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

SOUTH WEST KHASI HILLS 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 SOUTH WEST KHASI HILLS DISTRICT, MEGHALAYA"

(AAP 2018-19)

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Preface

Under National Aquifer Mapping and Management Plan (NAQUIM) program, Central Ground Water Board, State Unit Office, Shillong has carried out aquifer mapping and management plan in South West Khasi 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 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.

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 untiring 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.

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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.

I thank all the officials and staff of CGWB, SUO, Shillong for their help and support during the course of this work.

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ABBREVIATION

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

EXECUTIVE SUMMARY

Aquifer Mapping studies and Management Plan has been carried out in South West Khasi 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.These studies has been done through multi-disciplinary approach so as to achieve the said objectives.

Out of the total area of 1401 sq.km of the district, the total coverage area of aquifer mapping and management plan is 609 sq.km, which is underlain by consolidated rocks of Granite, Gneiss, Sandstone and Limestone.

Occurrence of ground water in the study area is mainly of weathered and fractured Granite, Gneiss, Sandstone and Limestone. Being a hard rock terrain, 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. The second aquifer is the deeper aquifer which tapped the fractured zone.

A detailed study of these two aquifers could not be carried out as CGWB has not carried out any ground water exploration studies in the area and during the NAQUIM program, sites were selected for ground water exploration but some miscreants burned down the rig while it was on its way. Therefore, delineation of the potential aquifers and their geometry, determining the hydrogeological parameters of the aquifer systems could not be established.

Monitoring of water level in one dug well was done. Study of spring was also carried out in the study area. Most of these springs were depression and topographic or fractured springs. It is observed that the discharge of springs in this area ranges from 0.06 to 62.4 litre/minute during May 2018 and 0.06 to 3 litre/minute during December 2018.

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 and were analyzed and it was found that the water quality is good and all the parameters are within permissible limit.

Surface Geophysical studies in the study area were carried out to delineate the subsurface geology in the study area. A total of 12 VES were conducted in South West Khasi Hills district during AAP 2010-11.

Dynamic Groundwater Resources of the study area has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'15). The annual extractable ground water resources are 11562.46 ham and the stage of ground water extraction is 0.08% which comes under safe category.

Finally 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 Khasi Hills district, Meghalaya during AAP 2018-19 covering an entire area of 609 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 hydro-geochemical analysis, remote sensing, besides detailed hydrogeological surveys to delineate multi aquifer system; to bring out the efficacy of various geophysical techniques and a protocol for use of geophysical techniques for aquifer mapping in different hydrogeological environs.

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

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

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

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

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

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

(iv) Pumping test of bore wells, soil infiltration test, 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.

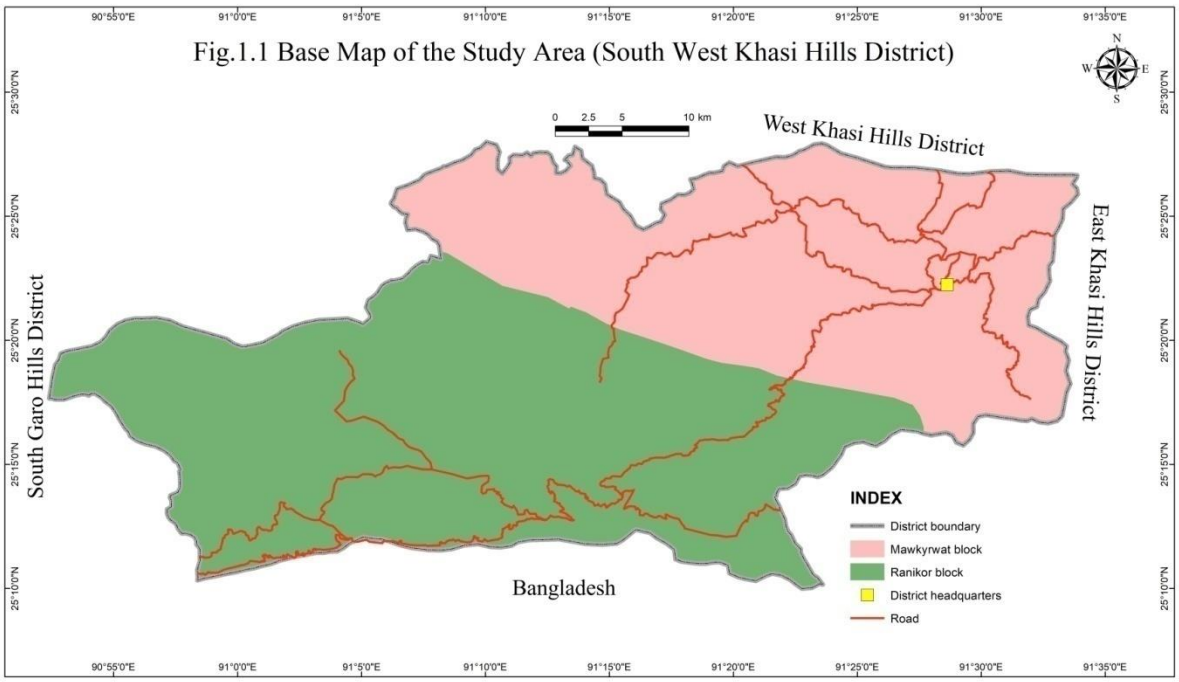
(v) Collection of various relevant technical data from the field in aquifer mapping area and also from the concerned State Govt. Agencies and other Institutes dealing with ground water and incorporating these data along with CGWB data for final output.

(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 Area details: South West Khasi Hills district lies between E 90˚53’00” to E 91˚34’00” Longitude and N 25˚10’00” to N 25˚27’00” Latitude. The district is having an area of 1341 sq.km and out of this, 609 sq.km of map able area was covered under NAQUIM program. The district has two C. &R.D. which are given Mawkyrwat C & R.D. block and Ranikor C & R.D. block.

This area falls partly or fully in the quadrants of Survey of India Toposheets bearing nos. 78 K/15, 78 K/16, 78 O/3, 78 O/4, 78 O/7, 78 O/8 and 78 O/11 and is bounded by East Khasi Hills district in the East, Bangladesh in the south and West Khasi Hills district in the North and West Khasi Hills and South Garo Hills in the West. The base map of the study area is shown in fig.1.1



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 Gap is shown in Fig.1.2 and Data Requirement, Data Availability and Data Gap Analysis are presented in table 1.1and annexure 6.

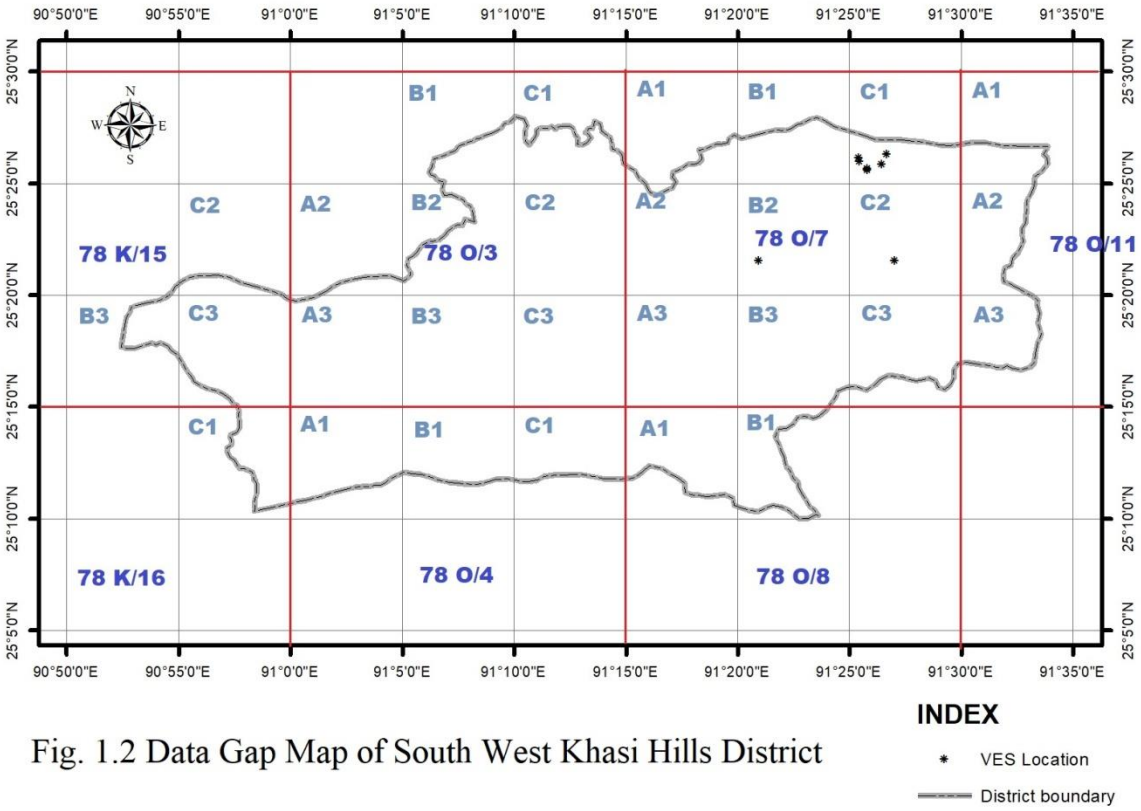


Fig. 1.2 Data Gap Map of South West Khasi Hills District

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

Sl. No.	Items	Data Requirement	Data Availability	Data Gap
1	Ground Water Exploration Data	Both first aquifer and second aquifer	NIL	I Aquifer : 16 nos. of EW & OW. II Aquifer : 16 nos.of EW & OW.
2	Geophysics	Geophysical data of the Study area	12 VES	Entire study area
3	Ground Water Monitoring Regime	Representative Monitoring Wells well-distributed over the Study Area	Nil	I Aquifer : 29 nos. II Aquifer : 29 nos.
4	Ground Water Quality	Representative water quality data well-distributed over the Study Area.	Nil	I Aquifer : 29 nos. II Aquifer : 29 nos.
5	Specific yield (Shallow and deeper aquifer)	Both aquifers	Nil	Entire study area
6	Climate	Season-wise Rainfall pattern	Monthly Rainfall, 1 Rain gauge station	Available
7	Soil	Soil map and Soil Infiltration Rate	Soil map	Soil Infiltration studies covering the entire study area
8	Land use	Latest Land Use pattern	Latest Land Use pattern	Data Available

