केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

WEST 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 WEST KHASI HILLS DISTRICT, MEGHALAYA"

(AAP 2018-19)

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ABBREVIATION

AAP	Annual Action Plan
AMP	Aquifer Management Plan
AQM	Aquifer Mapping
BIS	Bureau of Indian Standards
BDL	Below detectable level
BCM	Billion Cubic Metres
BW	Bore well
CGWB	Central Ground Water Board
DGM	Directorate of Geology and Mining
DTWL	Depth to water Level
DW	Dug Well
EC	Electrical Conductivity
EW	Exploratory Well
Fe	Iron
GL	Ground Level
GSI	Geological Survey of India
GEC	Ground water Estimation Committee
GW	Ground Water
GWMS	Ground Water Monitoring Stations
Ha	Hectare
Ham/ham	Hectare meter
ham/yr	Hectare meter per year
IMD	Indian Meteorological Department
Km	Kilometer
LPM/lpm	Litres per minute
LPS/lps	Litres per second
m	metre
m bgl	meters below ground level
MCM	Million Cubic Meter
mm	Milli meter
mg/l	milligram/litre
MP	Measuring Point
m amsl	Metre above mean sea level
NER	North Eastern Region
NAQUIM	National Aquifer Mapping and Management Plan
NESAC	Norh Eastern Space Applications Centre
OW	Observation Well
pH	Potential of Hydrogen
Ppm	Parts per million equivalents to mg/l
Pz	Piezometer
Sq.Km/sq.km.	Square Kilometre
SWL	Static water level
TDS	Total dissolved solid
TH	Total Hardness
µS/cm	Microsimens/centimetre
°C	Degree Celsius
FAO	Food and Agriculture Organization (United Nations)
8”	Eight Inches
NA	Not Available

EXECUTIVE SUMMARY

Aquifer Mapping studies and Management Plan has been carried out in 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.

The total coverage area (mapable area of the district) of aquifer mapping and management plan is 1302 sq.km, out of 3911 sq. km of the district. The area is underlain by consolidated rocks, semi consolidated and unconsolidated rocks. Consolidated group of rocks comprises Archaean Gneissic Complex, acid / basic intrusive, and the Pre-Cambrian quartzite and phyllites of Shillong Group of rocks. Semi-consolidated formation includes limestone, sandstone, and shale inter bedded with the coal seams

The northern part of the consolidated unit is considerably more compact and the development of fractures is few. These formations lack primary porosity and the movement and occurrence of ground water is controlled by physiography, depth of weathering and interconnected zones of weakness or secondary porosity like joints, faults etc. Yield is expected to be moderate in the intermontane valleys and moderate to good along the fractures where intersection of more than one set of fractures and joints are present. The weathered portion acts as ground water reservoir within shallow depth. Groundwater occurs under unconfined condition in the weathered residuum and semi-confined conditions in secondary pore spaces like fractures, fissures etc. At hydrogeological feasible situations, well drilled down to a depth of about 40 -162 m below ground level may yield a moderate discharge of 1.5-8 m^3/hr in Archaean and Pre-Cambrian Group of rocks whereas the acid and basic counterparts have a discharge of 1.3-1.5 m^3/hr. Water level is found to occur between 2 to 7 m bgl. The valley areas are found to be favourable for the construction of dug wells and bore wells. The southern portion of this consolidated unit is dissected plateau with a number of low hills giving rise to undulating topography. As compared to the northern section, this unit is more dissected by a good number of fractures which allows a good amount of ground water for its recharge. Here, the weathered zone is also thick (about 10-12m) though it is not distributed over large area. Therefore, in this area, ground water prospect is better than the northern belt.

In semiconsolidated unit, where dissection is severe, the ground water prospect is good. As the rocks of this place are argillaceous in nature, the permeability is low. Sandstone with limited porosity yields water through secondary fissures like joints. Shale in many cases acts as aquiclude. The aquifers are thick and discontinuous in nature. The areas which are favorable for construction of shallow as well as deep tube well are the synclinal and intermontane valleys.

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 residum where ground water occurs under water table condition and is mainly developed through construction of dug wells. The second aquifer is the deeper aquifer which tapped the

fractured zone and is mainly developed through boring and construction of tubewells Based on the study of litholog and analysis of depth of construction of dug wells and bore wells, it is found that the first aquifer occur within 2 to 30 m bgl. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures upto the maximum explored depth of 161.45 m bgl.

Earlier 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 behavior, both in phreatic and semi-confined condition, were carried out in the aquifer mapping area. Study of springs was also carried out in the study area. Most of these springs are dentified as depression and topographic or fractured springs. A large number of rural villagers are utilising the naturally available springs in this district to fulfill their various needs. It is observed that the discharge of springs in this area ranges from 0.6 to 60 litre/minute during pre-monsoon and 2 to more than 96 litre/minute during post-monsoon season.

In order to study the chemical quality of ground water in the district, water samples from dug wells and springs were collected during the course of field work and were analysed. Chemical analyses reveal that water from dug wells is slightly acidic at some places. Rest all other parameters in both shallow and deeper aquifers are within permissible limits.

Surface Geophysical studies in the study area were carried out during earlier AAPs to delineate the subsurface geology. Earlier a total of 31 VES were conducted as part of geophysical data prospecting in the whole district.

Dynamic Groundwater Resources of the study area has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). The annual extractable ground water resources is accessed as 30068.40 ham and the stage of ground water development as 0.05 % which indicate the study area falls under "**safe**" category.

Finally, the aquifer map of the study area is generated based on the inputs from geological, hydrogeological, geophysical and hydrochemical studies and a management plan is prepared with an emphasis on providing irrigation facilities through ground water development as agriculture is the main means of livelihood of the people living in the district. With the help of agricultural professionals and using "CROPWAT" model software, developed by FAO, a cropping plan is designed for the district through using groundwater irrigation.

1. INTRODUCTION

Central Ground Water Board, North Eastern Region has carried out Aquifer mapping and management plan in West Khasi Hills District, Meghalaya during AAP 2018-19 covering an area of 1302 sq.km out of the total geographical area of 3911 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 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 programme 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, analysed, 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 (exploratory drilling could not be carried out in the district due to rig problem and some unrest in the district, geophysical techniques could not be deployed in the district due to non availability of geophysical team in the office).

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 amulti-disciplinary approach:

(i) Earlier Geophysical Surveys data through Vertical Electrical Sounding (VES)
(ii) Earlier data generated through exploratory drilling and construction of tube/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 during the course of study.
(iv) 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.
(v) Preparations of a micro level mapping of existing aquifers, their potentials depth wise and sideways in 2D forms viewed from different angles by various GIS Layers.
(vi) Formulating a complete sustainable aquifer management plan for ground water development.

1.4 Area details: The West Khasi Hills district is situated in the central part of Meghalaya and is bounded by Kamrup district of the Assam on the northwest side, on northeast side by Ri Bhoi district, on the east by East Khasi Hills district, on the south by Bangladesh and Southwest Khasi Hills district and on the west by West Garo and South Garo Hills district. The district comprises an area of about 3911 sq.km which is about 17 percent of the total area of the state. Nongstoin, covering an area of about 76 sq. km, is the district headquarter. The district is situated approximately between 25°10″ and 25°51″ N latitude and 90°44″and 91°49″ E longitude. The district has four Community and Rural Development Blocks the details of the block along with their respective headquarters are given in Table 1.1. The whole district was covered under NAQUIM programme.

Table 1.1: Administrative Set up of West Khasi Hills district

Demography	**Value**
Area	3911 Sq Km
Total Population	2,87,781
Urban Population	43105
Rural Population	95680
No. of Villages	834
Literacy Rate	78.83%
Households	48,424
Decadal Population Growth 2001 -2011	66249 (29.9%)

(Source: Directorate of Cenus Operations, Meghalaya)

This area falls partly or fully in the quadrants of Survey of India Toposheets bearing nos. 78O/1, 78O/2, 78O/3, 78O/5, 78O/6, 78O/7, 78O/9, 78O/10, 78O/11, 78K/14 and 78K/15.

1.5 Data availability, data adequacy and data gap analysis:

Aquifer mapping and management plan is carried out by sharing different data. The required data on various attributes of the study are collected from the available literatures of Central Ground Water Board, Water Resources Department of Meghalaya and various Central and

State Government agencies. Toposheet wise (grid wise) the data gap was analysed for the whole district of West Khasi Hills which is shown in table 1.4. Fig 1.1 shows existing data in the district for data gap analyses. The Data Requirement, Data Availability and Data Gap Analysis are presented in table 1.2.

Table 1.2: Data Availability and Data Gap Analysis in Aquifer Mapping Studies

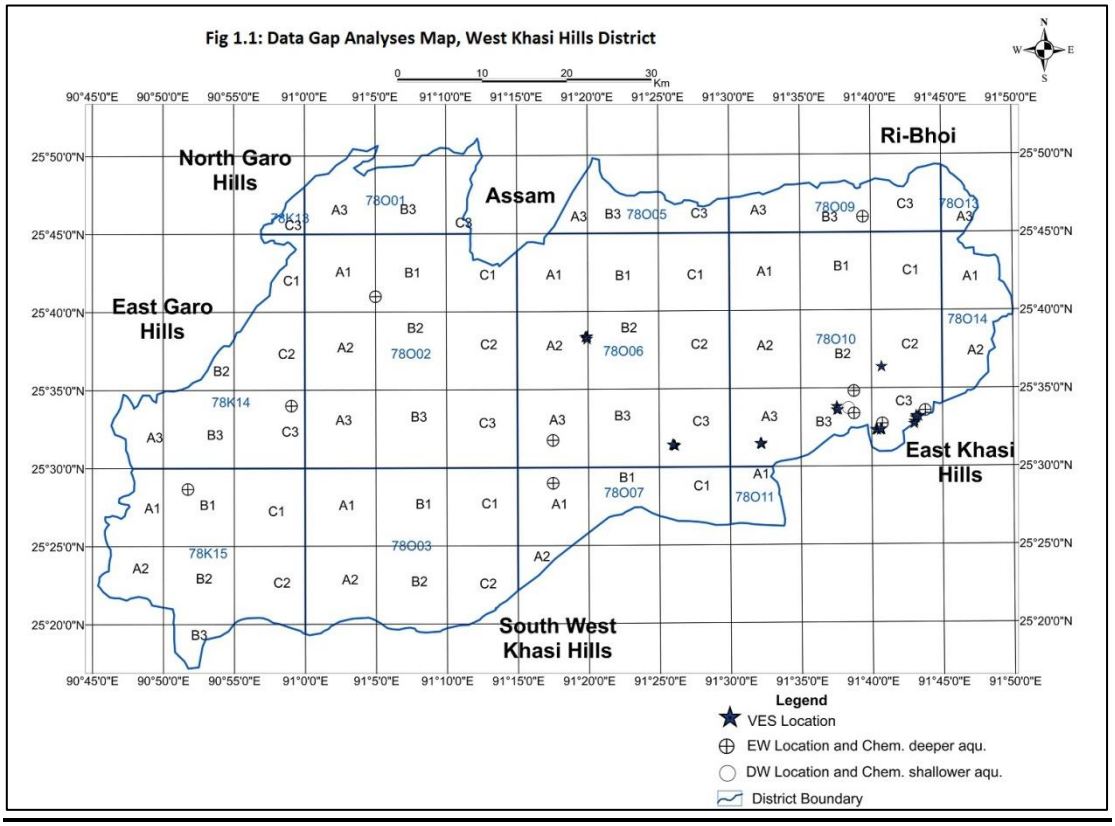
Sl. No.	Items	Data Requirement	Data Availability	Data Gap
1	Ground Water Exploration Data	As per requirement of Advanced Geophysical Studies for Integration of data and Validation of Techniques	10 EW	Entire study area
2	Geophysics	Geophysical data of the Study area	31 VES	Entire study area
3	Ground Water Monitoring Regime	Representative Monitoring Wells well distributed over the Study Area	1 Monitoring Well	Entire study area
4	Ground Water Quality	Representative Monitoring Wells well distributed over the Study Area	Water quality data of 1 monitoring well	Representative Monitoring key Wells covering the entire study area
5	Specific yield (Shallow and deeper aquifer)	Data well distributed over the Study Area	1 DW	Entire study area
6	Climate	Monthly meteorological data	Rainfall data Available	Monthly other meteorological data
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	2016-17 data is available	Data Available
9	Geomorphology	Detailed Information on Geomorphology of the area	District level information	Data available from website of Bhuban
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 2011 Census, West Khasi Hills district has a population of 2, 87,781 out of which 1, 45,132 were male and 1, 42,649 were female respectively. Mairang block has the maximum number of people (82,437) followed by Nongstoin block which have 81,840 persons. Total number of inhabited and uninhabited villages in the district is 832 and 3 respectively. Block level population figure as per 2011 census is given in Table 1.3.

Table 1.3: Block wise population of West Khasi Hills District as per census, 2011

Name of District/C.D. Block/Town	Headquarter	Rural Population	Urban Population	Total
Mawshyrnut	Riangdo	74490	0	74490
Nongstoin	Nongstoin	53098	28742	81840
Mawthadraishan	Nongshillong	49014	0	49014
Mairang	Mairang	68074	14363	82437

(Source: Directorate of Cenus operations, Meghalaya)



1.7 Communication: Headquaters of West Khasi Hills district, Nongstoin, is well connected to East Khasi Hills districts through the National Highway 106. Guwahati Railway Station at Guwahati City, the capital of Assam, is about 184Km from the District HQ via NH44E and another 145Km from an alternate route via NH6 and NH106. West Khasi Hills is not completely accessible by air transport not withstanding its geographic location and topography against which special helipads are identified for emergency purposes only for helicopter service. Umroi Airport at Ribhoi district is about 119 km from the district HQ and can be reached through NH 44 E.

1.8 Land use: Land utilisation 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 West Khasi Hills district is shown in the Table1.5 and land use map is shown in Fig. 1.2.

