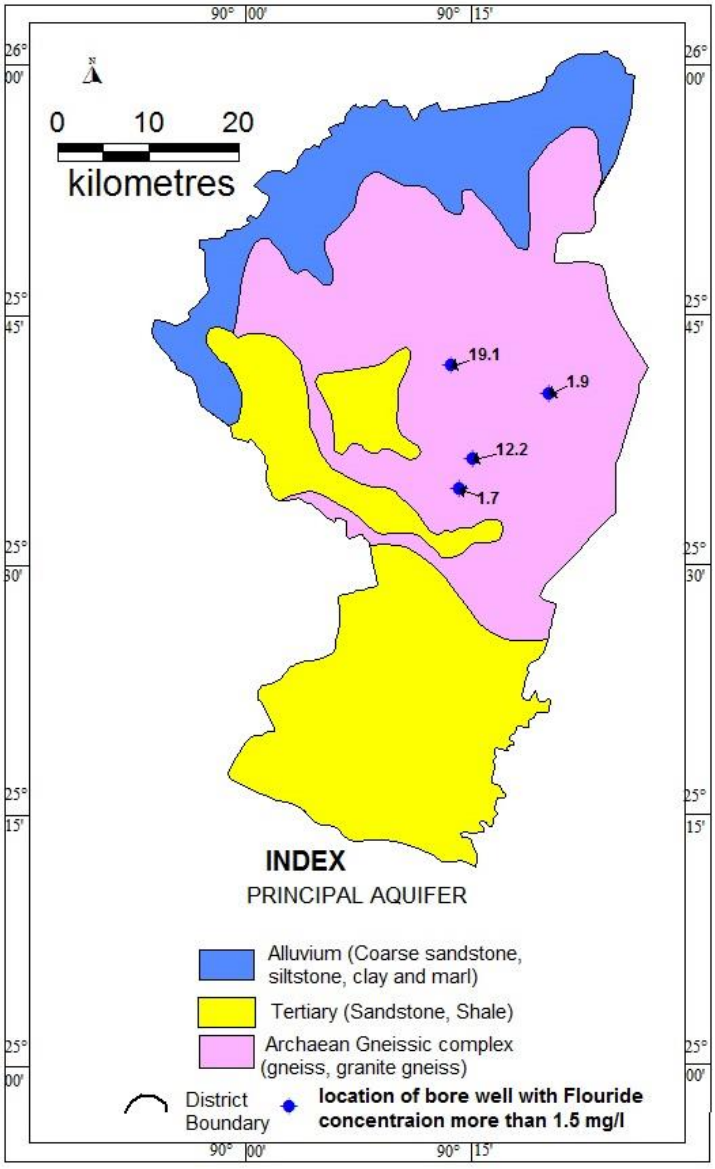


Table 3.15: Location map of bore well having high flouride content

4. GROUNDWATER RESOURCES

Dynamic Groundwater Resources of West Garo Hills district has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'97). The resources computed for the groundwater year 2017. In the present resource estimation, the smallest administrative unit considered for resource estimation is district since block-wise data is not available. 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 1830 sq.km.

Poor Groundwater Quality Area: In the district, there is no 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.

Lithological sub-units: The district is underlain by consolidated rocks like Archaean Gneissic complex, semi consolidated rock such as sandstone and shale and unconsolidated rock of sand and clay.

4.1 Groundwater Resources – Recharge for Various Seasons:

For calculating recharge from return flow from irrigation, an average water requirement of 1.2 m & 0.1 m for paddy & non-paddy has been considered (as per discussion with Agriculture department, Govt. of Meghalaya). Computation factor for return flow from surface water irrigation is taken as 0.30 – 0.50 as per GEC'97 methodology. Return flow from surface water irrigation has not been considered for monsoon season because aquifers remains fully saturated during the periods of intensive rainfall, additional recharge from ponds & tanks during this period is negligible. Recharge from ponds and tanks during non-monsoon period are considered for 100 days.

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.

Groundwater Draft for Various Purposes: Groundwater draft 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 on number of structures used in different industrial units. Unit draft of bore well used by industry is 1 ham/yr. The groundwater resources computed as on March 2017 is given in table 4.1.

Table 4.1: Groundwater resources in the district

Particulars	(ham)
Rainfall recharge during monsoon	23157
Rainfall recharge during non-monsoon	9411
Recharge from other sources	720
Annual GW recharge	32628
Net GW availability	29365
GW draft for irrigation	102
Gross GW draft	415
Annual Allocation of ground water for domestic & industrial water supply upto 2025	625
Balance GW for future irrigation development	28638
Stage of development	1.41%

Stage of Groundwater Development &Categorization of the district: The district falls under "**SAFE"** category. The stage of development is 1.41%.

5. GROUND WATER RELATED ISSUES

There are two major ground water related issues found in the district.

5.1 Low stage of ground water development: As per ground water resource estimation 2017-18, the stage of ground water development is only 1.41 %. Majority of 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 district to bring more area under irrigation. At present the irrigation practice by utilizing ground water (constructing bore well) is not practice 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.

5.2 Ground water quality: As per water quality analysis data, it was found that there is a moderately high concentration of iron and fluoride in deeper aquifer which needs to be treated before consumption.

6. MANAGEMENT STRATEGIES

The groundwater management involves the optimum utilization of sub-surface water based on geological, hydrological, economic, ecological and legal consideration for the welfare and benefit of the society. The management of the ground water resources has to be taken up after understanding the varied hydrogeological characteristics. In addition, the development of ground water requires thorough understanding of the heterogeneity of the formation. The peneplained surfaces, buried pediments and valley fills are the most favorable localities for development of ground water. Structures such as dug well and tube well are the feasible ground water structures.

The objective of management is to utilize the available ground water resources to fulfill human needs and also to boost economy of an area without hampering the interest of future generation. That objective can be achieved by finding out demand of various sectors and adjusting the demand with available resource.

As per dynamic ground water resource of West Garo Hills District for 2017, net ground water availability is 29365 ham and stage of development is 1.41%. The district is having balance net ground water availability for future irrigation use in the tune of 28638 ham. If an irrigation plan is made to develop 60% of the balance dynamic ground water resources available, then 17183 ham of groundwater resources is available in the district for future irrigation uses. The source of water for all these schemes is mainly from surface water. Hence, there is ample scope for ground water development for irrigation purpose which will help the district in achieving self-reliance on food grain. During 2015-16, net sown area in the district is 73233 ha, area sown more than once is 18663 ha and cropping intensity is about 125%. 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. Moreover, crops grown on the hills like pineapple, turmeric and ginger are having negligible or nil irrigation requirements.

During kharif season, paddy is cultivated in 11361 ha. After kharif crops were grown the area remains fallow during rabi season. The intention is to bring this fallow land of 11361 ha under assured irrigation during rabi season which will help to increase gross cropped area to 22722 ha and thereby increase cropping intensity up to 200%. In rice fallow, pulses, potato, mustard and rabi vegetables can be grown with the support of irrigation.