9	Geomorphology	Detailed Information on Geomorphology of the area	District level information	Available
10	Recharge Parameters	Recharge parameters for different soil and aquifer types based on field studies	Recharge parameters given in GEC 2015	Entire study area

1.6 Demography: As per Census 2011 the total population of the District is 98,583 with 49,845 males and 48,738 females. The literacy rate is 76.84 %.

Total population	98583
Male population	49845
Female population	48738
Population Growth	30.25%
Area Sq. Km	1335.78
Density/sq.km	73

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

Name of Block	Total no. of household	Population			Literacy
		Adult	Children	Total	
Mawkyrwat C & RD Block	9037	42577	11788	54365	80.96%
Ranikor C & RD Block	7772	31871	8918	40789	63.30%

1.7 Communication: South West Khasi Hills district forms the southern portion of Meghalaya and the State Highway passes through the heart of the district and serves as the main communication line to other districts of the state. The headquarters of the district is at Mawkyrwat which is located at 78 km away from the state capital Shillong.

1.8 Climate: The climate of the district is mildly tropical in the northern and southern foothills, while in the central upland zone, the climate is temperate and places at medium altitude in the northern, western and southern parts of the district, experience sub-tropical climate. The district is influenced by the south-west monsoon and rainfall is assured during summer, but differs greatly in intensity from area to area within the district. The average rainfall ranges from 1200 mm to 3000 mm per annum.

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

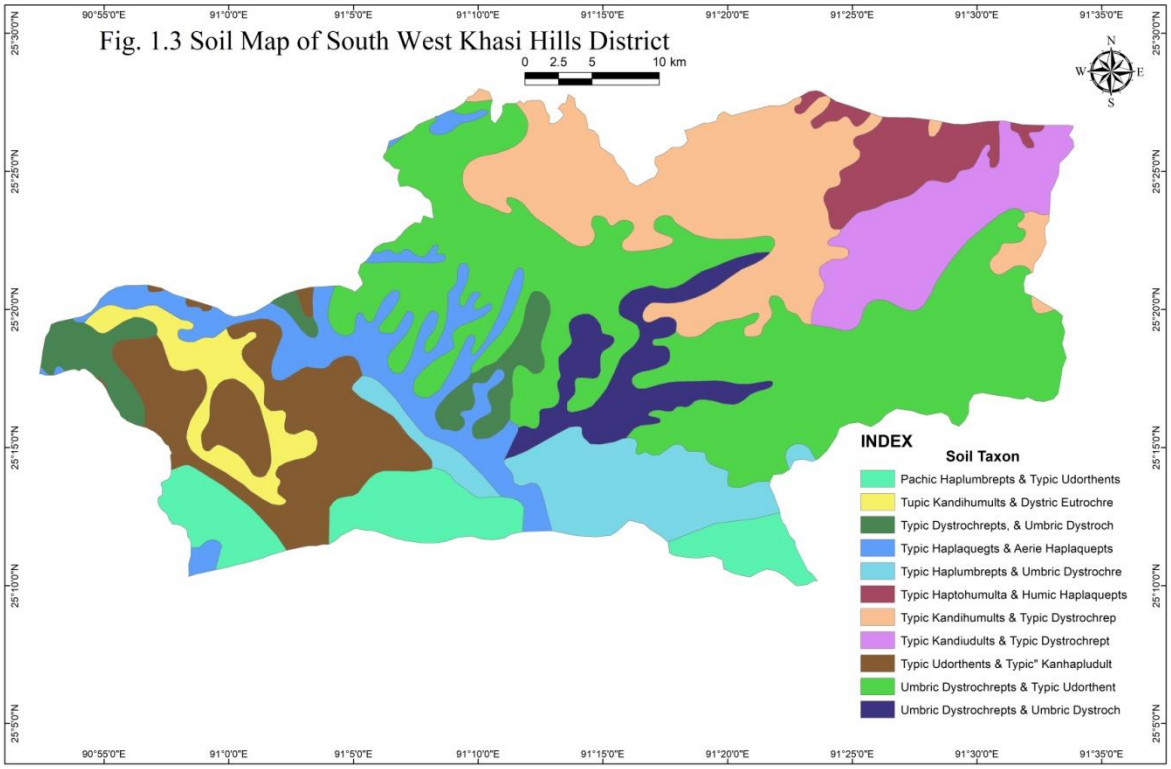
Table 1.2: Land use pattern in South West Khasi Hills, 2015-16

Land Classifications	**Area in hectares**
A. Geographical Area	140100
B. Reporting Area	140090
1. Forests (classed & unclassed)	50508
2. Area not available for cultivation (i)Area under non-agricultural uses	
a. Area under non-agricultural uses	
b. Water logged land	0
c. Social Forestry	910
d. Land under still water	2134
e. Other land	5120
TOTAL (Column a to e)	
(ii) Barren and uncultivable lands	16654
TOTAL = Col. i& ii	24818
3. Other uncultivable lands a. Permanent pastures and other grazing lands	
b. Land under Misc. tree crops & grooves etc.	11156
c. Cultivable wastelands	23733
TOTAL = (a+b+c)	34889
4. Fallow lands a. Fallow lands other than current fallows	12504
b. Current fallows	6361
TOTAL = (a+b)	18865
5. Net area sown	11010
6. Area sown more than once	2122
7. Total Cropped area	13132

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

1.10 Soil: High rainfall, humid subtropical climate and favorable topography have resulted in the formation of soil profile (1-8 m) in the study area. The soil in the study area is mostly loamy, 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 in the area gave

rise to sandy and permeable texture soils. 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 1.3.



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

1.11 Agriculture: Agriculture is the main means of livelihood of the people in the district and majority of the population is dependent on agriculture. The area is endowed with diversified climatic condition thereby offering good scope for cultivation of temperate and subtropical crops. The principal crops of the study area are Rice, Maize, Potato, Soya-bean, Mustard, Betel Nuts & Betel Vine, Kharif & Rabi Vegetables, Spices, Mandarin Oranges, Plum, Peach, Papaya, Jackfruit, Lichi, Pineapple, Mangos, Tamarin, and Banana etc. The season wise cropping pattern of South West Khasi Hills is shown in Table 1.3.

Table 1.3 Season wise cropping pattern of South West Khasi 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.

Present area under different crops and their productivity is shown in table 1.4.

Table 1.4: Area under different crops and their productivity, South West Khasi Hills district (2015-16)

Crops	Area (ha)	Avg.Yield (kg/ha)
Autumn rice	64	2250
Winter rice	1724	1848
Spring rice	38	2658
Maize	2027	1677
Pulses	9	2556
Rape and mustard	5	1400
Soyabean	5	1600
Small Millets	39	133
Sesamum	7	1429
Citrus fruits	1116	5118
Pineapple	527	6213
Banana	279	5351
Papaya	20	6150
Potato	2020	12890
Sweet Potato	296	3334
Tapioca	277	6502
Ginger	61	9656
Turmeric	51	4529
Chillies	22	1227
Black pepper	86	884
Arecanut	598	1261
Rubber	260	135
Coffee	34	382
Total	**9565**	**3443**

Source: Agriculture Department, Govt. of Meghalaya.

1.12 Irrigation: The district does not have any major or medium irrigation projects. Agriculture is dependent mainly on rainfall. There are 11 nos. of minor irrigation schemes available in the district. All these minor irrigation schemes are based on surface water sources. Salient features of minor irrigation schemes in South West Khasi Hills district are given in Table1.5.

Table 1.5 Salient features of minor irrigation schemes/project in South West Khasi Hills

Sl. No.	Name of the Project	Potential area created (Hectare)	Remarks
1	Umkynja	75	
2	Upper Umrilang	121	
3	Pynden Mawramhah FIP	219.54	
4	Pyndendiwah FIP	18	
5	Mawpen Markhew FIP	85	
6	Sobma FIP	19.45	
7	Beimariang FIP	18.5	
8	Bribakaw FIP	20	
9	Diwah FIP	18	
10	Diliengriem FIP	9.5	
11	Thynniaw FIP	19.5	

Source: Water Resource Department, Govt. of Meghalaya.