Table 1.4: Toposheet wise Data availability, data gap and required data generation in the study area

		Data Existing										***Data required/Data gap***									
		Aquifer II					***Aquifer I***					***Aquifer II***					***Aquifer I***				
Toposheet No.	***Grid***	***EW***	***OW***	***VES***	***CHE***	***WL***	***EW***	***OW***	***VES***	***CHE***	***WL***	***EW***	***OW***	***VES***	***CHE***	***WL***	***EW***	***OW***	***VES***	***CHE***	***WL***
78O/01	**A3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/01	**B3**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/01	**C3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/05	**A3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/05	**B3**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1

78O/05	**C3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/09	**A3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/09	**B3**	1	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/09	**C3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/13	**A3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78K/14	**A3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78K/14	**B2**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78K/14	**B3**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78K/14	**C1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78K/14	**C2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78K/14	**C3**	1	0	0	0	1	0	0	0	0	0	0	1	2	1	1	1	1	2	1	1
78O/02	**A1**	1	0	0	1	0	0	0	0	0	0	0	1	2	1	1	1	1	2	1	1
78O/02	**A2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/02	**A3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/02	**B1**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/02	**B2**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/02	**B3**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/02	**C1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/02	**C2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/02	**C3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/02	**C3**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/06	**A1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/06	**A2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/06	**A3**	1	0	0	1	0	0	0	0	0	0	0	1	2	1	1	1	1	2	1	1
78O/06	**B1**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/06	**B2**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/06	**B3**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/06	**C1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/06	**C2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/06	**C3**	0	0	3	0	0	0	0	3	0	0	1	1	0	1	1	1	1	0	1	1
78O/10	**A1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/10	**A2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/10	**A3**	0	0	2	0	0	0	0	2	0	0	1	1	0	1	1	1	1	0	1	1
78O/10	**B1**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/10	**B2**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/10	**B3**	2	0	3	2	0	0	0	3	1	1	0	1	0	0	0	0	0	0	1	1
78O/10	**C1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/10	**C2**	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/10	**C3**	2	0	3	2	0	0	0	3	0	0	0	1	0	1	1	1	1	0	1	1
78O/14	**A1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/14	**A2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78K/15	**A1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78K/15	**A2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78K/15	**B1**	1	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1

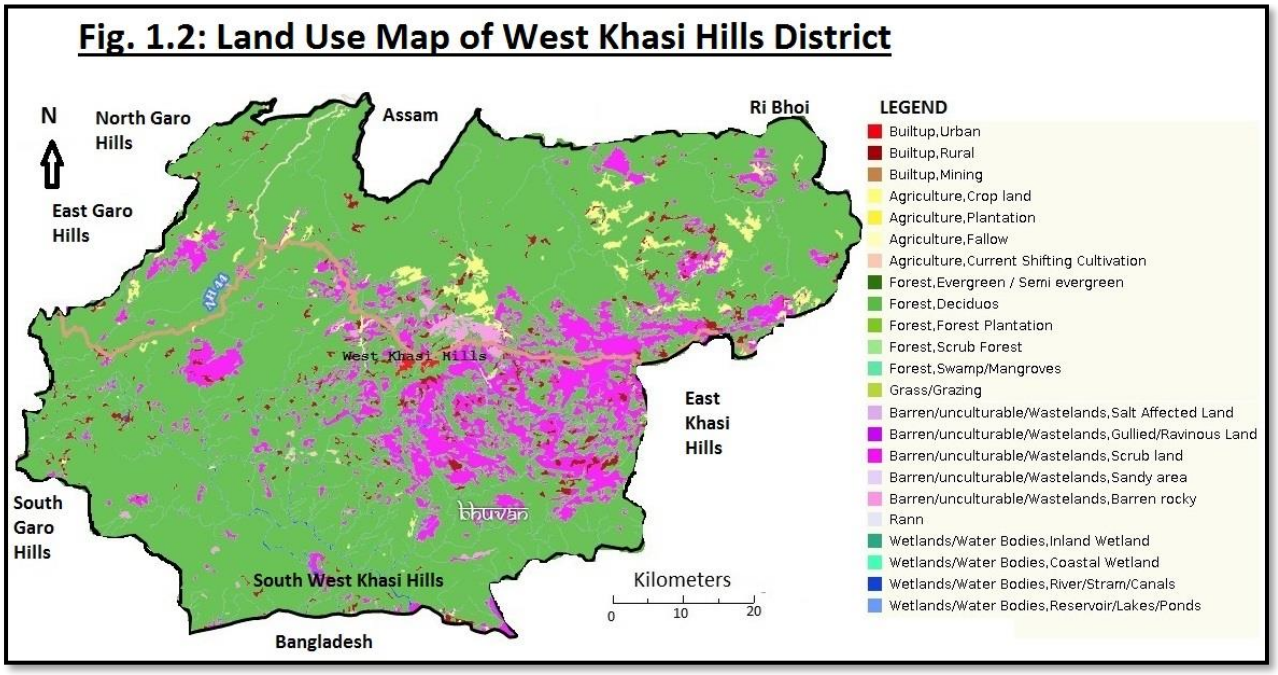
78K/15	**B2**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78K/15	**B3**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78K/15	**C1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78K/15	**C2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/03	**A1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/03	**A2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/03	**B1**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/03	**B2**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/03	**C1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/03	**C2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/07	**A1**	1	0	0	1	0	0	0	0	0	0	0	1	2	1	1	1	1	2	1	1
78O/07	**A2**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/07	**B1**	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	1	1
78O/07	**C1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
78O/11	**A1**	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	2	1	1
	Total	**11**	**0**	**12**	**9**	**1**	**0**	**0**	**11**	**1**	**1**	**32**	**38**	**120**	**37**	**37**	**37**	**37**	**120**	**64**	**64**

(CHE= Chemical data, WL= Water level data, VES= Vertical Electrical Sounding data, EW=Exploratory well, OW= Observatory well)

Table 1.5: Land use pattern in West Khasi Hills District, 2015-16

Land Classifications	**Area (in hectares)**
A. Geogrphical Area	3,84,600
B. Reporting Area	3,48,599
1. Forests (classed & unclassed)	1,56,012
2. Area not available for cultivation a.(i) Area under non-agricultural uses	
b. Barren and uncultivalble lands	
c. Water logged land	
d. Social Forestry	2,392
e. Land under still water	3,781
f. Other land	12,304
TOTAL = (a+b)	
TOTAL (Column a to f)	18,477
(ii) Barren and unculturable lands	31,807
TOTAL = Col. I & ii	50,284
3. Other uncultivable lands	
a. Permanent pastures and other grazing lands	
b. Land under Misc. tree crops & grooves etc.	32,832
c. Cultivable wastelands	77,409
TOTAL = (a+b+c)	1,10,241
4. Fallow lands a. Fallow lands other than current fallows b. Current fallows	 35,255 12,547
TOTAL = (a+b)	47,802
5. Net area sown	20,260
6. Area sown more than once	4,724
7. Total Croped area	24,948

(Source: Directorate of Economics & Statistics, Govt. of Meghalaya.)



(Source: www.bhuvan-nrsc.gov.in)

1.9 Soil: Geomorphologically, the West Khasi hill is an undulatory one. It comprises of denudational high and low hills with deep gorges. The district represents a remnant of ancient plateau of Indian Peninsular Shield which is deeply dissected suggesting several geotectonic and structural deformities that the plateau has undergone. The northern portion of the district is a dissected Shillong plateau gradually rising southwards to the rolling grasslands with gentle river valleys, and then falls sharply in the Southern portion forming deep gorges and ravines in Mawsynram and Shella Bholaganj, bordering Bangladesh. Soil type of an area is dependent on factors like geology, relief, climate and vegetation. Red Loamy soil is a product of weathering of rocks like granites, gneisses etc which are relatively rich in clay forming minerals. This soil type are rich in organic matter, nitrogen and acidic in nature. They are found exposed in the central part of the district.

Soil is one of the most important components of the land through which the interaction of all natural factors takes place. 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. Accordingly, the soils types are broadly classified into three orders as given below.

- Red loamy soils
- Laterite soils
- Alluvial soils

Red loamy soil: This soil occupies the central part of the study area. It is generally loamy and red in colour. These are the result of weathering of rocks such as granites, gneisses, diorites and those which are relatively richer in clay forming minerals but poorer in silica. The exposed red loamy soil is rich in organic matter and nitrogen due to humus contains from the litters of tree leaves, grasses etc. These are acidic and suitable for the cultivation of potatoes, rice, fruits in hills slope and terraces.

Laterite soils: This soil is found in the Northern part of the study area. These are resulted due to the weathering of rocks like granites, quartzite, schist, gneisses, conglomerates etc. This area is rich in iron and aluminum and is yellowish red in colour.

Alluvial Soils: The alluvial soils are found the in the southern part of the district, along Bangladesh border. The soil texture varies from sandy to clayey-loam with varying degree of nitrogen and is acidic in nature. The soils are rich in potash but poor in phosphate content.

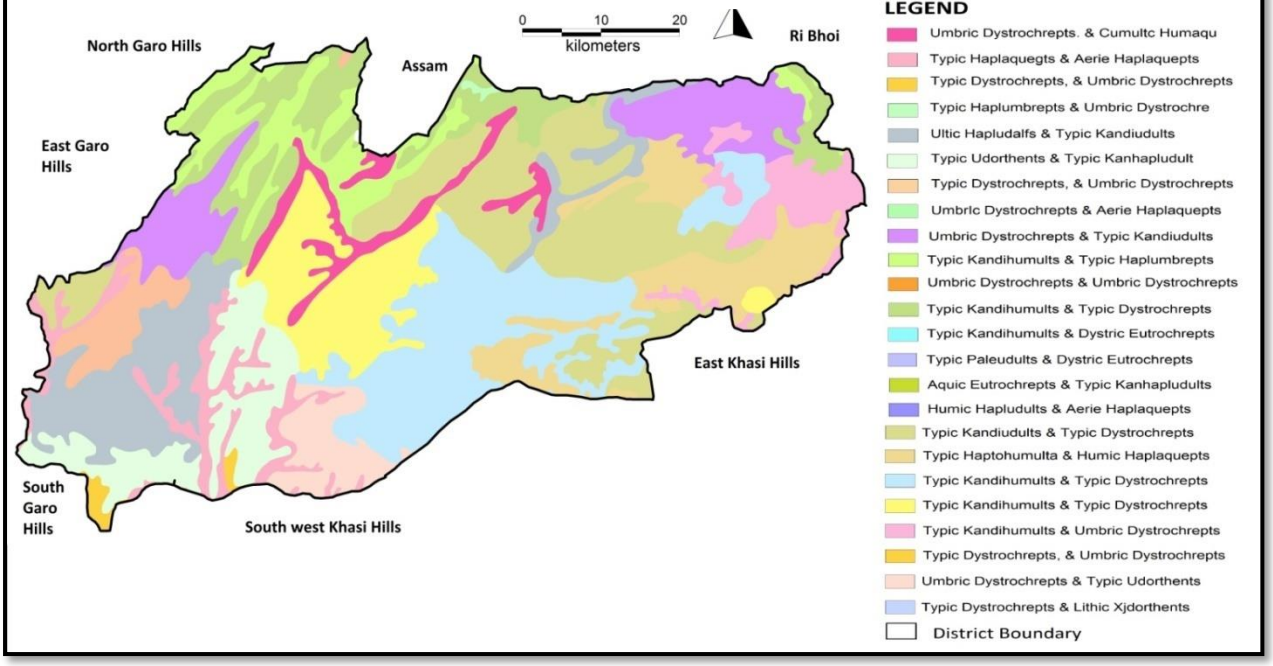
It is suitable for cultivation of rich and jute.

Soil character in West Khasi Hills district is briefly given below:

- ❖ Red Gravelly and Red Loamy Soil are the common soil types.
- ❖ The soils are acidic in nature with pH ranging from 5 to 5.5
- ❖ Rich in Nitrogen due to low temperature and high rainfall.
- ❖ Phosphorus status of the soils is low, except in Mawkyrwat Block.
- ❖ Potash content is medium in fertility status.
- ❖

Soil map of the area is given in Fig 1.3.

Fig 1.3: Soil Map of West Khasi Hills District, Meghalaya



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

1.10 Agriculture: Agriculture is the main stay of the population in the district. As per census 2011, 52% of the population is engaged in agriculture and 22.8% of total workers population is engaged as agriculture labourers. The area is endowed with diversified climatic condition thereby offering good scope for cultivation of temperate and subtropical crops. Principal crops grown in the district are rice, maize, millets, oilseeds and pulses. Horticulture products include orange, pineapple and many local fruits. Vegetables like potato, cucumber, squash, beans etc. are also grown. Present area under different crops and their productivity is shown in table 1.6.

Table 1.6: Area under different crops and their productivity, West Khasi Hills (2015-16)

Crops	**Area (ha)**	**Avg.Yield (kg/ha)**
Autumn rice	29	2552
Winter rice	5984	1840
Spring rice	23	2261
Maize	4579	1939
Millets	267	1228
Pulses	71	2169
Rape and Mustard	33	970
Soyabean	44	1136
Citrus fruits	126	4103
Arecanut	783	1236
Papaya	38	5974

Pineapple	245	6351
Potato (summer)	2608	7375
Ginger	294	9724
Turmeric	55	5218
Sugarcane	11	2818
Tobacco	42	1524
Black Pepper	29	862

(Source: Agriculture Department, Govt. of Meghalaya)

1.11 Irrigation: Irrigation in the district is mainly dependent on surface water. As per Water Resources Department, Meghalaya, there are in total 104 surface water irrigation structures in the district covering command area of 5426.98 hectares. There are no ground water irrigation structures till now in the district.

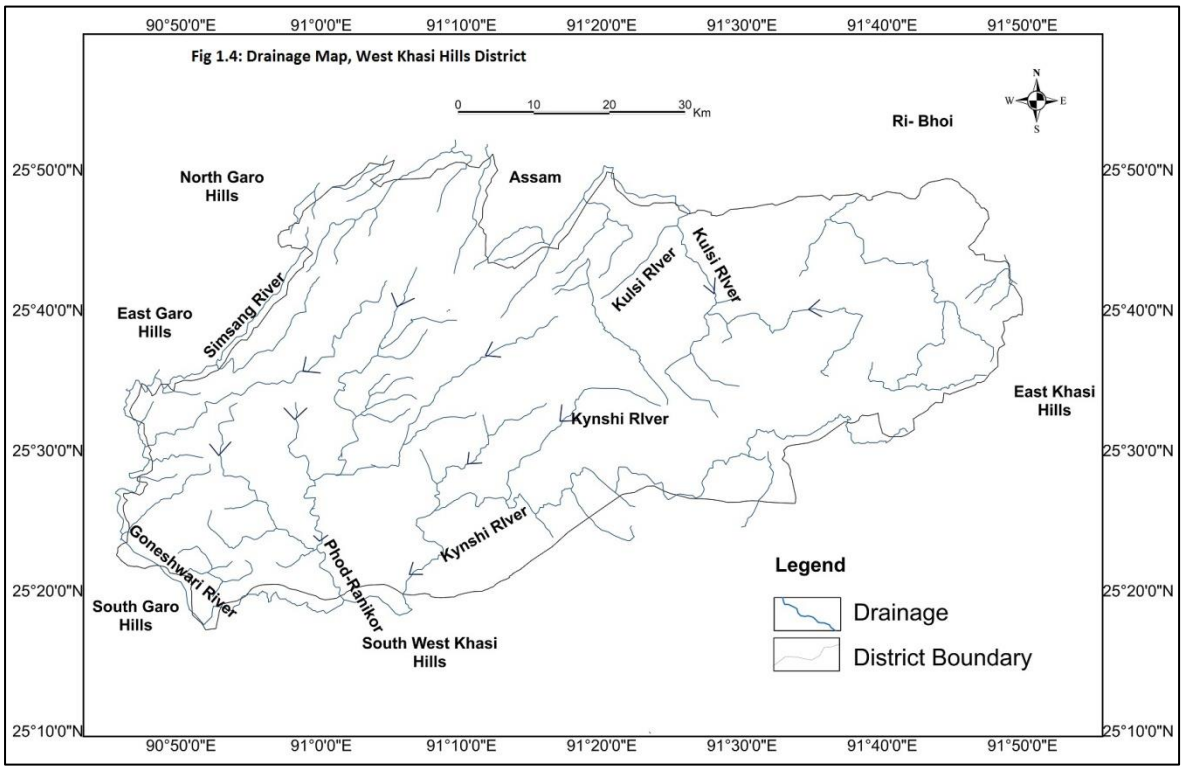
1.12 Minerals and Industries: Although the district is endowed with many economically important minerals but the operations are limited mostly to the mining of these minerals. The minerals found in the district are coal, limestone, sillimanite and uranium, among these last two are major deposits in the district (coal mining is carried out at minor scale at shallang and rambari, Coalfields are mainly found and extracted in large scale from Nongri, Nonghyllam Nongkulang areas. Mining of Uranium has not so far been undertaken due to opposition from the people. As per census, 2011, there are many small scale industries in the district. From medium and large scale industries pont of view, the study area is still.

1.13 Forest: As per Directorate of Economics & Statistics, Government of Meghalaya, West Khasi Hills district has a total area of 1560.12 sq.km (as per 2015-16) under forest (classed & unclassed) and social forestry area of 23.92 of sq.km.

1.14 Drainage: The topography and structure controls the drainage system as it divides the state of Meghalaya into two watersheds namely the Brahmaputra system in the North and Meghna /Surma system in the South. A centrally situated hill range trending NWN-SES and sloping both northerly and southerly divide the district into two unequal water shades. There are two important river systems in the district, the Kynshi and the Khri, with a number of tributaries. The northern water shed occupying an area of approximately 1400 sq.km is drained by rivers Khri, Um Rambrai, Synthi, Kyon, Jatra etc. forming a part of Brahmaputra basin. The Khri River rises near Kyllang rock and flows northwards and is joined by Khri Synnia River before it enters the plains of Assam. The bigger southern water shed is cup-shaped being drained from almost all sides east, north and west. The river Kynshi is the main river in the southern water shed with its tributaries Nongbah, Rilang, Umiang, Umblei, Riwang etc. confluences from the eastern side. River Kynshi rises in the southern slopes of Marpna Peak near Mawmaram village (about 10 kms from Mairang on way to Shillong). It follows a westerly course for a considerable distance then takes a sharp bend to the south and under a changed name Jadukata enters the plains of Bangladesh at Nalikata. Broadly, the drainage pattern of this district is angular which clearly indicates the control of lineament trend via. NE-SW, NW-SE, EW-NS are clearly reflected by these drainage system. In Mawshynrut block the drainage pattern is mainly dominated by NE-SW trending lineaments. This drainage orientation is met with a set of NW-SE trending drainage in Nongstoin and part of Mawkyrwat block. As a whole the entire drainage trend takes a large arcuate turn in the central part of this district, resulting in a prominent concentric and radial drainage pattern, on either side of this arcuate.