To use the groundwater for irrigation purpose a cropping plan has been designed for the district by using CROPWAT model developed by FAO. Crop-wise and month-wise irrigation

water requirement (Precipitation deficit) has been taken from CROPWAT after giving necessary meteorological, soil, crop plan inputs. Present cropping pattern, proposed cropping pattern, intended increase in cropping intensity were shown in table 6.1 and 6.2. Proposed cropping pattern with water deficit months, IWR and peak water requirement for Irrigation 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 and proposed cropping pattern in the district

CROPPING PATTERN DATA
(File: C:\ProgramData\CROPWAT\data\sessions\Tura.PAT)

Cropping pattern name: Tura

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	15/01	29/04	10
8	...CROPWAT\data\crop	Small Vegetables	05/02	10/05	10
9	...CROPWAT\data\crop	Small Vegetables	15/02	20/05	10

Table 6.2: Cropping pattern, proposed cropping pattern, intended cropping intensity

Cropping pattern (s)				
Rice based cropping pattern				
Rice-Mustard	Present Cultivated area	Area to be cultivated	Area to be cultivated (ha)	Irrigation requirement (ha m)
Rice-Vegetables	(ha)	(%)		
Rice-Pulses				
Rice-Millet				
	1	2 (= % of 1)	3	4
Rice (main crop)	11361		11361	1984
Mustard	0	20	1591	369
Pulses	0	20	2272	344
Millet	0	20	1818	273
Vegetables	0	40	2272	494
Net cultivated area (Paddy)	11361	100	11361	
Gross cultivated area (Paddy + Pulses +Millet+ Veg)	11361		22722	

Cropping intensity	100% (Present)		200% (Intended)	3464

Table 6.3: Proposed cropping pattern with water deficit months, IWR and peak water requirement for Irrigation

Crop	Growing period (Months)	Periods/months of water deficit	Irrigation requirement (ham)	Peak water requirement for Irrigation
Rice	4	1 – 2	1984	June
Mustard	5	4	369	December
Vegetables	3	3	494	March
Pulses	4	4	344	December
Millet	3	3	273	November
		Total Water Requirement	3464	

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

Crop	Area (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total IWR (ham)
1. Rice	15	0	0	0	0	502.383	213.7	0	0	0	10.22	0	0	726.31
2. Rice	15	0	0	0	0	168.37	334.01	0	0	0	0	0	0	502.38
3. Rice	10	0	0	0	0	139.286	269.03	0	0	0	0	0	0	408.31
4. Rice	10	0	0	0	0	0	334.92	0	0	0	12.5	0	0	347.42
5. Mustard	10	105.89	72.48	0	0	0	0	0	0	0	0	88.161	102.7	369.23
6. Pulses	10	132.47	28.18	0	0	0	0	0	0	0	0	57.941	125.65	344.24
7. MILLET	10	17.27	95.89	150.192	9.9977	0	0	0	0	0	0	0	0	273.35
8. Small Vegetables	10	0	87.48	153.828	36.5824	0	0	0	0	0	0	0	0	277.89
9. Small Vegetables	10	0	50.44	130.652	35.6735	0	0	0	0	0	0	0	0	216.77
Total	100	255.62	334.47	434.672	82.2536	810.04	1151.67	0	0	0	22.72	146.103	228.36	3465.9

Under ground water exploration programme, CGWB has constructed 26 tube/bore wells in this district and has established that the aquifer is having discharge from 1.50 m^3/hr to 150 m^3/hr. The average discharge of the well is 25 m^3/hr. A bore/tube well in district is expected to yield at least 20 m^3/hr. If such a well runs for 8 hrs/day for 120 days, then it will create a draft of 1.92 ham. Tube wells can be designed within a depth of 100 m, expected to encounter 20 – 30 m thickness of granular zone. Low-lying valley areas are feasible for sustainable ground water development through tube wells.

Therefore, to meet irrigation demand of 3464 ham, 1804 numbers of tube well/bore well have to be constructed. Considering 200m safe distance between two bore/tubewells, total numbers of bore/tube wells that can be constructed in the area is 2825 nos. Hence to meet the irrigation demand of 3464 ham, it can construct 1804 numbers of tube/bore well especially in alluvium and tertiary formation which is free from fluoride.

Moreover, One yield test was conducted at Phulbari for 30 minutes with a discharge of 0.750 lps and drawdown is 0.59m. The data was analysed using Romani method and it was found that the optimal discharge is calculated as 13 m^3/day. One dug well can irrigate 0.013 ha of land. Therefore, 1000 dugwells can irrigate 13 ha of land. Therefore, these areas especially in Alluvium formation bordering Assam and Bangladesh can be brought under irrigation by developing ground water through large diameter dug wells of size 2 to 3 m (dia) X 10 to 15 m (depth) can be constructed.

In addition, roof top rainwater harvesting may be adopted effectively to meet the demand of the people residing on hilltops for domestic use.

Groundwater in the district is infested with Fluoride and Iron in deeper aquifer in certain pocket of the district, therefore before consumption for domestic use, filtering/installation of fluoride/Iron removal plant have to be adopted.

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

Sl No.	Location	X	Y	Elavation (m)	Depth drilled (mbgl)	Aquifer type	Aquifer tap/zone (m)	SWL (mbgl)	Discharge (m3/hr)	DD (mbgl)	T (m2/day)
1	Jugirjhar	90.17248	25.95267	29	28.39	Alluvial		2.85	31.8	6.83	90.37
2	Kadamsali	90.20833	25.95833	39	28.5	Sandstone, clay	16-27	1	44.7	4.86	343
3	Lalmatighat	89.90139	25.73333	38	64.65	Sandstone, Shale		1.17	1.86		4.29
4	Phulbari	90.025	25.88944	31	37	Alluvium	18.46-25.16,25.53-34.4	4.18	66	3	369.4
5	Shyamding	90.0375	25.87917	27	73.8	Gneiss	40-55,60-68	4.32	18	1.5	19.55
6	Garobandha	90.03889	25.57917	79	218.2	Sandstone		3.3	150	3	833.3
7	Gimigiri	90.04722	25.81472	33	30.5	Alluvium	6.0-16.0	3.3	52	3.3	
8	Harigaon	90.06389	25.575	31	192.23	Sandstone, clay		----	----	----	---
9	Kaimbhatpara	90.07361	25.86667	46	37.2	Clay,sand,gravel	18.0-35.5	2.08	42.4	12.56	95.8
10	Chibinang	90.08611	25.85139	34	35.75	S.stone & Granite		2.6	15	---	14.2
11	Jewelgiri	90.1	25.55	73	241.9	Clay,sand,gravel	141.73-151.11,170.25-177.25,193.52-209.26	3.2	42.47	19	76.99
12	Paham	90.1	25.91667	33	55.45	Alluvium	31.0-52.38	3.4	222	2.4	
13	Williampur	90.13056	25.94028	24	36.5	-do-		6.4	1.5	---	4.88
14	Romgiri	90.14722	25.73222	240	31.7	Alluvium		31.7	8.3	18	
15	Jagijhar	90.18139	25.95278	32	28.4	Alluvial	17.35-26.75	2.85	31.8	6.83	90.37
16	Barengapara	90.22211	25.22139	34	172	Sandstone, clay		1.98	4.8	6.05	68.29
17	Berengapara	90.2214	25.21633	33	155.5	Sandstone, clay		3.29	---	----	95.89
18	Damjongre	90.24028	25.64917	364	85	Shale, gneiss		6.5	5.4	12.7	11.3
19	EW Sangsanggre	90.21194	25.49506	261	19.57	Sandstone, Shale					ABD
20	EW Sangsanggre	90.21194	25.49444	261	33.72	Sandstone, Shale	23-25	12.85	2.16	1.13	12.65
21	EW Dakopgre	90.18944	25.52722	262	59.06	Sandstone, Shale	dry				
22	EW Chasingre	90.23667	25.575	427	203.59	Gneiss	80 to 87	67	6.85		
23	OW Chasingre	90.23639	25.57486	427	203.59	Gneiss	65 to 72 m, 80 to 85	54	9		
24	EW Rongram	90.2525	25.60417	382	140.69	Gneiss	122-125	23.08	28	2.73	22.08

25	OW Rongram	90.2525	25.60389	382	203.57	Gneiss	119 to 124	26.92	1.52		
26	EW Jengjal	90.33694	25.67056	677	203.59	Gneiss	28-31, 45-46, 117-119	10.08	2.52		
27	OWJengjal	90.33722	25.67028	677	203.59	Gneiss	13-14, 48-50, 141-142	9.73	3.96	28	0.73
28	EW Dadenggre	90.1908	25.72403	132	118.77	Gneiss	49-50, 116-118	3.3	28.8	2.12	253
29	OW Dadenggre	90.1908	25.72403	132	117.77	Gneiss	115-117	3.2	29.52		
30	EW Phulbari	90.03528	25.99944	25	201.46	Sandstone, Shale, Gneiss	53-56, 160163	7.7	8	10	20.8