1.13 Industries: In South West Khasi Hills district, there are no major industries however there has been a steady increase in the number of registered small scale units which are mostly in the tiny sector like printing press, betelnut processing, bakeries, furniture making, Iron and steel fabrication, tailoring, knitting, Handicrafts, car washing centre, electronic repairing, refilling centre etc.

1.14 Forest: The District is very rich in natural resources. The forest types of the District comprise of Sub-Tropical Pine Forest, Tropical Semi evergreen, Tropical Moist dry deciduous, Tropical dry and Bamboo mixed. As per Directorate of Economics and Statistics, the forest cover area is about 50508 ha (2015-16).

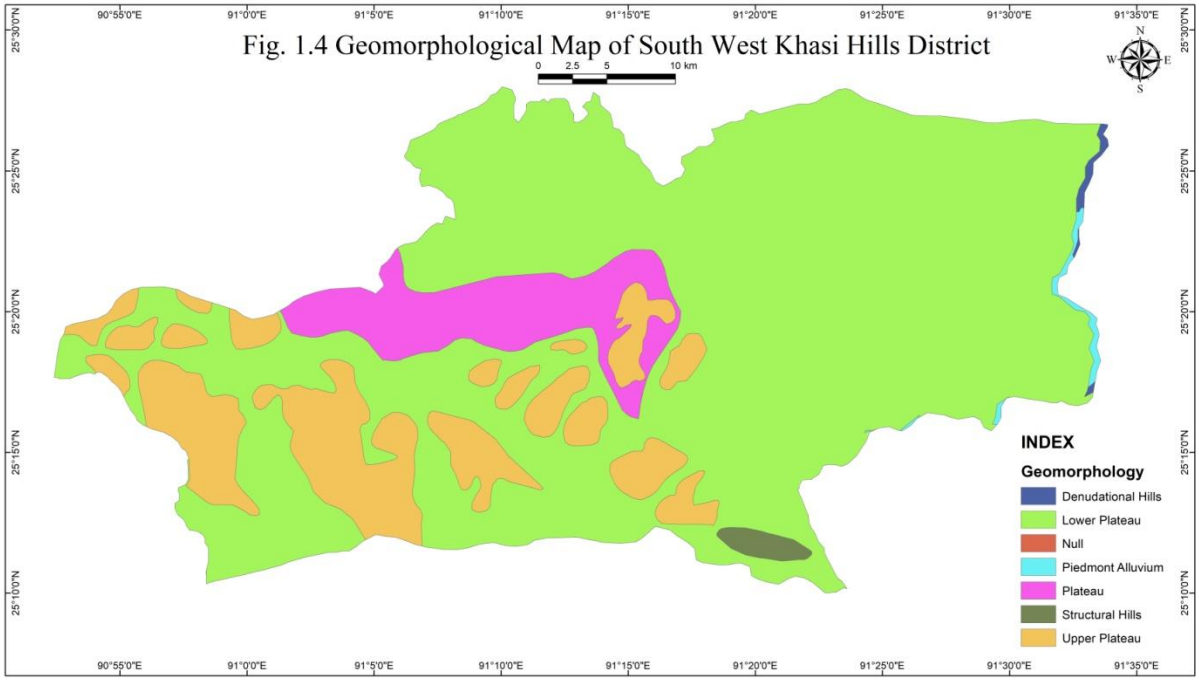
1.15 Geomorphology: Geomorphologically the district is an undulatory terrain with the E-W trending Khasi hill ranges of Central Upland zone. The South West Khasi Hills district also represents the remnant of ancient plateau of Indian Peninsular shield that is deeply dissected suggesting several geotectonic and structural deformities that the plateau has undergone. The average altitude of the Central Upland is about 1000 m above Mean Sea Level. Geomorphologically, the district represents denudational hills of old gneissic rocks and a highly dissected plateau is observed as shown in figure 1.4. Few narrow elongated intermontane valleys are seen along major lineaments. Broadly, the district can be differentiated into the following geomorphic units

i. Denudational Low and High Hills: It occupies minor part of the district on the eastern side comprising of hard rock like granite and gneiss. It is moderately dissected by fractures and joints forming a good number of narrow intermontane valleys.

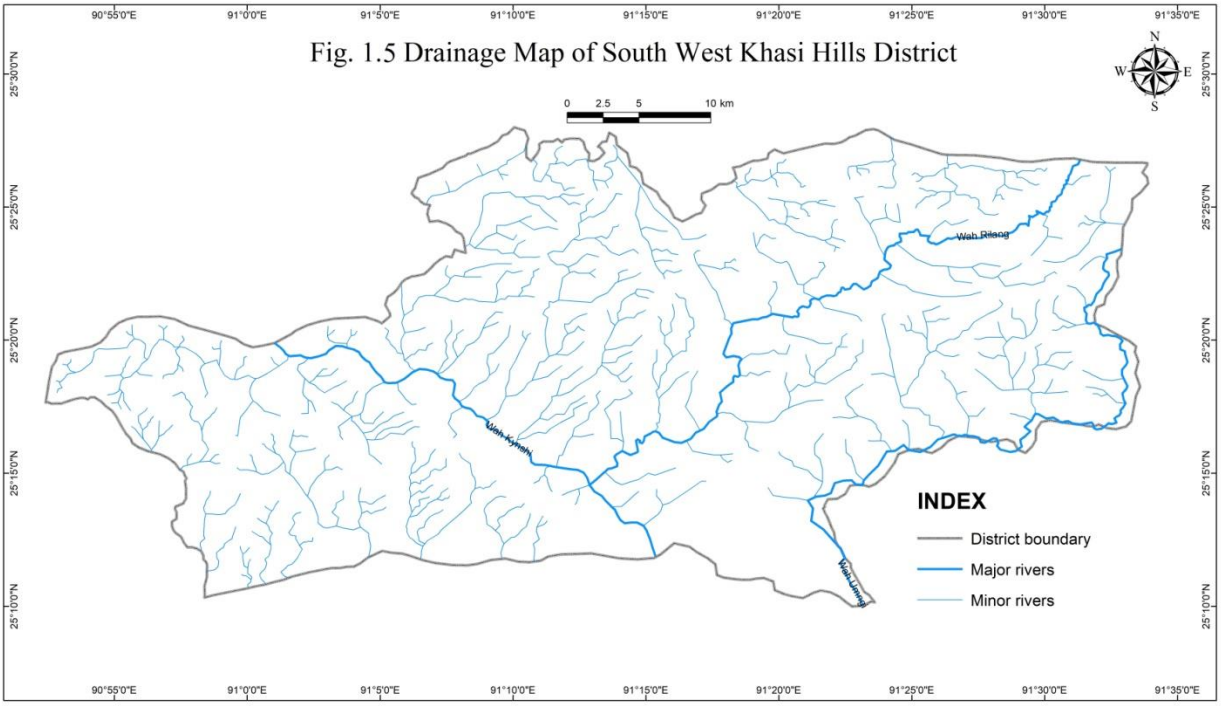
ii. Plateau: It occupies the major portion of the district comprising of rocks like sandstone, Limestone, Granite and Gneiss.

iii. Deep Gorges: It is exposed in the southern parts comprising of Tertiary rocks like sandstone and limestone.

iv. Structural hills: It is found on the southern most portion of the district as shown in the figure.



1.16 Drainage: The drainage pattern of dendritic, angular, trellis types are found in the area which indicates both topographic and structural control. The major rivers in South West Khasi Hills district are Wah Rilang, Wah Umngi and Wah Kynshi and minor river includes Wah Sala, Wah Umjarain, Wah Langdew and Wah Mawlongroh etc. The drainage map is shown in Fig 1.5.



2. DATA COLLECTION AND GENERATION

One of the main objectives of the study was to collect various relevant technical data from the concerned State Government agencies and other Institutes dealing with ground water and incorporating these data along with CGWB data to generate strong data base. Based on the data availability and data gap analysis, the required sub-surface hydrogeological data, 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 Hydrogeology: Occurrence of ground water in the study area is mainly of weathered and fractured Granite, Gneiss, Sandstone and Limestone formation. The different hydrogeological data are generated through intensive field data collection.

2.1.1 Water level monitoring: In the study area, 1 dug well and 9 springs were established as key wells to study the water level, quality, spring discharge and its behavior periodically.

Phreatic Aquifer: Only one dug well was found in the study area which was established as key well for periodical monitoring of water level behavior and seasonal fluctuation. The details of key observation wells are presented in Annexure 1 & 2. Depth to Water Level and Spring discharge maps are presented in Fig 3.2 and Fig 3.3 respectively.

Confined/ Semi-confined Aquifer: Piezometric head in the district could not be monitored as no bore well was found in the district.

Springs: A total of 9 springs were established and monitored to know the type, discharge and their behavior. These springs could not be monitored periodically because of disturbed area and some NGOs not allowing to do field work.

The locations of these springs are given in table 2.1.

