केन्द्रीय भूमि जल बोर्ड
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विभाग, जल शक्ति मंत्रालय
भारत सरकार

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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

SOUTH WEST GARO HILLS DISTRICT
MEGHALAYA

उत्तर पूर्वी क्षेत्र, गुवाहाटी
North Eastern Region, Guwahati

July 2022

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

REPORT
ON

"AQUIFER MAPPING AND MANAGEMENT PLAN OF SOUTH WEST GARO HILLS DISTRICT, MEGHALAYA"
(AAP 2021-22)

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CONTENTS

List of figures Page no.

List of tables

ABBREVIATION

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

EXECUTIVE SUMMARY

Aquifer Mapping Studies and Management Plan has been carried out in South West Garo Hills district, Meghalaya under National Aquifer Mapping and Management Plan (NAQUIM) program with an objective to know the different aquifer system prevailing in the study area, to decipher the vertical and lateral extend of the aquifer down to the depth of 300 m, its characteristic, quantity as well as quality so as to bring a complete sustainable and effective aquifer management plan for ground water resources development in the study area. These studies have been done through multi-disciplinary approach so as to achieve the said objectives.

The total coverage area of aquifer mapping and management plan is 546 sq.km out of 822 sq.km of the district and is underlain by alluvium and semi-consolidated rock of Sandstone.

Ground water occurs in the study area mainly in alluvium aquifer i.e. within the saturated intergranular pore spaces of unconsolidated sand and sandstone aquifer. The different hydrogeological data are generated through intensive field data collection and testing. The aquifers present in the district can be divided into a two aquifer system viz., first aquifer (shallow) and second aquifer (deeper). Shallow or first aquifer consists of alluvium and weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells, shallow tube wells or hand pump. The second aquifer is the deeper aquifer constitute of tertiary sandstone. Based on the study of litholog and analysis of depth of construction of dug wells and shallow tube wells, it is found that the first aquifer occur within 2 to 50 m bgl. Ground water in the second aquifer occurs under semi-confined condition upto the maximum depth of 300 m bgl.

Ground water exploration has been carried out in different parts of the district to delineate the potential aquifers and their geometry and to determine the hydrogeological parameters of the aquifer systems.

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

In order to study the chemical quality of ground water in the district, water samples from first aquifer (dug wells and springs) were collected during the course of field work. The samples were analyzed and found that there is a moderately high concentration of iron in some dug well and pH value is also low in one of the springs. Based on the analysis using various method and chemical index such as sodium absorption ratio (SAR), sodium percentage(SP), residual sodium carbonate (RSC), Kelly's ratio Permeability index and magnesium ratio, it is found that the ground water in the district is suitable for irrigation purpose.

Dynamic Groundwater Resources of the study area has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). The net ground water availability was 6898 ham and the stage of ground water extraction was 29.62% which comes under safe category.

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

1. INTRODUCTION

Central Ground Water Board, North Eastern Region has carried out Aquifer mapping and management plan in South West Garo Hills district, Meghalaya during AAP 2021-22 covering an entire area of 546 sq.km (total district area is 882 sq.km). Under National Aquifer Mapping and Management (NAQUIM) program, combination of geologic, geophysical, hydrologic and hydrochemical information is applied to characterize the quantity, quality and sustainability of ground water aquifers. Systematic aquifer mapping will improve our understanding of the geologic framework of aquifers, their hydrogeologic characteristics, quality and also quantifying the available ground water resources potential and proposing plans appropriate to the scale of demand and the institutional arrangements for management. Aquifer mapping at the appropriate scale can help to prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of our precious ground water resources, which, in turn, will help achieve drinking water security, improved irrigation facilities and sustainability in water resources development.

1.1 Objectives: The objectives of this project are to understand the aquifer systems up to 200-300 m depth, to define the aquifer geometry, type of aquifers, ground water regime behaviours, 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 and geophysical surveys to delineate multi aquifer system.

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

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

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

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

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

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

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

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

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

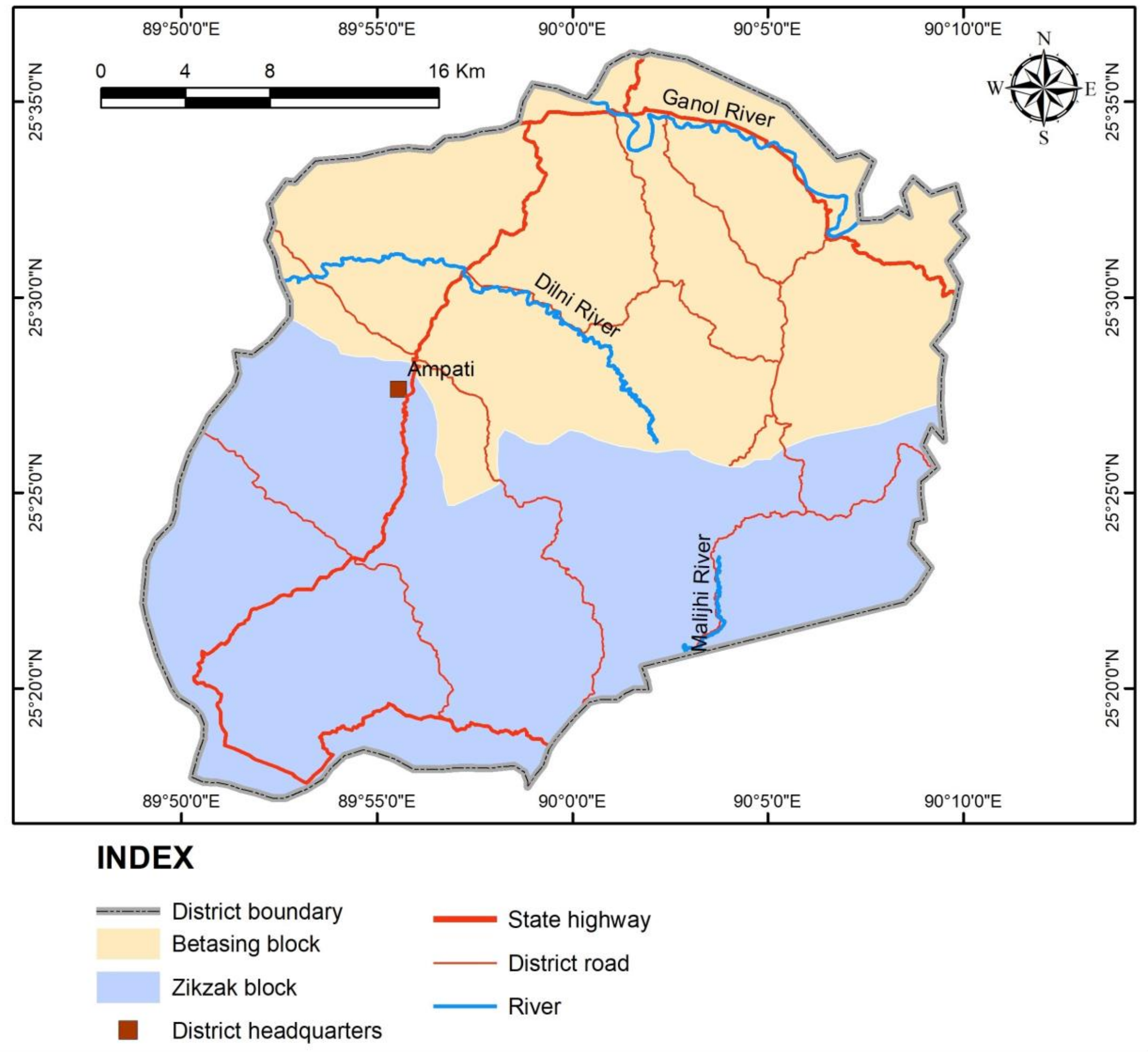
(vii) Formulating a complete sustainable aquifer management plan for ground water development.

1.4 Area details: South West Garo Hills district lies between E 89˚49’00” to E 90˚10’00” Longitude and N 25˚18’00” to N 25˚34’00” Latitude. The district is having an area of 882 sq.km. Out of this, 546 sq.km of mappable area was covered under NAQUIM program during AAP 2021-22. Ampati is the district headquarter of South West Garo Hills District and is the only town in the district. The total population of the South West Garo Hills district as per 2011 census is 172,495. The district has three C & RD blocks viz., Betasing C& R.D. block, Zikzak C & R.D and Damalgre C & R.D block. Nearly one third of the total area is said to be covered with hills. While the rest is, literally a plain region dotted with small hillocks here and there. A large and continuous strip of plain land stretches from Garobadha towards Mankachar extending upto Mahendraganj and Gopinath Killa along the border of Dhubri District of Assam and Bangladesh.

This area falls partly or fully in the quadrants of Survey of India Toposheets bearing nos. 78 G/14, 78 G/15, 78 K/02 and 78 K/03 and district is bounded in the west boundary by Dhubri and Kurigram district of Assam and Bangladesh respectively, Dalu and Gambegre Development Blocks. In the East, Selsella and Rongram Development Blocks in the North and Sherpur and Jamalpur District of Bangladesh and Dalu & Gambegre Development Block (Meghalaya, India) in the South. The base map of the study area is shown in Fig.1.1.

Fig 1.1 BASE MAP

SOUTH WEST GARO HILLS DISTRICT, MEGHALAYA



1.5 Data availability, data adequacy and data gap analysis:

Aquifer mapping and management plan is carried out through collaborative of different data. The required data on various attributes of the study are collected from the available literatures of Central Ground Water Board, State Water Resources Department of Meghalaya and various Central and State Government agencies. The Data Requirement, Data Availability and Data Gap Analysis are presented in table 1.1 and Fig1.2 and 1.3.

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

Sl. No.	**Items**	**Type**	**Data Availability**	**Data Gap**	**Data Generation**
1	Ground Water Exploration Data	Tube well	15 EW	6 EW	Nil
2	Geophysical data	VES	Nil	28 nos.	Nil
3	Ground Water Monitoring Regime	Dug well (Aquifer-I)	5 nos.	11 nos.	14 nos.
		Piezometer (Aquifer-II)	Nil	14 nos.	Nil
		Spring	Nil	10 nos.	2 nos.
4	Ground Water Quality	Dug well (Aquifer-I)	5 nos.	11 nos.	14 nos.
		Piezometer (Aquifer-II)	Nil	14 nos.	Nil
		Spring	Nil	10 nos.	2 nos.
5	Specific yield		Nil	6 nos.	Nil
6	Soil Infiltration Test		Nil	15 nos.	3 nos.

Fig.1.2 Data gap map of South West Garo Hills district

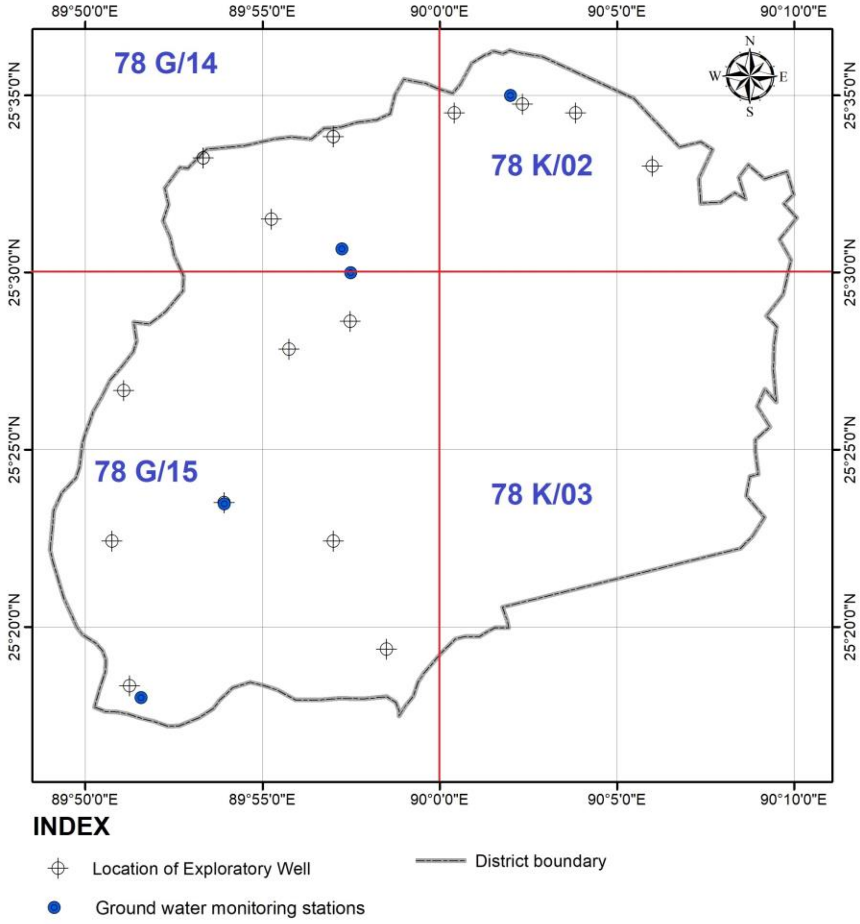
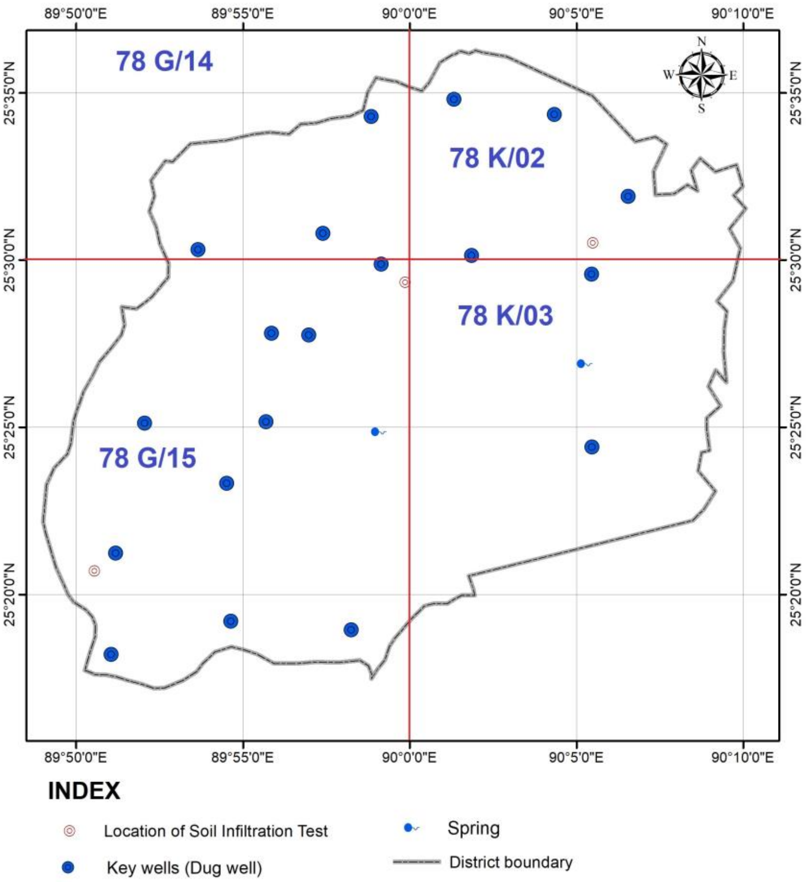


Fig.1.3 Data generation map of South West Garo Hills district



1.6 Demography: The total population of the South West Garo Hills district are as per 2011 Census is 172495.

South West Garo Hills District	Total
Total population	172495
Male population	87135
Female population	85360

The block wise population of the community and Rural Development Blocks of South West Garo Hills District as per the 2011 census is as below: -

Name of C & RD Block	Population			Remarks
	Male	Female	Total	
Betasing C & RD Block	24511	24218	48729	After creation of Damalgre C & RD Block on 17.01.2017
Zikzak C & RD Block	39339	38138	77477	After merging of Babelapara GS circle of Dalu & RD Block
Damalgre C & RD Block	26093	25257	51350	

1.7 Climate: The climate in the area is characterized by moderate temperature and is highly humid in nature. The climatic condition is accordingly much warmer than other districts of the State. The coldest months in the district are December and January and the warmest months are June, July, August, September and October. Winter season starts in November and continues till the end of February. The months of March, April and May are the period of Pre-monsoon season. The temperature begins to rise from the month of March. The frequency of storms also increases during these months. During the monsoon period, due to heavy rainfall, the weather is suitable for crops growing in the hills and the plain areas. The average annual rainfall in the district is about 2000 mm. The annual rainfall data of South West Garo Hills District during 2016 to 2020 is presented in the table below,

Table 1.2 Annual rainfall data in South West Garo Hills district during the period of 2016-2020

Sl.No.	**Year**	**Annual rainfall (mm)**
1	2016	1191.6
2	2017	2453.4
3	2018	280.6
4	2019	2107.8
5	2020	2011.8

(Source- Department of Agriculture, Govt. of Meghalaya)

1.8 Land use: Land utilization statistics provide detailed information of the land use pattern in the area. The socio-cultural factor plays a dominant role in land use both in rural and urban areas. Landforms, slope, soil, natural calamities and natural resources are the important factors which control the land use pattern of the area. Based on the land utilization, the total area is divided into various types of landforms such as forest, cultivable land, fallows land, crops area etc. which in turn reflects the degree of development of agricultural activities and cultivation potential. The land utilization statistics of South West Garo Hills district is shown in the Table1.3.