Annexure 2: Dynamic water level data of dug well key

X	Y	Unique ID	Name of village/site	RL (mamsl)	Total depth of Pz/DW (mbgl)	Type (DW/Pz/ Spring)	Aquifer group	Measuring point (magl)	Diameter	DTWL 06/2018	DTWL 08/2018	DTWL 11/2018	DTWL 01/2019	DTWL 03/2018
90.32242	25.61514	1	Jendragre	714	3.4	DW	I	0.7	0.9	1.3	1.31	1.25	1.35	1.89
90.24356	25.58836	2	Georagre	388	2.7	DW	I	0.4	2	1	1.01	0.98	1.2	1.66
90.23367	25.549	3	Rongkhon	389	3	DW	I	0.65	1	1.7	1.6	1.48	1.89	2.56
90.20961	25.25283	4	Adugachal (Barengapara I)	50	5.4	DW	I	0.7	0.8	2.9	2.89	2.55	2.99	3.87
90.20717	25.23272	5	Dalu	41	6	DW	I	0.7	0.9	2.9	2.92	2.64	2.91	3.66
90.19344	25.23808	6	Barengapara II	53	8.4	DW	I	0.8	0.8	4.8	4.5	4.44	4.82	5.87
90.17211	25.23322	7	Adanggri	36	6.2	DW	I	0.8	0.7	3.5	3.3	3.3	3.67	4.78
90.13206	25.23142	8	Thekmanpara	35	4.7	DW	I	1.01	0.6	2.6	2.58	2.45	2.74	4.02
90.04822	25.27497	9	Kotchu Adok/ Dalu	41	5.4	DW	I	1	0.6	2.7	2.69	2.62	2.89	4.88
89.98736	25.31017	10	Hathimara	34	4.2	DW	I	1	0.8	3	3.05	3	3.44	4.1
90.02611	25.57811	11	Garobandha	32	8.3	DW	I	0.3	0.8	3.3	3.31	3.01	3.56	4.65
90.08247	25.56692	12	Gatgre	43	5.01	DW	I	0.8	0.9	2.4	2.41	2.3	2.89	4.72
90.10139	25.54417	13	Balagre	47	5.57	DW	I	0.8	0.7	1.35	1.36	1.24	1.66	3.52
90.22256	25.62153	14	Tebrongre	513	1.8	DW	I	1	0.7	1.2	1.15	1.03	1.56	1.76
90.18458	25.70769	15	Tomagre	194	5.3	DW	I	1.02	2	3.3	3.26	3.1	3.78	4.89
90.13181	25.71514	16	Rangbandokgre	215	4	DW	I	0.8	0.7	1.6	1.55	1.4	2.01	3.54
90.08775	25.74639	17	Nunmati Jn.	159	2.9	DW	I	1	0.7	1.1	1.05	0.89	1.52	2.56

90.07597	25.79814	18	Takimagiri	105	2	DW	I	1	0.7	1.2	1.22	1.02	1.89	dry
90.06283	25.80933	19	Darangirri	65	2.9	DW	I	0.8	0.7	1.7	1.68	1.42	1.99	2.89
90.03453	25.85992	20	Masangpani	43	6.3	DW	I	0.6	0.7	2.15	2.14	2.01	2.56	4.23
90.02877	25.87857	21	Phulbari	43	7.8	DW	I	0.8	0.8	2.1	2.03	1.56	2.56	4.56
90.04639	25.88083	22	Shamnagar	21	5	DW	I	0.9	0.8	2.65	2.5	1.99	3.01	4.71
90.06686	25.87028	23	Chibinang I	21	4.3	DW	I	1	0.8	1.1	1.1	0.95	1.56	3.58
90.11261	25.88339	24	Chibinang II	25	3	DW	I	0.6	0.8	1.4	1.36	1.2	1.89	2.87
90.1105	25.92264	25	Pahan Tilapara	23	6	DW	I	0.9	0.8	2.8	2.8	2.57	3.12	5.14
90.16072	25.94433	26	Khamari	27	6.3	DW	I	1.02	0.7	2.4	2.38	2.12	2.89	5.56
90.21761	25.95231	27	Tetrikilla	25	6.8	DW	I	1	2	5.5	5.45	4.95	5.67	6.25
90.2395	25.95169	28	Pragatipur	27	4.6	DW	I	0.9	0.8	1.9	1.88	1.84	2.12	4.02
90.26319	25.93689	29	Bondukmati	30	4.9	DW	I	0.8	0.7	1.8	1.78	1.65	2.06	4.36
90.31242	25.96647	30	Nagaupara	38	6.2	DW	I	1	2	5.9	5.52	4.98	6.01	6.01
90.33819	25.97264	31	Belguri	41	8.1	DW	I	0.9	0.8	5	4.96	4.55	5.26	6.58
90.34842	26.00167	32	New Dalchenkona	28	4	DW	I	0.2	0.8	1.7	1.65	1.23	1.99	3.56
90.21361	25.3445	33	Kherapara	178	12.5	DW	I	1.05	0.8	5.1	5	4.55	5.23	6.89
90.20706	25.23831	34	Barengapara I	55	11.96	DW	I	0.8	0.8	3.21	3.01	2.85	3.33	6.55
90.00936	25.29733	35	Jarangkhona	49	14.1	DW	I	0.9	0.7	3.04	2.99	2.42	3.12	5.89

Annexure 3: Spring discharge data

X	Y	Unique ID	Location	Block	RL (mamsl)	Discharge (lpm) 06/18	Discharge (lpm) 08/18	Discharge (lpm) 11/18	Discharge (lpm) 01/19	Discharge (lpm) 03/19
90.29475	*25.60686*	1	Rongram	Rongram	666	12	15	25	6	dry
90.23628	25.55647	2	Chasingre/NEHU	Rongram	406	7.5	8	10	dry	dry
90.21861	25.51153	3	Tura (2 springs)	Rongram	336	20 &8	20 & 8	30 &15	15 & 5	7 & dry
90.21544	25.50556	4	Dobasipara	Rongram	288	24	30	35	-	-
90.21506	25.49878	5	Dobasipara/KVK	Rongram	282	8	15	21	7	5
90.20419	25.63808	6	Marakapara	Rongram	482	30	-	-	-	5
90.21306	25.49361	7	Home Sc. Tura	Rongram	226	20	23	30	5	dry