Table 2.1 Location of springs in South West Khasi Hills district

Sl. No.	Location	Block	Latitude	Longitude	RL (m)	Type of Spring	Lithology
1	Mawsdei	Mawkyrwat	25°24’17.89”	91°32’30.02”	1476	Fracture	Granite
2	Jakrem	Mawkyrwat	25°23’32.71”	91°30’38.30”	1608	Depression	Granite
3	Mawkyrwat	Mawkyrwat	25°21’57.70”	91°27’16.94”	1561	Fracture	Granite
4	Nonsmawlein	Mawkyrwat	25°22’26.98”	91°25’21.51”	1508	Fracture	Granite
5	Pottdei	Mawkyrwat	25°22'58.03"	91°23’05.22”	1555	Depression	Gneiss
6	Mawiong	Mawkyrwat	25°24’41.31"	91°22’48.39"	1518	Fracture	Granite
7	Nonglwai -II	Mawkyrwat	25°27’13.05”	91°19’55.57”	1494	Depression	Granite
8	Mawthenrew	Mawkyrwat	25°20’27.60”	91°23’32.41”	1553	Depression	Gneiss
9	Nongkdait	Ranikor	25°16’00.86”	91°19’08.42”	972	Fracture	Sandstone

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 analyzed in the regional chemical laboratory, Central Ground Water Board, North Eastern Region, Guwahati for 17 parameters. The analytical data are given in Annexure 3.

2.3 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 12 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 4. The locations of the survey carried out are tabulated below;

Table 2.2 Location of VES survey carried out in South West Khasi Hills District

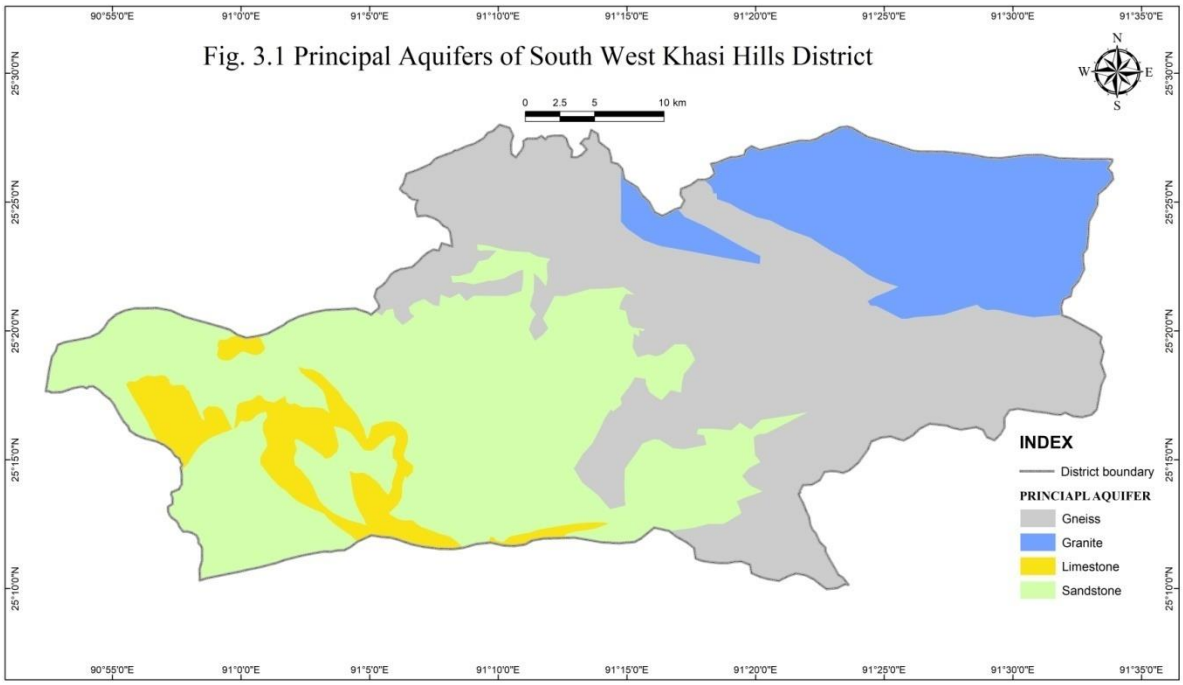
Sl. No.	Village	Coordinates	Layer Resistivity in Ohm-m					Layer Thickness in meters						Total Depth in m.	Remarks with expected zones/ fractures (for recommended sites)
			ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	P_6	h_1	h_2	h_3	h_4	h_5		
1	Mawramhoh	N 25°25'39.7" E 91°25'48.4"	3000	1800	150	450			1	6.1	11			18	
2	Mawramhoh	N 25°25'36.7" E 91°25'47.5"	2800	2200	400	750			1	7	14			22	
3	Mawsap	N 25°25'51.0" E 91°26'26.3"	6500	1600	5000	400	250		1	1.5	6.5	31		49	
4	Mawsap	N 25°26'18.5" E 91°26'39.6"	4000	2500	3500	150			1	2.2	7			10	
5	Mawsynrap (West)	N 25°25'59.6" E 91°25'26.1"	4500	1500	150	200			1	4.4	8.5			14	Zones 15-80m
6	Mawsynrap (West)	N 25°26'08.0" E 91°25'25.4"	4500	1000	80	180			1	2.9	8			12	
7	Mawkyrwat		450	900	25	200			1	1.4	8.6			11	
8	Mawkyrwat		100	200	50	500			1	3.7	24			28	
9	Mawkyrwat	N 25°21'32.7" E 91°27'01.1"	130	70	230				6	19				25	Zones up to 25m and fractures up 90m
10	Mawkyrwat		170	30	300				3	8.5				11	
11	Mawkyrwat	N 25°21'32.5" E 91°20'57.0"	80	150	40	350			1	3	26			30	
12	Kynshi	N 25°25'59.6" E 91°25'26.1"	2100	140	650				5	13				18	

2.4 Ground water Exploration: The district has not been explored earlier. To know the aquifer CGWB & PHED has jointly selected 3 sites for ground water exploration. However, the studies could not be carried out in the district because the rig got burned down by some miscreants while it was on its way to the selected sites. Photographs of the incident are shown below.

Fig.1.6: Photographs of burnt Rig and Air Compressor Truck near Umngi River Bridge.

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

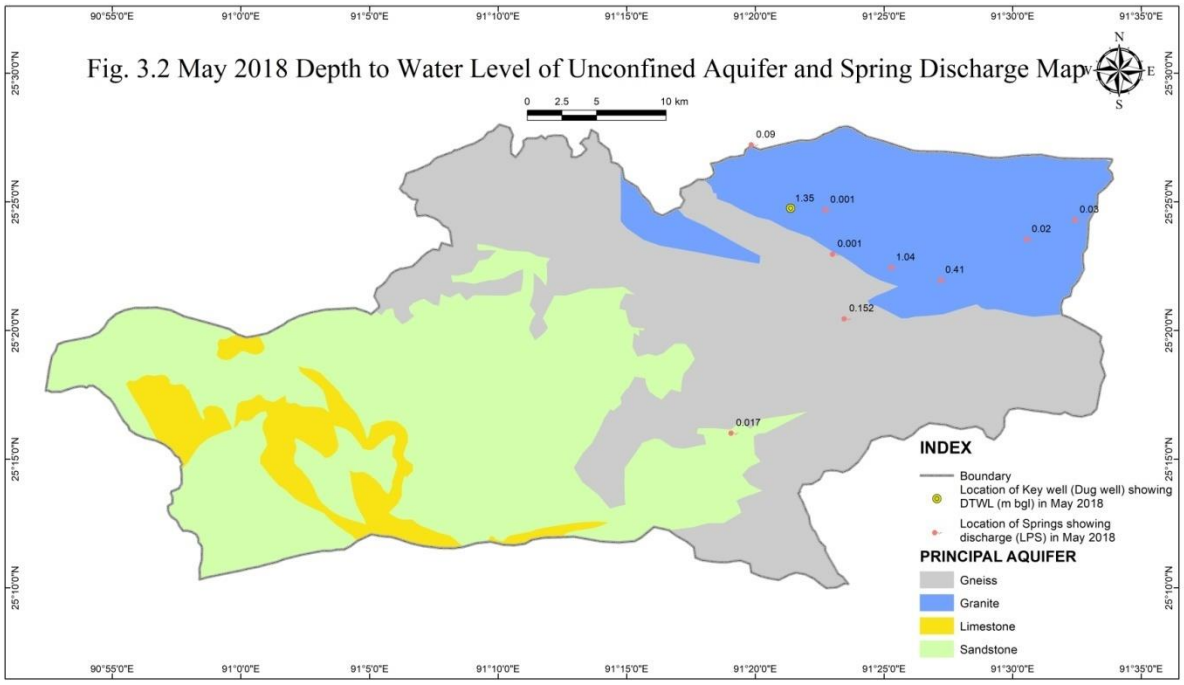
3.1 General Hydrogeology and Occurrence of Ground Water: The hydrogeological formation of the study area comprised of Gneiss, Granite, Sandstone and Limestone. The presence of weak planes like fractures and joints in these hard rock formation forms the principal aquifer in the district. The ground water in the district occurs under unconfined to semi-confined conditions. The principal aquifer of the district is shown in fig 3.1.