Table 1.3: Land use statistic in South West Garo Hills, 2018-19

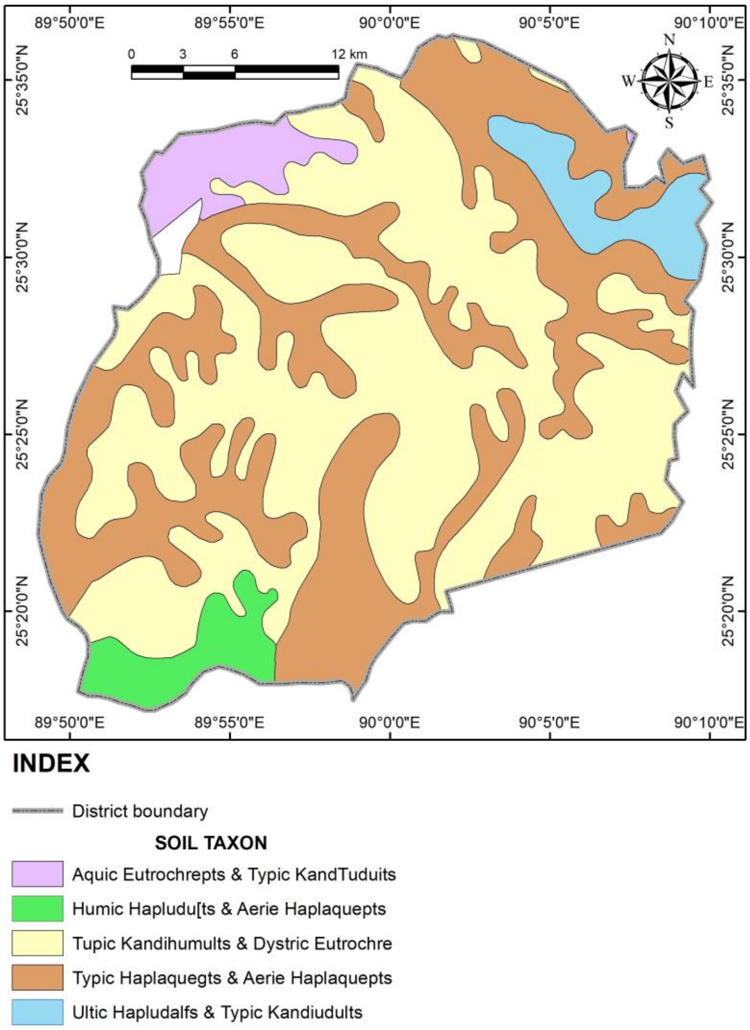
Land Classifications	**Area in hectares**
1. Geographical Area	86600
2. Reporting Area	86585
3. Forests (classed & unclassed)	32580
4. Area not available for cultivation	6412
5. Other uncultivable lands	8590
6. Fallow land	10096
7. Net area sown	28909
8. Area sown more than once	6699
9. Total cropped area	35607

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

1.9 Soil: The soils of the district are mainly of clayey loam soil, fine sandy loam, loamy soil and fine loamy soil. The texture of soils varies from loamy to fine loamy. The soils of the alluvial plains in the northwestern part are very deep, dark brown to reddish-brown in colour and clayey loam to sandy loam in texture. Soils are rich in organic carbon, which is a measure of nitrogen supplying potential of the soil, deficient in available phosphorous and medium to low in available potassium. Most of the soils occurring on higher altitudes under high rainfall belt are strongly acidic due to intense leaching. The types of soil available in the district differ widely and four major types of soil are commonly found. They are (i) Clayey loam soil- found in the northern parts of the district. (ii) Fine sandy loan soil - the most prevalent one covering the western and central parts of the district, (iii) Loamy soil - found along the southwestern fringe of the district and (iv) Fine loamy soil – found in the southern part. Soil map of the area is given in Fig 1.4.

Fig. 1.4 SOIL MAP

SOUTH WEST GARO HILLS, MEGHALAYA



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

1.10 Agriculture: Agriculture is the main means of livelihood of the people in the district and about 90% of the population of South West Garo Hills is dependent on agriculture. Rice is the most important food crop that is grown in the district, both in the plains and the hills. Other food crops that are widely grown in the district are maize, Tur (ahar), millet, jute, mesta, cotton, pineapple and pulses. The area is endowed with diversified climatic condition thereby offering good scope for cultivation of temperate and subtropical crops. Broadly the low-lying areas were put under paddy during Kharif and with pulses, paddy, vegetables during the Rabi season depending on the availability of residual moisture and irrigation facilities. Present area under different crops and their productivity is shown in table 1.4.

Table 1.4: Area under different crops, their productivity and yield in South West Garo Hills district (2019-20)

Sl No.	Types of Crops	Area (Hectare)	Production (Metric tonnes)	Yield (Kg/Ha)
Kharif Crops				
1	Autum rice (including Jhum)	5414	11938	2205
2	Winter rice (Sali)	7407	21447	2896
3	Maize	1498	3637	2428
4	Tur (Arhar)	325	464	1428
	Total Foodgrains	**14644**	**37486**	**2560**
5	Soyabean (Green)	97	573	5907
6	Sweet potato	201	789	3925
7	Cotton	436	585	228
8	Jute	1754	18875	1937
9	Mesta	1307	7911	1090
10	Ginger	195	5459	27995
11	Tapioca	447	3104	6944
12	Banana	441	5815	13186
13	Papaya	34	330	9706
14	Pineapple	618	6225	10073
15	Winter Potato	220	2039	9268
16	Jackfruit	77	803	10429
Rabi Crops				
17	Spring Rice	4918	23577	4794
18	Wheat	207	421	2034
19	Millets	234	162	692
20	Gram pulses	287	348	1213
21	Rabi pulses	932	1164	1249
	Total Foodgrains	**6578**	**25672**	**3903**

Source: District Agriculture Department, South West Garo Hills, Govt. of Meghalaya

1.11 Irrigation: There is some minor irrigation scheme in the district and mostly agriculture is rainfed. A few minor irrigation schemes based on surface water sources like Flow Irrigation Projects (FIP) and Lift Irrigation Project (LIP) exist. Flow Irrigation Projects (FIP) are gravity flow type which involves water diversion from rivers/streams and irrigating the field by the aid of gravitational flow. It is used widely where water is spread across land using basin, border and furrow method. Lift Irrigation Project (LIP) involves pumping/lifting water from the river using electric pump and irrigating the fields. Irrigation through ground water is practiced in the district where Water Resources department has constructed some deep tube well and shallow tube well for irrigation covering about 1672.45 ha. Apart from these, many shallow tube well were constructed by private party for irrigation purpose. Irrigation statistics in South West Garo Hills district are given in Table 1.5.

Table 1.5:Irrigation Statistics for the year 2018-19.

South West Garo Hills	Net Irrigated Area (Ha)			Gross Irrigated Area (Ha)		
	Govt.	Private	Total	Govt.	Private	Total
Total	4993	4456	9449	6252	4536	10788

Source: District Agriculture Office, South West Garo Hills, Govt. of Meghalaya.

1.12 Industries: There are no major or minor industries in the district at present. The district is not industrially developed. Among the small scale industries, important industries are wooden furniture, bakery, tailoring, motor repairing, sawmills, cane and bamboo works, tyre rethreading, steel fabrication, etc.

1.13 Forest: The District is very rich in natural resources. Majority of the forests areas of this district falls under Tropical Moist Deciduous Forest Zone. The district does not have any Reserve Forest as well as protected forest. As per Directorate of Economics and Statistics, the forest cover area is about 32580 ha (2018-19) which is about 38% of the total district area.

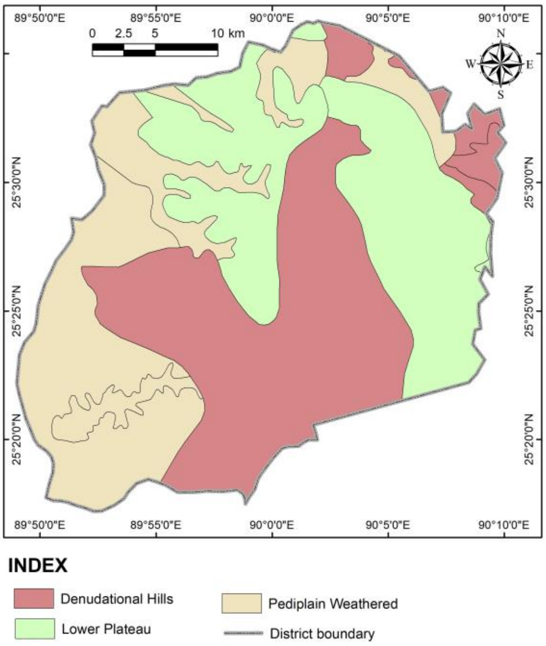
1.14 Geomorphology: Geomorphologically, the district can be differentiated into three geomorphic units,

i. Denudational Hills: These are the undulatory hills found in the southern and eastern corner part of the district where it covers Damalgiri, Okkapara, mellim and Salmanpara areas.

ii. Lower plateau: These are intermontane valley existing between hills. They are found mainly in the South Eastern and North Western part of the district.

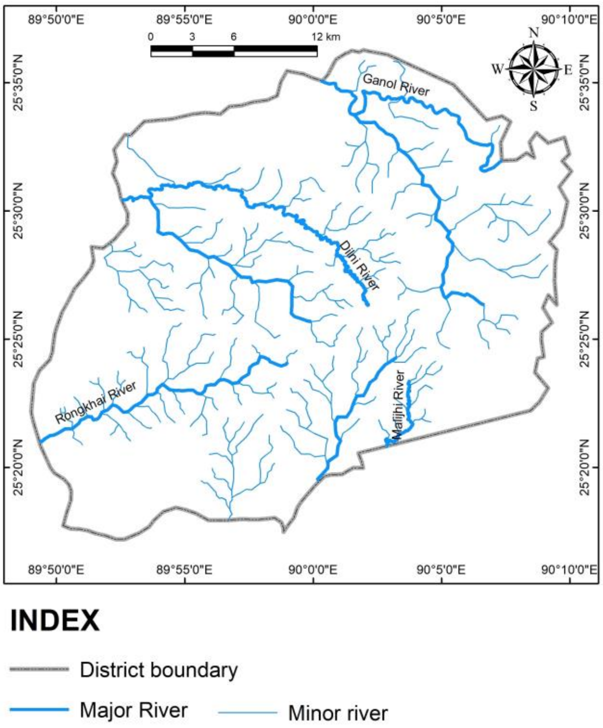
iii. Pediplain Weathered : It is found in the western parts of the district and comprises mainly of alluvium. This is of a large and continuous strip of plain land stretches from Garobadha towards Mankachar extending upto Mahendraganj and Gopinathkilla along the border of Dhubri of Assam and Bangladesh.

Fig. 1.5 GEOMORPHOLOGICAL MAP
SOUTH WEST GARO HILLS, MEGHALAYA



1.15 Drainage: The drainage system of the district is controlled mainly by physiographic features and geological structures. The prevailing climate and environment in the district is characterised by heavy rainfall, which favours the action of streams to a considerable extent. The drainage pattern is mainly of dendritic type which is controlled by topographic and structural. Some of the major river are Ganol, Dilni, Rongkhai, Daru, Muji etc.

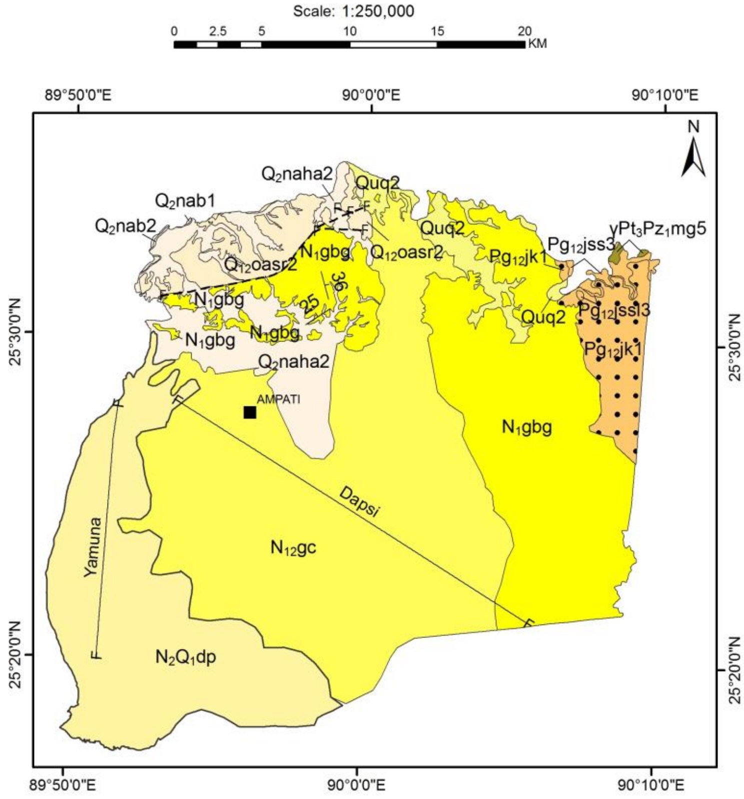
Fig 1.6 DRAINAGE MAP
SOUTH WEST GARO HILLS, MEGHALAYA



1.16 Geology: The oldest rocks in South West Garo Hills are represented by Mylliem granitoid of Neoproterozoic to Early Palaeozoic age which is grey/pink in colour and porphyritic in nature. The sedimentary rocks of Tertiary age overlie Mylliem granitoid. The Shella Formation of Jaintia Group consists of sandstone, lithomargic clay, shale and some coal seams followed by Kopili Formation which is an alternate sequence of shale and sandstone with phosphatic nodules at places. Kopilli Formation is overlain by Baghmara Formation of Garo Group of Miocene Age which consists of conglomerate, siltstone and sandstone followed by Changapara Formation of coarse sandstone, siltstone, mudstone and marl. Garo Group is overlain by Dupitila Group having brown clay and sand, siltstone, grit, conglomerate and sandstones. Undifferentiated quaternary sediments are characterised by undifferentiated sand, silt and clay. Sorbhog Formation of Older Alluvium of Recent Age comprises of oxidised to feebly oxidised brown sand, silt and clay while the Newer Alluvium consists of unstabilised and unoxidized sand, silt, clay and pebbles. Yamuna faults and Dapsi faults have been established in the area. The geological map of South West Garo Hills district is shown in fig. 1.7.

Fig. 1.7 GEOLOGICAL MAP OF SOUTH WEST GARO HILLS DISTRICT

Parts of TS No. 78G/14 &15 and 78K/02 & 03



Legend

	Lithology	Formation	Group	Age
Q_2nab2	Unstabilised and unoxidised sand silt and clay	Barpeta - II	Newer Alluvium	Late Holocene
Q_2nab1	White to gyeyish sand silt pebble and clay	Barpeta - I		
Q_2naha2	Feebly oxidized sand, silt and clay	Hauli		Holocene
Q_{12}oasr2	Oxidised tofeebly oxidized brown sand, silt and clay	Sorbhog	Older Alluvium	Pleistocene - Holocene
Quq2	Undifferentiated fluvial sediments- sand, silt and clay	Undifferentiated Quaternary		Quaternary
N_2Q_1dp	Brown clay & sand, siltstone, grit, conglomerate and sandstone	Dupitila	Dupitila	Pliocene - Pleistocene
N_{12}gc	Coarse sandstone, siltstone, mudstone & marl	Changapara	Garo	Miocene - Pliocene
N_1gbg	Conglomerate, sandstone and siltstone	Baghmara		Miocene
• Pg_{12}jk • •	Sandstone, siltstone, shale & phosphatic nodules,	Kopili	Jaintia	Palaeocene - Eocene
Pg_{12}jssl3	Fossiliferous limestone with shale & marl	Shella		
Pg_{12}jss3	Arkose/gritty sandstone, coal, fireclay & shale			
γPt_3Pz_1mg5	Granitoid		Mylliem Granitoid	Neoproterozoic - Early Palaeozoic

Structural Index

30 Bedding Inclined

■ Location

F——F Fault Observed

F- - - -F Fault Inferred

Map compiled and finalised by M&C Division, GSI, NER, Shillong

2. DATA COLLECTION AND GENERATION

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

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

2.1.1 Water level monitoring: In the study area, only 19 dug wells and 2 spring were established as key wells to study the water level, quality and spring discharge.

Phreatic aquifer: A total of 19 dug wells were established as key wells for periodical monitoring to know the water level trend and its behaviour. The key observation wells details are presented in Table 2.1. The pre-monsoon and post- monsoon depth to water level maps are depicted in Fig 3.3.