Annexure 4.1: Ground water quality data of dug well in Aquifer mapping area

X	Y	Location	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
90.23367	25.549	Rongkhon	7.53	177.40	BDL	98.41	BDL	15.01	15.01	21.27	69.12	10.52	0.35	22.02	16.98	125.00	3.41	2.06	0.13
90.19344	25.23808	Barengapara	6.73	47.88	BDL	26.34	BDL	35.03	35.03	24.82	5.28	BDL	0.13	4.00	7.28	40.00	13.24	1.50	BDL
90.20717	25.23272	Dalu	6.99	131.20	BDL	71.91	BDL	50.04	50.04	35.45	6.81	BDL	0.10	14.01	8.49	70.00	12.74	2.75	0.15
90.275556	25.663889	Beljek	6.40	39.02	0.20	21.54	BDL	15.01	15.01	35.45	2.94	BDL	0.06	2.00	7.28	35.00	11.82	3.19	0.002
90.274167	25.600833	Asanang	6.92	125.40	BDL	69.29	BDL	45.04	45.04	46.09	7.54	BDL	0.13	10.01	8.49	60.00	17.54	3.13	0.07
90.246944	25.592222	Rongram	6.59	132.70	BDL	72.72	BDL	25.02	25.02	35.45	4.77	3.54	0.06	10.01	9.70	65.00	3.29	9.28	0.79
90.24356	25.58836	Georagre	6.04	153.90	0.50	83.83	BDL	20.02	20.02	49.63	4.28	5.13	0.15	12.01	4.85	50.00	16.74	5.90	BDL
90.32242	25.61514	Jendragre	5.88	29.39	BDL	16.14	BDL	20.02	20.02	24.82	4.80	BDL	0.09	6.00	7.28	45.00	4.19	3.88	BDL
90.22256	25.62153	Tebrongre	6.13	61.38	BDL	33.90	BDL	25.02	25.02	28.36	4.03	BDL	0.09	8.01	6.06	45.00	4.52	5.82	BDL
90.18458	25.70769	Tomagre	7.13	188.00	BDL	103.90	BDL	45.04	45.04	39.00	9.09	5.54	0.17	16.01	8.49	75.00	8.69	17.24	BDL
90.07597	25.79814	Takimagre	6.88	68.99	BDL	37.96	BDL	45.04	45.04	28.36	6.32	BDL	0.23	14.01	2.42	45.00	11.14	5.36	0.42
90.06283	25.80933	Darengre	6.85	78.75	0.20	43.31	BDL	40.03	40.03	28.36	1.98	BDL	0.16	8.01	6.06	45.00	8.28	4.12	0.31
90.03453	25.85992	Masangpani	7.38	171.10	BDL	94.12	BDL	80.06	80.06	31.91	8.68	BDL	0.26	10.01	9.70	65.00	23.69	1.08	0.02
90.2395	25.95169	Pragatipur	7.21	122.90	BDL	67.95	BDL	65.05	65.05	39.00	14.38	BDL	0.25	16.01	8.49	75.00	9.21	13.87	0.13
90.26319	25.93689	Bondukmati	7.19	98.90	0.30	54.56	BDL	45.04	45.04	28.36	9.04	BDL	0.14	14.01	10.92	80.00	3.19	2.55	0.13
90.31242	25.96647	Nagaupara	7.27	191.00	0.10	105.00	BDL	60.05	60.05	35.45	6.76	4.10	0.18	20.02	8.49	85.00	4.00	10.20	BDL
90.33819	25.97264	Belguri	6.86	41.75	BDL	22.94	BDL	25.02	25.02	24.82	3.04	BDL	0.19	10.01	4.85	45.00	3.76	3.38	BDL
90.34842	26.00167	New Dalchenkona	7.08	75.77	BDL	41.69	BDL	40.03	40.03	35.45	5.79	BDL	0.19	12.01	4.85	50.00	6.57	13.50	0.09
90.4	25.76	Jengjal	7.63	67.32	BDL	35.12	BDL	40.03	40.03	24.82	2.68	0.74	0.28	8.01	8.49	55.00	4.52	2.22	0.01
90.32242	25.61514	Jendragre	6.67	60.63	BDL	31.63	BDL	35.03	35.03	31.91	4.03	1.49	0.11	6.00	9.71	55.00	7.60	3.26	BDL
90.22256	25.62153	Tebrongre	6.44	67.59	0.2	35.54	BDL	25.02	25.02	35.45	3.09	2.92	0.08	10.01	3.64	40.00	12.87	2.45	BDL
90.18458	25.70769	Tomagre	7.16	108.60	BDL	56.59	BDL	35.03	35.03	39.00	19.38	2.36	0.12	10.01	9.70	65.00	12.38	3.35	0.00
90.32	25.829	Dadengre	7.28	118.90	BDL	61.48	BDL	40.03	40.03	39.00	7.67	5.02	0.11	12.01	10.92	75.00	9.49	1.49	BDL

90.131	25.715	Rangbandokgre	6.05	31.18	0.3	16.25	BDL	10.01	10.01	31.91	7.75	0.68	0.05	4.00	6.07	35.00	8.47	3.01	BDL
90.06283	25.80933	Darengre	6.96	79.39	BDL	41.44	BDL	45.04	45.04	39.00	4.93	0.61	0.17	12.01	6.06	55.00	14.15	3.26	BDL
90.025	25.889	Phulbari	8.35	278.30	BDL	146	20	80.08	100.08	35.45	16.60	4.04	0.54	18.01	26.69	155.00	4.64	0.48	0.03
90.067	25.87	Chibinang	8.33	328.90	0.1	172.3	30	95.10	125.10	63.81	19.17	0.97	0.36	20.02	21.83	140.00	30.40	10.36	0.08
90.18458	25.70769	Tetrikilla	8.48	243.50	0.1	127.7	40	75.09	115.09	42.54	14.76	1.13	0.44	18.01	23.05	140.00	20.48	1.03	0.34
90.26319	25.93689	Bondukmati	8.04	125.90	BDL	65.83	BDL	70.06	70.06	24.82	10.73	0.32	0.25	20.02	6.06	75.00	8.15	2.33	BDL

Annexure 4.2: Ground water quality data of bore well in Aquifer mapping area

X	Y	**Location**	**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**
90.21194	25.49444	Samgsanggre, Tura	7.57	128.00	1.40	64.21	BDL	35.03	35.03	17.70	9.53	BDL	0.22	10.01	2.42	35.00	13.61	5.62	0.07
90.23667	25.575	EW, Chasingre Tura	7.97	183.60	BDL	110.70	BDL	110.09	110.09	31.91	69.82	BDL	1.70	24.02	9.70	100.00	24.33	29.17	2.22
90.23639	25.57486	OW, Chasingre Tura	6.58	58.89	BDL	38.87	BDL	45.04	45.04	35.45	7.46	BDL	0.56	14.01	7.27	65.00	8.70	2.85	0.12
90.2525	25.60417	EW, Rongram	8.73	320.10	BDL	211.27	30.00	135.13	165.13	14.18	13.60	3.47	9.10	18.01	1.20	50.00	47.30	39.65	BDL
90.2525	25.60389	OW, Rongram	8.94	323.10	BDL	213.25	30.00	135.13	165.13	10.64	10.30	1.17	12.20	14.01	3.63	50.00	48.96	34.31	BDL
90.3369	25.67	EW Jengjal	8.37	187.80	BDL	99.06	30.00	15.04	45.04	21.27	9.11	2.74	1.40	12.01	7.28	60.00	16.60	1.54	0.27
90.3369	25.67	OW Jengjal	8.38	212.90	BDL	111.80	30.00	90.10	120.10	24.82	7.63	2.44	1.90	8.01	12.13	70.00	38.00	3.52	0.22
91.12	25.43	Dadenggre	10.51	458.70	BDL	240.60	30.00	10.03	40.03	67.35	79.81	0.10	19.10	6.00	4.85	35.00	86.26	28.99	0.16

Annexure 4.3: Ground water quality data of spring in Aquifer mapping area

location	**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**
Tura II	7.61	163.00	BDL	89.79	BDL	65.05	65.05	35.45	22.21	0.60	0.09	24.02	8.48	95.00	7.84	5.17	BDL
Tura	6.97	144.80	BDL	79.74	BDL	40.03	40.03	35.45	14.82	1.52	0.19	16.01	7.27	70.00	10.65	4.42	BDL

Annexure 5: Lithological log of exploratory wells

Village	Lalmatighat
Taluka/Block	Selsella
District	West Garo
Latitude	25.7333
Longitude	89.901
RL (m amsl)	38
Drilled Depth	64.65
SWL (mbgl)	1.17
Discharge (m^3/hr)	1.86

Depth range (m)	Thickness (m)	**Lithological description**
0.0-7.50	7.50	Sandstone, brown coarse grained, weathered
7.50-10.10	2.60	Carbonaceous shale, weathered
10.10-13.60	3.50	Sand stone, dirty white, fine grained
13.60-16.70	3.10	Carbonaceous shale
16.70-20.45	3.75	Sandstone, grey, fine to medium grained
20.45-21.45	1.00	Sandstone, grey, coarse grained
21.45-26.30	4.85	Sandstone, dirty white, fine to medium grained
26.30-28.55	2.25	Carbonaceous shale
28.55-37.75	9.20	Sandstone grey, fine to medium grained
37.75-38.75	1.00	Carbonaceous shale
36.75-39.35	1.00	Sandstone, grey, medium to coarse grained
39.75-41.75	1.00	Carbonaceous shale
41.75-45.85	4.10	Sandstone, grey, fine to medium grained
45.85-47.85	2.00	Carbonaceous shale
47.85-52.95	5.10	Sandstone, grey, fine to medium grained
52.95-54.95	2.00	Carbonaceous shale
54.95-61.05	6.10	Sandstone, grey, medium grained
61.05-64.65	3.60	Carbonaceous shale

Village	Jugirhar
Taluka/Block	Tikrikilla
District	West Garo
Latitude	25.952
Longitude	90.174
RL (m amsl)	29
Drilled Depth	28.39
SWL (mbgl)	2.85
Discharge (m^3/hr)	31.8