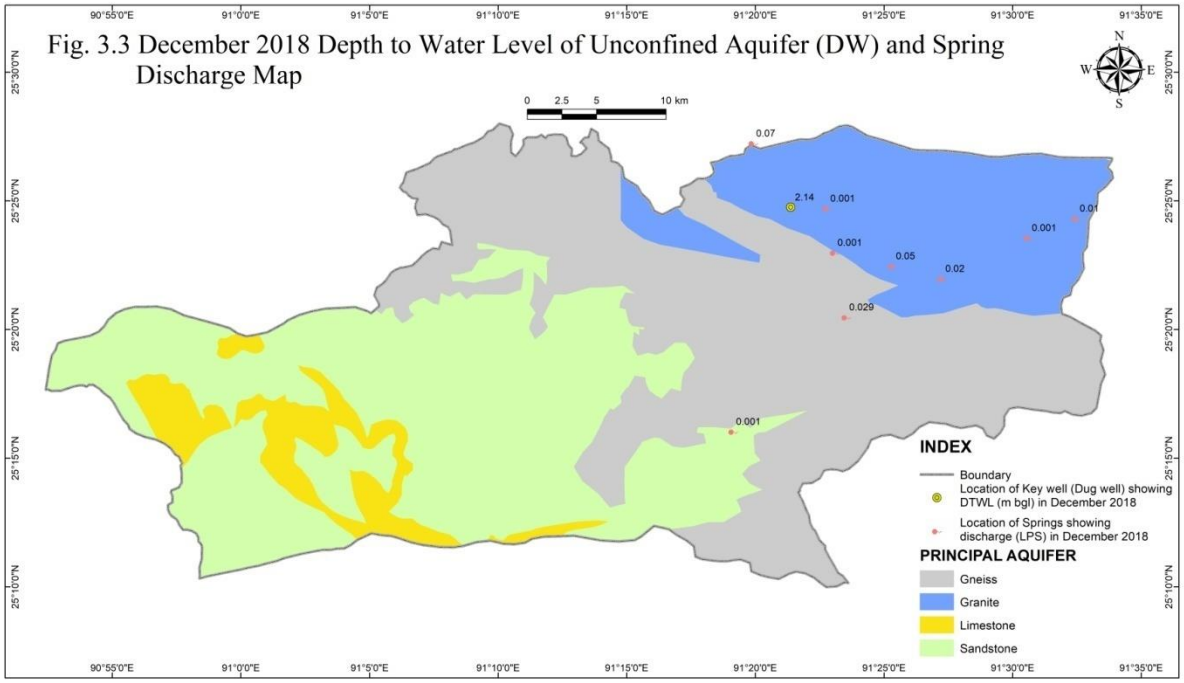


3.1.1 Occurrence of Ground Water in Shallow Aquifer: The depth of shallow aquifer in the district ranges from 5 to 30 meters. Groundwater occurs under unconfined condition in this shallow aquifer. In the valleys, people use to dig 1 to 4 m to collect water and these structures are called as spring tap chamber. Whereas, during field studies (especially along Jakrem – Mawkyrwat section) it was found that many of these structures are actually very shallow dug wells and during rainy season (April to October) water from these structures used to overflow. This happens because the area receives heavy rainfall, most of the water percolated through weathered residuum comes to narrow valley and makes them water logged. Ground water from shallow aquifer is exploited through dug wells/ spring tap chambers. One dug well found at Rangblang was established as key well for periodical monitoring of water level. The depth to water level in these dug well was 1.35 m bgl during

May 2018 and 2.14 m bgl during December 2018 and is shown in fig 3.2 and fig. 3.3 and the seasonal water level fluctuation is 0.79 m.

3.1.2 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. Most of the villagers are highly depended on the springs for their drinking and domestic purposes. A total of 9 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 in this area ranges from 0.06 to 62.4 litre/minute during May 2018 and 0.06 to 3 litre/minute in the month of December 2018 and is show in fig 3.2 and fig 3.3. It has also been observed that the discharge of springs has been increased during monsoon season and gradually decreases in post-monsoon and pre-monsoon.





3.2 Aquifer System: The entire study area is underlain by consolidated rocks of Granite, Gneiss, Sandstone and Limestone. The aquifer system exists in all the rock formations as weathered formation and fractured system. The depth of weathered zone varies from 5 to as high as 30 m below ground level.

3.3 Aquifer Geometry: 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/ spring tap chambers. It is presumed from the hydrogeological studies in the same type of rock formations exist in other parts of Meghalaya that a second (deeper) aquifer tapping the fractured zones of consolidated rocks is likely to exist between a depth of 30 to 200m. Based on the study of depth of construction of dug wells, it is found that the first aquifer occur upto a depth of 30 m bgl. Ground water in the second aquifer could not be studied as ground water exploration studies have not been carried in the district.

3.4 Aquifer Properties

Aquifer I: It is the unconfined aquifer where the tapping of aquifer zone ranges within 30 m depth and generally exhibits unconfined nature of the aquifer. In the study area tapping of Aquifer I is feasible only in valley area.

Aquifer II: The deeper aquifer in the district could not be explored. Hence, aquifer properties of this aquifer are also unknown.

3.5 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 springs, exploratory bore wells and dug wells were collected during the course of field work. The parameters analyzed are pH, EC, Turbidity, TDS, CO_3, Cl, SO_4, $CaCo_3$, Na, K, HCO_3, NO_3, F, Ca, Mg, TH and Fe. The details of chemical analysis were given in the Annexure 3.

3.5.1 Ground Water Quality of Unconfined Aquifer:

A total of 1 ground water sample from dug well was collected during post-monsoon studies and the range of concentrations of different chemical constituents present in the ground water samples are given in table 3.1.

Table 3.1: Chemical quality of water samples from dug well, South West Khasi Hills district

Sl. No.	Chemical Constituents	Value (Concentrations in mg/l except pH, EC, Turbidity & TDS)
1	pH*	7.17
2	EC* µS/cm at 25°C	84.00
3	Turbidity(NTU)	0.30
4	TDS	50.53
5	CO_3	BDL
6	HCO_3	25.02
7	TA as $CaCO_3$*	25.02
8	Cl*	42.54
9	SO_4	3.84
10	NO_3	1.46
11	F^-	0.06
12	Ca*	10.01
13	Mg*	7.28
14	TH*	55.00
15	Na*	5.81
16	K*	11.40
17	Fe	BDL

* NABL Accredited parameters

It is deciphered from table 3.1 that all of the chemical parameters are within permissible limit for all uses. The EC values are shown in fig 3.4, pH values in fig 3.6 and Fe conc. in fig. 3.5.

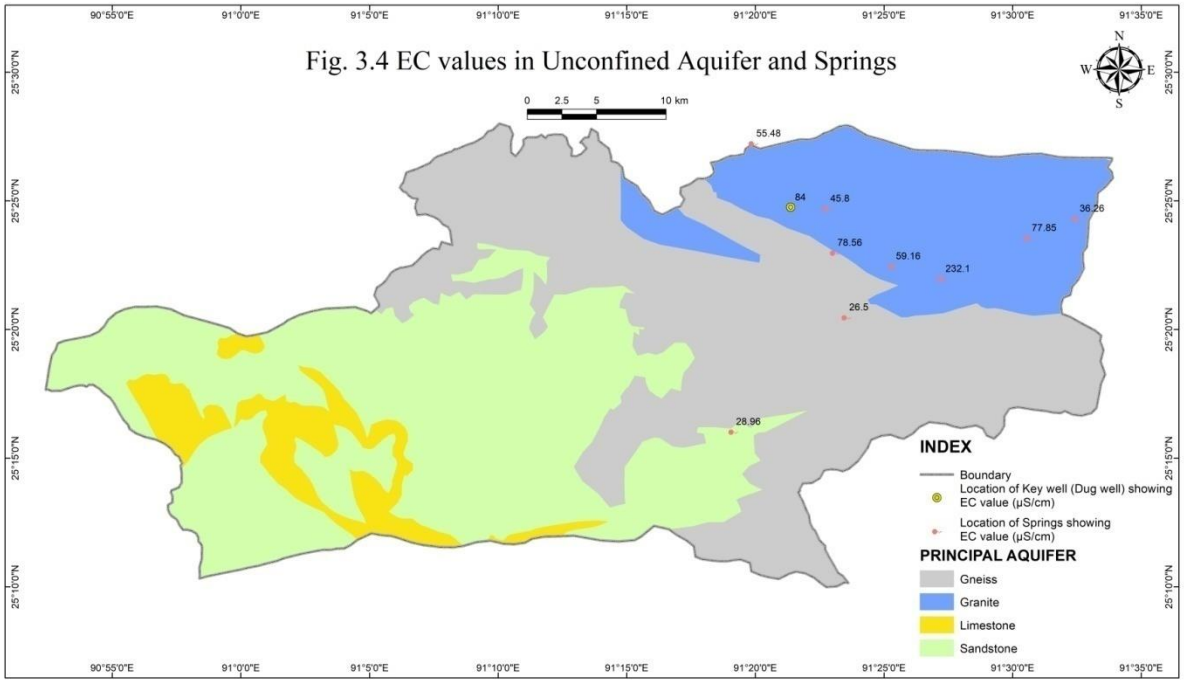
3.5.2 Water Quality of Springs: A total of 9 water samples from spring were collected during post-monsoon studies and the range of concentrations of different chemical constituents present in the spring samples are shown in table 3.2.