By and large, the drainage density of this district is moderate. But in part of Mairang block the density is comparatively high.The drainage pattern is structurally controlled and radial to

angular in nature. Unlike the terrain of the East Khasi Hills District that lends itself to formation of numerous waterfalls, the terrain of the West Khasi Hills District does not lend itself to forming waterfalls worth the name. Also the district does not have natural lakes of appreciable size. The drainage map is shown in Fig 1.4.



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 and groundwater quality data were generated.

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

2.1.1 Water level monitoring: In the study area, 4 dug wells (1 existing GWMS), and 25 nos. of springs are established to study the water level, quality, spring discharge and its behavior periodically.

Phreatic aquifer: A total of 4 dug wells (1 existing GWMS) were established as key wells for periodical water evel monitoring to know the water level trend and its behavior. The details of dugwells established during course of study is given in annexure 1(B). The pre- and post- monsoon Depth to Water Level maps are presented in Fig 3.6 and 3.7 respectively.

Confined/Semi-confined aquifer: For study of piezometric head in the district, static water level of earlier 10 numbers of bore wells drilled under Ground Water Exploration programme of CGWB are taken into account. Details of these key observation wells are presented in Annexure 1 and the Depth to Water Level (static) in Fig 3.9. The exploratory wells location is shown in fig 3.8.

Springs: A total of 25 springs were established and monitored to know the type, discharge and their behaviour. The locations of these springs are given in table 2.1. The discharge of the selected springs during Pre-Monsson and Post-Monsoon are shown in fig 3.3 and fig. 3.4 respectively.

2.1. Preliminary Yield Test (PYT): Preliminary yeild tests were carried in the wells drilled in West Khasi Hills district before NAQUIM (as per Ground Water Exploration Programme 10 exploratory wells were drilled during different AAPs). The hydraulic properties of the aquifer as an outcome of these tests have been summaried in annexure 1(A).

Table 2.1 Location of springs in West Khasi Hills district

S.No.	Name of village/site	Latitude	Longitude	Elevation (mAMSL)	Type	Aquifer	Source
	1	2	3	4	5	6	7
1	Umniangriang	25°44'41.7"	91°40'7.5"	743	Depression	I	CGWB
2	Nongkhlaw	25°40'52.3"	91°38'11.4"	1367	Depression	I	CGWB
3	Marido Village	25°38'34.2"	91°37'47.3"	1350	Depression	I	CGWB
4	Songshaw	25°33'18.7"	91°38'10.3"	1652	Depression	I	CGWB
5	Nongstoin Market	25°31'16.1"	91°16'3.9"	1326	Depression	I	CGWB
6	Tshaw	25°32'04.6"	91°16'21.5"	1375	Depression	I	CGWB
7	Mawlangdep	25°34'27.6"	91°11'48.0"	1257	Depression	I	CGWB
8	Nongstoin - Riangdo Road	25°43'29.4"	91°03'28.7"	806	Depression	I	CGWB
9	Langlur	25°34'36.8"	91°17'54.8"	1480	Depression	I	CGWB
10	Nongstoin Rambrai Road	25°37'09.9"	91°18'48.8"	1408	Fracture	I	CGWB
11	Rambrai	25°38'17.4"	91°19'33.3"	1403	Depression	I	CGWB
12	Mawphalnur	25°32'34.4"	91°25'46.5"	1819	Depression	I	CGWB
13	Umkrem	25°29'43.6"	91°28'46.3"	1571		I	CGWB
14	Mawkhangai	25°30'41.5"	91°28'25.2"	1578	Depression	I	CGWB
15	Nongshillong	25°30'58.6"	91°28'38.0"	1556	Depression	I	CGWB
16	Umjei	25°31'13.8"	91°29'29.7"	1603	Fracture	I	CGWB
17	Tynrongriankhon	25°41'21.0"	91°03'24.0"	902	Depression	I	CGWB
18	Sanduli II	25°39'28.7"	91°08'40.40"	1151		I	CGWB
19	Tieshaw	25°31"33.9"	91°24'0.9"	1508	Depression	I	CGWB
20	Donki-Ingding	25°44"59.8"	91°39'56.7"	770	Depression	I	CGWB
21	Pariong Road	25°29"43.6"	91°28'46.3"	1571	Fracture	I	CGWB
22	Pariong Road	25°28"06.3"	91°28'45.1"	1610	Depression	I	CGWB
23	Kynshi	25°31'30"	91°31'40.8"	1577	Depression	I	CGWB
24	Wahlakhaw	25°32'29.4"	91° 40' 01.4"	1771	Fracture	I	CGWB
25	Umsaw	25°34'01.2"	91° 13' 08.5"	1301	Depression	I	CGWB

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 many chemical parameters. The analytical data are given in Annexure 2(A) and 2 (B).

2.3 Geophysical studies: Surface Geophysical studies in the study area were carried out before the NAQUIM programme to delineate the subsurface geology as well as to supplement the data gap under the assignment of Aquifer Mapping. A total of 31 VES were conducted (during earlier AAPs). In West Khasi Hills district a total of 31 VES were conducted and 9 sites were recommended for drilling.

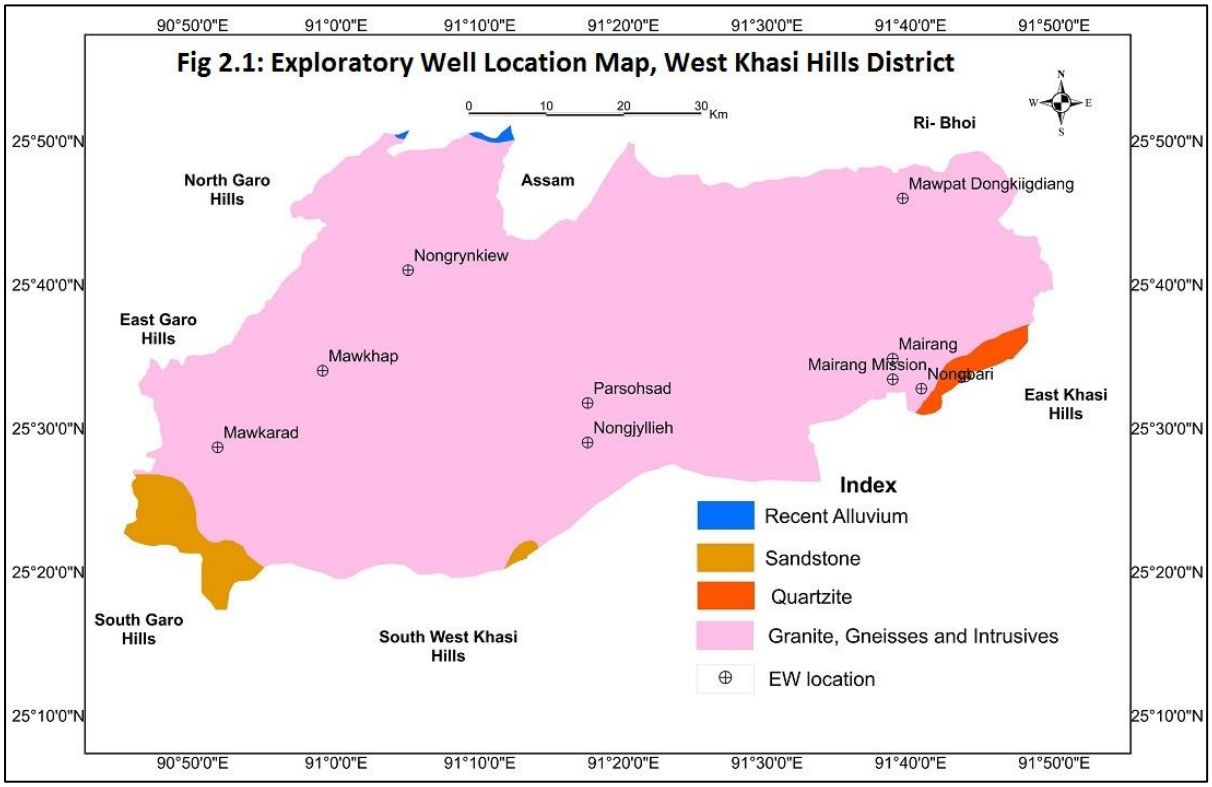
The inferences drawn on the basis of interpreted results could not be obtained for deeper formation due to the limitations of unavailability of large and straight stretch for current electrode separation. However, taking into account the interpreted results as well as the apparent resistivity, inferences have been approximated to shallow to deeper depth at fewplaces. The detail results are given in Annexure 7.

2.4 Ground Water Exploration Studies: Ground water exploration has been carried out in different parts of the district to delineate the potential aquifers and their geometry and to

determine the hydrogeological parameters of the aquifer systems. Before NAQUIM programme was started in the district, 10 EW were constructed and during the course of study no wells could be drilled in the district due to nonfunctional exploratory rig and unrest in the district regarding drilling operations. Details of the exploratory wells are presented below in the table 2.2. Ten (10) numbers of exploratory bore wells have been drilled in West Khasi Hills district out of which 3 wells were abandoned due to poor discharge. Depth of the bore holes drilled ranges from 24 to 161.45 m bgl. The aquifer system of the district is mainly Granitic gneiss and at some places quartzite. The discharge value ranges from 1.5 to 8.4 m^3/hr with a maximum draw down of 15 m. The exploratory wells which were constructed before NAQUIM are shown in fig 2.1.

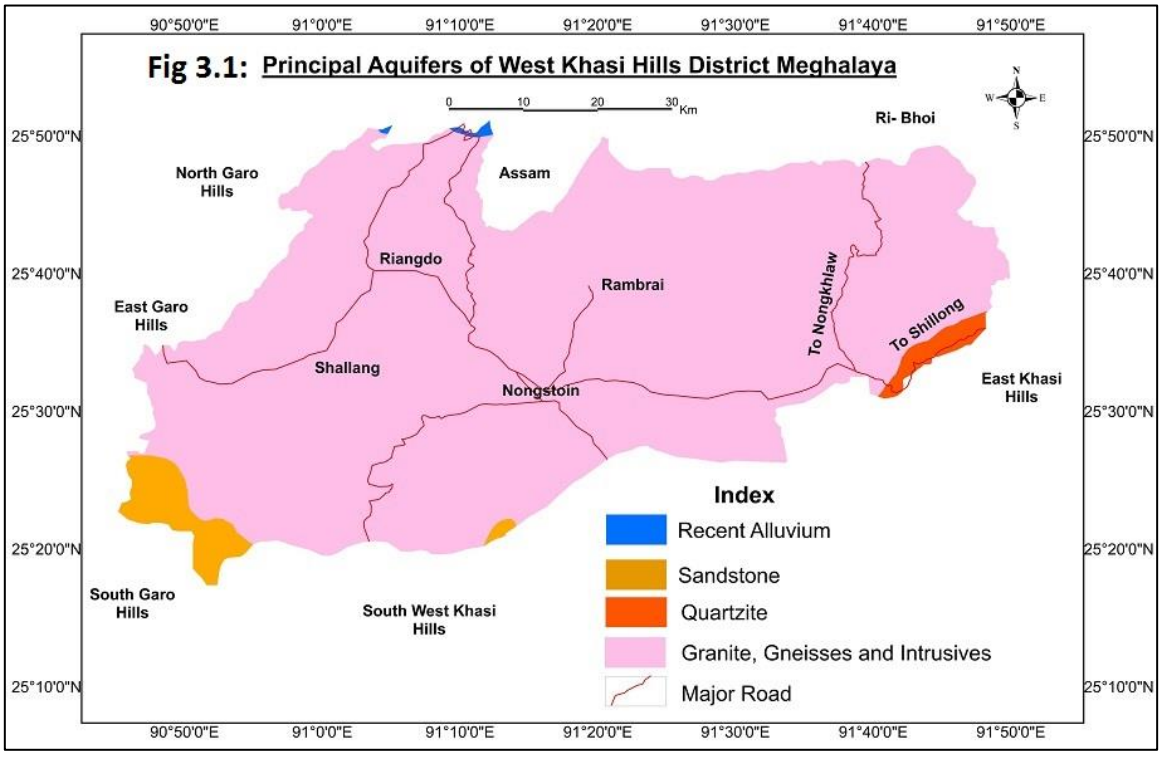
Table 2.2: Locations of Groundwater Exploration, West Khasi Hills District

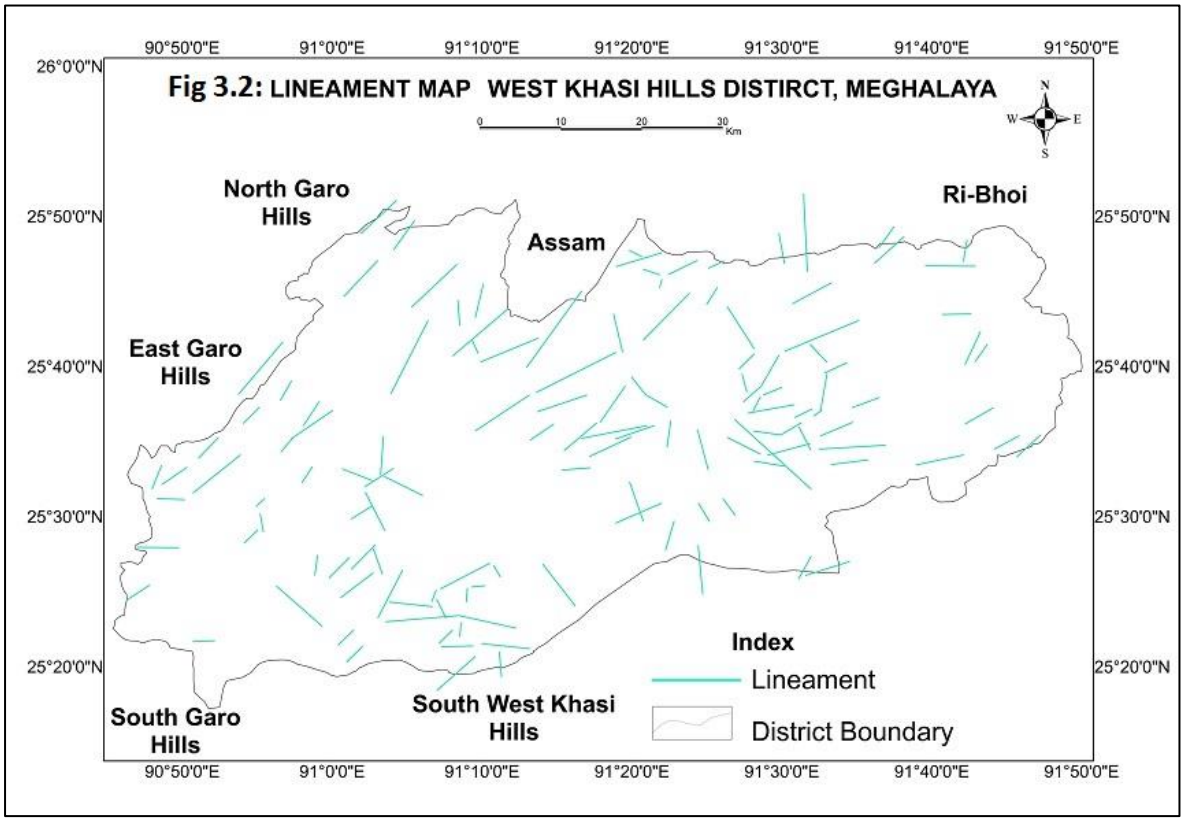
S.No.	Site Name	Latitude	Longitude	Elevation(m)	AAP Year	Depth drilled (m)
1	Mairang	25°34'50"	91°38'45"	1611	1997 - 98	39.5
2	Mawkarad	25°28'40"	90°51'44"	469	1995 - 96	24.5
3	Mawkhap	25°34'00"	90°59'03"	847	1997 - 98	80.3
4	Mawpat Dongkiigdiang	25°46'00"	91°39'27"	796	1997 - 98	61.8
5	Nongbari	25°32'45"	91°40'45"	1773	1997 - 98	31.5
6	Nongjyllieh	25°29'00"	91°17'30"	1504	1997 - 98	80
7	Nongrynkiew	25°41'00"	91°05'00"	1001	1997 - 98	80
8	Parsohsad	25°31'45"	91°17'30"	1433	1997 - 98	80
9	Umtholong	25°33'35"	91°43'47"	1761	1997 - 98	80
10	Mairang Mission	25°33'24"	91°38'45"	1686	2011 -12	161.45



3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 General Hydrogeology and Occurrence of Ground Water: The hydrogeological formation of the study area comprises of (1) Archean Gneissic Complex of Archean to Proterozoic age. The lithology of this group of rock/formation is mainly biotite hornblende gniess, granite gniess and mica schist. The ground water potential of wells drilled in this formation is usually poor (discharge ranges from 2 to 5 m^3/hr) and is mainly restricted to the weathered and fractured portion. This group of rock is predominantly found in the distrcit. (2) Granitic plutons of Neo-Proterozoic to Early Paleozoic age. This formation of rocks comprises mainly of coarse granite and pegmatite with quartz veins and is second most commonly found rock type in the district. The presence of weak planes like fractures and joints in these hard rock formation forms the principal aquifer in the area. The ground water potential of the wells drilled in this group of rocks is slightly higher than those drilled in Archean Gniessic complex. (3) Jaintia group of rocks of Paleocene to Eocene age comprising mainly of sandstone and shale. The yield of wells drilled in these formations is good (more than 10 m^3/hr on an average). Although no wells in the district is drilled so far in this formation but the wells drilled in this formation in other districts of Meghalaya led to this conclusion. (4) Alluvium of Quaternary age comprising of sand, gravel and clay. This group of rocks is very limited in extent and is found in very narrow area adjoining North Garo Hills and Assam boundary of the district. The yield of wells drilled in this alluvium is very good as indicated by some of the high yield wells drilled in other districts in Meghalaya and Assam. Till now no well has been drilled in this formation in the district. (5) Khasi Grenstone of rocks comprising dolerite and ultrabasic sills and dykes of Proterozoic age. These rocks are limited to very narrow extent in the Northwestern part of the district. The ground water potential of wells drilled in these formations is usually poor. The ground water in the district occurs under unconfined, semi-confined to confined conditions. Study of dug wells and exploration data reveals the presence of phreatic, shallow and deep fractured aquifers in the district. The principal aquifer of the study area is shown in Fig 3.1 and lineament map is shown in Fig 3.2.