Table 2.1. Details of key wells established in South West Garo Hills district during AAP 2021-2022

Sl. No.	Location	Latitude	Longitude	RL (m)	MP (m)	Depth (mbgl)	Dia (m)	Pre-Monsoon Water Level (mbgl)	Post-Monsoon Water Level (mbgl)
1	Dalmalgre	25°31’54.37”	90°06’33.08”	40	1	3.5	1.9	2.4	1.5
2	Garobadha	25°34’49.02”	90°01’20.16”	31	0.8	5.5	0.8	4	3.35
3	Harigaon	25°34’21.76”	90°04’20.39”	41	1	3.25	2.4	1.1	0.9
4	Garodoba	25°34’17.64”	89°58’51.05”	33	0.8	2.5	0.9	1.05	0.6
5	Betasing	25°30’48.16”	89°57’24.04”	31	0.7	3.7	1	2.7	2.15
6	Ampati	25°27’48.96”	89°55’51.55”	19	0.9	5.4	1	4.4	4
7	Jangnapara	25°25’10.08”	89°55’41.76”	48	0.8	2.2	1	0.3	0.2
8	Zikzak	25°23’19.80”	89°54’30.79”	36	1.1	5.2	0.9	4.6	4.6
9	Dhromch	25°21’14.08”	89°51’11.55”	26	0.9	6	0.8	5.9	2.2
10	Mahendraganj	25°18’12.61”	89°51’03.25”	8	0.9	3.7	0.2	2.7	1.7
11	Debajani	25°19’12.15”	89°54’38.46”	35	0.7	4.1	0.9	3	2.4
12	Rimtangpara	25°18’56.61”	89°58’15.03”	46	0.7	2.8	1	2	1.8
13	Chigitchakgre Dabanbil	25°27’45.61”	89°56’58.72”	36	0.8	6.6	1	5.8	4.4
14	Dengnakpara	25°29’34.94”	90°05’27.46”	39	0.9	3.9	1	3.15	1.8
15	Sakaboldamgri	25°24’24.87”	90°05’28.10”	228	0.8	4.9	0.8	4.7	1.4
16	Kasibil	25°30’8.30”	90°01’51.26”	76	0.8	4.1	0.9	3.9	2.5
17	Godalgre	25°29’52.92”	89°59’08.97”	48	0.65	4.45	1	2.05	1.8
18	Jholgaon	25°30’19.06”	89°53'39.68”	17	0.9	4.2	0.9	3.3	2.8
19	Hatibelpara	25°25’07.57”	89°52'03.62”	38	0.5	2.2	1	1	0.6

Springs: A total of 2 springs were established and monitored to know the type, discharge and their behaviour. Pre-monsoon and post- monsoon spring discharge is shown in Fig 3.2. Details of spring monitored during NAQUIM (2021-2022) is given in table 2.2.

Table 2.2: Details of Spring established in South West Garo Hills district during AAP 2021-2022

Sl. No.	**Location**	**Latitude**	**Longitude**	**Geology**	**Spring Type**	**RL (m)**	**Post-Monsoon Discharge (lps)**	**Pre-Monsoon Discharge (lps)**
1	Salmanpara	25°24’51.73”	89°59’04.07”	Sandstone	Fractured	94	0.01	0.01
2	Mellim	25°26’54.43”	90°05’14.17”	Sandstone	Depression	65	0.34	0.091

2.2 Hydrochemistry: The quality of ground water is as important as that of the quantity. In order to study the chemical quality of ground water in the district, water samples from first aquifer (dug wells and springs) were collected during the course of field work. Ground water samples were analysed in the regional chemical laboratory, Central Ground Water Board, North Eastern Region, Guwahati for 17 parameters. The analytical data are given in Annexure 4 & 5.

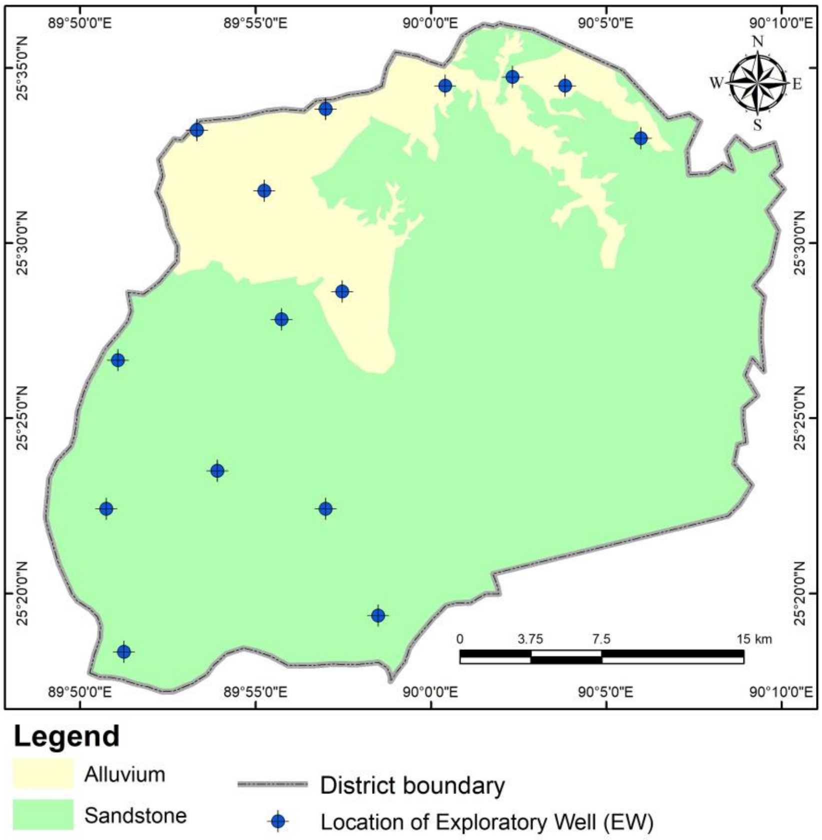
2.3 Ground water exploration studies: Ground water exploration has been carried out in different parts of the district before NAQUIM programme initiated in the district where EWs were constructed. A total of 15 exploratory wells were constructed by CGWB. Details of the exploratory wells are presented below in the table 2.3.

Table 2.3 Details of the exploratory wells constructed by CGWB in South West Garo Hills

Sl. No.	**Location**	**Longitude**	**Latitude**	**Type of well**	**Drilled depth**
1	Ampati	89.92917	25.46389	EW	295.68
2	Amtuli	89.84583	25.37361	EW	300.15
3	Bairagipara	90.00694	25.575	EW	229.5
4	Betasing	89.958	25.477	EW	251.7
5	Borkona	89.95	25.56389	EW	247.4
6	Gandhigiri	89.85139	25.44444	EW	279.5
7	Garobandha	90.03889	25.57917	EW	218.2
8	Gopinathkilla	89.975	25.32278	EW	169
9	Harigaon	90.06389	25.575	EW	192.23
10	Ichaguri	89.88889	25.55389	EW	273.4
11	Jewelgiri	90.1	25.55	EW	241.9
12	Kalaigaon	89.95	25.37361	EW	274.05
13	Mahendraganj	89.85417	25.30556	EW	268.4
14	Ulubari	89.92083	25.525	EW	253.39
15	Zikzak	89.89861	25.39167	EW	209.06

The exploratory wells which were constructed before NAQUIM are shown in fig 2.1.

Fig. 2.1 EXPLORATORY WELL LOCATION MAP
SOUTH WEST GARO HILLS DISTRICT, MEGHALAYA



2.4 Soil Infiltration Test: Soil infiltration test were conducted using double ring infiltrometer and the constant infiltration rates of different soils were calculated by double ring infiltrometer method. The Horton's equation method was used for calculation of infiltration rate. The infiltration factor was calculated by dividing infiltration rate with quantum of water applied and multiplied with specific yield into 100. These studies were carried out in different locations to know the infiltration rates at different soil conditions, topography, geology and environment. This will provide a scientific approach of groundwater recharge, its suitability and the amount of water recharging in that area, rainfall infiltration factor and will help in calculating ground water resource estimation. The details are shown in table 2.4.

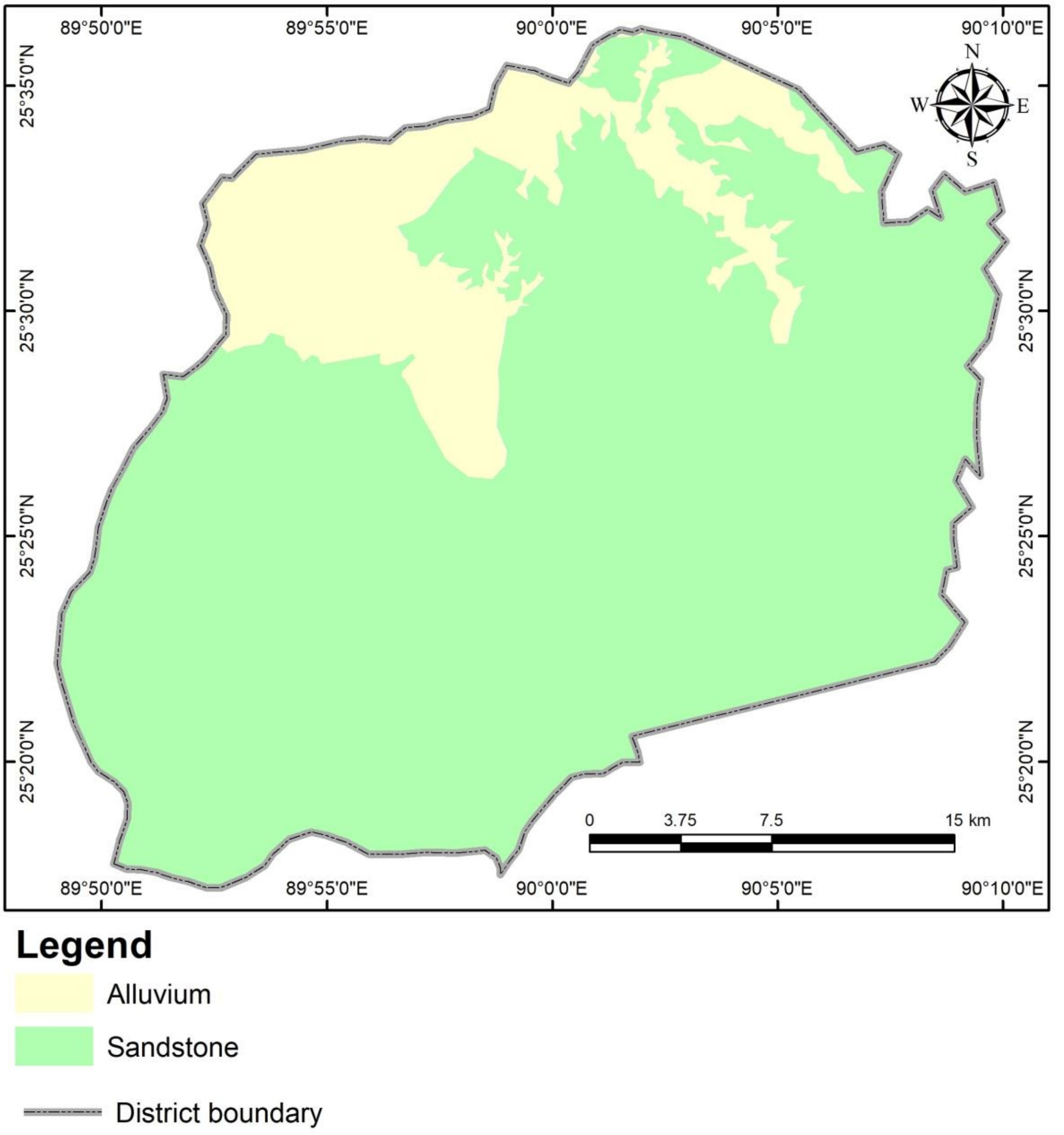
Table 2.4 Details of Soil Infiltration Test studies results

Sl. No.	Location	Longitude	Latitude	Soil type	Soil thickness (m)	Infiltration rate (cm/hr)	Rainfall Infiltration Factor
1	Dengnakpara	90.091425	25.508581	Sandy loam, brown	1 to 2	24	1.89
2	Baladinggre	89.997769	25.488897	Sandy loam, brown	5 to 6	28.5	7.73
3	Bakalai Chimik	89.842411	25.344997	Clayey loam, Brown reddish	1 to 3	1.2	4.92

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 General hydrogeology and occurrence of ground water: The hydrogeological formation of the study area comprised of alluvium and Sandstone. The ground water in the district occurs under unconfined and semi-confined conditions. Study of dug wells and ground water exploration data reveals the presence of phreatic/ shallow and deeper aquifers in the district. The principal aquifers in the district is shown in Fig 3.1.

Fig.3.1 PRINCIPAL AQUIFER
SOUTH WEST GARO HILLS DISTRICT, MEGHALAYA

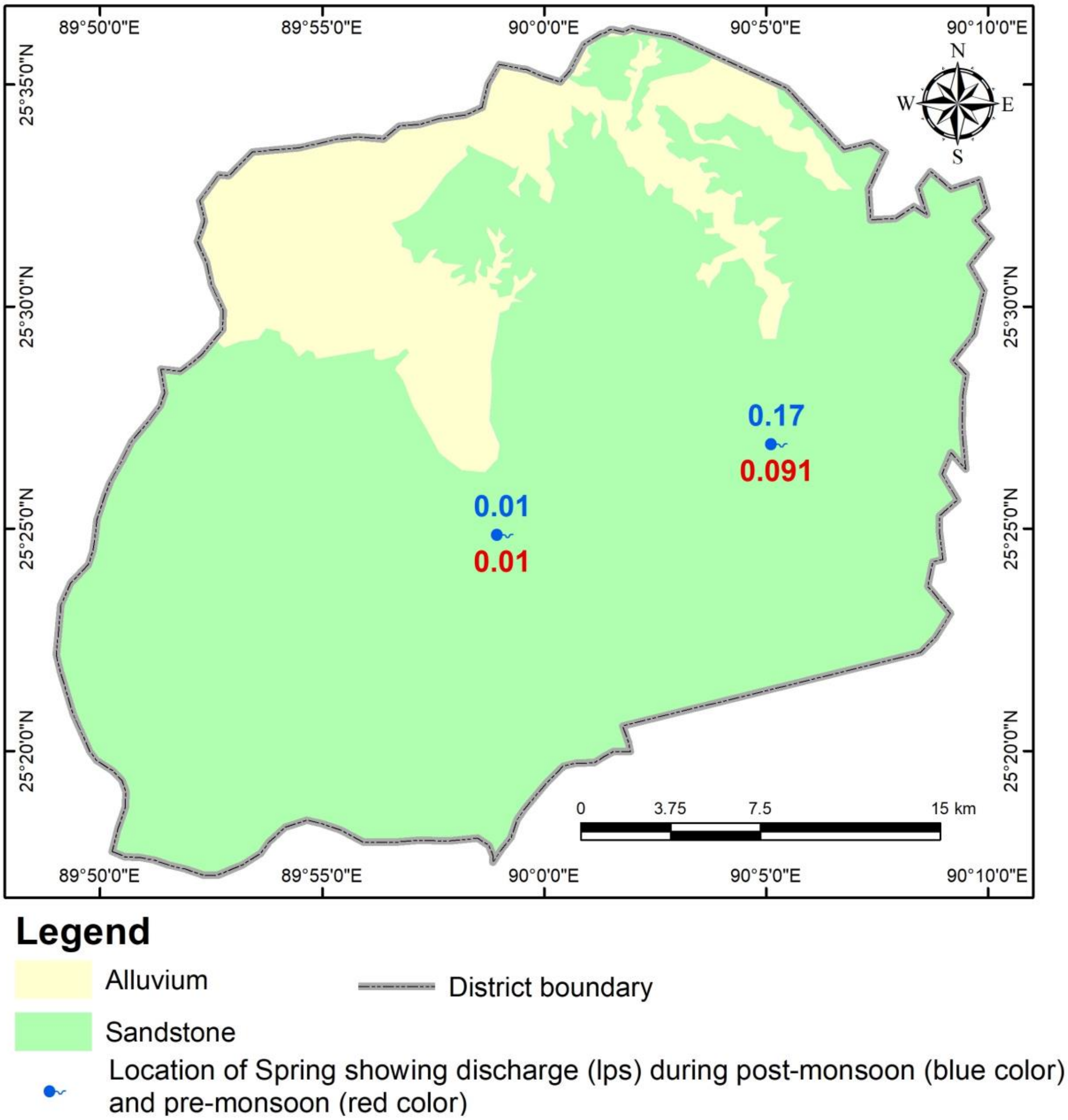


3.1.1 Occurrence of ground water in shallow aquifers: The depth of shallow aquifer in the district ranges from 2 to 50 meters. This shallow aquifer occurs under unconfined condition. Ground water from shallow aquifer is exploited through different types of ground water extraction structures such as dug wells (Kachha dug wells and ring well) and shallow tube well. This well tapped the unconfined aquifer generally down to 2 to 50 meters. This unconfined aquifer extends upto 50 meters which is the alluvium and weathered portion.

3.1.2 Occurrence of ground water in deeper aquifers: The deeper aquifer occurs as semi-confined condition where ground water is found in the semi-consolidated Sandstone. The drilled depth of exploratory wells tapping this aquifer ranges from 50 to the explored depth of 280 m bgl. The number of productive zone encountered varies from place to place which show the complexity of the hydrogeology in the area.