Table 3.2: Chemical quality of spring water, South West Khasi Hills district

Sl. No.	Chemical Constituents	Range (Concentrations in mg/l except pH, EC, Turbidity & TDS)	
		Minimum	**Maximum**
1	pH*	6.75	7.51
2	EC* µS/cm at 25°C	26.5	232.1
3	Turbidity(NTU)	BDL	0.4
4	TDS	15.84	140.4
5	CO_3	BDL	BDL
6	HCO_3	25.02	50.04
7	TA as $CaCO_3$*	25.02	50.04
8	Cl*	21.27	67.35
9	SO_4	1.62	14.96
10	NO_3	BDL	6.51
11	F^-	0.07	0.16
12	Ca*	6	24.02
13	Mg*	4.85	7.28
14	TH*	35	95
15	Na*	2.07	18.68
16	K*	3.37	17.36
17	Fe	BDL	0.11

* NABL Accredited parameters

It is deciphered from table 3.2 that all of the chemical parameters are within permissible limit for all uses. The EC values are shown in fig 3.4, pH values in fig 3.6 and Fe conc. in fig. 3.5.



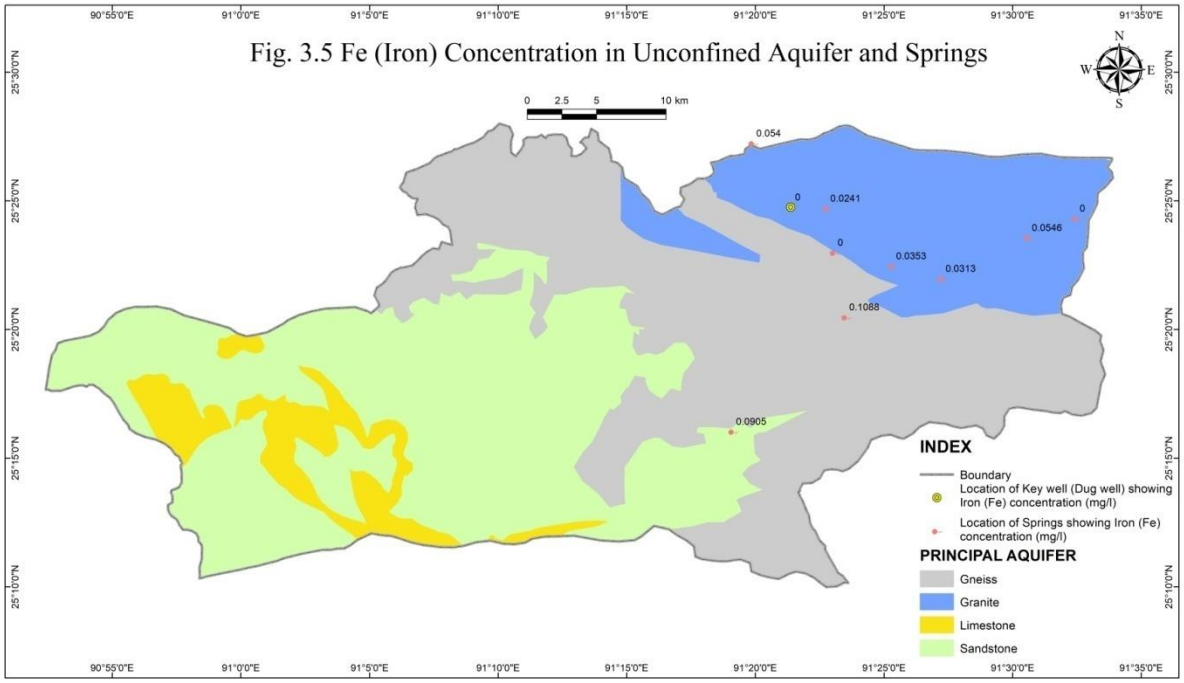


Fig. 3.5 Fe (Iron) Concentration in Unconfined Aquifer and Springs

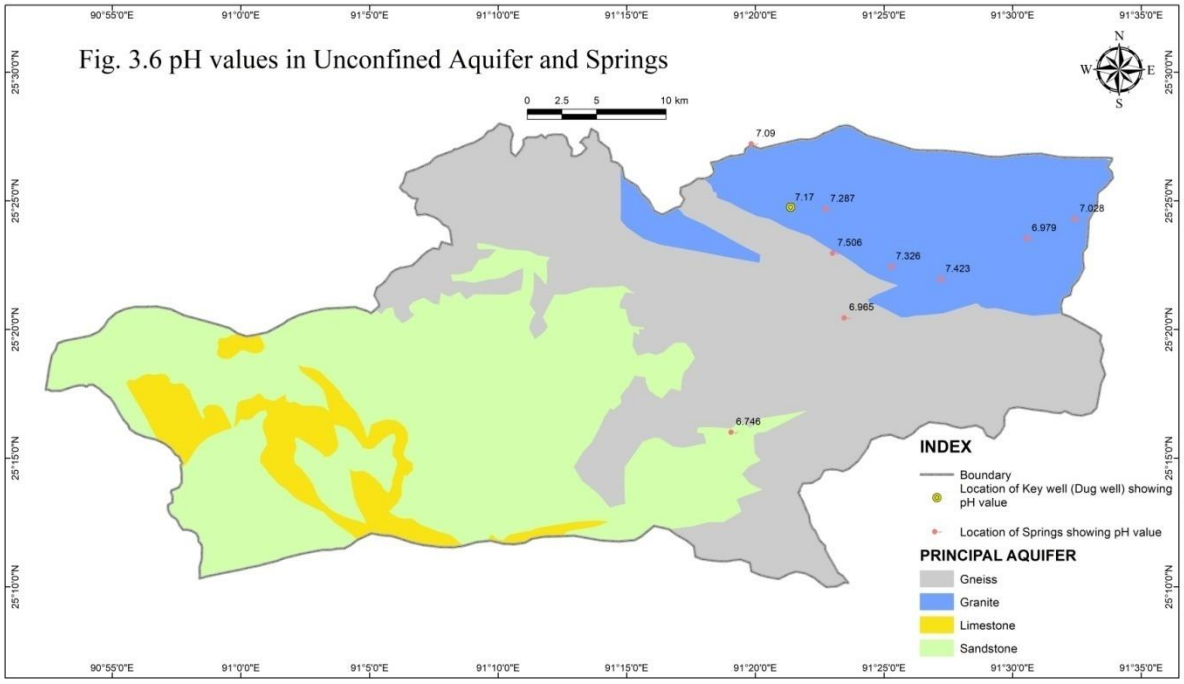


Fig. 3.6 pH values in Unconfined Aquifer and Springs

4. GROUNDWATER RESOURCES

Dynamic Groundwater Resources of South West Khasi Hills district has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'15). The resources computed for the groundwater year 2017-18. 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 1001 sq.km.

Poor Groundwater Quality Area: In the district, there is no map able 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 entire district is underlain by consolidated rocks of Granite, Gneiss, Sandstone and Limestone. Different units considered for computation of recharge are Granite, Gneiss, Sandstone and Limestone**.**

4.1 Groundwater Resources – Recharge for Various Seasons: The rainfall infiltration factor recommended by GEC'15 for Granite & Gneiss is 0.05 and Sandstone & Limestone is 0.06.

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 5.

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: Recharge from various sources (ham).

District	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	Resultant flow	Total Annual Recharge
South West Khasi Hills	10174.64	24.39	2642.25	5.90	0	12847.18

Recharge from rainfall in the district is 12816.89 ham .Comparison of monsoon & non-monsoon rainfall recharge shows that monsoon recharge accounts for 79%. In comparison to recharge from rainfall, recharge from sources other than rainfall shows that the later accounts for about than 0.2 % of the total recharge.

4.2 Groundwater extraction for Various Purposes: Groundwater extraction for domestic use has been estimated based on number of households using groundwater (Census 2011 data) and number of bore wells used by PHED to supply water and on number of structures used in different industrial units. Groundwater extraction for irrigation is nil. It was found that groundwater extraction for all uses in the district is 9.01 ham.

4.3 Stage of Groundwater extraction & Categorization of the Blocks: The district falls under "**SAFE"** category. The stage of Ground Water extraction is 0.08 %. Summary of groundwater resources, stages of development and categorization are given in annexure 5.

5. GROUND WATER RELATED ISSUES

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

5.1 Low Stage of Ground Water Extraction: As per ground water resource estimation 2017-18, the stage of ground water development is just 0.08 % and there is no utilization of ground water for irrigation in this area. All the irrigation schemes in the district are dependent upon the surface water resources. Therefore, there is enough scope for future development of ground water in the study area to bring more area under irrigation practice. At present the irrigation practice by utilizing ground water (constructing bore well) is not accepted by villagers due to small land holding, high cost for construction and running of a well compared to production outcome. Another major obstacle in accelerating ground water irrigation is the absence of power lines in most of the cultivated/cultivable area.