Depth Range (m bgl)	**Thickness (m)**	**Lithological description**
00 –10.87	10.87	Clay, dark grey in colour, sticky
10.87 -17.35	6.48	Sandy clay, brown with fine grained sand
17.35 – 23.84	6.49	Sand, brownish, fine to coarse grained with occasional gravel in form of ferruginous nodules.
23.84 – 26.84	3.00	Sand, Light grey, fine to coarse grained
26.84 28.01	1.17	Weathered granite, dark grey, sub angular to angular chips
28.01 – 28.39	0.38	Chip of granite, geyish, angular to sub angular (bed rock)

Village	Barengapara
Taluka/Block	Dalu
District	West Garo
Latitude	25.221
Longitude	90.222
RL (m amsl)	34
Drilled Depth	172
SWL (mbgl)	1.98
Discharge (m^3/hr)	4.8

Depth Range (m bgl)	Thickness (m)	Lithological Description
00 - 5.93	5.93	Sand, fine to medium with occasional grains of feldspar
5.93 - 8.93	3.00	Sand, fine to medium with dark brownish clay particles
8.93 - 15.93	7.00	Fine sand with medium grains of quartz & feldspar
27.23 - 33.33	6.10	Fine sand with occasional grains of quartz
33.33 - 36.43	3.10	Sandy clay, non-sticky, plastic
36.43 - 39.43	3.00	Clay with occasional grains of quartz
39.43 - 48.63	9.20	Sand, fine to medium grains of quartz
48.63 - 57.83	9.20	Clay, grey ,sticky
57.83 - 60.83	3.00	Sand and medium to fine grains quartz
60.83 - 63-93	3.10	Sand, clay with fine sand
63.93 - 66.93	3.00	Dark clay, sticky, plastic
66.93 - 70.03	3.10	Sand, medium to fine grains of quartz
70.03 - 73.03	3.00	Clay, Sticky, plastic
73.03 - 79.13	6.10	Reddish clay, sticky plastic
79.13 - 82.23	3.10	Sand, fine grains of quartz with occasional large grains
82.23 - 100.50	18.27	Reddish clay, sticky plastic
100.50 - 106.60	6.10	Reddish clay mixed with fine grain of quartz
106.60 - 146.10	39.50	Reddish clay, sticky, plastic
146.10 - 152.20	6.10	Sandy clay, reddish, sticky, plastic
152.20 - 171.50	19.30	Reddish clay, sticky plastic
171.50 - 172.00	0.50	Hard, sandy formation

Village	Williampur,
Taluka/Block	Tikrikilla
District	West Garo
Latitude	25.940
Longitude	90.130
RL (m amsl)	24
Drilled Depth	36.5
SWL (mbgl)	6.4
Discharge (m^3/hr)	1.5

Depth range (m bgl)	Thickness (m)	Lithological description
00 - 5.00	5.00	Sticky clay, yellowish to brownish.
5.00 - 7.10	2.10	Slit and fine grained sand with little clay.
7.10 - 8.10	1.00	Sticky clay yellowish to brownish.
8.10 - 12.20	4.10	Slit and fine grained sand with little clay.
12.20 - 13.20	1.00	Gravels and pebbles of quartz, sandstone etc.
13.20 - 20.05	6.85	Fragments of quartz, feldspar, sometimes biotite granite formation, mixed with less amount of loose sand.
20.05 - 21.05	1.00	Chip of quartz (quartz vein?)
21.05 - 24.30	3.25	Fragments of ultra-basic rock with flaky minerals massive.
24.30 - 26.40	2.10	Larger chips of granitic formation fracture.
26.40 - 30.40	4.00	Fragments of ultrabasic rock with flaky minerals massive.
30.40 - 32.50	2.10	Chips of biotite rock granitic rock.
32.50 - 35.50	3.00	Fragments of ultrabasic rock with flaky minerals massive
35.50 - 36.50	1.00	Chip of granite rock with quartz feldspar etc.

Village	Damjongre
Taluka/Block	Daddenggre
District	West Garo
Latitude	25.649
Longitude	90.240
RL (m amsl)	364
Drilled Depth	85
SWL (mbgl)	6.5
Discharge (m^3/hr)	5.4

Depth range (m bgl)	Thickness (m)	Lithological description
00 - 3.00	3.00	Top soil, yellowish to brownish sand and silt
3.00 - 7.10	4.10	Pea size gravel of quartz and feldspar.
7.10 - 25.5	18.40	Sand to pea size fragments of grayish carbonaceous shale.
25.50 - 26.50	180	Fragment of quartz and feldspar.
26.52 - 38.70	12.20	Fragments of greyish carbonaceous shale with pieces of quartz & feldspar
38.70 - 46.80	8.10	Fragments of dolerite formation with a few pieces of quartz& feldspar.
46.80 - 48.80	2.00	Large fragments of carbonaceous shale.
48.80 - 49.80	1.10	Sandy fragment of carbonaceous shale.
49.80 - 56.00	6.10	Sandy fragments of quartz & feldspar (genetic formation)
56.00 - 62.10	6.10	Sandy grains of dolerite formation
62.10 - 66.10	4.10	Coarse grained formation of doleritic formation.
66.10 - 82.40	16.30	Coarse grained formations of quartz & feldspar (granitic formation)
82.40 - 85.00	2.60	Coarse grained fragments of doleritic formation.

Village	Romgiri,
Taluka/Block	Daddenggre
District	West Garo
Latitude	25.7322
Longitude	90.1472
RL (m amsl)	240
Drilled Depth	31.7
SWL (mbgl)	-
Discharge (m^3/hr)	8.3

Depth range (m bgl)	Thickness (m)	Lithological description
00 - 00	3.00	Top soil, brownish to yellow clay & silt.
3.00 - 9.10	6.10	Medium to coarse sand mixed with little clay, yellowish to brown.
9.10 - 14.20	5.10	Sticky clay, grayish, mixed with fragments of clay-stone.
14.20 - 1930	5.10	Fine to medium sand, greyish to brownish, mixed with grayish clay.
19.30 - 21.30	2.00	Claystone (shale?), grayish mixed with little sand, brownish.
21.30 - 23.30	2.00	Medium grained brownish sand.
23.30 - 29.40	6.10	Sticky greysh clay.
29.40 - 31.70	2.30	Fine to medium grained grayish to brownish sand.

Village	Shyamding
Taluka/Block	Selsella
District	West Garo
Latitude	25.879
Longitude	90.037
RL (m amsl)	27
Drilled Depth	73.8
SWL (mbgl)	4.3
Discharge (m^3/hr)	18

Depth range (m bgl)	Thickness (m)	Lithological description
00 - 2.00	2.00	Haemotised red clay (Top soil)
2.00 - 18.00	16.00	Yellowish clay (top alluvium).
18.00 - 22.00	4.00	Angular sometimes rounded pieces of amphibolite and quartz with sand.
22.00 - 53.00	31.00	Highly weathered quartzite, while, with fine very fine grained sand.
53.00 - 54.00	1.00	Grey weathered quartzite with pieces of amphibolite.
54.00 - 57.10	3.10	White to pale pink weathered quartzite.
57.00 - 57.10	8.20	Angular pieces (sometimes rounded) of amphibolite mixed with pink quartzite (loss).
68.30 - 73.80	5.50	Angular pieces of amphibolite, pink quartzite associated with fine to medium grained brownish sand.