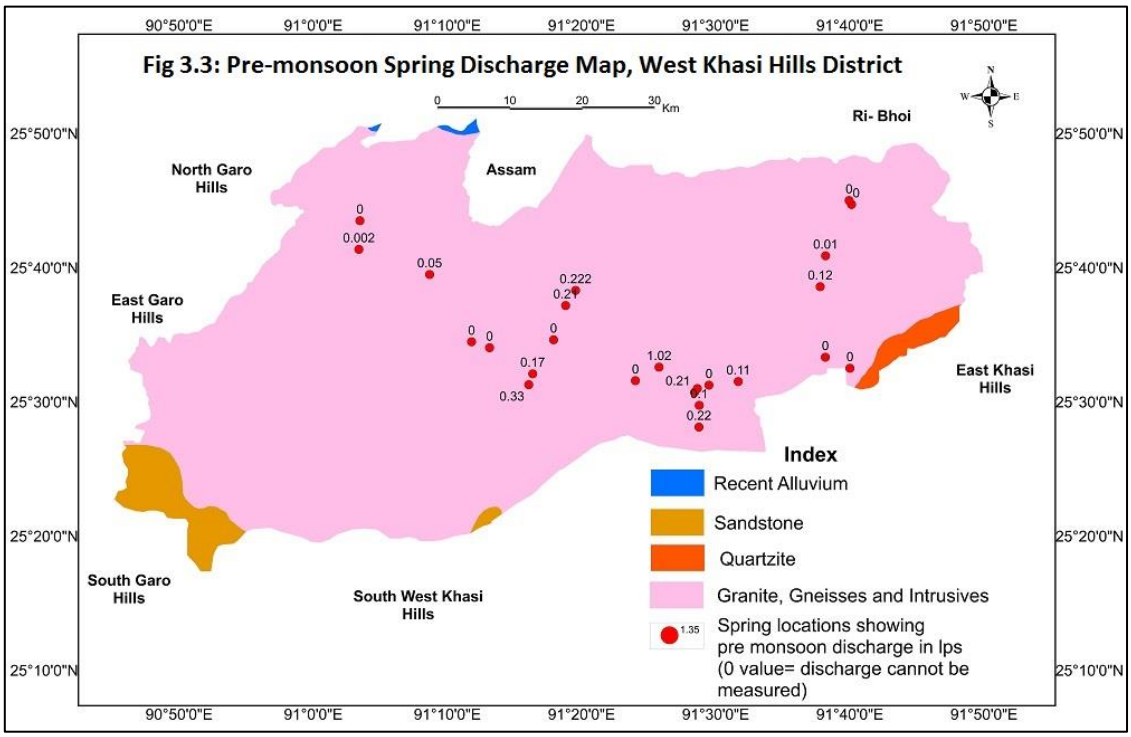


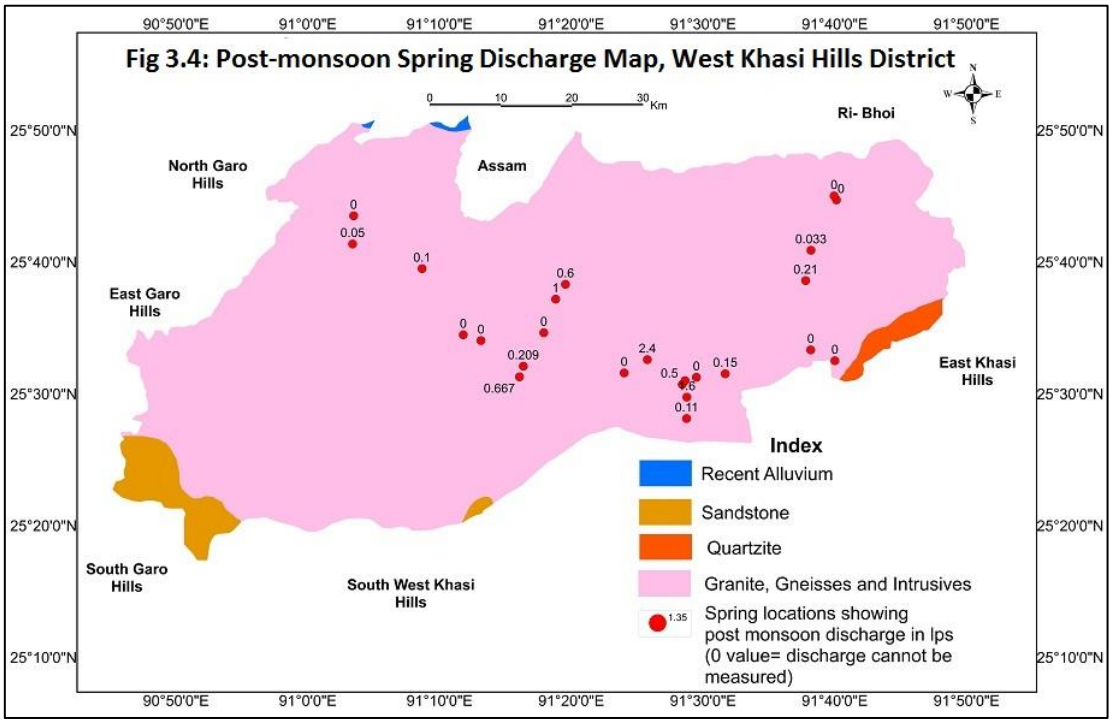
3.1.1 Occurrence of Ground Water in Shallow Aquifers: The depth of shallow aquifer in the district ranges from 1 to 3 meters. This shallow aquifer occurs under unconfined to semi confined condition. Ground water from shallow aquifer is extracted through different types of ground water extraction structures such as dug wells.

3.1.2 Occurrence of Ground Water in Deeper Aquifers: The deeper aquifer occurs as semi-confined to confined condition where ground water is found in the fractured zone of consolidated Quartzite, Granite Gneiss and Granitic Plutons. The drilled depth of exploratory wells tapping this aquifer ranges from 30 to 161.45 m bgl.The static water level in these wells varies from 1.0 to 6.84 m bgl. The number of fractures and its zones encountered varies in all the places which show the complexity of the hydrogeology of consolidated hard rock formation.

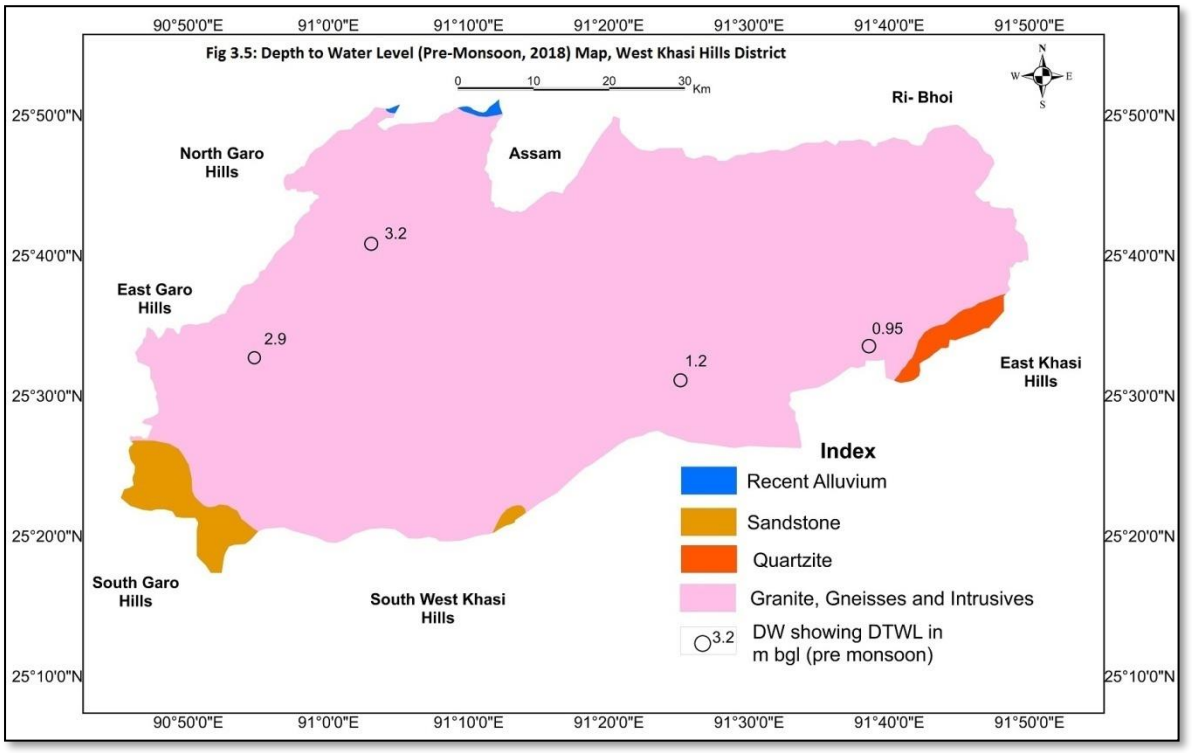
3.1.3 Springs: Spring is defined as a localized natural discharge of ground water appearing at the ground surface as a current of flowing water through well-defined outlets. The discharge may vary from a trickle to a stream. Groundwater flow from springs is governed mainly by three inter-related factors: geology (type, distribution and permeability characteristics of geologic units), topography (landforms and relief), and climate (timing and amount of precipitation). Topography drives the groundwater flow downhill and largely dictates the occurrence of the spring itself. Climate would influence the timing and amount of recharge to the flow system and the volume and variability of discharge. Groundwater obtained from springs is similar to water pumped from shallow wells. The study of spring has been carried out in the aquifer mapping area and it was found that the location of the springs 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 25 springs were established for periodical monitoring during the course of study. Most of these springs are depression and topographic or fractured springs. It is observed that most of the springs in the district are either depression or topographic or fractured springs. Discharge of springs in general varies from 0.6 to 60 litre/minute during pre-monsoon and from 2 to more than 96 litre/minute

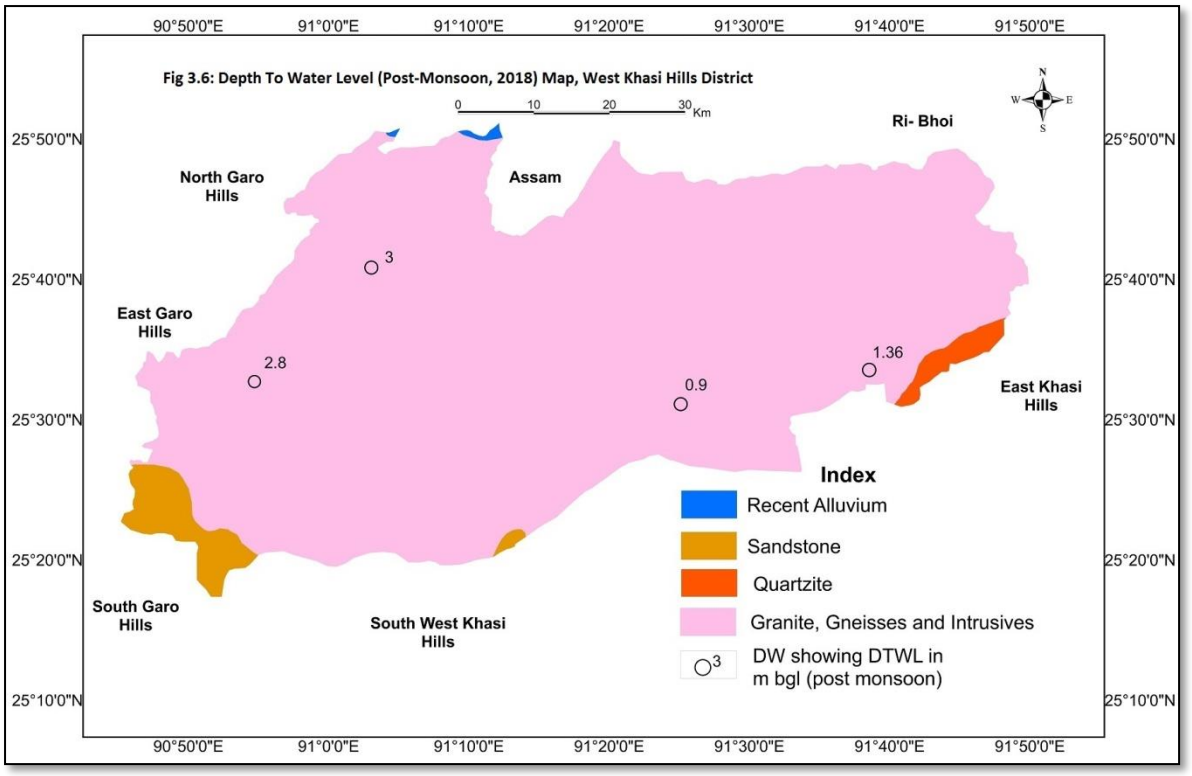
during post-monsoon season. Discharge from springs during pre-monsoon and post-mosoon season is shown in Fig 3.3 & 3.4 respectively. Some springs have quite fair discharge even in premonsoon season viz., springs at Nongstoin Market and Mawphalnur (about 19 and 60 litres/minute respectively) while some went dry during premonsoon season. It is observed that the discharge of springs increases during post-monsoon. Most of the springs showed drastic increase in discharge during post-monsoon season suggesting the direct influence of rainfall on the discharge of springs. While a few springs have a gradual impact of rainfall on their discharge. Some of the springs were chambered with no conduit so measuring their accurate discharge was not possible.