6. MANAGEMENT STRATEGIES

As per dynamic ground water resource estimation of South West Khasi Hills District for 2017-18, annual extractable ground water is 11562 ham and stage of ground water extraction is only 0.08%. The district is having balance net ground water availability for future development in the tune of 11544 ham. If an irrigation plan is made to develop 60% of the balance dynamic ground water resources available, then 9626 ham of groundwater resources is available in the district for the future irrigation uses. From this available resource (planned for future development) 9626 nos. of shallow tube wells (considering a unit draft of 1 ham/year) can be constructed in the aquifer mapping area. Therefore, there is enough scope for future development of ground water in the study area to bring more area under irrigation practice.

Present land under irrigation during kharif season is 1724 ha, during rabi season it is 309 ha. All the schemes which are used for irrigation is using surface water sources. Present irrigation from ground water source is almost nil. Hence, there is ample scope for ground water development for irrigation purpose which will bring prosperity to the society and help the district in achieving self-reliance on food grain. To use the groundwater for irrigation purpose a cropping plan has been designed for the district by using CROPWAT model developed by FAO. Cropping pattern data for the district is presented in table 6.1.

During 2015-16, net sown area in the district is 10999 ha, area sown more than once is 2121 ha and cropping intensity is about 100%. The net sown area included field crops as well as horticulture and plantation crops on slopes and hills. Cropping intensity is calculated generally from field crops, which are of short duration whereas horticulture (like citrus, banana, pineapple) and plantation crops like spices are long duration crops. Again crops grown on the hills like pineapple, turmeric and ginger are having negligible or nil irrigation requirements. During kharif season, paddy is cultivated in 1724 ha and land under Maize cultivation is 1364 ha. After Kharif crops were grown major portion of this area remains fallow during Rabi season. The intention of this plan is to bring this fallow land of about 1415 ha under assured irrigation during Rabi season and increase cropping intensity up to 200%. In rice fallow, pulses, mustard and rabi vegetables can be grown with the support of irrigation. 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\Mawkyrwat.PAT)

Cropping pattern name: Mawkyrwat

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	15
7	...CROPWAT\data\crop	Small Vegetables	05/02	10/05	13
8	...CROPWAT\data\crop	Small Vegetables	15/02	20/05	12

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

Cropping pattern (s)				
1. Rice 2. Rice-Pulses 3. Rice-Mustard 4. Rice-Vegetables	Present Cultivated area (**ha**)	Area to be cultivated (**%**)	Area to be cultivated (**ha**)	Irrigation requirement (**ha m**)
	1	2 (= % of 1)	3	4
Rice (main crop)	1415		1415	229
Pulses	23	15	400	46
Mustard	6	10	307	33
Vegetables	242	25	708	53
Net cultivated area	1415		**1415**	
Gross cultivated area (1+potato/+mustard/+Veg)	1686		**2830**	
Total irrigation requirement				361
Cropping intensity	**119% (Present)**		**200% (Intended)**	
Total (South West Khasi Hills district)				361

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

Rice based cropping pattern			
Crop	**Growing period (Months)**	**Periods/months of water deficit**	**Irrigation requirement (ha m)**
Rice	4	2-3	229
Pulses	4	4	46
Mustard	6	4	33
Vegetables	3	2	53

Table 6.3: Crop-wise and month-wise precipitation deficit (IWR) from CROPWAT 8, South West Khasi 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	147.3	59.5	0	0	0	2.4	0	0
2. Rice	0	0	0	0	49.2	98	0	0	0	0	0	0
3. Rice	0	0	0	0	59.5	62.7	0	0	0	0	0	0
4. Rice	0	0	0	0	0	147.1	0	0	0	4.3	0	0
5. Mustard	17.2	29.2	0	0	0	0	0	0	0	0	29.4	42.3
6. Pulses	26.4	10.5	0	0	0	0	0	0	0	0	21	50
7. Small Vegetables	0	35.5	49.9	0	0	0	0	0	0	0	0	0
8. Small Vegetables	0	21.7	41.3	0	0	0	0	0	0	0	0	0

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

Crops	% of total area of 2830 ha	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation deficit (ham)														
1. Rice	15	0	0	0	0	62.5	25.3	0	0	0	1.02	0	0	89
2. Rice	15	0	0	0	0	20.9	41.6	0	0	0	0	0	0	62
3. Rice	10	0	0	0	0	16.8	17.7	0	0	0	0	0	0	35
4. Rice	10	0	0	0	0	0	41.6	0	0	0	1.22	0	0	43
5. Mustard	10	4.87	8.26	0	0	0	0	0	0	0	0	8.32	11.97	33
6. Pulses	15	11.21	4.46	0	0	0	0	0	0	0	0	8.91	21.23	46
7. Small Vegetables	13	0	13.06	18.36	0	0	0	0	0	0	0	0	0	31
8. Small Vegetables	12	0	7.37	14.03	0	0	0	0	0	0	0	0	0	21
Total	100	16.07	33.15	32.38	0	100.25	126.23	0	0	0	2.24	17.23	33.20	361

Annual irrigation water requirement is 361 ham while irrigation water requirement during dry season spanning from October to March it is 134 ham. Again proportionate dynamic groundwater resources available for future irrigation use in the considered area are 11544.44 ham. Hence, this area can be brought under assured irrigation from groundwater sources. The demand of 361 ham can be harnessed by constructing dug/ bore wells. At possible places water harvesting methods should be employed.

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

The intermontane valleys are the most favorable places for ground water development. Structures like ring/dug well are feasible for ground water abstraction in the valley low lying area especially from Mawkyrwat towards Rangblang area. Hydrogeological studies have indicated that lineament, joint, fracture and fault are the main controlling factors for the occurrence and distribution of ground water. These structures can be targeted for ground water development.

A bore well in the area is expected to yield 8-10 m^3/hr. Bore wells can be designed within a depth of 100m, expected to encounter 2-3 fractures. Bore wells can be constructed by using 7.5$^{//}$ or 8$^{//}$ dia and a casing pipe down to 30 m or up to overburden.

The chemical quality of ground water indicates that groundwater in the area is good for drinking, domestic, irrigation and industrial uses. Chemical analysis shows that the spring water is of excellent quality and is suitable for drinking purposes as per BIS standard. The basic parameters of groundwater quality in the area are within permissible limit however detail water quality analysis of radioactive elements concentrations in the district can be further analyzed to know whether the water has higher concentrations of uranium which is very harmful for human consumption.

As the people in the rural areas are mainly dependent on spring water, there is an urgent need for scientific approach for proper development and management of these springs. It may be recommended that the development of springs will help in mitigating the water requirement of the people to a large extent.

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iv. **Central Ground Water Board, Ministry of Water Resources, NER, Guwahati** Dynamic Groundwater resources of Meghalaya State (as on march 2017)

v. **Central Groundwater Board, Ministry of Water Resources, New Delhi** Manual on Aquifer Mapping

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viii. **District Disaster Management Authority (2015),** District Disaster Management Plan, South West Khasi Hills district, Mawkyrwat.

Annexure 1: Dynamic water level data of dug well during 2018-19

Sl. No.	State*	District*	Block*	Village	Lat*	Long*	Well* Type	MP* (m)	RL* (m)	Drilled depth* (m)	Dia* (m)	Water Level (mbgl) May-18*	Water Level (mbgl) Dec-18*
KEY WELLS (NAQUIM 2018-19) DATA ENTRY FORM													
1	Meghalaya	South West Khasi Hills	Mawkyrwat	Rangblang	25°24’45.32"	91°21’21.78"	Dug well	0	1527	3.4	1.1	1.35	2.14

Annexure 2: Spring discharge data collected during 2018-19

Sl. No.	State	District	Block	Location	Latitude	Longitude	RL (m)	Type of Spring	Lithology	Discharge (LPS) May-18*	Discharge (LPS) Dec-18*
1	Meghalaya	South West Khasi Hills	Mawkyrwat	Mawsdei	25°24’17.89”	91°32’30.02”	1476	Fracture	Granite	0.03	0.01
2	Meghalaya	South West Khasi Hills	Mawkyrwat	Jakrem	25°23’32.71”	91°30’38.30”	1608	Depression	Granite	0.02	0.001
3	Meghalaya	South West Khasi Hills	Mawkyrwat	Mawkyrwat	25°21’57.70”	91°27’16.94”	1561	Fracture	Granite	0.41	0.02
4	Meghalaya	South West Khasi Hills	Mawkyrwat	Nonsmawlein	25°22’26.98”	91°25’21.51”	1508	Fracture	Granite	1.04	0.05
5	Meghalaya	South West Khasi Hills	Mawkyrwat	Pottdei	25°22'58.03"	91°23’05.22”	1555	Depression	Gneiss	0.001	0.001
6	Meghalaya	South West Khasi Hills	Mawkyrwat	Mawiong	25°24’41.31"	91°22’48.39"	1518	Fracture	Granite	0.001	0.001
7	Meghalaya	South West Khasi Hills	Mawkyrwat	Nonglwai -II	25°27’13.05”	91°19’55.57”	1494	Depression	Granite	0.09	0.07
8	Meghalaya	South West Khasi Hills	Mawkyrwat	Mawthenrew	25°20’27.60”	91°23’32.41”	1553	Depression	Gneiss	0.152	0.029
9	Meghalaya	South West Khasi Hills	Ranikor	Nongkdait	25°16’00.86”	91°19’08.42”	972	Fracture	Sandstone	0.017	0.001