Village	Chibinang
Taluka/Block	Selsella
District	West Garo
Latitude	25.851
Longitude	90.086
RL (m amsl)	34
Drilled Depth	35.75
SWL (mbgl)	2.6
Discharge (m^3/hr)	15

Depth Range (m bgl)	Thickness (m)	Lithological description
00 - 3.00	3.00	Top soil mixed with clay, fine to medium grained, brownish.
3.00 - 4.00	1.00	Medium to coarse grained sand, brownish.
4.00 - 5.00	1.00	Coarse grained sand, granite
5.00 - 5.75	0.25	Quartz gravel mixed with coarse sand
5.75 - 6.25	1.00	Weathered granite
6.25 - 19.55	13.30	Massive quartz-rich granite, fractured at few places
19.55 - 20.55	1.00	Slightly fractured biotite - rich granite
20.55 - 28.65	8.10	Massive quartz rich granite
30.65 - 33.75	3.10	Fractured feldspar- rich granite
33.75 - 35.75	2.00	Slightly fractured feldspar rich pink granite

Village	Gemigiri
Taluka/Block	Selsella
District	West Garo
Latitude	25.814
Longitude	90.0472
RL (m amsl)	33
Drilled Depth	30
SWL (mbgl)	3.3
Discharge (m^3/hr)	52

Depth range (m bgl)	Thickness (m)	Lithological description
00 - 6.00	6.00	Clay, reddish brown, sticky
6.00 - 8.00	2.00	Sand, coarse grained, yellowish
8.00 - 9.50	1.50	Sand, coarse grained, yellowish mixed with clay, grey, sticky.
9.50 - 16.50	7.00	Sand, coarse grained yellowish
16.50 - 18.00	1.50	Sand, coarse grained, yellowish mixed with clay, grey, sticky.
18.00 - 30.50	12.50	Clay, grey, sticky mixed with a little sand, coarse grained

Village	Harigaon
Taluka/Block	Selsella
District	West Garo
Latitude	25.575
Longitude	90.0638
RL (m amsl)	31
Drilled Depth	192
SWL (mbgl)	-
Discharge (m^3/hr)	-

Depth range (m)	Thickness (m)	Lithological description
00 - 5.00	5.00	Top soil brown in colour
5.00 - 16.76	11.76	Sand, medium to coarse, sub-rounded to rounded
16.76 - 18.29	1.53	Clay, grey in colour, hard plastic with ferruginous material.
18.21 - 45.73	27.44	Clay, grey in colour, hard plastic with little fine sand.
45.73 - 51.82	6.09	Clay, grey in colour hard plastic
51.82 - 92.96	41.14	Clay, grey in colour hard plastic with little fine sand.
92.16 - 131.09	32.13	Clay grey in colour, hard plastic with little ferruginous materials.
131.09 - 181.70	50.31	Clay grey in colour hard plastic with very little fine san.
181.90 - 189.92	7.82	Sand, medium to coarse with grey clay.
189.02 - 192.23	3.1	Sand, medium to coarse with quartz and feldspar pieces, hard rock.

Village	Kaimbhatpara
Taluka/Block	Selsella
District	West Garo
Latitude	25.866
Longitude	90.073
RL (m amsl)	46
Drilled Depth	37.2
SWL (mbgl)	2.08
Discharge (m^3/hr)	42.4

Depth range (m bgl)	Thickness (m)	Lithological description
00 - 4.80	4.80	Top soil, yellowish brown, silty coarse grained with occasional nodules of ferruginous matter and weathered feldspar.
4.80 - 10.97	6.17	Sand, grayish brown, fine to medium grained.
10.97 - 18.01	7.04	Sandy clay, brownish black, mixed with fine grained sand with occasional mica flakes.
18.01 - 28.04	10.03	Sand, grayish brown, fine grained.
28.04 - 31.53	3.44	Gravel, light grey, mainly composed of quartz, sub- angular to sub- rounded, mixed with little amount of fine to coarse grained sand.
31.53 - 34.53	31.00	Gravel, pinkish mainly composed of quartz, sub-angular to sub- rounded, mixed with little amount of fine to coarse grained sand
34.53 - 37.00	2.47	Weathered granite, dark grey, with angular to sub-angular chips.
37.00 - 37.20	0.20	Chips of grayish granite, sub- angular to angular (Bed rock).

Village	Paham
Taluka/Block	Selsella
District	West Garo
Latitude	25.916
Longitude	90.10
RL (m amsl)	33
Drilled Depth	55.45
SWL (mbgl)	3.4
Discharge (m^3/hr)	22

Depth range (m bgl)	Thickness (m)	Lithological description
00 - 3.58	3.58	Loamy Soil
3.58 - 25.73	22.15	Sand, grayish, fine grained with mica flakes.
25.73 - 35.26	9.53	Sand, grayish, fine to medium grained with mica flakes.
35.26 - 38.26	3.00	Sand, grayish, coarse to medium grained with occasional gravel mainly composed of quartz rounded to sub- rounded.
28.26 - 44.51	6.26	Gravel sandy, light grayish, mainly composed of quartz sub rounded to sub – angular with considerable amount of sand grayish, fine to coarse grained.
44.51 - 51.03	9.52	Sand, grayish, medium to coarse grained with occasional gravel rounded to sub rounded.
54.03 – 55.05	1.02	Weathered granite, dark grey sub angular to angular pieces
55.05 - 55.45	0.40	Chips of granite, grayish, sub angular to angular (bed rock)

Village	Kadamsali
Taluka/Block	Tikrikilla
District	West Garo
Latitude	25.958
Longitude	90.208
RL (m amsl)	39
Drilled Depth	28.5
SWL (mbgl)	1
Discharge (m^3/hr)	44

Depth Range (m bgl)	Thickness (m)	Lithological description
00 - 13.15	13.15	Clay, yellowish brown, sticky,
13.15 - 16.15	3.00	Sand, opaque light brown, fine to medium grained with occasional gravel.
16.15 - 27.00	10.85	Sand and gravel mixed with little clay, light yellowish brown gravel rounded to sub-rounded sand, medium to coarse grained.
27.00 - 28.10	1.10	Weathered granite, dark grey, sub- angular ships of granite.
28.10 - 28.50	0.40	Chip[s of granite, dark grey, angular to sub angular (bed rock)

Village	Garobandha
Taluka/Block	Selsella
District	West Garo
Latitude	25.579
Longitude	90.038
RL (m amsl)	79
Drilled Depth	218
SWL (mbgl)	3.3
Discharge (m^3/hr)	150

Depth range (m bgl)	Thickness (m)	Lithology
00 - 10.80	10.28	Top soil reddish brown color sand grey in color
10.80 - 19.90	9.10	Very coarse sand with gravel rounded and sub- rounded with little feldspar
19.90 - 23.00	3.10	Fine to medium sand with feldspar material
23.00 - 102.30	79.30	Clay, grey in color, hard plastic coarse sand and ferruginous
102.30 - 105.30	3.00	Medium to coarse sand with little clay
105.30 - 108.40	3.10	Medium to fine sand with a little clay.
108.40 - 129.70	21.30	Clay, grey in colour, hard plastic with little ferruginous material fragments
129.70 - 132.80	3.10	Fine sand with grey clay.
132.80 - 154.10	21.30	Clay, sticky hard plastic with little ferruginous material.
154.10 - 157.20	3.10	Medium to coarse sand, sub rounded to rounded
157.20 - 206.00	18.80	Clay sticky hard with little ferruginous material.
206.0 - 218.20	12.20	Clay, sticky hard grey with little medium to coarse sand.

Village	Jewelgiri
Taluka/Block	Selsella
District	West Garo
Latitude	25.55
Longitude	90.1
RL (m amsl)	73
Drilled Depth	241
SWL (mbgl)	3.2
Discharge (m^3/hr)	42

Depth range (m bgl)	Thickness (m)	Lithological description
00 - 7.70	7.70	Top soil, reddish brown in color
7.70 - 21.28	13.58	Sand grey medium to coarse rounded to sub rounded with a little gravel
21.28 - 24.65	3.37	Gravel with very coarse sand
24.65 - 132.04	107.39	Clay sticky hard plastic
132.04 - 147.73	9.69	Clay grey sticky plastic with a little fine sand.
141.73 - 151.11	9.38	Sand, medium to very coarse rounded to sub rounded, grey color with little gravel
151.11 - 154.49	3.38	Clay, grey sticky plastic with little sand.
154.49 - 167.25	12.76	Clay, grey sticky plastic
167.25 - 170.25	3.00	Clay grey sticky plastic, mixed with sand.
170.25 - 177.27	7.20	Sand grey medium to very coarse sub rounded to rounded
177.27 - 190.06	12.49	Clay grey sticky hard plastic with a little quartz
190.06 - 193.52	3.48	Clay grey sticky hard plastic mixed with sand
193.52 - 209.26	15.74	Sand medium to very coarse with little gravel
209.36 - 241.90	32.64.	Clay, grey sticky hard plastic in colour mixed with sand