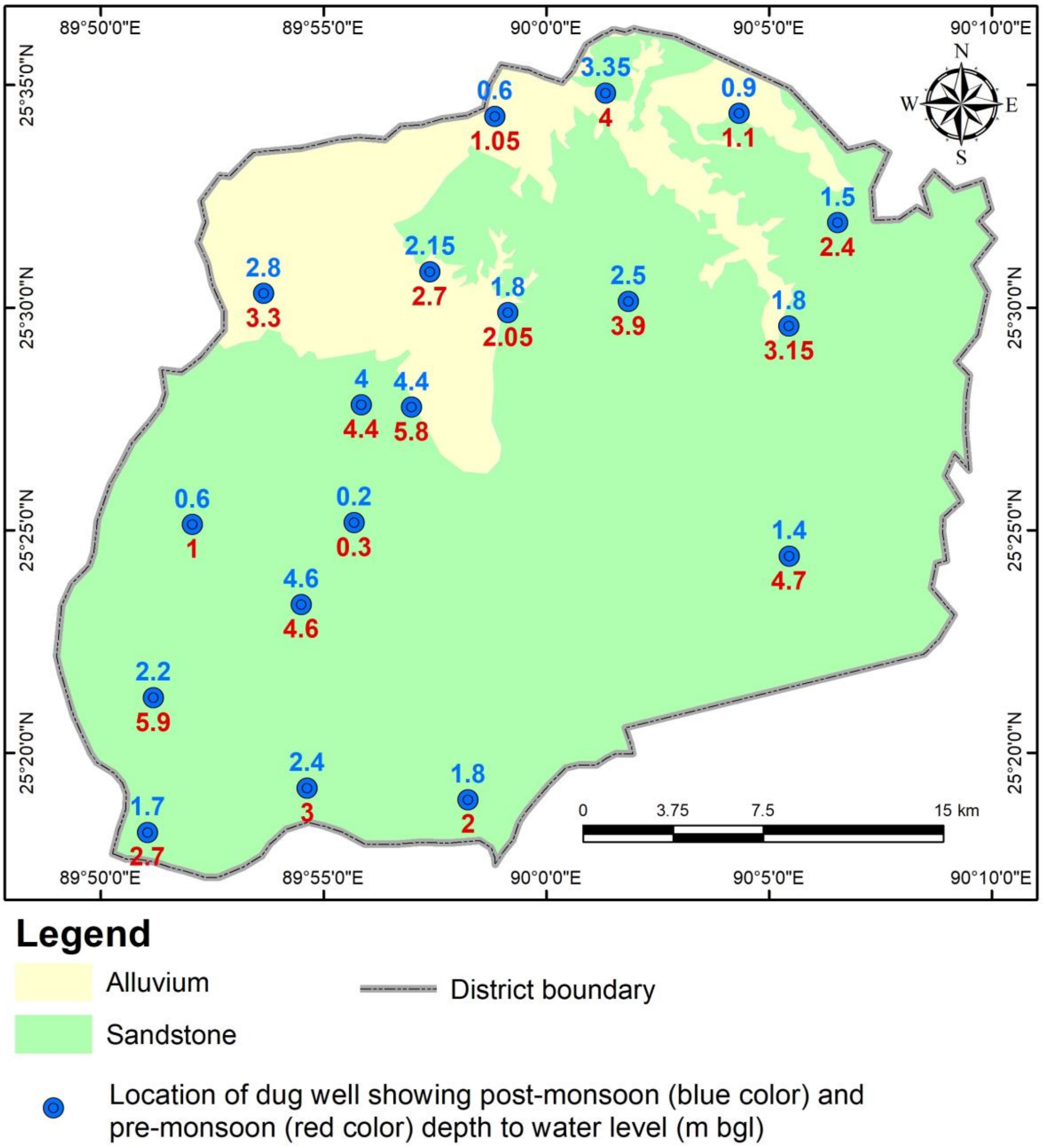
3.1.3 Springs: Spring is defined as a localized natural discharge of ground water appearing at the ground surface as a current of flowing water through well-defined outlets. The discharge may vary from a trickle to a stream. Groundwater flow from springs is governed mainly by three inter-related factors: geology (type, distribution and permeability characteristics of geologic units), topography (landforms and relief), and climate (timing and amount of precipitation). Topography drives the groundwater flow downhill and largely dictates the occurrence of the spring itself. Climate would influence the timing and amount of recharge to the flow system and the volume and variability of discharge. Groundwater obtained from spring is similar to water pumped from shallow wells. The study of spring has been carried out in the aquifer mapping area and it was found that the location of the spring is mainly restricted to foothills and intermontane valleys. A total of 2 springs were established and monitored periodically during the course of study. It was observed that the discharge of springs were 0.01 to 0.09 litre/second during pre-monsoon and 0.01 to 0.34 litre/second during post-monsoon season which is shown in Fig 3.2. It has also been observed that the discharge of springs has been increased during monsoon season and gradually decreases in post-monsoon and pre-monsoon.

Fig. 3.2 SPRING DISCHARGE
SOUTH WEST GARO HILLS DISTRICT, MEGHALAYA



3.2 Depth to Water Level: Study of water level and its behaviour both in phreatic and semi-confined condition were carried out in the aquifer mapping area. A total of 19 dug well were established as key well for periodical monitoring to know the water level trend and its behavior in phreatic condition. The depth to water level in the phreatic aquifer vary from 0.3 to 5.9 m bgl during pre-monsoon and 0.2 to 4.6 m bgl during post-monsoon season and is shown in fig 3.3 and the average water level fluctuation is 0.9 m.

Fig. 3.3 POST-MONSOON AND PRE-MONSOON DEPTH TO WATER LEVEL OF UNCONFINED AQUIFER SOUTH WEST GARO HILLS DISTRICT, MEGHALAYA



To study the piezometric head, 15 bore wells drilled by Central Ground Water Board previously were considered. The piezometric head ranges from 9.30 m agl to 4.51 m bgl.

3.3 Aquifer System: The study area is mainly underlain by alluvium and semi-consolidated rocks of sandstone. The major aquifers of the district have been delineated based on the litholog of exploratory wells. The North Western part of the district is cover by older and newer alluvium where the prolific aquifer made up of medium sand and gravel occurs between the depth ranges 3-50 meters bgl. The thickness of the saturated zones found in the alluvial cover varies from 10 to 25 meters. The remaining areas are mainly cover by tertiary sandstone where it consist of clay, shale, siltstone and fine to medium grained sand. The aquifer within 50 m depth are made of coarse and gravelly sand whereas the deeper aquifer are fine to medium grained sandstone. Thus, hydrogeologically, the study area can be categorised into two group viz. (i) Alluvium aquifer – comprised of both older and newer alluvium where medium sand and gravel occurs between the depth ranges 3-50 meters bgl. (ii) Sandstone aquifer – comprised of tertiary sandstone which are friable sandstone , siltstone and shale.

3.4 Aquifer Geometry: The major aquifer system in the district can be divided into two aquifer system viz., alluvium aquifer and sandstone aquifer.

Alluvium aquifer – The alluvium aquifer consist of medium grained sand, gravel and clay. It is found in the northern and north-western part of the district. From the study of litholog and as shown in fig. 3.4, 3.5 & 3.6, the thickness of alluvium ranges from 10 to 50 meters and ground water in this aquifer occurs under unconfined condition.

Sandstone aquifer – The sandstone aquifer comprised of tertiary sandstone which are friable sandstone , siltstone and shale. This aquifer covers the major portion of the district and in the northern and north-western part of the district, it is overlain by alluvial. As shown in fig. 3.4, 3.5 & 3.6, ground water in the top weather portion which ranges from 10-50 meters depth occurs under unconfined aquifer and the productive sandstone zone which usually starts from 50 meters till drilled depth i.e. about 280 meters depth where they are overlain by shale occurs as semi-confined to confined condition.

3.5 Aquifer Properties:

Aquifer I: It is the unconfined aquifer which occur between 2 to 50 m depth. Tapping of this Aquifer by the villagers were done through ground water extraction structures like kachha dug well or ring well or shallow tube well. The properties of Aquifer-I could not be established due to unavailability of pump for conducting dug well/ shallow tube well pump test.

Aquifer II: This is the deeper aquifer which occurs as semi confine to confined condition where ground water is found in the semi-consolidated sandstone. The drilled depth of exploratory wells tapping this aquifer ranges from 50 to 280 m bgl.

3.6 Aquifer Parameters:

The yield of the aquifer ranges from 9 to 165 m^3/hr and many auto flow wells exist in the southern and western part of the district. The transmissivity ranges from 76.98 to 1595 m^2/day and the Storativity ranges from 3.6×10^{-4} to 5×10^{-4}.

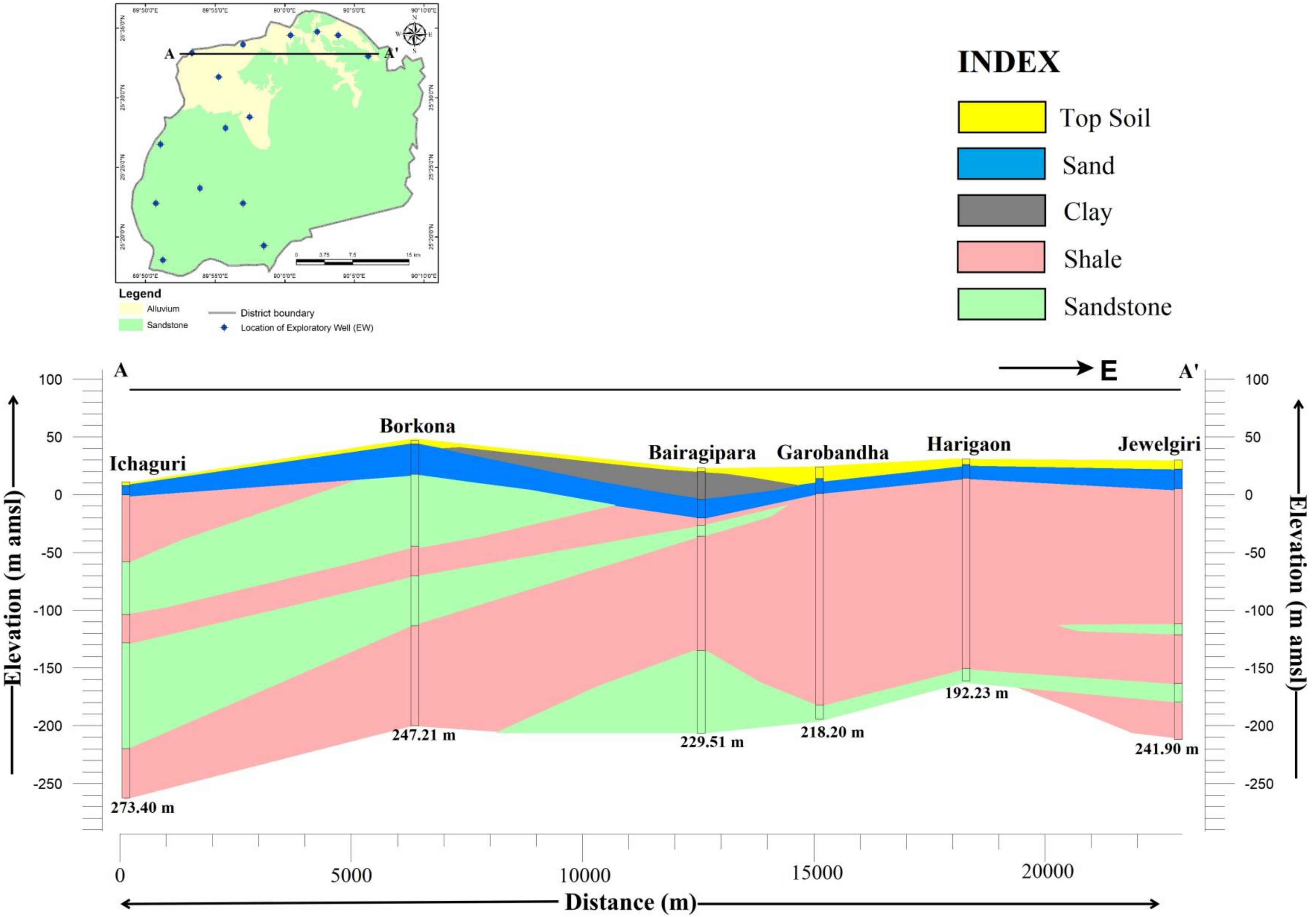


Fig 3.4 Hydrogeological cross section along A-A’

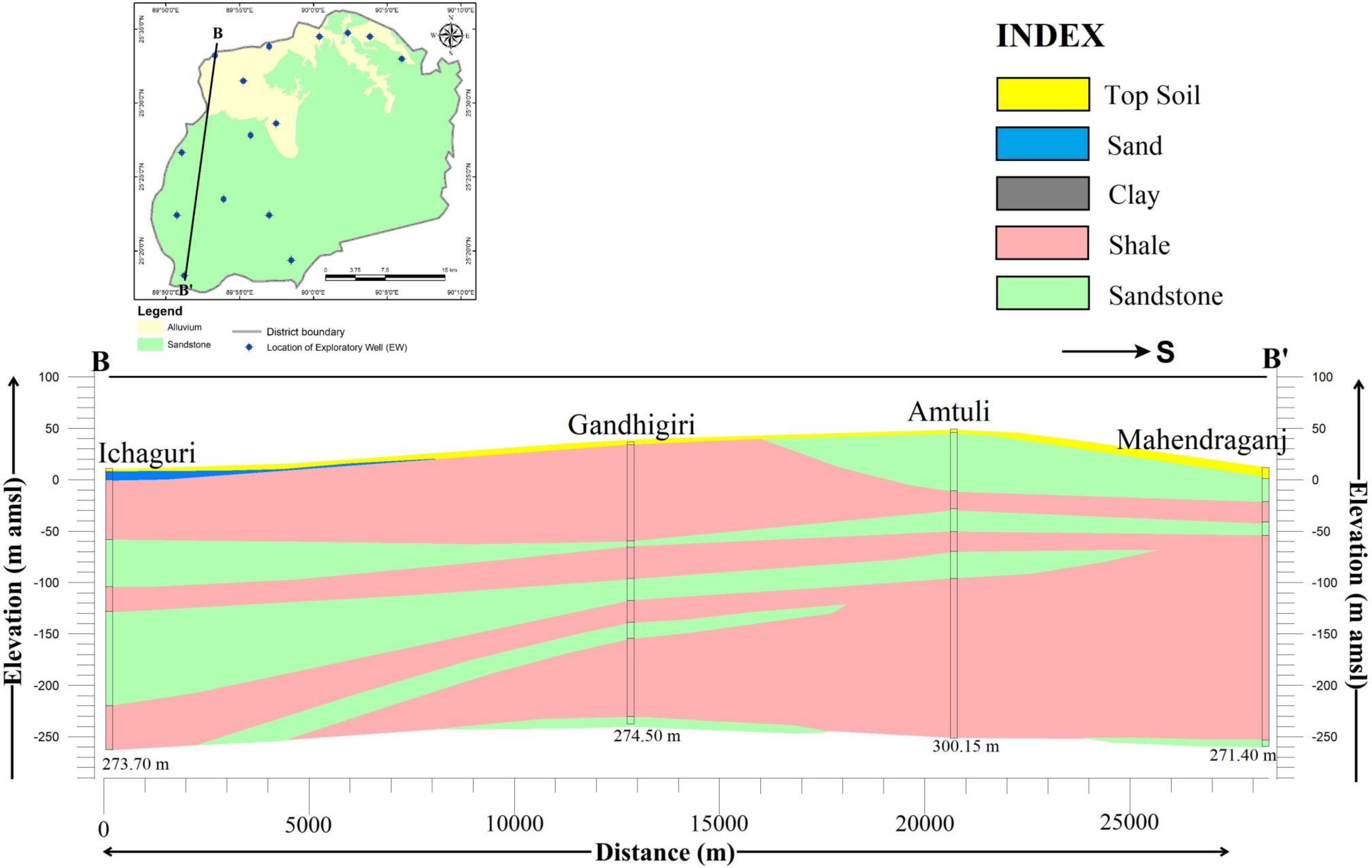


Fig 3.4 Hydrogeological cross section along B-B'

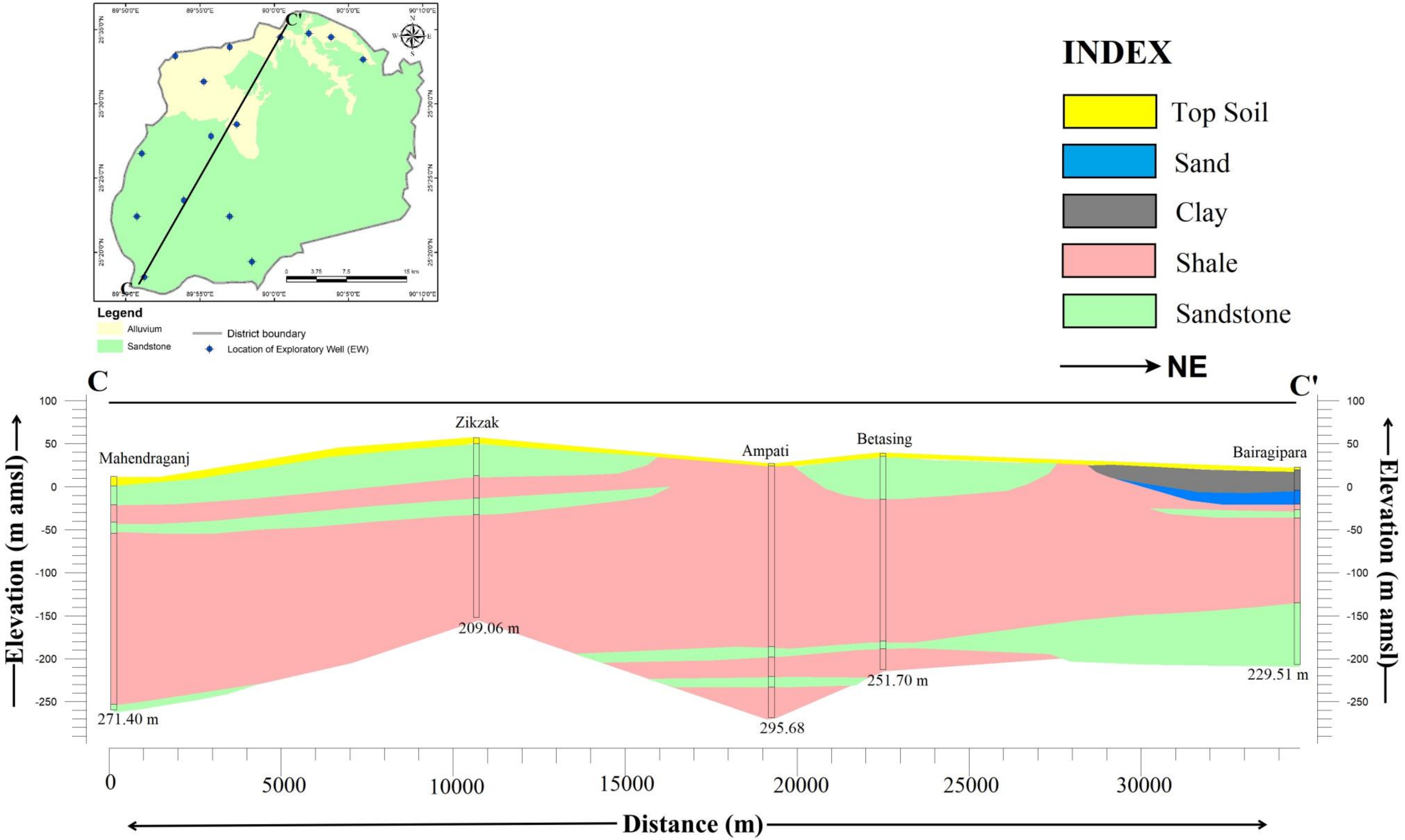


Fig 3.4 Hydrogeological cross section along C-C’

3.7 Hydrochemistry:

The quality of ground water is as important as that of the quantity. In order to study the chemical quality of ground water in the district, a total of 21 numbers of ground water samples were collected and analyzed during the course of study. Out of these, 19 water samples from dug well and 2 sample from springs were analyzed for the parameters like pH, EC, Turbidity, TDS, CO_3, Cl, SO_4, Na, K, HCO_3, NO_3, F, Ca, Mg, TH, U, As and Fe. Table 3.2 and 3.3 summarizes the results of chemical analysis of groundwater samples from South West Garo Hills district during pre-monsoon and post-monsoon season and the details of chemical analysis were given in the Annexure 4 and 5.