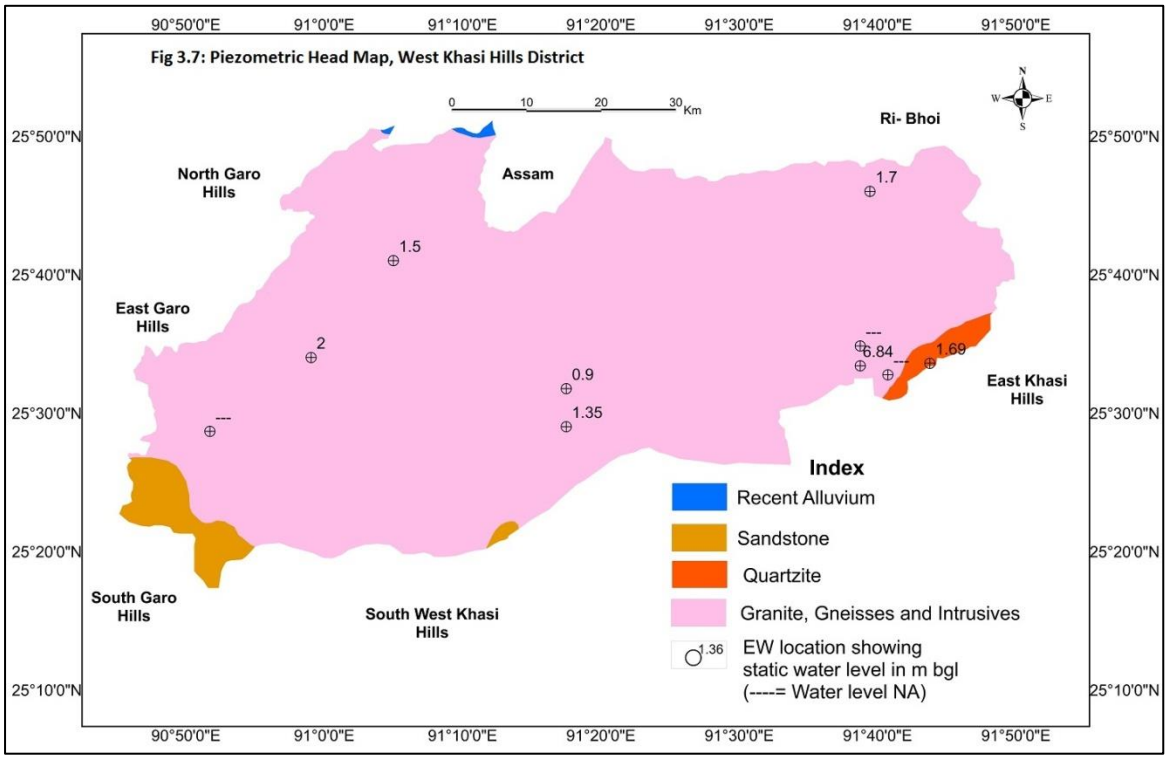


3.2 Depth to Water Level: Study of water level and its behaviour both in phreatic and confined condition were carried out in the aquifer mapping area. A total of 4 Dug wells were established as key wells for periodical monitoring to know the water level trend and its behaviour in phreatic condition. The depth to water level in these dug wells ranges from 0.95 to 2.9 m bgl during pre-monsoon and 0.9 to 3.00 m bgl during post-monsoon season and is shown in fig 3.5 and fig. 3.6 respectively. Average water level fluctuation is 0.25 m.





To study the piezometric head, static water level of exploratory wells drilled in the district were taken into account. Regular monitoring of these wells could not be done during NAQUIM studies because either the wells were abondoned, or not functional or fitted with pump. The observation wells were also not drilled in the vicinity of those exploratory wells so the regular monitoring was not possible. In addition the sources from state government indicate that there are only 2 nos. of deep tubewells (details of which have been given in table 3.4) in the district. The static water level in these wells during the time of drilling ranges from 0.9 to 6.84 m bgl. The piezometric heads are shown in Fig 3.7.



3.3 Aquifer system: The entire study area is underlain by consolidated rocks like Archaean Gneissic complex, Granite pluton, Quartzite, Intrusives and with small patches of weathered/fractured sandstone/shale (Jaintia group and Quaternary) in the southeast, southwest and northwest part of the district. Northwestern part of the district has dolerite and ultrabasic dykes and sills. Intrusives and sandstone/ sand/ shale/ alluvium are unexplored and are very limited in aerial extent also in the district. The aquifer system exists mainly in Granitic plutons, Archaean Gneissic complex and the quartzites. It also exists in both weathered formation as well as fractured system down to the maximum explored depth of 161.45 m bgl. Thus, hydrogeologically, the study area can be categorized into three groups, i.e., (i) Granitic gneissic complex aquifer of Archaean and Granitic plutons aquifer of Neo-Proterozoic to Early Paleozoic (ii) Quartzite aquifer of Shillong Group (iii) sand/ Sandstone/ shale/ alluvium aquifer of Jaintia Group and Quaternary. The aquifer system in these hard rock terrains is a complex one. Number, depth and thickness of fractures were observed not only in different geological formations but also in same geological formation. Disposition of fractures and aquifer disposition in the study area is shown in Figs. 3.8 and 3.9.

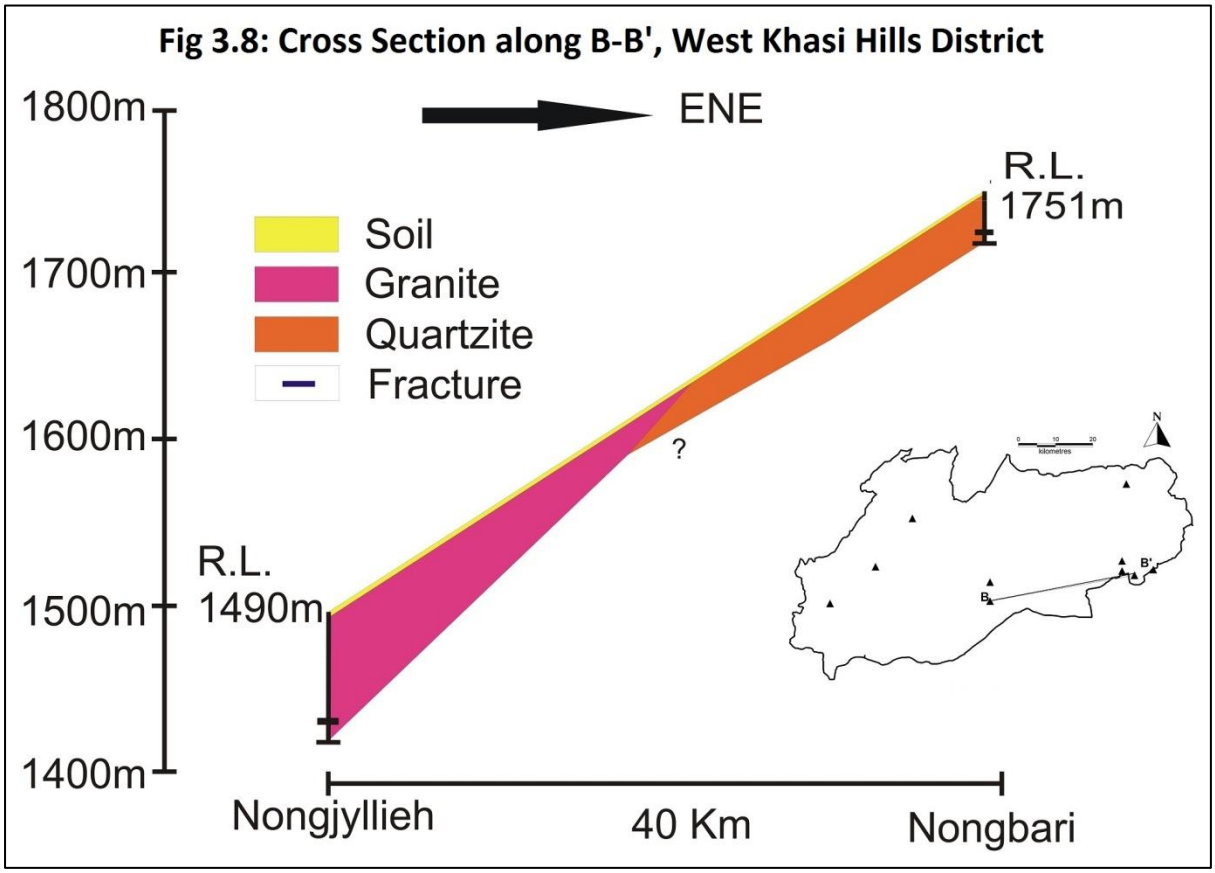


Fig 3.8: Cross Section along B-B', West Khasi Hills District

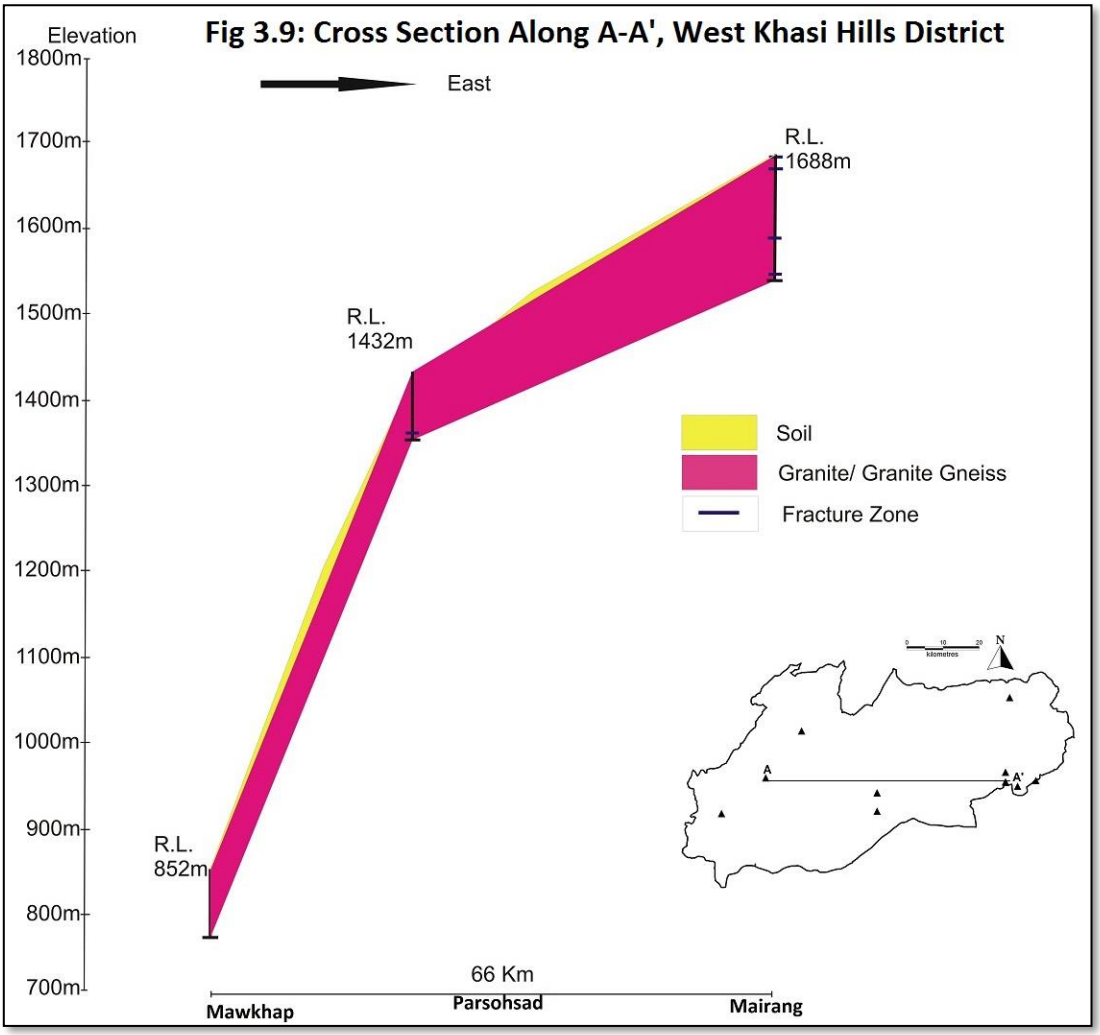


Fig 3.9: Cross Section Along A-A', West Khasi Hills District

3.3.1 Formation-wise Hydrogeology of the district:

3.3.1.1 Granitic Gneissic Complex and Granitic Plutons: Aquifers found in this group do not have very good potential for ground water. The occurrence of ground water in this formation is largely controlled either by weathering or by fractures patterns. In fractured rocks, ground water movement mainly takes place along the fracture and their openings. Groundwater in these formations occurs under phreatic conditions in weathered mantle and under semi-confined to confined conditions in the fractured rocks, which is governed by topography and drainage. Most of the drilling in the district has been done in this group of aquifer (this group of rock formation covers almost whole district). In this aquifer group, depth of first aquifer ranges from 6 to 20 m bgl and the second aquifer ranges from 25 to 161.45 m bgl. Discharge of the exploratory wells ranges from 1.5 to 10 m3/hr. Distribution of fractures at various depths and cumulative discharge is tabulated in table 3.1.

Table 3.1 Location wise details of fracture encountered in Granitic gneissic complex

Location	**Depth drilled (in m bgl)**	**Number of fractures encountered**					**Discharge (in m^3/hr)**
		0 to 50 m	50 to 100 m	100 to 150 m	150 to 200 m	200 to 250 m	
Mawkarad	24.5	NA	NA	----	----	---	NA
Mawkhap	80.3	NA	NA	----	----	---	NA
Nongjyllieh	80	1	1	----	----	---	8.4
Nongrynkiew	80	NA	NA	----	----	---	10
Parsohsad	80	1	1	----	----	---	1.5
Umtholong	80	2	2	----	----	---	5.33
Mairang Mission	161.45	2	2	NA	----	----	36

The above table reveals that in most of the places, 1 to 2 numbers of fractures were encountered within 50 m and 50-100 m depth.

3.3.1.2 Quartzite of Shillong Group: This aquifer system provides low to average ground water potential. Ground water occurs in the area under watertable conditions in the top weathered quartzite and in semi-confined to confined condition in the interconnected joints and fractures of the underlying hard quartzite. Exploratory bore wells were constructed in this formation within a depth range of 31.5 to 61.8 m bgl. Discharge in the wells ranges from 0.6 to 1.55 m^3/hr. Distribution of fractures at various depth and cumulative discharge is tabulated in table 3.2.

Table 3.2: Location wise details of fracture encountered in Quartzite

Location	**Depth drilled (in m bgl)**	**Number of fractures encountered**					**Discharge (in m^3/hr)**
		0 to 50 m	50 to 100 m	100 to 150 m	150 to 200 m	200 to 250 m	
Mairang	39.5	NA	----	---	----	----	1.5
Nongbari	31.5	NA	----	----	----	----	0.6
Mawpat Dongkiigdiang	61.8	1	----	----	----	----	1.55

3.4 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. The second aquifer is the deeper aquifer which tapped the fractured zones. Based on the study of litholog and analysis of depth of construction of dug wells and shallow bore wells, it is found that the first aquifer occur within 2 to 20 m bgl. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures upto the maximum depth of 161 m bgl.

3.5 Aquifer Properties:

Aquifer I: It is the unconfined aquifer where the tapped aquifer zone ranges within 2 to 30 m depth and generally exhibits unconfined nature of the aquifer.

Aquifer II: This is the deeper aquifer delineated in Gneiss and Granite, quartzites which occurs as semi-confined condition. Drilled depth of the exploratory wells ranges from 24.5 to 161.45 m bgl. The number of fractures and depth of encountering fractures varies widely which show the complexity of the hydrogeology of consolidated hard rock formation. The piezometric head ranges from 0.9 to 6.84 m bgl. Through PYT test it is found that drawdown varies from 8 to 15 m. The discharge in these wells ranges from 1.5 to 10 m^3/hr.

3.6 Hydrochemistry:

The quality of ground water is as important as that of the quantity. In order to study the chemical quality of ground water in the district, water samples from springs and dug wells were collected during the course of field work. The parameters analyzed are pH, EC, Turbidity, TDS, CO_3, Cl, SO_4, Na, K, HCO_3, NO_3, F, Ca, Mg, TH and Fe. The details of chemical analysis were given in the Annexure 2(A) and 2(B).

3.6.1 Ground Water Quality of Unconfined Aquifer:

A total of 4 ground water samples from dug well were collected during pre-monsoon and post-monsoon studies and the range of concentrations of different chemical constituents present in the ground water samples are given in table 3.3.

It is deciphered from table 3.3 that all of the chemical parameters are within permissible limit for all uses. But the water at one dug well i.e., Nongdaju, Mawsyrnut is found to be acidic in nature.