Village	Sangsangre 1
Taluka/Block	Rongram
District	West Garo
Latitude	25.495
Longitude	90.2119
RL (m amsl)	261
Drilled Depth	19.57
SWL (mbgl)	-
Discharge (m^3/hr)	-

Depth range (in m bgl)	Thickness (m)	Lithological description
G.L. to 8.00	8	Top soil: mixed with weathered rock fragments
8.00 to 19.57	11.57	Sandstone along with shale, loose formation (Remarks: air lose and caving-aboundand)

Village	Sangsangre
Taluka/Block	Rongram
District	West Garo
Latitude	25.494
Longitude	90.2119
RL (m amsl)	261
Drilled Depth	33.72
SWL (mbgl)	12
Discharge (m^3/hr)	2.2

Depth range (in m bgl)	Thickness (m)	Lithological description
G.L. to 7.00	7	Top soil: mixed with weathered rock fragments
7.00 to 20.00	13	Sandstone, hard and compact in nature.
20.00 to 23.00	3	Shale, thinly laminated, grey
23.00 to 25.00	2	Sandstone, fractured zone.
25.00 to 30.00	5	Shale, thinly laminated, loose formation
30.00 to 33.50	3.5	Sandstone, hard and compact in nature.

Village	Dakopgre
Taluka/Block	Rongram
District	West Garo
Latitude	25.527
Longitude	90.189
RL (m amsl)	262
Drilled Depth	59
SWL (mbgl)	-
Discharge (m^3/hr)	-

Depth range (in m bgl)	Thickness (m)	Lithological description
0-6	6	Surface soil: Brown colour, lateritic
6-12	6	Clay: Dark grey, sticky
12-15	3	Gravel: Variegated colour, rock fragments of clay, sandstone, calcite, laterite, etc. present. Grains are sub-angular. Clay fragments nearly 10%
15-18	3	Sand: Light brown colour, fine to very coarse sand. Gravel size rock fragments of quartz, feldspar, other weathered rock fragments present. Grains are angular to sub-angular. Poorly sorted
18-21	3	Sand: Brown colour, fine to coarse sand. Gravel size rock fragments of quartz, feldspar, other weathered rock fragments present. Grains are angular to sub-angular. Sticky clay (nearly 5%).Poorly sorted
21-24	3	Sand: Off white colour, medium to coarse grained, gravel size quartz, feldspar and brown coloured weathered rock fragments present. Moderate sorting.
24-27	3	Sand: Light brown colour, medium to very coarse sand. Few gravel size rock fragments of quartz, feldspar, other weathered rock fragments present. Grains are angular to sub-angular. Poorly sorted
27-30	3	Gravel: Light brown colour, grains size gravel (2-4mm), fragments of quartzite, calcite, etc. present. Grains are angular to sub-angular. Sorting good.
30-33	3	Sand: Brown colour, fine to very coarse sand. Gravel size rock fragments of quartz, feldspar, other weathered rock fragments present. Grains are angular to sub-angular. Poorly sorted
33-36	3	Sand and clay: Brown colour fine to coarse sand. Clay is dark grey colour, hard, compact
36-39	3	Clay: Dark grey colour, sticky
39-45	6	Sandy clay: Sand light brown, fine to coarse grained. Clay is dark grey and sticky. Sand is nearly 10% of total volume
45-48	3	Sand: Greyish brown, medium sand. Claystone chips are found.
48-54	6	Sand: Grey colour, medium sand.
54-59	5	Sand: Grey colour, medium sand. Clay (5%).

Village	Chasingre
Taluka/Block	Rongram
District	West Garo
Latitude	25.575
Longitude	90.236
RL (m amsl)	427
Drilled Depth	203
SWL (mbgl)	67
Discharge (m^3/hr)	6

Depth range (in m bgl)	Thickness (m)	Lithological description
0-6	6	Top soil, reddish and sandy material
6-49	43	Sand- fine to medium grained mixed with weathered and altered rock
49-80	31	Gneiss, Grey colour, hard, sample cuttings are fine to medium grained size, brownish grey in colour
80-87	7	Gneiss, fractured zone, sample cuttings are coarse to very coarse grained size, greyish black in colour
87-203.59	116.59	Gneiss, hard and compact, grey in color, sample cuttings are fine to medium grained size

Village	OW Chasingre
Taluka/Block	Rongram
District	West Garo
Latitude	25.575
Longitude	90.236
RL (m amsl)	427
Drilled Depth	203
SWL (mbgl)	54
Discharge (m^3/hr)	9

Depth range (m)	Thickness (m)	Lithological description
0-5	5	Top soil, reddish and sandy material
5-29	24	Sand- coarse grained mixed with weathered and altered rock
29-65	36	Gneiss, Grey colour, hard and compact, sample cuttings are very fine to fine grained size,
65-72	7	Gneiss, fractured zone, sample cuttings are coarse to very coarse grained size, greyish black in colour.
72-80	8	Gneiss, grey colour, hard and compact, sample cuttings are medium grained size
80-85	5	Gneiss, fractured zone, sample cuttings are coarse to very coarse grained size, greyish black in colour.
85-177	92	Granitic gneiss, massive, grey, sample cuttings are medium grained size
177-185	8	Granitic gneiss, massive, sample cuttings are fine to medium grained size, light grey in colour
185-203.59	18.59	Granitic gneiss, massive, sample cuttings are medium grained size, grey in colour.

Village	Rongram
Taluka/Block	Rongram
District	West Garo
Latitude	25.604
Longitude	90.232
RL (m amsl)	382
Drilled Depth	140
SWL (mbgl)	23
Discharge (m^3/hr)	9

Depth range (m)	Thickness (m)	**Lithological description**
0-8	8	Top soil, reddish and sandy material
8-41	33	Sand- fine to medium grained mixed with weathered and altered rock
41-122	81	Gneiss, hard, sample cuttings are fine to medium grained size, brownish grey in colour
122-125	3	Gneiss, fractured zone, sample cuttings are coarse to very coarse grained size, greyish black in colour
125-140.69	15.69	Gneiss, hard and compact, grey in color, sample cuttings are fine to medium grained size

Village	OW Rongram
Taluka/Block	Rongram
District	West Garo
Latitude	25.604
Longitude	90.232
RL (m amsl)	382
Drilled Depth	203
SWL (mbgl)	26
Discharge (m^3/hr)	1.5

Depth range (m)	Thickness (m)	**Lithological description**
0-7	7	Top soil, reddish and sandy material
7-39	32	Sand- medium grained mixed with weathered and altered rock
39-119	80	Gneiss, Grey colour, hard and compact, sample cuttings are very fine to fine grained size,
119-124	5	Gneiss, fractured zone, grey in colour, sample cuttings are coarse to very coarse grained size.
124-162	38	Gneiss, grey colour, hard and compact, sample cuttings are medium grained size
162-203.57	41.57	Gneiss, brownish colour, hard and compact, sample cuttings are fine to medium grained size

Village	Jengjal
Taluka/Block	Rongram
District	West Garo
Latitude	25.670
Longitude	90.336
RL (m amsl)	677
Drilled Depth	203
SWL (mbgl)	10
Discharge (m^3/hr)	2.5

Depth range (m)	Thickness (m)	**Lithological description**
0-10	10	Top soil, reddish and sandy material
10-28	18	Sand- fine to medium grained mixed with weathered and altered rock
28-31	3	Gneiss, fractured zone, sample cuttings are coarse to very coarse grained size, grey in colour
31-45	14	Gneiss, hard, sample cuttings are fine to medium grained size, grey in colour
45-46	1	Gneiss, fractured zone, sample cuttings are coarse grained size, grey in colour
46-117	71	Gneiss, hard, sample cuttings are fine to medium grained size, greyish black in colour
117-119	2	Gneiss, fractured zone, sample cuttings are coarse to very coarse grained size, greyish black in colour
119-203.59	84.59	Gneiss, hard and compact, pink in color, sample cuttings are fine grained size