Table 3.1: Chemical quality of water samples from dug well and springs in South West Garo Hills district during pre-monsoon

Sl. No.	**Chemical constituents (Concentrations in mg/l except pH, EC, U and As)**	**Dug Well**	**Spring**
		Range	
1	pH	5.98 to 8.5	4.88 to 6.81
2	EC (µs/cm) 25°C	9.93 to 525.3	36.74 to 132.40
3	Turbidity (NTU)	BDL to 0.40	BDL to 0.30
4	TDS	6.55 to 346.70	24.25 to 87.38
5	CO_3^{-2}	BDL to 24	BDL
6	HCO_3^{-1}	42.73 to 335.77	42.73 to 48.84
7	TA (as $CaCO_3$)	42.73 to 350.77	42.73 to 48.84
8	Cl^-	7.090 to 99.260	24.815 to 35.450
9	SO_4^{-2}	BDL to 35.57	BDL to 6.90
10	NO_3^{-1}	0.16 to 5.66	003 to 0.15
11	F^-	BDL to 0.65	0.01 to 0.22
12	Ca^{+2}	18.01 to 54.04	14.01 to 6
13	Mg^{+2}	4.84 to 38.81	10.92 to 16.99
14	TH (as $CaCO_3$)	70 to 295	80 to 85
15	Na	4.45 to 44.14	1.54 to 3.67
16	K	2.02 to 13.75	1.13 to 1.67
17	Fe	BDL to 2.832	BDL to 0.025

Table 3.2: Chemical quality of water samples from dug well and springs in South West Garo Hills district during post-monsoon

Sl. No.	**Chemical constituents (Concentrations in mg/l except pH, EC, U and As)**	**Dug Well**	**Spring**
		Range	
1	pH	6.23 to 8.25	5.70 to 7.05
2	EC (µs/cm) 25°C	40.76 to 486.50	35.94 to 38.37
3	Turbidity (NTU)	BDL to 0.30	BDL to 0.10
4	TDS	22.74 to 271.30	19.90 to 21.15
5	CO_3^{-2}	BDL	BDL
6	HCO_3^{-1}	12.21 to 293.03	18.31 to 24.42
7	TA (as $CaCO_3$)	12.21 to 293.03	18.31 to 24.42
8	Cl^-	7.09 to 46.09	21.27 to 28.36
9	SO_4^{-2}	1.11 to 24.18	0.46 to 6.36
10	NO_3^{-1}	BDL to 20.20	BDL
11	F^-	BDL to 0.31	BDL to 0.11
12	Ca^{+2}	2 to 56.04	4
13	Mg^{+2}	1.20 to 26.67	7.28 to 8.49
14	TH (as $CaCO_3$)	10 to 250	40 to 45
15	Na	0.95 to 31.40	1.52 to 10.82
16	K	0.05 to 12.56	0.44 to 1.45
17	Fe	BDL to 5.04	BDL to 0.07

Table 3.3: Concentration of Fe and pH value in ground water during pre-monsoon

Type of Structure	No. of Sample analysed	Conc. of Iron (mg/l)			pH value	
		<0.3	0.3 to 1	>1	<6.5	6.5 to 8.5
Dug well	19	12	6	1	1	18
Spring	2	2	0	0	1	1

Table 3.4: Concentration of Fe and pH value in ground water during post-monsoon

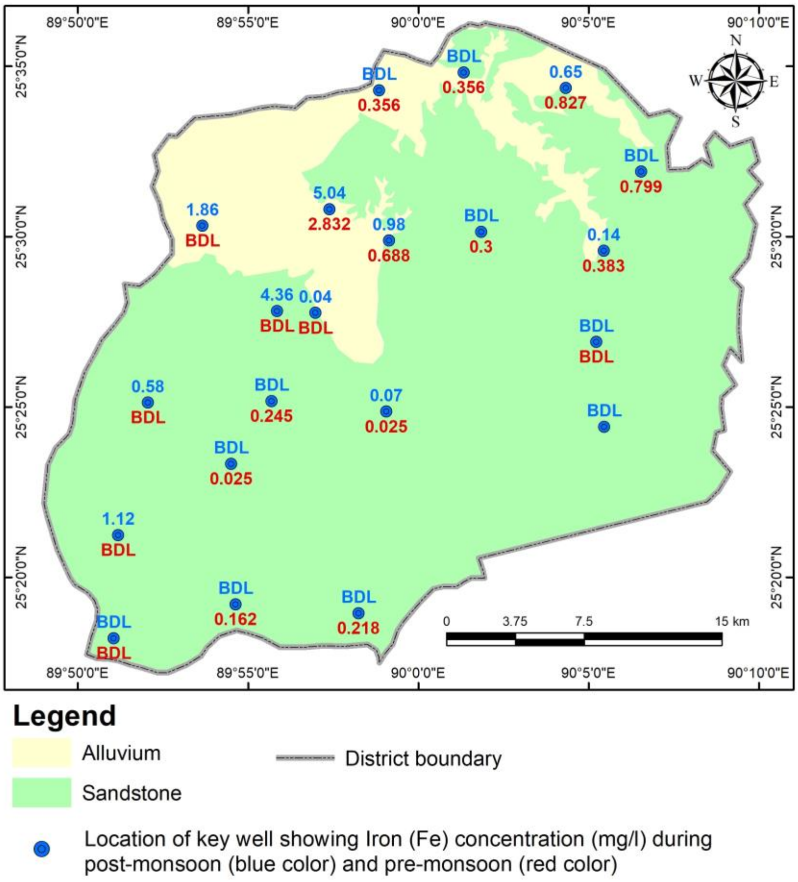
Type of Structure	No. of Sample analysed	Conc. of Iron (mg/l)			pH value	
		<0.3	0.3 to 1	>1	<6.5	6.5 to 8.5
Dug well	19	12	3	4	0	19
Spring	2	2	0	0	1	1

3.7.1 Ground water quality of unconfined aquifer:

A total of 19 ground water samples from dug well were collected during pre-monsoon and post-monsoon. The range of concentrations of different chemical constituents present in the ground water samples are given in table 3.1 and 3.2.

It is deciphered from table 3.1 and 3.2 that except Iron (Fe), all the other chemical parameters are within permissible limit. From table 3.3 and 3.4, the concentration of Iron beyond permissible limit is found in 1 dug wells during pre-monsoon and 4 dug wells during post-monsoon. The Fe conc. during pre-monsoon and post-monsoon are shown in fig 3.

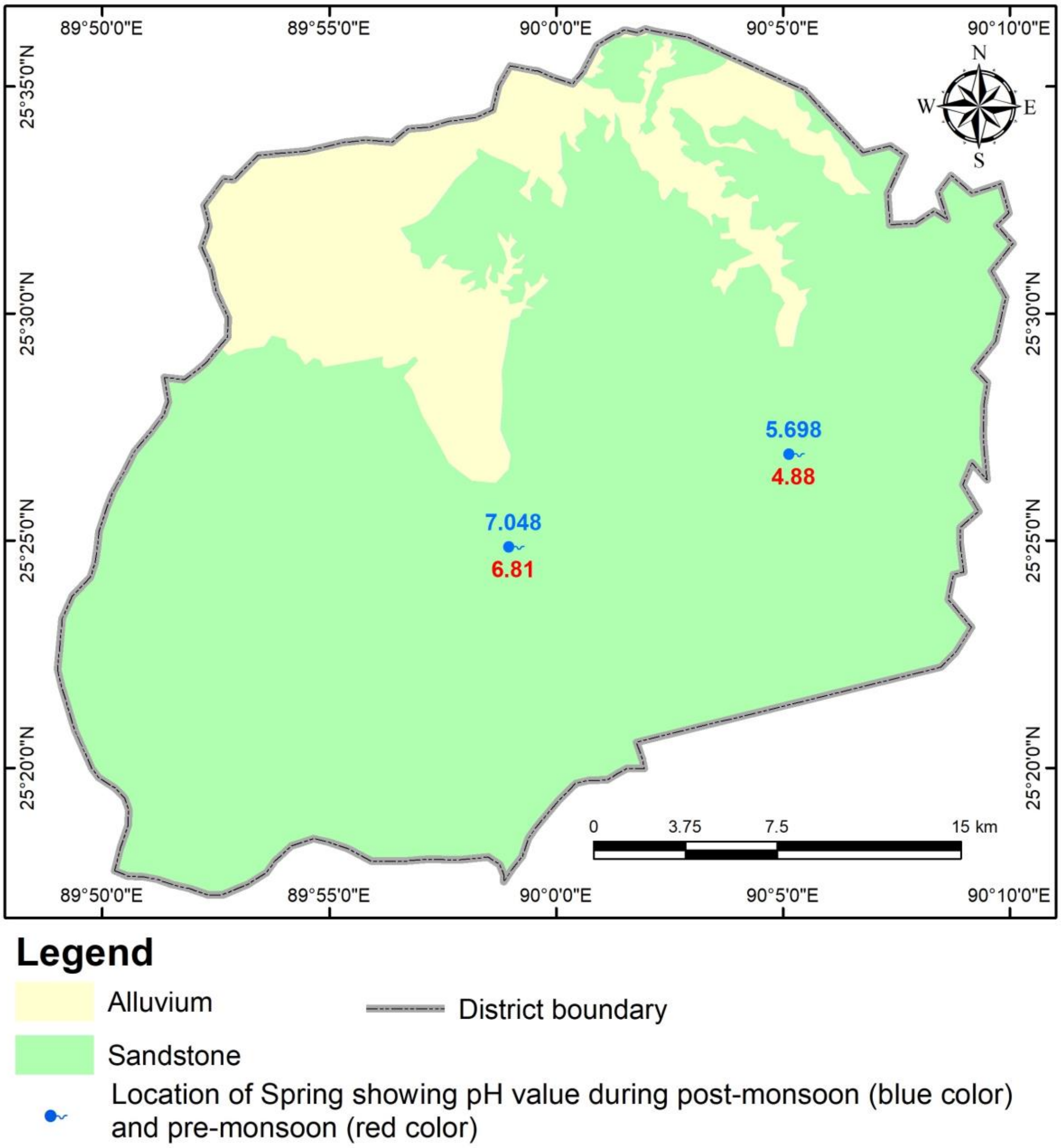
Fig. 3.5IRON (Fe) CONCENTRATION IN UNCONFINED AQUIFER SOUTH WEST GARO HILLS DISTRICT, MEGHALAYA



3.7.2 Water quality of Spring: A total of 2 ground water samples from Spring were collected during pre-monsoon and post-monsoon. The range of concentrations of different chemical constituents present in the ground water samples are given in table 3.1 and 3.2.

It is deciphered from table 3.1 and 3.2 that except pH, all the other chemical parameters are within permissible limit. From table 3.3 and 3.4, the pH value is found less than 6 in 1 Spring during pre-monsoon and post-monsoon. The pH value during pre-monsoon and post-monsoon is shown in fig 3.

Fig. 3.6 pH VALUE IN SPRING
SOUTH WEST GARO HILLS DISTRICT, MEGHALAYA



3.7.3 Assessment of ground water quality with various chemical diagram

Ground water quality has been assessed with the help of various chemical diagram such as Piper diagram, Wilcox diagram and Stiff diagram prepared with the help of Aquachem 9 software.

3.7.3.1 Piper diagram

In order to understand water composition and chemical relationship between dissolved ions, Pipers trilinear diagram for graphical analysis (Figure 3.7) is used. This diagram reveals similarities and differences among water samples. Most of the water samples analyzed fall within the no dominant type and Calcium type in case of cations. In case of anions, most of the samples are under bicarbonate type and chloride type. These trends are reflected in the central diamond of the diagram where most of the samples fall under the category of alkaline dominant field in case of cations within which around 38% of the samples falls under Magnesium bicarbonate (Mg-HCO3) type ,52% of the samples falls under mixed type and 9% under calcium chloride (CaCl) type. The results suggest that mixed type are the dominant hydro chemical facies for the studied groundwater samples.

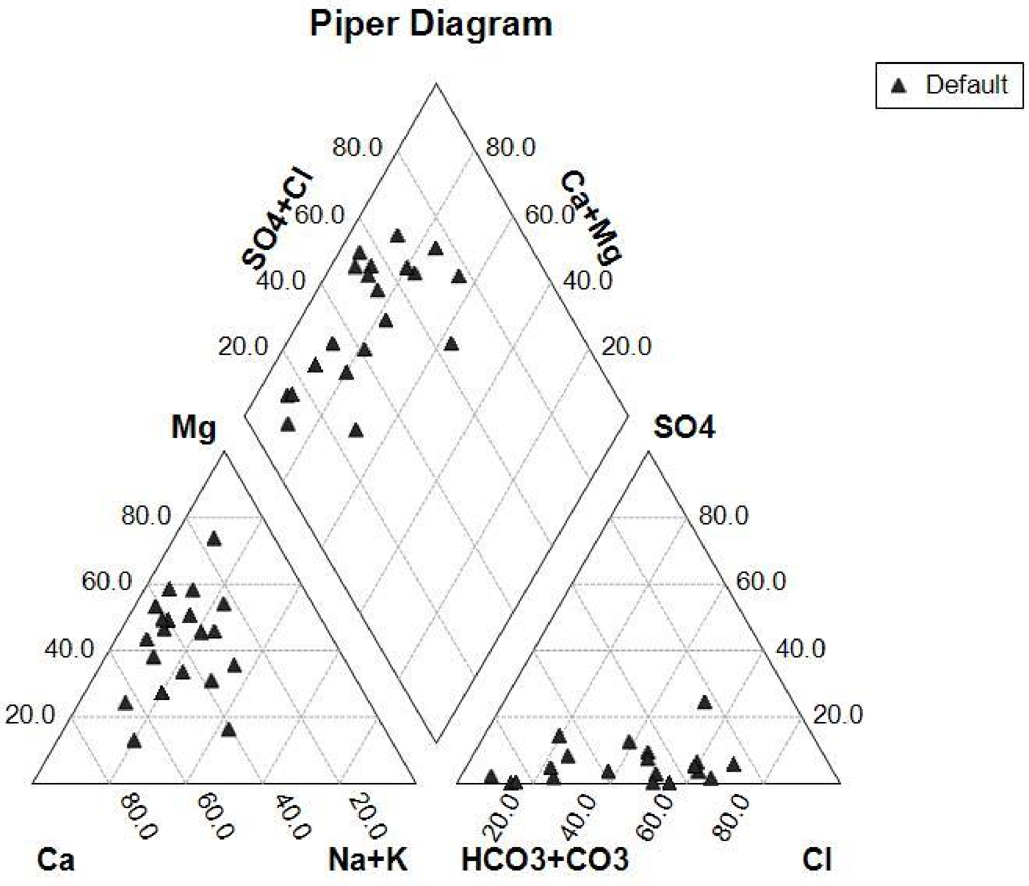


Fig. 3.7 Piper diagram for representing the analysis of ground water

3.7.3.2Wilcox diagram

According to Wilcox diagram (US Salinity Laboratory's diagram) in Figure 3.8, salinity and alkalinity hazard class of water samples were C1–S1 (81 %) and C2–S1 (19 %). The result shows that a majority of the ground water samples possess low salinity with low sodium (C1–S1). Such water can be used directly for irrigation purpose. However, water samples falling in medium salinity and low sodium class(C2-S1) should be treated before using for irrigation purposes.