The EC values, pH values and Fe conc. of water samples collected from dug wells during premonsoon season are shown in fig 3.10 in fig 3.11 in fig. 3.12 respectively.

Table 3.3: Chemical Quality of water samples from Dug wells, West Khasi Hills district (2018-19)

Sl.No.	Chemical constituents	Range (Concentrations in mg/l except pH)	
		Min	Max
1	pH	5.98	7.70
2	E.C. in *micro seimens/cm at 25°C*	47.32	175.40
3	Turbidity(NTU)	BDL	BDL
4	TDS	28.59	105.30
5	TH	35	110
6	Ca	8.01	22.02
7	Mg	2.42	13.34
8	Na	4.05	19.87
9	K	5.60	8.89
10	CO_3	BDL	BDL
11	HCO_3	15.01	90.07
12	SO_4	3.58	18.01
13	NO_3	BDL	2.06
14	Fe	BDL	0.71

3.6.2. Ground Water Quality in Deeper Aquifer: As per data available from PHE department, Nongstoin, West Khasi Hills district, there are only two deep tube wells in the district whose details are given below in the table 3.4.

Table 3.4: Chemical quality of Ground Water from deeper aquifer in West Khasi Hills district

Village	Block	Yield (m3/hr)	Depth (m)	SWL (m)	Drawdown (m)	pH	Total Hardnes	Iron (mg/l)	Chloride (mg/l)
New Nongstoin	Nongstoin	0.06	57	24	8	6.8	90	0.3	
Teishsaw		0.09	48	12	4	6.5	110	0.3	

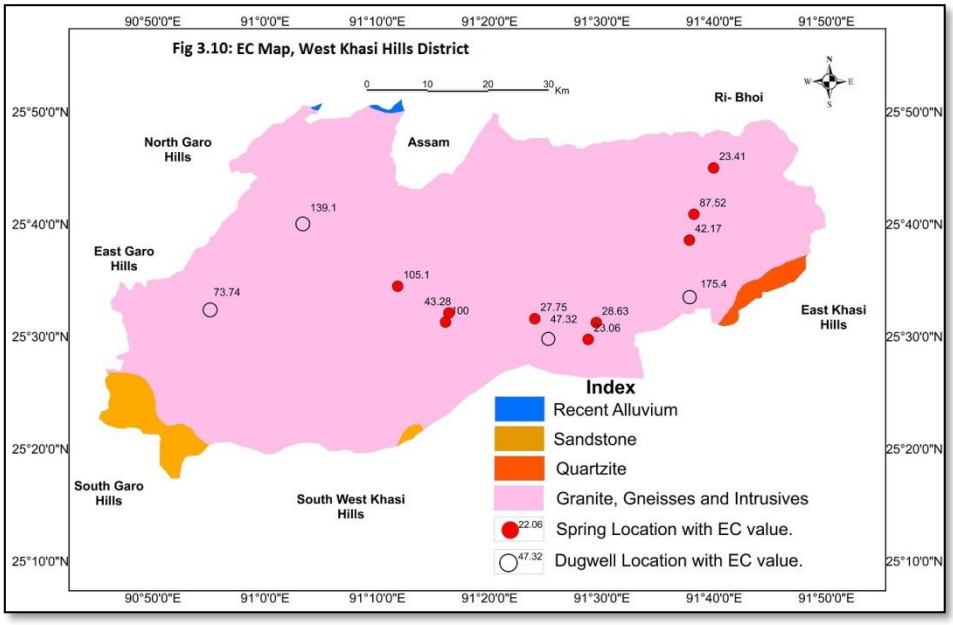
(Source: PHE, West Khasi Hills)

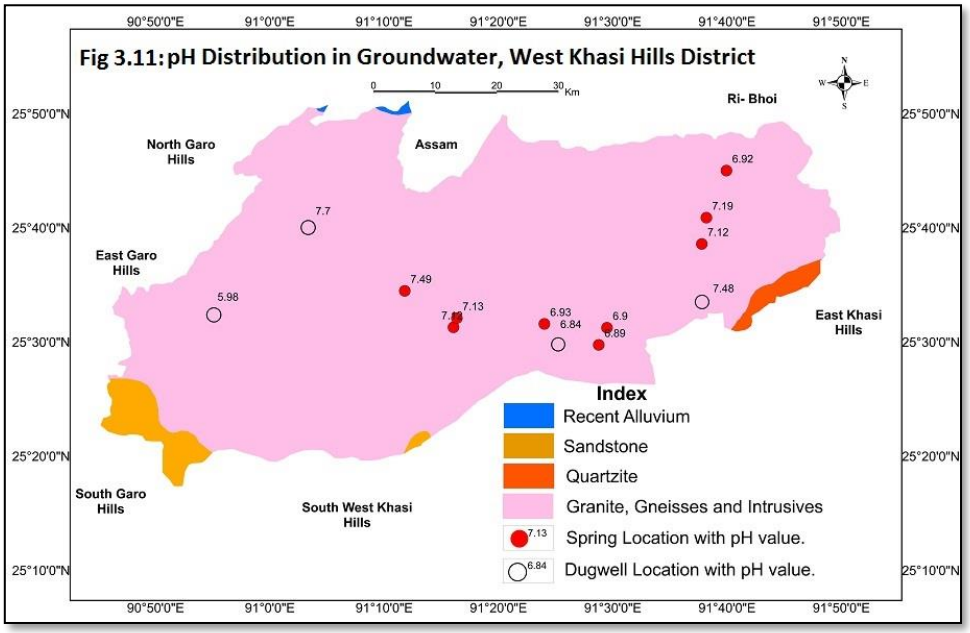
3.6.3 Water Quality of Springs: A total of 9 water samples from springs were collected during the course of study and the range of concentration of different chemical constituents present in the spring samples is shown in table 3.5, which reveals that all parameters are within the permissible limit.

Table 3.5: Chemical Quality of spring water, West Khasi Hills district, 2018-19

Sl.No.	Chemical constituents (Concentrations in mg/l except pH)	Range	
		Min	Max
1	pH	6.89	7.49
2	E.C. in micromhos/cm at 25º C	23.06	105.10
3	Turbidity(NTU)	BDL	0.30
4	TDS	13.84	63.17
5	TH	50	80
6	Ca	6	14.01
7	Mg	8.49	13.35
8	Na	1.95	8.9

9	K	1.59	3.48
10	CO_3	BDL	BDL
11	HCO_3	10.01	45.04
12	SO_4	1.72	22.95
13	NO_3	BDL	3.05
14	Fe	BDL	0.08





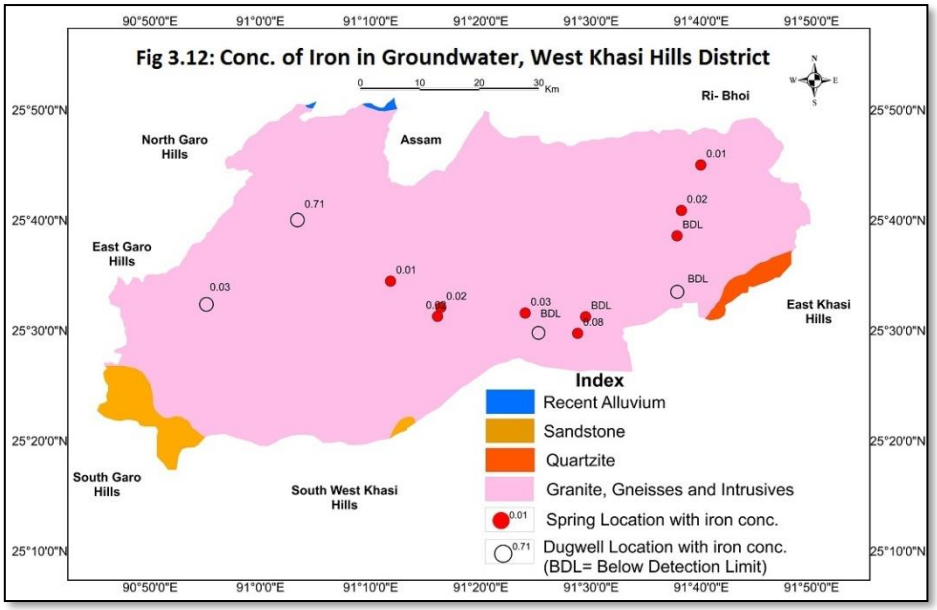


Fig 3.12: Conc. of Iron in Groundwater, West Khasi Hills District
0 10 20 30 Km
N
W E
S
90°50'0"E
91°0'0"E
91°10'0"E
91°20'0"E
91°30'0"E
91°40'0"E
91°50'0"E
25°50'0"N
25°40'0"N
25°30'0"N
25°20'0"N
25°10'0"N
Ri- Bhoi
North Garo Hills
Assam
East Garo Hills
East Khasi Hills
South Garo Hills
South West Khasi Hills
0.01
0.02
BDL
0.71
0.03
0.01
0.02
0.03
BDL
BDL
0.08
BDL
Index
Recent Alluvium
Sandstone
Quartzite
Granite, Gneisses and Intrusives
0.01 Spring Location with iron conc.
0.71 Dugwell Location with iron conc.
(BDL= Below Detection Limit)

4. GROUNDWATER RESOURCES –WEST KHASI HILLS DISTRICT

Dynamic Groundwater Resources of West Khasi Hills district has been estimated based on the methodology recommended by Groundwater Estimation Committee (GEC'2015). 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 1652.43 sq. km.

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

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

Lithological sub-units: The entire district is underlain by consolidated rocks like Archaean Gneissic complex, Granite pluton, Shillong group of Qartzite and limestone/sandstone. Different units considered for computation of recharge are Granitic-Gneissic complex, Quartzites, valley fills and alluvium.

4.1 Groundwater Resources – Recharge for Various Seasons: The rainfall infiltration factor recommended by GEC'2015 for Granitic- Gneissic complex and Quartzites are 0.05, for alluvium it is 0.20.

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.

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	Total Annual Ground Water Recharge	Provision for Natural Discharges	Annual Extractable Ground Water
West Khasi Hills	28913.66	122.90	4374.25	29.63	33440.44	3344.04	30096.40

Recharge from rainfall in the district is 33287.85 hams. Comparison of monsoon & non-monsoon rainfall recharge shows that monsoon recharge accounts for 86.85%. Recharge from other sources is 152.53 hams. Comparison of recharge from rainfall, to recharge from sources other than rainfall shows that the later accounts for only about 0.45 % 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 tube wells used by PHED to supply water and on number of structures used in different industrial units. Groundwater extraction for irrigation is nil whereas for domestic and industrial supply it is 14 ham in the district. It was found that groundwater extraction for all uses in the district is 14 ham. Provision for domestic and industrial requirement supply to 2025 is 28 ham. Net Ground Water Availability for future development in the district is 30068.40 ham.

4.3 Stage of Groundwater Development & Categorization of the Blocks: The district falls under "**SAFE"** category. The stage of development is only 0.05%. Summary of groundwater resources, stages of development and categorization are given in Annexure 8.

5. GROUND WATER RELATED ISSUES

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

5.1 Low Stage of Ground Water Development: As per ground water resource estimation 2017-18, the stage of ground water development is just 0.05 % 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 utilising 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.

5.2 Ground Water Quality: As per water quality analysis data, it is found that all the chemical parameters are within permissible limit, except at one palce water was found to be slightly acidic i.e. at Nongjadu in Mawshyrnut block.

6. MANAGEMENT STRATEGIES

As per dynamic ground water resource estimation of West Khasi Hills for 2016-17, Annual Extractable Ground Water Resources is 30096.40 ham and stage of extraction is only 0.05 %. The district is having balance net ground water availability for future irrigation use in the tune of 30068.40 ham. If an irrigation plan is made to develop 60% of the balance dynamic ground water resources available, then 18040 ham of groundwater resources is available in the district for the future irrigation uses.

Present land under irrigation during kharif season is 5427 ha. Present minor irrigation schemes are using surface water sources only. Present irrigation from ground water sources is 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. A suitable cropping plan for the district was prepared in consultation with Water Management Division of ICAR, Umiam. Cropping pattern data for the district is presented in Table 6.1.

During 2015-16, net sown area in the district is 20,260 ha and cropping intensity is 123%. The net sown area included field crops as well as horticulture and plantation crops cultivated on hills and their slopes. Cropping intensity is calculated generally from field crops, which are of short duration whereas horticulture (like citrus, banana and pineapple) and plantation crops like spices are long duration crops. Again crops grown on the hills like orange, turmeric and ginger are having negligible or nil irrigation requirements. During kharif season, paddy is cultivated in 5984 ha. After Kharif crops, potato are cultivated in 2608 ha, pulses in 69 ha and oilseeds in 33 ha. Major portion of paddy cultivated area remains fallow during Rabi season. The intention of this plan is to utilize this paddy fallow land of about 2322 ha under assured irrigation during Rabi season which will help to increase gross cropped area to 4644 ha and thereby increase cropping intensity up to 200%. In rice fallow, potato, mustard and Rabi vegetables can be grown with the support of irrigation. Present cropping pattern, proposed cropping pattern, targeted 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 estimated from CROPWAT after giving necessary meteorological, soil, crop plan inputs and the same has been shown in Table 6.1. Cropping pattern, proposed cropping pattern, intended cropping intensity, West Khasi Hills district, proposed cropping pattern with water deficit months and IWR, West Khasi Hills district Crop-wise and month-wise precipitation deficit (mm) using CROPWAT 8 for West Khasi Hills District has been presented in Table 6.2(a), 6.2(b) and 6.3 respectively.

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\Nongstoin.PAT)

Cropping pattern name: Nongstoin

No.	Crop file	Crop name	Planting date	Harvest date	Area %
1	...Data\CROPWAT\data	Rice	03/06	30/09	12
2	...Data\CROPWAT\data	Rice	11/06	08/10	15
3	...Data\CROPWAT\data	Rice	25/06	22/10	15
4	...Data\CROPWAT\data	Rice	02/07	29/10	8
5	...\CROPWAT\data\cro	Potato	25/11	03/04	25
6	rape___mustard.CRO	Mustard	15/10	26/02	12
7	...CROPWAT\data\crop	Small Vegetables	05/02	10/05	7
8	...CROPWAT\data\crop	Small Vegetables	15/02	20/05	6

Source: CROPWAT

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

Cropping pattern				
Rice based cropping pattern				
1. Rice-Potato 2. Rice-Mustard 3. Rice-Vegetables	Present Cultivated area (ha)	Area to be cultivated (%)	Area to be cultivated (ha)	Irrigation requirement (ham)
	1	2	3(= % of 1)	4
Rice (main crop)	2322	2322		351
Potato	0	1161	50	133
Mustard	0	580	25	41
Vegetables	0	581	25	29
Net cultivated area	2322			
Gross cultivated area (1+potato/+mustard/+Veg)		4644		
Total irrigation requirement				554
Cropping intensity	100% (Present)	200% (Intended)		

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

Rice Based Cropping Pattern			
Crop	Growing period (Months)	Periods/months of water deficit	Irrigation requirement (ha m)
Rice	4	1 – 2	351
Potato	5	5	133
Mustard	5	4	41
Vegetables	3	3	29
Total			554

During kharif season, rice is cultivated from June to mid-July. Since this huge area cannot be cultivated in a single day (one planting date), so it is considered/ planned to cultivate rice in four stages during this period.

It is planned to utilize rice fallow of 2322 ha for the cultivation of potato, mustard and vegetables. It is considered to cultivate potato in 1161 ha, mustard in 580 ha and vegetable in 581 ha, including present cultivation area for these crops. Area under vegetable cultivation is also considered/ planned to cultivate in two stages during this period.

The peak water requirement for irrigation for rice is in the month of June, for potato it is in the month of March, for mustard it is in the month of January and for vegetables it is in the month of March.

Under ground water exploration programme, CGWB has constructed 10 bore wells in this area and has established that the aquifer in most part of the district is having low potentiality. Only three bore wells are having discharge of 8 m^3/hr or more. Other bore wells are having very less discharge and cannot be converted into irrigation wells. The wells which are having relatively high discharge are located near (1) Mairang valley, (2) Lumpyngngad valley and (3) Nongstoin-Nongkhlaw (Nongstoin – Mawkyrwat road) area. In these valley/ areas borewells can be sustainably developed for irrigation purpose.

The ground water potentiality of the area is low. However, low-lying valley areas 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.