Village	OW Jengjal
Taluka/Block	Rongram
District	West Garo
Latitude	25.670
Longitude	90.336
RL (m amsl)	677
Drilled Depth	203
SWL (mbgl)	9.7
Discharge (m^3/hr)	4

Depth range (m)	Thickness (m)	**Lithological description**
0-9	9	Top soil, reddish and sandy material
9-13	4	Sand- medium grained mixed with weathered and altered rock
13-14	1	Gneiss, fractured zone, grey in colour, sample cuttings are coarse to very coarse grained size.
14-48	34	Gneiss, Grey colour, hard and compact, sample cuttings are very fine to fine grained size,
48-50	2	Gneiss, fractured zone, sample cuttings are coarse grained size. grey in colour
50-141	91	Gneiss, Grey colour, compact, sample cuttings are very fine to fine grained size,
141-142	1	Gneiss, fractured zone, sample cuttings are coarse to very coarse grained size.
142-203.59	61.59	Gneiss, brownish colour, hard and compact, sample cuttings are fine to medium grained size

Village	Daddengre
Taluka/Block	Rongram
District	West Garo
Latitude	25.724
Longitude	90.190
RL (m amsl)	183
Drilled Depth	118
SWL (mbgl)	3.3
Discharge (m^3/hr)	28

Depth range (m)	Thickness (m)	**Lithological description**
0-7	7	Top soil, reddish and sandy material
7-30	23	Sand- fine to medium grained mixed with weathered and altered rock, light grey
30-49	19	Gneiss, hard, sample cuttings are fine grained size, light grey in colour
49-51	2	Gneiss, fractured zone, sample cuttings are coarse to very coarse grained size, grey in colour
51-116	65	Gneiss, hard, sample cuttings are fine to medium grained size, grey in colour
116-118.77	2.77	Gneiss, fractured zone, sample cuttings are coarse grained size, dark grey in colour

Village	OW Daddengre
Taluka/Block	Rongram
District	West Garo
Latitude	25.724
Longitude	90.190
RL (m amsl)	183
Drilled Depth	117
SWL (mbgl)	3.2
Discharge (m^3/hr)	29

Depth range (m)	Thickness (m)	**Lithological description**
0-8	8	Top soil, reddish and sandy material
8-35	27	Sand- medium grained mixed with weathered and altered rock
85-115	80	Gneiss, Grey colour, hard and compact, sample cuttings are very fine to fine grained size,
115-117.77	2.77	Gneiss, fractured zone, sample cuttings are coarse grained size, dark grey in colour

Village	Phulbari
Taluka/Block	Selsella
District	West Garo
Latitude	25.999
Longitude	90.035
RL (m amsl)	27
Drilled Depth	201
SWL (mbgl)	7.7
Discharge (m^3/hr)	8

Depth Range (m bgl)	**Thickness (m)**	**Lithological description**
00 - 9.00	9.00	Top soil mixed with clay, fine to medium grained, brownish.
9.00 - 53.00	44.00	Clay, grey in colour, hard plastic with little fine sand
53.00 - 56.00	3.00	Coarse grained, sand
56.00 – 160.00	104.00	Massive, Gneiss, fractured at few places, pinkish
160.00-163.00	3.00	Fractured feldspar- Gneiss, Greyish
163.00 to 201.46	38.46	Massive, Gneiss, Greyish

Annexure 6: Geophysical data of West Garo Hills District

Sl. No.	Village	Location	Coordinates	General Geology	Layer Resistivity in Ohm-m					Layer Thickness in meters						Total Depth in m.	Remarks with expected zones/fractures
					ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	P_6	h_1	h_2	h_3	h_4	h_5		
1	Rongram1	40m due east of the road where the other side of the road is a nursery.	N 25°35'42.9" E 90°15'02.5"	Archaean Gneissic Complex/Sandstone	1150	525	1000	225			1	4.3	21.7			27	
2	Rongram2	80m SE of VES-322.	N 25°35'40.5" E 90°15'02.3"	Archaean Gneissic Complex/Sandstone	1300	950	2500	250			1	2.3	8.7			12	
3	Rongram3	In the Mushroom farm opposite to tea garden.	N 25°35'49" E 90°15'01.3"	Archaean Gneissic Complex/Sandstone	225	1400	400				1	3				4	
4	Rongram4	120m East of VES-324.	N 25°35'51.9" E 90°14'59.3"	Archaean Gneissic Complex/Sandstone	700	2500	300	1500			1	6	7			14	
5	Rongram5	80m north of VES-325.	N 25°35'52.7" E 90°15'02.1"	Archaean Gneissic Complex/Sandstone	600	3000	250	3000	100		0.8	1.2	3	15		20	
6	Sangsangre1	In the District Ag. Research station20m NW of Banian tree near Science building.	N 25°29'41.2" E 90°12'40.5"	Archaean Gneissic Complex/Sandstone	375	50	5000				1	9				10	
7	Sangsangre2	80m south of eastern side of the green house near the straw godown and 70m N30°W of VES-327.	N 25°29'40.2" E 90°11'30.2"	Archaean Gneissic Complex/Sandstone	90	10	1500				1	4				5	
8	Sangsangre3	55m west of VES-328 and south of Bio fertiliser lab.	N 25°31'10" E 90°10'50"	Archaean Gneissic Complex/Sand	70	10	180	250	1500		1	1.5	3.5	12		18	

				stone														
9	Sangsangre4	18.5m due N65E of ICAR Horticulture main gate.	N 25°29'44.5" E 90°12'17.8"	Archaean Gneissic Complex/Sand stone	12	7	200				1	8				9	
10	Sangsangre5	82m S55°E of the main gate of ICAR Agro block farm.	N 25°29'44.3" E 90°12'14.1"	Archaean Gneissic Complex/Sand stone	25	12	25	50	400		1	4	10	20		35	Zones from 15m to 35m and fractures between 70m and 80m.

Annexure 7: Data gap and data requirement in West Garo hills district

Toposheet No.	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
78G/13	0	0	0	0	1	0	0	0	0	0	1	1	0	2	2	1	1	2	1	1
78G/14	0	0	0	0	0	1	0	0	0	0	1	1	0	2	2	1	1	2	1	1
78K/1	0	0	0	3	3	10	0	0	0	0	3	3	0	4	4	2	2	6	2	2
78K/2	0	0	0	3	3	5	0	5	0	0	3	3	0	4	4	4	4	6	4	4
78K/3	0	0	0	1	1	0	0	5	0	0	3	3	0	5	5	5	5	6	5	5
78K/4	0	0	0	1	1	2	0	0	0	0	1	1	0	1	1	1	1	3	1	1
78K/5	0	0	0	2	2	0	0	0	0	0	2	2	0	3	3	3	3	6	3	3
78K/6	0	0	0	3	3	0	0	0	0	0	1	1	0	3	3	4	4	6	4	4
78K/7	0	0	0	0	0	0	0	0	0	0	1	1	0	2	2	2	2	3	2	2
Total	0	0	0	14	14	18	0	10	0	0	16	16	0	26	26	23	23	40	23	23

FIELD PHOTOGRAPHS

PYT at Sangsanggre

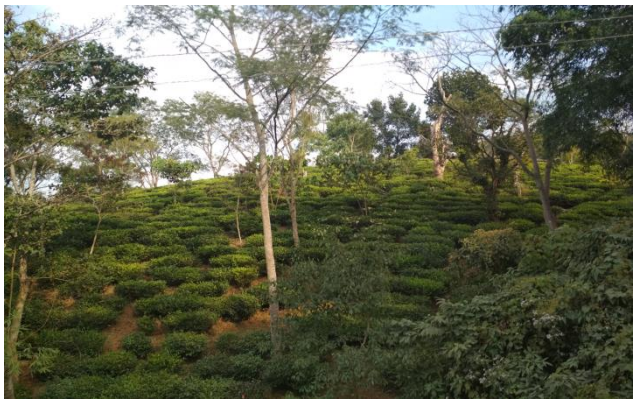
Ground Water Exploration at Jengal

Spring at Tura

Spring at Tura

Dug well at Daddenggre

Paddy field at Phulbari



Tea plantation at Rongram

Areca nut plantation at Chasingre