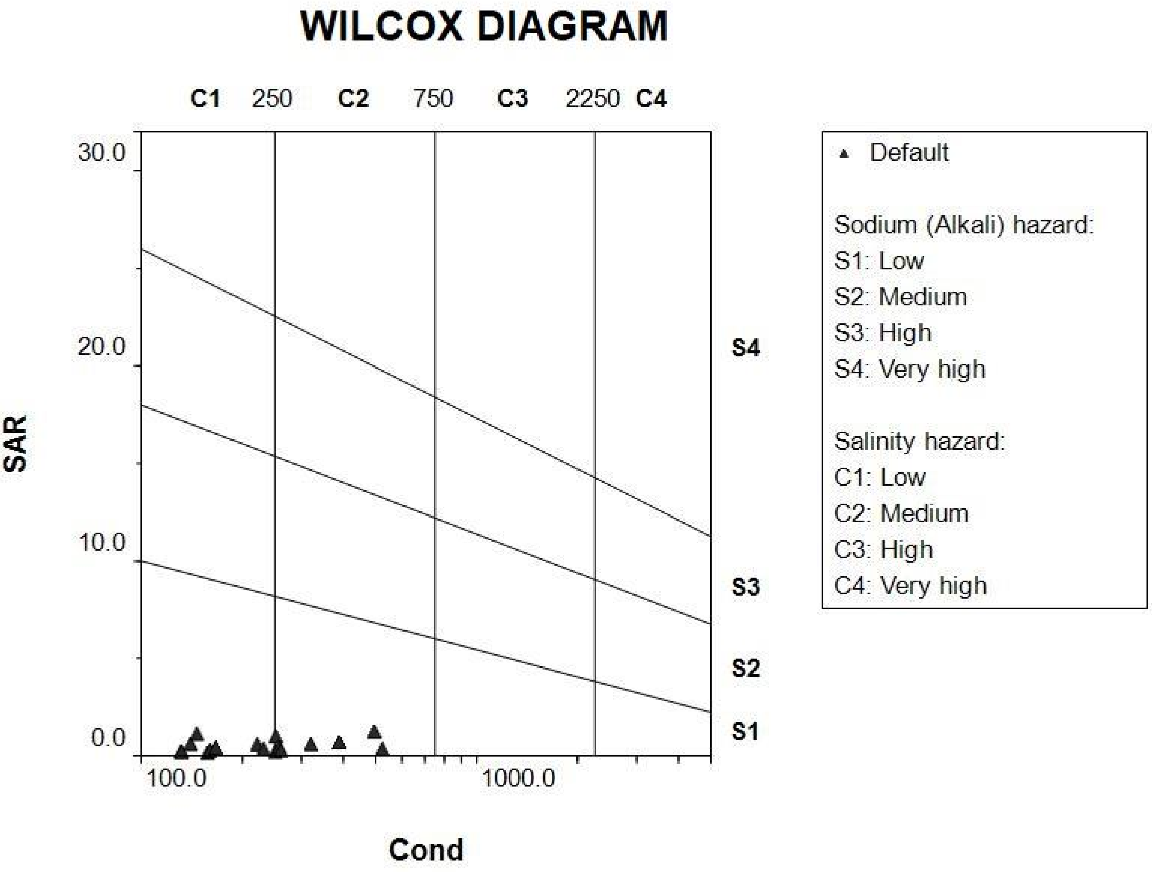


Fig.3.8 Wilcox diagram to analyze the quality of water in relationship to salinity & sodium hazard.

3.7.3.3 Stiff diagram

In the Figure 3.9 it can be seen that the ground water present in the study area shows a higher concentration of Magnesium(Mg) and Calcium(Ca) in comparison to Sodium (Na). In terms of anions the ground water of the study area has a higher concentration of Carbonate Bicarbonate ions (CO3+HCO3) and Chloride ions (Cl) in comparison to Sulphate ions (SO4).

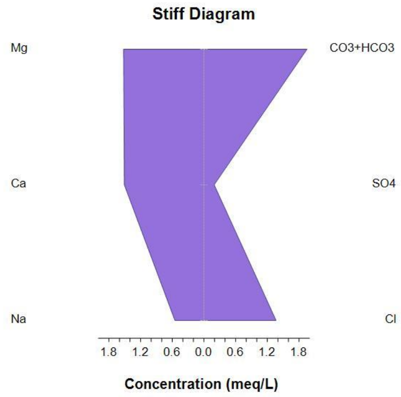


Fig. 3.9 Stiff diagram to analyze the concentration of various cations and anions present in the ground water

3.7.4 Water Quality Evaluation for Irrigation Purpose

To study the water quality for irrigation purpose, 21 water samples (both DW and Spring) are collected during pre-monsoon and post monsoon. Different chemical parameters like pH, electrical conductivity(EC), total dissolved solids (TDS), Ca2+, Mg2+, Na+, K+, Cl-, HCO3,CO3, SO4, F- and various chemical index such as sodium absorption ratio (SAR), sodium percentage(SP), residual sodium carbonate (RSC), Kelly's ratio and magnesium ratio were analyzed by adopting the standard procedures of water analysis. The feasibility check of ground water for irrigation purpose is given in Table No. 3.5.

Suitability of the groundwater for irrigation purpose was discussed by the following basic criteria.

Salinity Hazard

Determination of salinity hazard is very important in irrigation water, as high salt content renders the soil saline. This also affects the salt intake capacity of the plants through the roots. In the present study, the salinity hazard was evaluated by EC and TDS. EC varies from 9.93 to 525.3 µS/cm during pre-monsoon and 40.76 to 486.50 µS/cm during post monsoon. TDS varies from 6.55 to 346.70 mg/L during pre monsoon and 19.90 to 271.30 mg/L during post monsoon. Based on the classification of TDS as suggested by USSL, all the water samples both from pre and post monsoon are classified as non-saline. According to the EC grading standards as suggested by Wilcox, 81% samples are classified as excellent category and 19 % samples should be treated before use in irrigation.

Alkalinity Hazard (SAR)

Irrigation water is classified on the basis of SAR. Hence, the assessment of sodium hazard is necessary while considering the suitability for irrigation. The SAR values of the groundwater samples varies from 0.07-1.22. The SAR values of the water samples of the study area less than 10 and are classified as excellent for irrigation. To determine the hazardous effect of sodium on water quality for irrigation, Percent Sodium (%Na) and Kelly's Index are calculated. The percent sodium (%Na) varies from 5 – 43 % and around 95 % of the samples are categorized as excellent- permissible while 4 % of the samples as doubtful. 100% of the samples has Kellys Index less than 1 and is classified as suitable for irrigation.

Magnesium Ratio

In the study area, nearly 61% of the water samples has Mg ratio less than 50 % which is suitable for irrigation, as magnesium ratio of more than 50% indicate that the soil is more alkaline which adversely effects the crop yield.

Residual Sodium Carbonate (RSC)

The RSC values varies from -2.29 to 0.11 ppm in the water samples. 100% of the water samples are suitable for irrigation. The water with high RSC has high pH and land irrigated by such water becomes infertile owing to deposition of sodium carbonate as indicated by the black colour of the soil.

Table 3.5 - Feasibility check of ground water for irrigation purpose

	Range	Classification	Pre monsoon (No. samples)	Post monsoon (No. samples)
Total Dissolved Solid(TDS) (mg/L)	<1000	Non-saline	21	21
	1000-3000	Slightly saline	0	0
	3000-10000	Moderately saline	0	0
	>10000	Very saline	0	0
Salinity Hazard(EC) (µS/cm)	<250	Excellent	8	17
	250-750	Good	13	4
	750-2000	Permissible	0	0
	2000-3000	Doubtful	0	0
	>3000	Unsuitable	0	0
Alkalinity Hazard (SAR)	<10	Excellent	21	21
	Oct-18	Good	0	0
	18-26	Doubtful	0	0
	>26	Unsuitable	0	0
Percent Sodium (%Na)	<20	Excellent	13	13
	20-40	Good	7	7
	40-60	Permissible	1	1
	60-80	Doubtful	0	0
	>80	Unsuitable	0	0
Kelly’s Index (KI)	<1	Suitable	21	21
	>1	Unsuitable	0	0
Magnesium Ratio (MR)	>50%	Unsuitable	8	8
	<50%	Suitable	13	13
Residual Sodium Carbonate (RSC)	<1.25	Suitable	21	21
	1.25-2.5	Marginally suitable	0	0
	>2.5	Unsuitable	0	0

Based on the analysis using various chemical index such as sodium absorption ratio (SAR), sodium percentage(SP), residual sodium carbonate (RSC), Kelly’s ratio Permeability index and magnesium ratio, it is found that the ground water in the district is suitable for irrigation purpose.

4. GROUNDWATER RESOURCES

Dynamic Groundwater Resources of South West Garo Hills district has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). The present methodology used for resources assessment is known as Ground Water Resource Estimation Methodology – 2015 (GEC'2015). GEC 2015 recommends estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifers. In GEC'2015, two approaches are recommended – water level fluctuation method and norms of rainfall infiltration method. The resources computed for the groundwater year 2019-20. 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 868 sq.km.

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

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

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

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

Assessment Unit/ District	**Command/ Non-Command/ Total**	**Recharge from rainfall during monsoon season**	**Recharge from other sources during monsoon season**	**Recharge from rainfall during non-monsoon season**	**Recharge from other sources during non-monsoon season**	**Total Annual Ground Water Recharge**	**Provision for Natural Discharges**	**Annual Extractable Ground Water**
South West Garo Hills	Non-command	8798	83	2172	1024	12077	604	9866
	Total	8798	83	2172	1024	12077	604	9866

4.1 Groundwater extraction for Various Purposes: Groundwater extraction for domestic use has been estimated based on number of households using groundwater (Census 2011 data). Groundwater extraction for domestic use is 267 ham and for irrigation is 2655. It was found that groundwater extraction for all uses in the district is 2922 ham.

4.2 Stage of Groundwater extraction & Categorization of the district: The district falls under "**SAFE**" category. The stage of GW extraction is 29.62 %. Summary of groundwater resources, stages of development and categorization are given in annexure 8.

4.3 Summarized results of dynamic ground water resources of South West Garo Hills district as on March 2020: The summarized results of dynamic ground water resources estimation of South West Garo Hills district as on March 2020 is shown in the table below,

Table 4.2:Summarized results of dynamic ground water resources of South West Garo Hills district as on March 2020

Sl. No.	**ITEM**	**Year, 2019-20**
	Methodology	**GEC 2015 (in ham)**
1	Total Annual Ground Water Recharge	12077.07
2	Total Natural Discharges	603.85
3	Annual Extractable Ground Water Resource	9865.93
4	Total annual Ground water extraction	2922.31
5	Annual GW Allocation for for Domestic Use as on 2025	312.55
6	Net Ground Water Availability for future use	6897.98
7	Stage of GW Development (%)	29.62
8	Categorization of assessment unit i.e. district	Safe

5. GROUND WATER RELATED ISSUES

There are three major ground water related issues found in the study area.

5.1 Low stage of ground water development: As per ground water resource estimation 2020, the stage of ground water extraction is just 29.62 % and there is less utilization of ground water for irrigation in this area. All the irrigation schemes in the district are mainly dependent upon the surface water resources. Therefore, there is enough scope for future development of ground water in the study area to bring more area under irrigation practice.

5.2 Water logging: As per the pre monsoon water level data some portion of the district has depth to water level of less than 2 m. As a result, this portion of the district remains water logged. Most of the water-logged area is spread in the Northern part of the district. The alluvium cover in the area is mainly clayey in nature which prevents the water to percolate downward. High rainfall and low stage of ground water development also results in water logging in the area.

5.3 Ground Water Quality: As per water quality analysis data, it was found that there is a moderately high concentration of iron in some dug well. pH value is also low in some dug well and spring and needs to be treated before consumption.

6. MANAGEMENT STRATEGIES

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 estimation of South West Garo Hills District for 2020, annual extractable ground water is 9865.93 ham and stage of ground water extraction is only 29.62 %. The district is having balance net ground water availability for future development in the tune of 6898 ham. If an irrigation plan is made to develop 60% of the balance dynamic ground water resources available, then 4139 ham of groundwater resources is available in the district for the future irrigation uses. Hence, there is ample scope for ground water development for irrigation purpose which will help the district in achieving self-reliance on food grain. In this district, net sown area is 28909 ha, area sown more than once is 6699 ha and cropping intensity is about 123 %. 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.

To use the groundwater for irrigation purpose a cropping plan has been designed for the district by using CROPWAT model developed by FAO. Cropping pattern data for the district is presented in table 6.1.

During kharif season, paddy (winter & autumn paddy) is cultivated in 12,821 ha and during rabi season spring paddy is cultivated in 4918 ha. The total area which remains fallow during rabi season is about 7903 ha. The intention of this plan is to bring this fallow land under assured irrigation during rabi season which will help to increase gross cropped area to 25642 ha and thereby increase cropping intensity up to 200 %. In rice fallow, with the support of irrigation potato, mustard, pulses, millet and rabi vegetables can be grown. Present cropping pattern, proposed cropping pattern, intended increase in cropping intensity were shown in table 6.2a and 6.2b.

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

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

```
Cropping pattern name: South West Garo Hill

                                                     Planting    Harvest     Area
No.   Crop file               Crop name                date        date        %

 1    ...Data\CROPWAT\data    Rice                     04/06       01/10       15
 2    ...Data\CROPWAT\data    Rice                     11/06       08/10       15
 3    ...Data\CROPWAT\data    Rice                     18/06       15/10       10
 4    ...Data\CROPWAT\data    Rice                     25/06       22/10       10
 5    rape___mustard.CRO      Mustard                  15/10       26/02       10
 6    ...a\CROPWAT\data\cr    Pulses                   25/10       11/02       10
 7    ...a\CROPWAT\data\cr    MILLET                   05/01       19/04       10
 8    ...\CROPWAT\data\cro    Potato                   05/02       14/06       10
 9    ...CROPWAT\data\crop    Small Vegetables         10/02       15/05       10
```

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

Cropping pattern (s)				
Rice based cropping pattern				
1. Rice-Mustard	Present Cultivated area	Area to be cultivated	Area to be cultivated **(ha)**	Irrigation requirement **(ham)**
2. Rice-Pulses	**(ha)**	**(%)**		
3. Rice-Millets				
4. Rice-Potato				
5. Rice-Vegetables				
	1	2 (= % of 1)	3	4
Rice (main crop)	7903		7903	513.1
Mustard		20	1580.8	105.34
Pulses		20	1580.8	97.7
Millet		20	1580.8	84.2
Potato		20	1580.8	82.7
Small vegetables		20	1580.8	83.5
Net cultivated area	7903		**7903**	
Gross cultivated area (1+pulses/+Millet/+potato/+mustard/+Veg)			**15806**	
Total irrigation requirement				966.54
Cropping intensity	**100% (Present)**		**200% (Intended)**	
Total (South West Garo Hills district)				**966.54**

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

Rice based cropping pattern			
Crop	**Growing period (Months)**	**Periods/months of water deficit**	**Irrigation requirement**
			(ham)
Rice	4	2-3	513.1
Mustard	4	4	105.34
Pulses	4	4	97.7
Millet	4	4	84.2
Potato	4	3	82.7
Small vegetables	3	3	83.5

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

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit (in mm)												
1. Rice	0	0	0	0	147.1	63	0	0	0	3	0	0
2. Rice	0	0	0	0	49.5	98	0	0	0	0	0	0
3. Rice	0	0	0	0	49.6	71.4	0	0	0	0	0	0
4. Rice	0	0	0	0	0	147.1	0	0	0	5.5	0	0
5. Mustard	43.8	33.5	0	0	0	0	0	0	0	0	38.8	51.1
6. Pulses	55.5	12.7	0	0	0	0	0	0	0	0	25.6	61.2
7. MILLET	12.7	54.6	65.7	0.6	0	0	0	0	0	0	0	0
8. Potato	0	26.3	57.3	47.7	0	0	0	0	0	0	0	0
9. Small Vegetables	0	32.2	64.3	36	0	0	0	0	0	0	0	0