A bore well in the area is expected to yield 8 m^3/hr. If such a bore well runs for 10 hrs/day for 120 days, then it will create a draft of 0.96 ham. Bore wells can be designed within a depth of 100m, expected to encounter 1 – 2 fractures. Bore wells can be constructed by using $8^{//}$ dia. casing pipe down to 30 m.

Considering the locations where borewells drilled by CGWB have discharge in the range of 8 m^3/hr (total area approximately 5 sq.Km), a maximum of 125 nos. of shallow bore wells can be constructed (considering 200 m distance between any two shallow bore well).

Annual irrigation water requirement is 554 ham while irrigation water requirement during dry season spanning from October to March it is 206 ham. However, proportionate dynamic groundwater resources available for future irrigation use in 2322 ha in the district are 254 ham. During Rabi season, irrigation water demand is 206 ham and availability is 254 ham. So, there is no shortage between irrigation demand and availability. But there is a shortage of 300 ham of irrigation water for entire year.

During Rabi season, If 100 nos. of large diameter dug wells is constructed, then 50 to 75 ha land can be brought under assured irrigation. Rest of area i.e., 2250 ha land can be brought under irrigation by constructing bore wells by using 241 ham of groundwater resources, that can be harnessed by constructing 250 bore wells. Locations where dug wells and bore wells can be constructed for irrigation purposes are shown in Fig 3.13.

Ground water at some places is acidic which need to be treated before consumption. This acidic water can be treated by acid neutralizing filters or chemical feed pump.

Table 6.3: Crop-wise and month-wise precipitation deficit (mm) using CROPWAT 8 for West Khasi Hills District

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit (mm)												
1. Rice	0	0	0	0	147.1	59.3	0	0	0	0	0	0
2. Rice	0	0	0	0	49.3	98	0	0	0	0	0	0
3. Rice	0	0	0	0	0	146.9	0	0	0	4.3	0	0
4. Rice	0	0	0	0	0	100.7	0	0	0	0	0	0
5. Potato	30.6	34.6	37.4	0	0	0	0	0	0	0	2.5	9.5
6. Mustard	23.5	7.3	0	0	0	0	0	0	0	0	17.7	24.8
7. Small Vegetables	0	11.8	36.6	6.3	0	0	0	0	0	0	0	0
8. Small Vegetables	0	6.2	28	5.9	0	0	0	0	0	0	0	0

Table 6.4: Irrigation water requirement (ham) of West Khasi Hills District

	% of Total Area of 4644 ha	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation deficit (mm)														
1. Rice	10	0.0	0.0	0.0	0.0	68.3	27.5	0.0	0.0	0.0	0.0	0.0	0.0	95.9
2. Rice	15	0.0	0.0	0.0	0.0	34.3	68.3	0.0	0.0	0.0	0.0	0.0	0.0	102.6
3. Rice	15	0.0	0.0	0.0	0.0	0.0	102.3	0.0	0.0	0.0	3.0	0.0	0.0	105.3
4. Rice	10	0.0	0.0	0.0	0.0	0.0	46.8	0.0	0.0	0.0	0.0	0.0	0.0	46.8
5. Potato	25	35.5	40.2	43.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	11.0	133.1
6. Mustard	12	13.1	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	13.8	40.8
7. Vegetables	7	0.0	3.8	11.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8
8 Vegetables	6	0.0	1.7	7.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2
Total	100	48.62	49.80	63.12	3.69	102.65	244.90	0	0	0	3	12.76	24.85	553.4

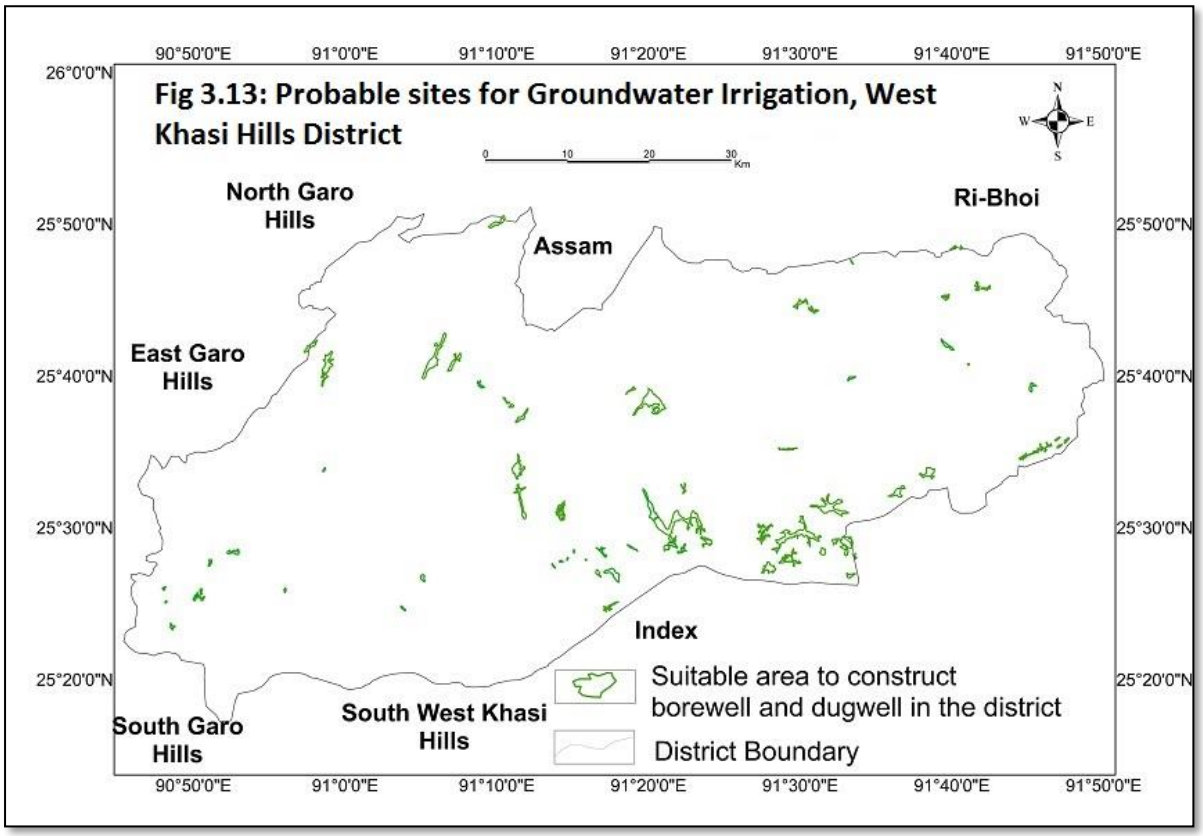


Fig 3.13: Probable sites for Groundwater Irrigation, West Khasi Hills District
90°50'0"E
91°0'0"E
91°10'0"E
91°20'0"E
91°30'0"E
91°40'0"E
91°50'0"E
26°0'0"N
25°50'0"N
25°40'0"N
25°30'0"N
25°20'0"N
0 10 20 30 Km
N
W
E
S
North Garo Hills
Ri-Bhoi
Assam
East Garo Hills
South Garo Hills
South West Khasi Hills
Index
Suitable area to construct borewell and dugwell in the district
District Boundary

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

Sl. No.	Location	Block	District	AAP year	Longitude	Latitude	Northing	Easting	Depth drilled (m)	Aquifer type	Aquifer Zone(m)	S.W.L (m bgl)	Discharge (m3/hr)	d.d (m)	T (m2/ day)
1	Mairang	Mairang	West Khasi Hills	1997 - 98	91.645833	25.580556	2829928.5	363992.49	39.5	Granitic gneiss		---	1.5	---	
2	Mawkarad	Mawshyrnut	West Khasi Hills	1995 - 96	90.862222	25.477778	285087.49	285087.49	24.5	Granitic gneiss		---	---	---	
3	Mawkhap	Mawshyrnut	West Khasi Hills	1997 - 98	90.984167	25.566667	2829234.1	297499.36	80.3	Granitic gneiss		2	3	8	
4	Mawpat Dongkiigdiang	Mairang	West Khasi Hills	1997 - 98	91.6575	25.766667	2850529.8	365373.71	61.8	Quartzite	23.0-25.0	1.7	1.55	---	
5	Nongbari	Mairang	West Khasi Hills	1997 - 98	91.679167	25.545833	2826049	367302.55	31.5	Granitic gneiss		---	0.6	---	
6	Nongjyllieh	Nongstoin	West Khasi Hills	1997 - 98	91.291667	25.483333	2819569.9	328276.97	80	Granitic gneiss	41.0-42.0,67.5-68.5	1.35	8.4	12	
7	Nongrynkiew	Mawshyrnut	West Khasi Hills	1997 - 98	91.083333	25.683333	2842010.4	307650.54	80	Granitic gneiss		1.5	10		
8	Parsohsad	Nongstoin	West Khasi Hills	1997 - 98	91.291667	25.529167	2824646.9	328342.17	80	Granitic gneiss		0.9	1.5	15	
9	Umtholong	Mairang	West Khasi Hills	1997 - 98	91.729722	25.559722	2827537.7	372396.81	80	Granitic gneiss	17.9-26.1,35.2-40.3,61.7-65.7,75.9-80.0	1.69	5.33	12	
10	Mairang Mission	Mairang	West Khasi Hills	2011 -12	91.645833	25.556667	2827282.6	363965.5	161.45	Granitic gneiss	12.5 –14.05, 20.6–21.15, 100.4-1005.5, 143.0-161.40	6.84		2.98	180

Annexure 1(B): Hydrogeological details of Dug wells established by CGWB in Aquifer mapping area

Sl. No.	State	District	Block	Location	Latitude	Longitude	RL (m)	Type	M.P. (m)	Depth (m)	Diameter (m)	DTWL (mbgl) Premonsoon 2018*	DTWL (mbgl) Monsoon-2018*	DTWL (mbgl) PostMonsoon-2018*
1	Meghalaya	West Khasi Hills	Mairang	Mairang	25.56242	91.63939	1663	DW	0.4	4.45	1.2	0.95	0.68	1.36
2	Meghalaya	West Khasi Hills	Mawshyrnut	Riangdo	25.6755	91.06	919	DW	0.65	8.92	0.68	3.2	2.9	3
3	Meghalaya	West Khasi Hills	Mawshyrnut	Nongdaju	25.55006	90.91686	726	DW	0.95	5.3	1.5	2.9	3.2	2.8
4	Meghalaya	West Khasi Hills	Mawthadraishan	Nongksen	25.52383	91.41681	1804	DW	0.47	1.5	L=1.54, B=1.63	1.2	0.65	0.9

Annexure 2(A): Aquifer wise water quality data of Aquifer mapping area

State	District	Location	Latitude	Longitude	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												
SPRINGS																					
Meghalaya	West Khasi Hills	Mawlyngdep	25.57433	91.19667	7.49	105.10	0.30	63.17	BDL	45.04	45.04	31.91	1.72	3.05	0.13	14.01	10.92	80.00	4.73	1.90	0.01
Meghalaya	West Khasi Hills	Pariong Road	25.49544	91.47953	6.89	23.06	0.10	13.84	BDL	20.02	20.02	14.18	22.95	BDL	0.11	6.00	10.92	60.00	1.95	1.68	0.08
Meghalaya	West Khasi Hills	Nongstoin Market	25.52114	91.26775	7.12	100.00	BDL	60.22	BDL	15.01	15.01	39.00	10.15	1.51	0.14	12.01	10.92	75.00	4.35	2.16	0.02
Meghalaya	West Khasi Hills	Teishaw	25.53461	91.27264	7.13	43.28	BDL	26.08	BDL	30.02	30.02	35.45	4.16	BDL	0.11	8.01	13.35	75.00	3.93	2.97	0.02
Meghalaya	West Khasi Hills	Teishaw	25.52608	91.40025	6.93	27.75	BDL	16.66	BDL	20.02	20.02	35.45	2.67	BDL	0.09	6.00	8.49	50.00	7.10	1.59	0.03
Meghalaya	West Khasi Hills	Umjei	25.5205	91.49158	6.90	28.63	0.10	17.24	BDL	25.02	25.02	35.45	2.57	BDL	0.08	8.01	10.92	65.00	2.97	2.77	BDL
Meghalaya	West Khasi Hills	Donki-Ingding	25.74994	91.66575	6.92	23.41	0.20	14.05	BDL	10.01	10.01	46.09	2.24	BDL	0.22	6.00	8.49	50.00	7.30	3.48	0.01
Meghalaya	West Khasi Hills	Nongkhlaw	25.68119	91.6365	7.19	87.52	BDL	52.71	BDL	25.02	25.02	42.54	5.25	1.18	0.15	10.01	8.49	60.00	8.90	3.42	0.02
Meghalaya	West Khasi Hills	Maroid	25.64283	91.62981	7.12	42.17	BDL	25.38	BDL	25.02	25.02	28.36	5.92	BDL	0.19	8.01	7.28	50.00	4.20	2.57	BDL

State	District	Location	Latitude	Longitude	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 →												
DUG WELLS																					
Meghalaya	West Khasi Hills	Nongdaju	25.55	90.91	5.98	73.74	BDL	44.72	BDL	15.01	15.01	10.64	18.01	2.06	0.21	10.01	2.42	35	4.05	6.68	0.03
Meghalaya	West Khasi Hills	Riangdo	25.67	91.06	7.70	139.10	BDL	84.35	BDL	90.07	90.07	63.81	3.58	BDL	0.27	22.02	13.3	110	15.2	8.89	0.71
Meghalaya	West Khasi Hills	Nongksen	25.52	91.41	6.84	47.32	BDL	28.59	BDL	25.02	25.02	42.54	4.12	BDL	0.08	8.01	7.28	50	9.67	5.60	BDL
Meghalaya	West Khasi Hills	Mairang	25.56	91.63	7.48	175.40	BDL	105.30	BDL	45.04	45.04	63.81	16.76	1.01	0.12	20.02	7.27	80	19.8	8.11	BDL

Annexure 3 Details of Monitoring Wells In West Khasi Hills District:

S. No.	State	District	Village	Well_No	Well_Type	Lat DMS	Long DMS	MP(m)	Present Status
1	Meghalaya	West Khasi Hills	Pindeng nongbri	78O2C2	Dug Well	25°32'25"	91°40'35"	NA	Abondened
2	Meghalaya	West Khasi Hills	Mairang	78O2C1	Dug Well	25°34'40"	91°38'30"	GL	Abandoned

Annexure 4: Dynamic water level data

Location	DTWL (mbgl) Mar 14	DTWL (mbgl) Aug 14	DTWL (mbgl) Nov 14	DTWL (mbgl) Jan 15	DTWL (mbg) Mar 15	DTWL (mbgl) Aug 15	DTWL (mbgl) Nov 15	DTWL (mbgl) Jan 16	DTWL (mbgl) Mar 16	DTWL (mbgl) Aug 16	DTWL (mbgl) Nov 16	DTWL (mbgl) Jan 17	DTWL (mbg) Mar 17	DTWL (mbgl) Aug 17	DTWL (mbgl) Nov 17	DTWL (mbgl) Jan 18	DTWL (mbgl) Mar 18	DTWL (mbgl) Aug 18	DTWL (mbgl) Nov 18	DTWL (mbgl) Jan 19	DTWL (mbg) Mar 19
Shallow Aquifer																					
Mairang	1.16	0.38	0.73	0.80	1.01	0.49	0.72	1.27	0.85	0.50	0.47		0.89	1.2	1.03	0.95	0.95	0.68	0.78	0.96	0.8
Pindeng nongbri	**Abondoned on November, 2000**																				

Annexure 5: Spring discharge monitored in West khasi Hills district during 2018-19