Annexure 3: Aquifer wise water quality data of Aquifer mapping area

Sl. No	State	District	Location	Source	pH*	EC* µS/cm at 25°C	Turbidity (NTU)	TDS	CO_3	HCO_3	TA as $CaCO_3$*	Cl*	SO_4	NO_3	F^-	Ca*	Mg*	TH*	Na*	K*	Fe
									Mg/l												
1	Meghalaya	South West Khasi Hills	Rangblang	Dug well	7.17	84.00	0.30	50.53	BDL	25.02	25.02	42.54	3.84	1.46	0.06	10.01	7.28	55.00	5.81	11.40	BDL
2	Meghalaya	South West Khasi Hills	Mawsdei	Spring	7.03	36.26	BDL	21.75	BDL	30.02	30.02	31.91	3.02	BDL	0.16	8.01	8.49	55.00	3.61	8.11	BDL
3	Meghalaya	South West Khasi Hills	Jakrem	Spring	6.98	77.85	BDL	46.88	BDL	30.02	30.02	39.00	5.29	1.00	0.09	10.01	7.28	55.00	5.51	10.93	0.05
4	Meghalaya	South West Khasi Hills	Mawkyrwat	Spring	7.42	232.10	BDL	140.40	BDL	50.04	50.04	67.35	14.96	6.51	0.12	24.02	8.48	95.00	18.68	6.70	0.03
5	Meghalaya	South West Khasi Hills	Nonsmawlein	Spring	7.33	59.16	0.40	35.57	BDL	35.03	35.03	39.00	5.02	BDL	0.08	10.01	4.85	45.00	8.36	17.36	0.04
6	Meghalaya	South West Khasi Hills	Pottdei	Spring	7.51	78.56	0.20	47.20	BDL	40.03	40.03	39.00	4.46	BDL	0.14	6.00	8.49	50.00	11.38	8.71	BDL
7	Meghalaya	South West Khasi Hills	Mawiong	Spring	7.29	45.80	BDL	27.43	BDL	25.02	25.02	38.99	1.62	BDL	0.09	8.01	7.28	50.00	7.62	3.37	0.02
8	Meghalaya	South West Khasi Hills	Nonglwai -II	Spring	7.09	55.48	BDL	33.19	BDL	25.02	25.02	35.45	2.21	BDL	0.08	6.00	7.28	45.00	2.07	13.89	0.05
9	Meghalaya	South West Khasi Hills	Mawthenrew	Spring	6.97	26.50	BDL	15.84	BDL	40.03	40.03	39.00	2.35	BDL	0.08	6.00	6.07	40.00	13.04	10.80	0.11
10	Meghalaya	South West Khasi Hills	Nongkdait	Spring	6.75	28.96	BDL	17.35	BDL	30.02	30.02	21.27	4.52	BDL	0.07	6.00	4.85	35.00	7.68	4.78	0.09

Annexure 4: Geophysical data

Sl. No.	District	Village	Location	Coordinates	General Geology	Layer Resistivity in Ohm-m					Layer Thickness in meters						Total Depth in m.	Remarks with expected zones/fractures (for recommended sites)
						ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	P_6	h_1	h_2	h_3	h_4	h_5		
1	South West Khasi Hills	Mawramhoh	8-m N45°W of VES-228.	N 25°25'39.7" E 91°25'48.4"	Granite/Shillong group	3000	1800	150	450			0.9	6.1	11			18	
2	South West Khasi Hills	Mawramhoh	90m S60°E of VES-228.	N 25°25'36.7" E 91°25'47.5"	Granite/Shillong group	2800	2200	400	750			1	7	14			22	
3	South West Khasi Hills	Mawsap	100m towards west of Umkynj river and 200m due N30°W of unfinished pillared structure on hill top.	N 25°25'51.0" E 91°26'26.3"	Granite/Shillong group	6500	1600	5000	400	250		1	1.5	6.5	31		49	
4	South West Khasi Hills	Mawsap	At the centre of the foot ball ground.	N 25°26'18.5" E 91°26'39.6"	Granite/Shillong group	4000	2500	3500	150			0.8	2.2	7			10	
5	South West Khasi Hills	Mawsynrap(West)	S50°E of school on road side.	N 25°25'59.6" E 91°25'26.1"	Granite/Shillong group	4500	1500	150	200			1.1	4.4	8.5			14	Zones 15-80m
6	South West Khasi Hills	Mawsynrap(West)	45m west of VES-233.	N 25°26'08.0" E 91°25'25.4"	Granite/Shillong group	4500	1000	80	180			1.1	2.9	8			12	
7	South West Khasi Hills	Mawkyrwat	90m North of the bridge near foot ball ground.		Granite/Shillong group	450	900	25	200			1	1.4	8.6			11	
8	South West Khasi Hills	Mawkyrwat	95m S15°W of VES-235.		Granite/Shillong group	100	200	50	500			0.8	3.7	23.5			28	
9	South West Khasi Hills	Mawkyrwat	95m west of VES-236	N 25°21'32.7" E 91°27'01.1"	Granite/Shillong group	130	70	230				5.6	19.4				25	Zones up to 25m and fractures up 90m
10	South West Khasi Hills	Mawkyrwat	60m NW of VES-237.		Granite/Shillong group	170	30	300				2.5	8.5				11	
11	South West Khasi Hills	Mawkyrwat	73m SW of VES-238.	N 25°21'32.5" E 91°20'57.0"	Granite/Shillong group	80	150	40	350			1	3	26			30	
12	South West Khasi Hills	Kynshi	100m due N20°W of indoor stadium's main gate.	N 25°25'59.6" E 91°25'26.1"	Archaean Gneissic Complex	2100	140	650				5	13				18	

Annexure 5: Ground water resource

a) General Description of Ground Water Assessment in South West Khasi Hills district for 2017-18 (area in ha)

Name of Ground Water Assessment Unit	South West Khasi Hills
Type of Ground Water Assessment Unit	District
Type of rock formation	Granite, Gneiss, Sandstone and Limestone
Total area of Groundwater Assessment Unit	134100
Hilly area	73227
Command area	0
Non-command area	60873
Poor ground water quality area	0
Area considered for groundwater recharge	60873

b) Ground Water Resource Potential in South West Khasi Hills district during 2017-18

Assessment Unit / District	South West Khasi Hills
Command/ Non-Command/ Total	Total
Recharge from rainfall during monsoon season	10174.64 ham
Recharge from other sources during monsoon season	24.36 ham
Recharge from rainfall during non-monsoon season	2642.25 ham
Recharge from other sources during non-monsoon season	5.90 ham
Total Ground Water Recharge	12847.18 ham
Annual Extractable Ground Water	11562.46 ham

c) Ground Water Extraction for All Uses in South West Khasi Hills district

District	South West Khasi Hills
Total ground water extraction for domestic and industrial purpose	9.01 ham
Total ground water extraction for irrigation	0 ham
Total groundwater extraction	9.01 ham

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

Assessment Unit / District	South West Khasi Hills
Command/ Non-Command/ Total	Total
Annual Extractable Ground Water	11562.46 ham
Existing Gross ground water extraction for irrigation	0 ham
Existing Gross Ground Water extraction for domestic and industrial water supply	9.01 ham
Existing Gross Ground Water Draft for All Uses	9.01 ham
Provision for domestic and industrial requirement supply upto next 25 years	18.02 ham
Net Annual Ground Water Availability for future irrigation development	11544.44 ham
Stage of ground water development	0.08%

e) Categorization for Ground Water Extraction of South West Khasi Hills district during 2017-18

Assessment Unit/ District	South West Khasi Hills
Stage Of Ground Water Extraction (%)	0.08%
Validation of Assessment using GW Level trends (Valid/to be Re-assessed)	Could not validate, WL data not sufficient/representative
Categorization (Safe / Semi-Critical/ Critical/ Over-Exploited)	Safe

Annexure 6: Data gap and data requirement in South West Khasi Hills district

Toposheet No.	Grid	Data Existing										Data required									
		Aquifer I					Aquifer II					Aquifer I					Aquifer II				
		EW	OW	VES	CHE	WL	EW	OW	VES	CHE	WL	EW	OW	VES	CHE	WL	EW	OW	VES	CHE	WL
78 K/15	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 K/15	B3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 K/15	C3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 K/16	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/3	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/3	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/3	A2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/3	B2	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/3	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/3	A3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/3	B3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/3	C3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/4	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/4	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/4	C1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/7	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/7	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/7	C1	0	0	4	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/7	A2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/7	B2	0	0	1	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/7	C2	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/7	A3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/7	B3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/7	C3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/8	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/8	B1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/11	A1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
78 O/11	A2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	1
78 O/11	A3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	2	1	1
	TOTAL	**0**	**0**	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**16**	**16**	**0**	**29**	**29**	**16**	**16**	**58**	**29**	**29**

FIELD PHOTOGRAPHS

1. Spring Tap Chamber/ Dug well

2. Irrigation Canal, Mawkyrwat

3. Water Harvesting Structure, Mawkyrwat Block