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

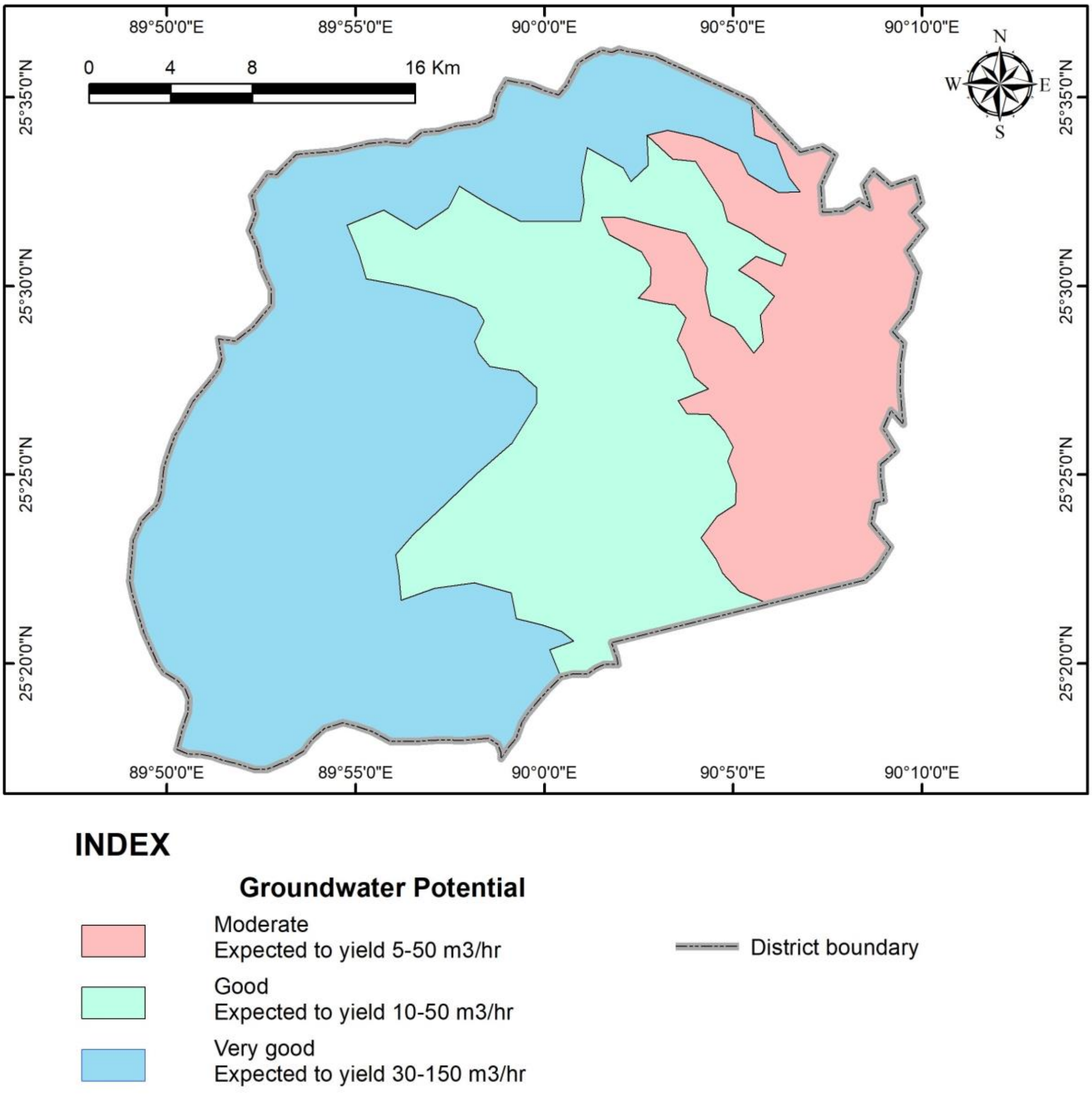
Crops	% of total area of 4294 ha	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation deficit (ham)														
1. Rice	15	0	0	0	0	139.0	59.5	0	0	0	2.835	0	0	201.4
2. Rice	15	0	0	0	0	46.8	92.6	0	0	0	0	0	0	139.4
3. Rice	10	0.0	0.0	0.0	0.0	31.2	45.0	0.0	0.0	0.0	0.0	0.0	0.0	76.2
4. Rice	10	0.0	0.0	0.0	0.0	0.0	92.7	0.0	0.0	0.0	3.5	0.0	0.0	96.1
5. Mustard	10	27.6	21.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	32.2	105.34
6. Pulses	10	35.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.1	38.6	97.7
7.Millet	10	8.0	34.4	41.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.2
8.Potato	10	0.0	16.6	36.1	30.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.7
9.Small Vegetables	10	0.0	20.3	40.5	22.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.5
Total	100	70.6	100.4	118.0	53.1	217.0	289.8	0.0	0.0	0.0	6.3	40.6	70.7	966.5

Under Ground water exploration studies, CGWB has constructed 15 tube wells in this area and has established that the aquifer in most part of the district is having discharge ranging from 9 m^3/hr to 165 m^3/hr. The average discharge of the well is about 50 m^3/hr from Alluvium/ Sandstone formation.

The ground water potentiality in the district is moderate to high which are feasible for sustainable ground water development. Therefore, these areas can be brought under irrigation by developing ground water through construction of tube wells.

The ground water potentiality map is shown in the Fig. 6.1

Fig. 6.1 GROUND WATER POTENTIAL MAP
SOUTH WEST GARO HILLS DISTRICT, MEGHALAYA



As shown in the figure, the ground water potential zone can be divided into three parts based on the hydrogeological conditions and the aquifer properties. The eastern part of the district has got a moderate potential where the expected yield is about 5 to 50 m^3/hr and is mainly consist of tertiary sandstone and small part of Granitoid. The central part of the district has got a good potential where the well is expected to yield about 10 to 50 m^3/hr. The western and northern part of the district has got a very good potential where the well can be expected to yield about 30 to 150 m^3/hr and auto flow well/ artesian well also exist in this area.

Based on the ground water potentiality map, it is recommended to construct a tube well in the good and very good potential zone area to provide the irrigation water requirement in the district. A tube well in this area is expected to yield at least 30 m^3/hr. If such a tube well runs for 10 hrs/day for 120 days, then it will create a draft of 3.6 ham. Tube wells can be designed within a depth of 100 m where it can be expected to yield good discharge.

Annual irrigation water requirement is 966.54 ham while irrigation water requirement during dry season spanning from October to March is 406.5 ham. Again proportionate dynamic groundwater resources available for future irrigation use in the considered area are 4139 ham. Hence, this area can be brought under assured irrigation from groundwater sources. The demand of 406.5 ham can be harnessed by constructing 113 nos. of shallow tube wells (which can irrigate 7903 ha). At possible places water harvesting methods should be employed.

When managing a precious and scarce resource such as groundwater, it is essential that the resource is not subjected to pollution. The chemical quality of ground water indicates that groundwater in most of the district is good for drinking, domestic and irrigation use however in some pockets there is moderately high iron concentration in the wells which are beyond the permissible limit, which warrant proper treatment before use. Removal of the iron is best effected by aeration process followed by sedimentation and filtration. Potassium permanganate or chlorine/chloride may be employed to oxidize the iron, which is then filtered from the waters. The process is applicable very much when bacteria is present in the water. Iron can also be removed by addition of a mixture of sodium carbonate and sodium phosphate to precipitate iron as insoluble, followed by settling and filtration.

Rain Water Harvesting

The area receives an average annual rainfall of about 2000 mm. Hence there is ample scope for roof top rainwater harvesting. In roof top rainwater harvesting, rain water can be collected through gutters fitted on the edge of the roof and stored in reservoirs. Water collected from roofs should be stored in a PVC or Concrete tank. Water thus collected can be used for domestic purposes and in case of emergency can be used for drinking purposes, after proper treatment.

Spring Development and Rejuvenation Plan

Some villages which are located in the hilly side of the district are dependent on spring for drinking and domestic purpose. However, there is lack of proper development in those springs and some of the springs are drying up or giving very less discharge. Therefore, it is recommended to develop and construct spring tab chamber in all the existing springs which are presently being used by the villagers for drinking and domestic purposes. It is also recommended to take up Spring rejuvenation program in those springs which are slowly drying up or giving less discharge by construction of contour trenches/ staggered trenches in the upper reach of the source.

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

Sl. No.	Location	Longitude	Latitude	Type of well	Drilled depth	Geology	Aquifer tapped zone	SWL M bgl	Discharge (m^3/hr)	DD (m)	T (m^2/day)	Storativity
1	Ampati	89.92917	25.46389	EW	295.68	Sand, clay	182.7-192.1,218.7-225,247.5-263	6.00 agl (auto flow)	72	5.85	1595	
2	Amtuli	89.84583	25.37361	EW	300.15	Sandstone, clay		---	---	---	---	
3	Bairagipara	90.00694	25.575	EW	229.5	Sandstone, clay		9.30 agl (auto flow)	96	9	1403.7	
4	Betasing	89.958	25.477	EW	251.7		54.3	0.60 agl (auto flow)	----			
5	Borkona	89.95	25.56389	EW	247.4	Clay,sand,gravel	69-87,118-130,141-159	4.51	151.8	10.53	540.86	5 x 10^{-4}
6	Gandhigiri	89.85139	25.44444	EW	279.5	Sandstone, clay	96.5-102.6,133.1-145.3,148.4-151.4,175.8-191.1	0.70 agl (auto flow)	18			
7	Garobandha	90.03889	25.57917	EW	218.2	Sandstone		3.3	150	3	833.3	
8	Gopinathkilla	89.975	25.32278	EW	169	Alluvium	46-52,70-76,96-99,103-106,124-127,138-144,149-152,160-163	15.0 agl (auto flow)	----	----	---	
9	Harigaon	90.06389	25.575	EW	192.23	Sandstone, clay		----	----	----	---	
10	Ichaguri	89.88889	25.55389	EW	273.4	Clay, sand, gravel	70.0-82.0,102-114,139-169	0.53	165	10.1	884.72	3.6 x 10^{-4}
11	Jewelgiri	90.1	25.55	EW	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	Kalaigaon	89.95	25.37361	EW	274.05	Clay		----	----	---	---	
13	Mahendraganj	89.85417	25.30556	EW	268.4	Alluvium	20-32,42-51,63-66	3.1 agl (auto flow)				
14	Ulubari	89.92083	25.525	EW	253.39	Sandstone, clay	75.0-93.0	0.90 agl	9	----	---	
15	Zikzak	89.89861	25.39167	EW	209.06	Sandstone, clay	71-80,83-89,99-102,160-167	1.0 agl (auto flow)	95.4	13.3	210.16	4.4 x 10^{-4}

Annexure 2: Dynamic water level data of dug well during 2021-22

S.No	Block*	Village	Lat*	Long*	Well* Type	RL* (m)	MP* (m)	Depth* (mbgl)	Dia* (m)	Water Level (mbgl) Nov.-2021*	Water Level (mbgl) Feb.-2022*
1	Betasing	Dalmalgre	25°31’54.37”	90°06’33.08”	Dug well	40	1	3.5	1.9	1.5	2.4
2	Betasing	Garobadha	25°34’49.02”	90°01’20.16”	Dug well	31	0.8	5.5	0.8	3.35	4
3	Betasing	Harigaon	25°34’21.76”	90°04’20.39”	Dug well	41	1	3.25	2.4	0.9	1.1
4	Betasing	Garodoba	25°34’17.64”	89°58’51.05”	Dug well	33	0.8	2.5	0.9	0.6	1.05
5	Betasing	Betasing	25°30’48.16”	89°57’24.04”	Dug well	31	0.7	3.7	1	2.15	2.7
6	Zikzak	Ampati	25°27’48.96”	89°55’51.55”	Dug well	19	0.9	5.4	1	4	4.4
7	Zikzak	Jangnapara	25°25’10.08”	89°55’41.76”	Dug well	48	0.8	2.2	1	0.2	0.3
8	Zikzak	Zikzak	25°23’19.80”	89°54’30.79”	Dug well	36	1.1	5.2	0.9	4.6	4.6
9	Zikzak	Dhromch	25°21’14.08”	89°51’11.55”	Dug well	26	0.9	6	0.8	2.2	5.9
10	Zikzak	Mahendraganj	25°18’12.61”	89°51’03.25”	Dug well	8	0.9	3.7	0.2	1.7	2.7
11	Zikzak	Debajani	25°19’12.15”	89°54’38.46”	Dug well	35	0.7	4.1	0.9	2.4	3
12	Zikzak	Rimtangpara	25°18’56.61”	89°58’15.03”	Dug well	46	0.7	2.8	1	1.8	2
13	Betasing	Chigitchakgre Dabanbil	25°27’45.61”	89°56’58.72”	Dug well	36	0.8	6.6	1	4.4	5.8
14	Betasing	Dengnakpara	25°29’34.94”	90°05’27.46”	Dug well	39	0.9	3.9	1	1.8	3.15
15	Zikzak	Sakaboldamgri	25°24’24.87”	90°05’28.10”	Dug well	228	0.8	4.9	0.8	1.4	4.7
16	Betasing	Kasibil	25°30’8.30”	90°01’51.26”	Dug well	76	0.8	4.1	0.9	2.5	3.9
17	Betasing	Godalgre	25°29’52.92”	89°59’08.97”	Dug well	48	0.65	4.45	1	1.8	2.05
18	Betasing	Jholgaon	25°30’19.06”	89°53'39.68”	Dug well	17	0.9	4.2	0.9	2.8	3.3
19	Zikzak	Hatibelpara	25°25’07.57”	89°52'03.62”	Dug well	38	0.5	2.2	1	0.6	1

Annexure 3: Spring discharge data collected during 2019-20

S.No	State*	District*	Block*	Village	Lat*	Long*	Spring* Type	RL* (m)	Discharge (lps)Nov.-2021*	Discharge (lps)Feb.-2022*
1	Meghalaya	South West Garo Hills	Zikzak	Salmanpara	25°24’51.73”	89°59’04.07”	Fractured	94	0.01	0.01
2	Meghalaya	South West Garo Hills	Betasing	Mellim	25°26’54.43”	90°05’14.17”	Depression	65	0.34	0.091

Annexure 4: Aquifer wise water quality data of Aquifer mapping area during post monsoon

Sl.No.	Location	Block	Lat DMS	Long DMS	Type of sample	TempºC	pH	EC	Turbidity	TDS	CO3-2	HCO3-1	TA (as CaCO3)	Cl-	SO4-2	NO3-1	F-	Ca+2	Mg+2	TH (as CaCO3)	Na	K	Fe
					(EW or DW or Spring)			(µs/cm) 25C	(NTU)	Mg/l													
1	Dalmalgre	Betasing	25°31’54.37”	90°06’33.08”	Dug well	29.8	7.97	221.40	0.30	122.80	BDL	115.99	115.99	7.09	11.01	6.24	0.23	18.01	1.20	50.00	23.59	9.89	BDL
2	Garobadha	Betasing	25°34’49.02”	90°01’20.16”	Dug well	29.4	6.86	186.90	BDL	103.80	BDL	24.42	24.42	46.09	24.18	1.89	0.08	16.01	8.49	75.00	14.45	2.07	BDL
3	Harigaon	Betasing	25°34’21.76”	90°04’20.39”	Dug well	29.2	8.07	364.80	BDL	202.90	BDL	152.62	152.62	35.45	11.61	BDL	0.31	38.03	20.61	180.00	8.06	3.76	0.65
4	Garodoba	Betasing	25°34’17.64”	89°58’51.05”	Dug well	27.2	7.26	130.50	BDL	72.35	BDL	30.52	30.52	31.91	1.11	9.23	0.16	10.01	3.64	40.00	15.32	1.80	BDL
5	Betasing	Betasing	25°30’48.16”	89°57’24.04”	Dug well	28.1	7.31	154.10	BDL	85.63	BDL	48.84	48.84	31.91	7.92	BDL	0.13	2.00	1.21	10.00	29.13	3.62	5.04
6	Ampati	Zikzak	25°27’48.96”	89°55’51.55”	Dug well	28.6	7.78	216.10	BDL	120.50	BDL	146.52	146.52	10.64	1.99	2.36	0.28	34.03	12.12	135.00	2.34	1.52	4.36
7	Jangnapara	Zikzak	25°25’10.08”	89°55’41.76”	Dug well	29.4	7.51	90.74	BDL	50.44	BDL	54.94	54.94	10.64	2.89	BDL	0.21	10.01	7.28	55.00	2.61	0.55	BDL
8	Zikzak	Zikzak	25°23’19.80”	89°54’30.79”	Dug well	28.4	7.27	94.92	BDL	52.72	BDL	24.42	24.42	14.18	3.31	6.25	0.07	8.01	4.85	40.00	3.93	1.29	BDL
9	Dhromch	Zikzak	25°21’14.08”	89°51’11.55”	Dug well	29.2	7.30	251.00	BDL	141.60	BDL	54.94	54.94	46.09	13.25	9.07	0.05	10.01	13.34	80.00	21.15	12.56	1.12
10	Mahendraganj	Zikzak	25°18’12.61”	89°51’03.25”	Dug well	29.1	8.25	486.50	BDL	271.30	BDL	256.40	256.40	46.09	13.91	10.62	0.24	54.04	19.39	215.00	31.40	7.89	BDL
11	Debajani	Zikzak	25°19’12.15”	89°54’38.46”	Dug well	29	7.46	149.10	BDL	82.67	BDL	54.94	54.94	14.18	6.51	14.41	0.22	12.01	8.49	65.00	2.56	11.41	BDL
12	Rimtangpara	Zikzak	25°18’56.61”	89°58’15.03”	Dug well	28.5	7.88	121.50	BDL	67.65	BDL	73.26	73.26	14.18	1.68	BDL	0.23	12.01	10.92	75.00	1.60	1.13	BDL
13	Salmanpara Spring	Zikzak	25°24’51.73”	89°59’04.07”	Spring	27.7	7.05	38.37	BDL	21.15	BDL	18.31	18.31	21.27	0.46	BDL	0.11	4.00	7.28	40.00	1.52	0.44	0.07
14	Chigitchakgre Dabanbil	Betasing	25°27’45.61”	89°56’58.72”	Dug well	28.6	7.31	77.99	BDL	43.46	BDL	42.73	42.73	10.64	1.57	4.11	0.09	8.01	6.06	45.00	3.40	0.05	0.04
15	Dengnakpara	Betasing	25°29’34.94”	90°05’27.46”	Dug well	28.7	8.00	220.80	BDL	123.60	BDL	115.99	115.99	21.27	8.22	BDL	0.13	32.03	8.48	115.00	4.88	7.78	0.14
16	Mellim Spring	Betasing	25°26’54.43”	90°05’14.17”	Spring	27.7	5.70	35.94	0.10	19.90	BDL	24.42	24.42	28.36	6.36	BDL	BDL	4.00	8.49	45.00	10.82	1.45	BDL
17	Sakaboldamgri	Zikzak	25°24’24.87”	90°05’28.10”	Dug well	28.1	6.23	40.76	BDL	22.74	BDL	12.21	12.21	10.64	4.66	BDL	BDL	4.00	4.85	30.00	0.95	0.66	BDL
18	Kasibil	Betasing	25°30’8.30”	90°01’51.26”	Dug well	29.7	7.50	108.40	0.20	60.08	BDL	54.94	54.94	14.18	3.74	BDL	0.06	10.01	7.28	55.00	4.89	2.61	BDL
19	Godalgre	Betasing	25°29’52.92”	89°59’08.97”	Dug well	29.5	7.68	141.60	BDL	80.95	BDL	73.26	73.26	21.27	10.00	11.96	0.09	12.01	10.92	75.00	12.29	1.23	0.98
20	Jholgaon	Betasing	25°30’19.06”	89°53'39.68”	Dug well	29.5	7.63	160.10	BDL	91.06	BDL	48.84	48.84	28.36	9.39	20.20	0.09	10.01	3.64	40.00	19.86	9.04	1.86
21	Hatibelpara	Zikzak	25°25’07.57”	89°52'03.62”	Dug well	30.7	7.70	418.60	BDL	239.40	BDL	293.03	293.03	28.36	2.90	BDL	0.28	56.04	26.67	250.00	6.66	1.02	0.58

Annexure 5: Aquifer wise water quality data of Aquifer mapping area during Pre-monsoon

Sl.No.	Location	Block	Lat DMS	Long DMS	Type of sample	pH	EC	Turbidity	TDS	CO3-2	HCO3-1	TA (as CaCO3)	Cl-	SO4-2	NO3-1	F-	Ca+2	Mg+2	TH (as CaCO3)	Na	K	Fe
					(EW or DW or Spring)		(µs/cm) 25C	(NTU)	Mg/l													
1	Dalmalgre	Betasing	25°31’54.37”	90°06’33.08”	Dug well	8.40	261.60	0.20	172.66	6.00	109.89	115.89	21.270	20.57	0.02	0.05	42.03	9.69	145.00	7.04	3.87	0.799
2	Harigaon	Betasing	25°34’21.76”	90°04’20.39”	Dug well	8.50	390.50	BDL	257.73	12.00	128.20	140.20	70.900	30.59	1.27	0.23	50.04	23.03	220.00	23.49	10.24	0.827
3	Garobadha	Betasing	25°34’49.02”	90°01’20.16”	Dug well	5.98	252.40	BDL	166.58	BDL	42.73	42.73	56.720	35.57	2.70	0.24	20.02	14.55	110.00	23.75	5.84	0.356
4	Garodoba	Betasing	25°34’17.64”	89°58’51.05”	Dug well	6.55	147.10	0.20	97.09	BDL	48.84	48.84	49.630	3.75	0.35	BDL	20.02	4.84	70.00	21.30	5.28	0.356
5	Betasing	Betasing	25°30’48.16”	89°57’24.04”	Dug well	7.46	222.20	0.20	146.65	BDL	97.68	97.68	95.715	11.04	0.50	BDL	50.04	15.75	190.00	17.51	7.83	2.832
6	Dengnakpara	Betasing	25°29’34.94”	90°05’27.46”	Dug well	7.53	258.20	0.10	170.41	BDL	146.52	146.52	31.905	13.99	0.16	BDL	52.04	6.04	155.00	12.19	9.93	0.383
7	Mellim Spring	Betasing	25°26’54.43”	90°05’14.17”	Spring	4.88	36.74	BDL	24.25	BDL	42.73	42.73	24.815	6.90	0.03	0.22	14.01	10.92	80.00	1.54	1.13	BDL
8	Kasibil	Betasing	25°30’8.30”	90°01’51.26”	Dug well	6.71	131.90	BDL	87.05	BDL	67.15	67.15	42.540	3.08	0.25	0.14	22.02	14.55	115.00	5.00	2.90	0.3
9	Godalgre	Betasing	25°29’52.92”	89°59’08.97”	Dug well	6.76	167.40	BDL	110.48	BDL	91.57	91.57	53.175	11.35	0.37	0.65	24.02	21.83	150.00	11.04	3.41	0.688
10	Ampati	Zikzak	25°27’48.96”	89°55’51.55”	Dug well	8.33	251.40	BDL	165.92	15.00	189.25	204.25	21.270	BDL	0.73	0.55	38.03	20.61	180.00	5.78	2.90	BDL
11	Chigitchakgre Dabanbil	Betasing	25°27’45.61”	89°56’58.72”	Dug well	7.24	161.00	BDL	106.26	BDL	134.31	134.31	7.090	2.38	0.23	0.32	26.02	12.12	115.00	6.27	2.39	BDL
12	Salmanpara Spring	Zikzak	25°24’51.73”	89°59’04.07”	Spring	6.81	132.40	0.30	87.38	BDL	48.84	48.84	35.450	BDL	0.15	0.01	6.00	16.99	85.00	3.67	1.67	0.025
13	Jholgaon	Betasing	25°30’19.06”	89°53'39.68”	Dug well	6.91	140.80	BDL	92.93	BDL	73.26	73.26	74.445	10.57	0.74	0.25	18.01	25.48	150.00	16.42	7.12	BDL
14	Jangnapara	Zikzak	25°25’10.08”	89°55’41.76”	Dug well	6.73	99.30	0.10	65.54	BDL	91.57	91.57	17.725	1.58	1.32	BDL	18.01	13.34	100.00	4.46	2.02	0.245
15	Zikzak	Zikzak	25°23’19.80”	89°54’30.79”	Dug well	6.41	9.93	BDL	6.55	BDL	54.94	54.94	63.810	1.89	3.65	0.24	18.01	21.84	135.00	7.35	3.08	0.025
16	Hatibelpara	Zikzak	25°25’07.57”	89°52'03.62”	Dug well	8.47	525.30	BDL	346.70	15.00	335.77	350.77	38.995	0.86	2.24	0.47	54.04	38.81	295.00	12.57	2.47	BDL
17	Dhromch	Zikzak	25°21’14.08”	89°51’11.55”	Dug well	6.98	321.30	BDL	212.06	BDL	61.05	61.05	99.260	10.92	0.33	BDL	26.02	24.26	165.00	16.81	13.75	BDL
18	Mahendraganj	Zikzak	25°18’12.61”	89°51’03.25”	Dug well	8.44	497.30	0.40	328.22	24.00	250.30	274.30	53.175	14.97	1.83	0.65	54.04	26.67	245.00	44.14	12.22	BDL
19	Debajani	Zikzak	25°19’12.15”	89°54’38.46”	Dug well	7.26	232.10	BDL	153.19	BDL	103.78	103.78	38.995	4.78	5.66	0.50	22.02	18.19	130.00	8.36	13.51	0.162
20	Rimtangpara	Zikzak	25°18’56.61”	89°58’15.03”	Dug well	7.33	158.30	BDL	104.48	BDL	115.99	115.99	70.900	0.16	0.23	0.15	30.02	30.33	200.00	4.45	3.49	0.218

Annexure 6: Ground water resource

a) General Description of Ground Water Assessment in South West Garo Hills district for 2019-20 (area in ha)

Name of Ground Water Assessment Unit	South West Garo Hills
Type of Ground Water Assessment Unit	District
Type of rock formation	Alluvium and Sandstone
Total area of Groundwater Assessment Unit	89600 ha
Hilly area	33577
Command area	0
Non-command area	56023
Poor ground water quality area	0
Area considered for groundwater recharge	56023

b) Ground Water Resource Potential in South West Garo Hills district during 2019-20

Assessment Unit / District	South West Garo Hills
Command/ Non-Command/ Total	Total
Recharge from rainfall during monsoon season	8789 ham
Recharge from other sources during monsoon season	83 ham
Recharge from rainfall during non-monsoon season	2172 ham
Recharge from other sources during non-monsoon season	1024 ham
Total Ground Water Recharge	12077 ham
Annual extractable Ground Water	9866 ham

c) Ground Water extraction for All Uses in South West Garo Hills district

District	South West Garo Hills
Total extraction for domestic and industrial purpose (as per households)	267 ham
Total extraction for irrigation	2655 ham
Total groundwater extraction	2922 ham

d) Balance Ground Water Resources Available and Stage of Groundwater extraction in the Study Area as On 31st March 2020

Assessment Unit / District	South West Garo Hills
Command/ Non-Command/ Total	Total
Annual Extractable Ground Water Availability	9866 ham
Existing Gross Ground Water extraction for Irrigation	2655 ham
Existing Gross Ground Water extraction for domestic and industrial water supply	267 ham
Existing Gross Ground Water extraction for All Uses	2922 ham
Provision for domestic, and industrial requirement supply to 2025	313 ham
Net Annual Ground Water Availability for future development	6898 ham
Stage of ground water extraction	29.62 %

e) Categorization for Ground Water Development of South West Garo Hills district during 2019-20

Assessment/ Administrative Uint	Stage of Ground Water extraction %	Quantity Categorization (Safe/Semi-Critical/ Critical/ Over Exploited)	Quality Tagging	Validation of Assessment using GW Level Trends (Valid/To be Re-assessed)
South West Garo Hills	29.62	Safe	Fresh	Could not validate , WL data not sufficient/ representative

Annexure 7: Soil Infiltration Test Data

a. Location – Dengnakpara

Time (t)	Time difference	After filling	Before filling	Depth of Infiltration	Cummulative Infiltration	Infiltration rate	f-fc	Remarks
min	min	cm	cm	cm	cm	cm/hr	f0	
0		20		0	0	f0 = 24 from the curve	ft	
1	1	20	17.6	2.4	2.4	144	120	
2	1	17.6	15.8	1.8	4.2	108	84	
3	1	15.8	14.5	1.3	5.5	78	54	
4	1	14.5	13.2	1.3	6.8	78	54	
5	1	13.2	12	1.2	8	72	48	
6	1	12	11.2	0.8	8.8	48	24	
7	1	11.2	10.4	0.8	9.6	48	24	
8	1	10.4	9.6	0.8	10.4	48	24	
9	1	9.6	8.8	0.8	11.2	48	24	
10	1	8.8	8	0.8	12	48	24	
15	5	20	16	4	16	48	24	Refilled
20	5		12.7	3.3	19.3	39.6	15.6	
25	5		10	2.7	22	32.4	8.4	
30	5	20	17	3	25	36	12	Refilled
35	5		14	3	28	36	12	
40	5		11.8	2.2	30.2	26.4	2.4	
50	10	20	15.5	4.5	34.7	27	3	Refilled
60	10		11	4.5	39.2	27	3	
70	10		6.4	4.6	43.8	27.6	3.6	
90	20	20	12	8	51.8	24	0	Refilled
110	20	20	12	8	59.8	24	0	Refilled
130	20	20	12	8	67.8	24	0	Refilled

Rainfall Recharge Factor	
Quantum of water applied in m	0.678
Quantum of water infiltrated in m	0.08
Sy (16 %)	0.16
Dengnakpara RRF	1.9

b. Baladinggre

Time (t)	Time difference	After filling	Before filling	Depth of Infiltration	Cummulative Infiltration	Infiltration rate	f-fc	Remarks
min	**min**	**cm**	**cm**	**cm**	**cm**	**cm/hr**	**f0**	
0		**25.3**		**0**	**0**	**f0 = 28.5 from the curve**	**ft**	
1	1	25.3	24.3	1	1	60	31.5	
2	1	24.3	23.3	1	2	60	31.5	
3	1	23.3	22.8	0.5	2.5	30	1.5	
4	1	22.8	22	0.8	3.3	48	19.5	
5	1	22	21.5	0.5	3.8	30	1.5	
6	1	21.5	21	0.5	4.3	30	1.5	
7	1	21	20.3	0.7	5	42	13.5	
8	1	20.3	19.8	0.5	5.5	30	1.5	
9	1	19.8	19.3	0.5	6	30	1.5	
10	1	19.3	18.8	0.5	6.5	30	1.5	
15	5	25.3	22.7	2.6	9.1	31.2	2.7	Refilled
20	5	22.7	20.1	2.6	11.7	31.2	2.7	
25	5	20.1	17.5	2.6	14.3	31.2	2.7	
30	10	17.5	15.7	1.8	16.1	10.8	-17.7	
40	10	25.3	20.5	4.8	20.9	28.8	0.3	Refilled
50	10	20.5	15.7	4.8	25.7	28.8	0.3	
60	10	15.7	10.9	4.8	30.5	28.8	0.3	
80	10	25.3	15.8	9.5	40	57	28.5	Refilled
100	20	25.3	15.8	9.5	49.5	28.5	0	Refilled
120	20	25.3	15.8	9.5	59	28.5	0	Refilled

Rainfall Recharge Factor	
Quantum of water applied in m	0.59
Quantum of water infiltrated in m	0.285
Sy (16 %)	0.16
Baladinggre RRF	7.73 %

c. Bakalai Chimi

Time (t)	Time difference	After filling	Before filling	Depth of Infiltration	Cummulative Infiltration	Infiltration rate	f-fc	Remarks
min	min	cm	cm	cm	cm	cm/hr	f0	
0		24.4		0	0	f0 = 1.2 from the curve	ft	
1	1	24.4	24	0.4	0.4	24	22.8	
2	1	24	23.9	0.1	0.5	6	4.8	
3	1	23.9	23.8	0.1	0.6	6	4.8	
4	1	23.8	23.7	0.1	0.7	6	4.8	
6	2	23.7	23.5	0.2	0.9	6	4.8	
8	2	23.5	23.4	0.1	1	3	1.8	
10	2	23.4	23.3	0.1	1.1	3	1.8	
15	5	23.3	23.1	0.2	1.3	2.4	1.2	
20	5	23.1	22.9	0.2	1.5	2.4	1.2	
25	5	22.9	22.8	0.1	1.6	1.2	0	
30	5	22.8	22.7	0.1	1.7	1.2	0	
35	5	22.7	22.6	0.1	1.8	1.2	0	
40	5	22.6	22.5	0.1	1.9	1.2	0	
50	10	22.5	22.3	0.2	2.1	1.2	0	
60	10	22.3	22.1	0.2	2.3	1.2	0	
70	10	22.1	21.9	0.2	2.5	1.2	0	
80	10	21.9	21.7	0.2	2.7	1.2	0	
100	20	21.7	21.3	0.4	3.1	1.2	0	
120	20	21.3	20.9	0.4	3.5	1.2	0	
140	20	20.9	20.5	0.4	3.9	1.2	0	

Rainfall Recharge Factor	
Quantum of water applied in m	0.039
Quantum of water infiltrated in m	0.012
Sy (16 %)	0.16
Bakalai Chimik RRF	4.92

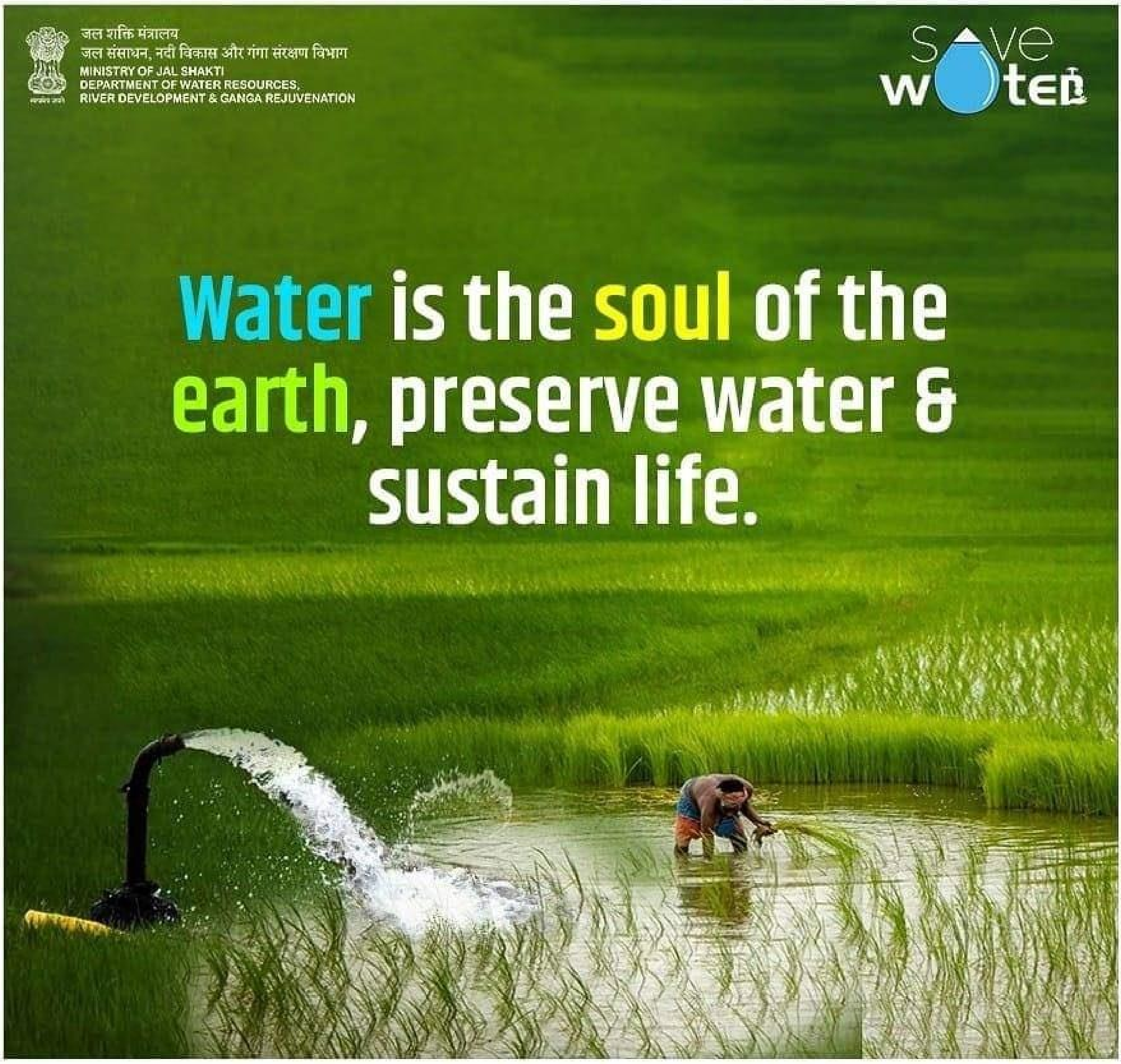
FIELD PHOTOGRAPHS

Spring discharge measurement during Post-Monsoon and pre-monsoon

Water level measurement during post-monsoon and pre-monsoon season

Interacting with farmers

Tube well irrigation for rabi paddy at Mahendraganj



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