State	District	Block	Name of village/site	Latitude	Longitude	RL	Type	Discharge (LPS) (Pre-Monsoon)-2018*	Discharge (LPS) (Monsoon)-2018*	Discharge (LPS) PostMonsoon-2018*
Meghalaya	West Khasi Hills	Mairang	Umniangriang	25°44’41.7”	91°40’7.5”	743	Depression	Can Not be measured		
Meghalaya	West Khasi Hills	Mairang	Nongkhlaw	25°40’52.3”	91°38’11.4”	1367	Depression	0.01	0.018	0.033
Meghalaya	West Khasi Hills	Mairang	Marido Village	25°38’34.2”	91°37’47.3”	1350	Depression	0.12	0.3	0.21
Meghalaya	West Khasi Hills	Mairang	Songshaw	25°33’18.7”	91°38’10.3”	1652	Depression			
Meghalaya	West Khasi Hills	Nongstoin	Nongstoin Market	25°31’16.1”	91°16’3.9”	1326	Depression	0.33	1	0.667
Meghalaya	West Khasi Hills	Nongstoin	Tshaw	25°32’04.6”	91°16’21.5”	1375	Depression	0.17	1	0.209
Meghalaya	West Khasi Hills	Nongstoin	Mawlangdep	25°34’27.6”	91°11’48.0”	1257	Depression	Can Not be measured		
Meghalaya	West Khasi Hills	Nongstoin	Nongstoin -Riangdo Road	25°43’29.4 ”	91°03’28.7”	806	Depression	Can Not be measured		
Meghalaya	West Khasi Hills	Nongstoin	Langlur	25°34’36.8”	91°17’54.8”	1480	Depression	Can Not be measured		
Meghalaya	West Khasi Hills	Nongstoin	Nongstoin Rambrai Road	25°37’09.9”	91°18’48.8”	1408	Fracture	0.21	0.5	1
Meghalaya	West Khasi Hills	Nongstoin	Rambrai	25°38’17.4”	91°19’33.3”	1403	Depression	0.222	0.294	0.6
Meghalaya	West Khasi Hills	Mawthadraishan	Mawphalnur	25°32’34.4”	91°25’46.5”	1819	Depression	1.02	1.8	2.4
Meghalaya	West Khasi Hills	Mawthadraishan	Umkrem	25°29’43.6”	91°28’46.3”	1571		0.1	0.125	0.267
Meghalaya	West Khasi Hills	Mawthadraishan	Mawkhangai	25°30’41.5”	91°28’25.2”	1578	Depression	0.21	0.5	0.5
Meghalaya	West Khasi Hills	Mawthadraishan	Nongshillong	25°30’58.6”	91°28’38.0”	1556	Depression	0.016	0.05	0.085
Meghalaya	West Khasi Hills	Mawthadraishan	Umjei	25°31’13.8”	91°29’29.7”	1603	Fracture	Can Not be measured		
Meghalaya	West Khasi Hills	Mawshyrnut	Tynrongriankhon	25°41’21.0”	91°03’24.0”	902	Depression	0.002	0.0167	0.05
Meghalaya	West Khasi Hills	Mawshyrnut	Sanduli II	25°39’28.7”	91°08’40.40”	1151		0.05	0.1	0.1
Meghalaya	West Khasi Hills	Mawthadraishan	Tieshaw	25°31''33.9"	91°24'0.9"	1508	Depression	Can Not be measured		
Meghalaya	West Khasi Hills	Mairang	Donki-Ingding	25°44''59.8"	91°39'56.7"	770	Depression	Can Not be measured		
Meghalaya	West Khasi Hills	Mawthadraishan	Pariong Road	25°29''43.6"	91°28'46.3"	1571	Fracture	0.05		1.6
Meghalaya	West Khasi Hills	Mawthadraishan	Pariong Road	25°28''06.3"	91°28'45.1"	1610	Depression	0.22		0.11
Meghalaya	West Khasi Hills	Mawthadraishan	Kynshi	25°31'30"	91°31'40.8"	1577	Depression	0.11	0.22	0.15
Meghalaya	West Khasi Hills	Mairang	Wahlakhaw	25° 32' 29.4"	91° 40' 01.4"	1771	Fracture	Can Not be measured		
Meghalaya	West Khasi Hills	Nongstoin	Umsaw	25° 34' 01.2"	91° 13' 08.5"	1301	Depression	Can Not be measured		

Annexure 6: Litholog of exploratory wells

Location	Mairang	Depth Range (m)	Thickness (m)	Lithological Description
Taluka/Block	Mairang	00-5.50	5.5	Yellow coloured clay
District	West Khasi Hills	5.50-10.00	4.5	Weathered quartzite partially weathered
Toposheet No	78 O/14	10.0 - 11.50	1.5	Weathered quartzite
Latitude	25°34'50"	11.0 - 20.0	8.5	Weathered quartzite
Longitude	91°38'45"	20.0 - 2.08	7	Calcareous powder with weathered quartzite
RL (m amsl)	1611	35.0 - 39.50	4.5	While powder slurry of quartzite
Drilled Depth	39.5			
Casing	11.5			
SWL (mbgl)	NA			
Discharge (lps)	0.4166			
Date/year	1997-98			

Location	Mawkhap	Depth Range (m)	Thickness (m)	Lithological Description
Taluka/Block	Mairang	00 - 4.0	4	Yellow colour muddy clay
District	West Khasi Hills	4.0 -5.50	1.5	Weathered granite yellow colour
Toposheet No	78 K/14	5.50-7.10	1.6	Weathered granite with some fresh cutting with rounded qty at
Latitude	25°34'00"	7.10-37.0	29.9	Granite fresh cutting random grey color
Longitude	90°59'03"	37.0-43.0	6	Granite (pink colour) cutting random cutting massive granite
RL (m amsl)	847	43.0 - 48.0	5	Red colour granite powder with leading zone
Drilled Depth	80.3	48.0 - 55.0	7	Black color (biotic granite) powder
Casing	5.6	55.0 - 62.0	6	Red color fresh cutting of granite
SWL (mbgl)	2	62.0-68.10	6.1	Black color granite sugar grain cutting
Discharge (lps)	0.84	68.10-80.30	12.2	Black colour powder of biotite granite
Date/year	1997-98			

Location	Nongebri	Depth Range (m)	Thickness (m)	Lithological Description
Taluka/Block	Mairang	00-3.50	3.5	Yellow colour mud clay
District	West Khasi Hills	3.50 - 15.0	11.5	Clay (mud) with quartzite weathered
Toposheet No	78 O/10	15.0 - 26.00	11	Weathered quartzite, fresh fragments of quartzite
Latitude	25°32'45"	26.0 - 26.50	0.5	Weathered quartzite, fractured
Longitude	91°40'45"	26.50 – 31.50	5	Weathered quartzite with clay powder (white colour)
RL (m amsl)	1773			
Drilled Depth	31.5			
Casing	2.8			
SWL (mbgl)	NA			
Discharge (lps)	0.167			
Date/year	1997-98			

Location	Nongjyllieh	Depth Range (m)	Thickness (m)	Lithological Description
Taluka/Block	Mairang	00-3.0	3	Weathered granite with yellow color clay
District	West Khasi Hills	3.0-24.0	21	Mica schist black grey color
Toposheet No	78 O/7	24.0-41.0	17	Feldspar (pink colour) granite hard rock powder with angular cutting
Latitude	25°29'00"	41.0 - 42.0	1	Zone of water leaching feldspar granite
Longitude	91°17'30"	42.0 - 50.0	8	Pink color granite massive angular cutting
RL (m amsl)	1504	50.0 - 55.0	5	Mica schist (black colour powder)
Drilled Depth	80	55.0 - 67.5	12	Granite feldspar with quartzite
Casing	3.5	67.5 - 67.5	2	Fracture in granite (rock cutting quartzite)
SWL (mbgl)	1.35	68.5-79.3	10.8	Hard granite (pink colour) rock powder + cutting of angular grain.
Discharge (lps)	2.34			
Date/year	1997-98			

Location	Parsohlad	Depth Range (m)	Thickness (m)	Lithological Description
Taluka/Block	Mairang	00-5.0	5	Weathered pink colored rock powder of granite
District	West Khasi Hills	5.0 -14	9	Hard rock powder black colour mica schist
Toposheet No	78 O/6	14.0 - 18.0	4	Small fragments of granite rock
Latitude	25°31'45"	18.0 - 32.0	12	Mica schist, black powder
Longitude	91°17'30"	32.0 - 36.0	4	Whitish powder with small quartz fragments
RL (m amsl)	1433	36.0 - 40.0	4	Small rock chips schist
Drilled Depth	80	40.0 - 58.0	18	Mica schist (small fragments of rock)
Casing	4.6	58.0 - 60.0	2	Rock chip of weathered mica schist
SWL (mbgl)	0.9	60.0 – 64.0	4	Black colour powder (mica chip)
Discharge (lps)	0.417	64.0 - 71.0	7	Small fragments of pink colourGranite
Date/year	1997-98	71.0-71.5	0.5	Mica schist, fractured, productive fracture
		71.5-80.00	8.5	Hard rock (black rock powder of mica schist)

Location	Parsohlad	Depth Range (m)	Thickness (m)	Lithological Description
Taluka/Block	Mairang	00-5.0	5	Weathered pink colored rock powder of granite
District	West Khasi Hills	5.0 -14	9	Hard rock powder black colour mica schist
Toposheet No	78 O/6	14.0 - 18.0	4	Small fragments of granite rock
Latitude	25°31'45"	18.0 - 32.0	12	Mica schist, black powder
Longitude	91°17'30"	32.0 - 36.0	4	Whitish powder with small quartz fragments
RL (m amsl)	1433	36.0 - 40.0	4	Small rock chips schist
Drilled Depth	80	40.0 - 58.0	18	Mica schist (small fragments of rock)
Casing	4.6	58.0 - 60.0	2	Rock chip of weathered mica schist
SWL (mbgl)	0.9	60.0 – 64.0	4	Black colour powder (mica chip)
Discharge (lps)	0.417	64.0 - 71.0	7	Small fragments of pink colourGranite
Date/year	1997-98	71.0-71.5	0.5	Mica schist, fractured, productive fracture
		71.5-80.00	8.5	Hard rock (black rock powder of mica schist)

Location	Mairang Mission	Depth Range (m)	Thickness (m)	Lithological Description
Taluka/Block	Mairang	00 - 1.85	1.85	Surface Soil
District	West Khasi Hills	1.85 - 12.50	10.65	Granite gneiss, pulverized sample, light grey
Toposheet No	78 O/10	12.50 - 14.05	1.55	Granite gneiss, little fractured, grey
Latitude	25°33'24"	14.05 - 20.60	6.55	Granite gneiss, massive, grey
Longitude	91°38'45"	20.60 - 21.15	0.95	Granite gneiss, little fractured, grey
RL (m amsl)	1686	21.15 - 100.45	79.3	Granite gneiss, massive, grey
Drilled Depth	161.45	100.45 - 105.55	5.1	Granite gneiss,little fractured,03 to 04 mm chips ofGranite gneiss,grey
Casing	20	105.55 - 143.15	37.6	Granite gneiss, massive, grey
SWL (mbgl)	6.84	143.15-161.45	18.3	Granite gneiss, highly fractured, 05 to 07 mm chips of Granite gneiss, grey
Discharge (lps)	10.0			
Date/year	2011-12			

Location	Umthlong	Depth Range (m)	Thickness (m)	Lithological Description
Taluka/Block	Mairang	00-5.0	5	Weathered pink colored rock powder of granite
District	West Khasi Hills	5.0 -14	9	Hard rock powder black colour mica schist
Toposheet No	78 O/10	14.0 - 18.0	4	Small fragments of granite rock
Latitude	25°33'35"	18.0 - 32.0	12	Mica schist, black powder
Longitude	91°43'47"	32.0 - 36.0	4	Whitish powder with small quartz fragments
RL (m amsl)	1761	36.0 - 40.0	4	Small rock chips schist
Drilled Depth	80	40.0 - 58.0	18	Mica schist (small fragments of rock)
Casing	5.5	58.0 - 60.0	2	Rock chip of weathered mica schist
SWL (mbgl)	1.69	60.0 – 64.0	4	Black colour powder (mica chip)
Discharge (lps)	1.48	64.0 - 71.0	7	Small fragments of pink colourGranite
Date/year	1997-98	71.0-71.5	0.5	Mica schist, fractured, productive fracture
		71.5-80.00	8.5	Hard rock (black rock powder of mica schist)

Annexure 7: Geophysical data, West Khasi Hills District

Location of Geophysical survey carried out in West Khasi Hills District during AAP 2010-11

Sl. No..	VES No.	Village	Location	Coordinates	Remarks with zones and expected fractures for recommended sites
1	190	Khurbawar	100m south of the road to Barapani and 50m west of church.	N 25°32'45.7" E 91°42'59.5"	
2	191	-do-	15m SE of poly house.	N 25°32'54.2" E 91°43'01.4"	
3	192	-do-	300m west of foot ball ground and 50m NE of natural spring pond.	N 25°33'07.2" E 91°43'06.6"	Fractures between 35m and 50m.
4	193	Tiehpdang	Near Holy cross hospital.	N 25°33'52.1" E 91°37'32.6"	
5	194	Nongbri	100m S65°E of water tank of LP School and 70m east of spring water collection tank.	N 25°32'23.1" E 91°40'22.2"	
6	195	-do-	43m S55°E of VES-194.	N 25°32'22.3" E 91°40'23.6"	
7	196	-do-	150m west of VES-194.	N 25°32'22.8" E 91°40'17.6"	
8	197	Tiehpdang	85m SW of the southern end of the bridge.	N 25°33'39.1" E 91°37'32.5"	
9	198	-do-	108m N40°E of the southern end of the bridge.	N 25°33'40.3" E 91°37'38.5"	
10	199	Nongthiliew	30m east of NE corner of the foot ball ground.	N 25°33'15.09" E 91°43'16.7"	
11	200	-do-	50m S35°E of VES-199.	N 25°33'13.5" E 91°43'18.0"	
12	201	Nongbri	100m north of the house of Sri Jngierwarjri and 60m north of the bund culvert.	N 25°32'21.7" E 91°40'36.8"	
13	202	-do-	60m N35°E of VES-201.	N 25°32'23.8" E 91°40'38.6"	
14	203	-do-	50m NE of VES-202.	N 25°32'24.2" E 91°40'39.8"	
15	204	-do-	50m S70°E of VES-203.	N 25°32'24.5" E 91°40'41.1"	

16	205	-do-	60m S70°E of VES-204.	N 25°36’24.7” E 91°40’42.6”	
17	206	-do-	65mNW of VES-202.	N 25°32’25.1” E 91°40’38.2”	
18	207	Nongthiliew	120m due N65°W from NW corner of the foot ball ground.	N 25°33’16.2” E 91°43’08.4”	
19	208	-do-	100m south of VES-207.	N 25°33’13.1” E 91°43’09.3”	
20	224	Mawranj-Rambrai	145m due NE from the house of Sri Kaslandwahlang	N 25°38’23.5” E 91°19’48.4”	
21	225	-do-	300m SE of VES-224.	N 25°38’15.4” E 91°19’55.8”	
22	226	Mawranj foot ball ground	Near the south western side goal post and 160 east of VES-224.	N 25°38’23.3” E 91°19’54.2”	Zones between 12m and 35 and fractures between 35m and 90m.
23	227	-do-	Near the North Eastern side goal post and 95m NE of VES-226.	N 25°38’25.4” E 91°19’56.8”	Zones from 16– 65m.
24	241	-do-	87m NE of VES-240.	N 25°31’29.2” E 91°32’12.6”	Zones 10-40m.
25	242	-do-	120m north of VES-241 and 120m from the northern pole of the eastern goal post.	N 25°31’33.1” E 91°32’12.2”	
26	243	-do-	S65°W of VES-242.	N 25°31’31.6” E 91°32’08.2”	Zones 10m-35m and fractures from 45m to 60m.
27	244	Markasa (Domsohphlang)	N40°E of the southern goal post of the foot ball ground and S85°E of village memorial (only one)	N 25°31’24.1” E 91°26’06.8”	
28	245	-do-	80m N60°E of VES-244	N 25°31’26.1” E 91°26’03.0”	Zones 10m to 40m and fractures between 45m-70m
29	246	-do-	173m S85°W of VES-244	N 25°31’27.2” E 91°26’00.0”	Fractures between 17m and 55m.
30	247	-do-	100m S85°W of VES-246	N 25°31’28.2” E 91°25’56.6”	
31	248	-do-	220m N70W of the bridge leading to the village.		

Annexure 8: Ground water Resources data of West Khasi Hills

a) General Description of Ground Water Assessment in East Khasi Hills district for 2016-17 (area in ha)

Name of Ground Water Assessment Unit	West Khasi Hills
Type of Ground Water Assessment Unit	District
Type of rock formation	Archean Granitic-Gneissic complex, Granitic Plutons Quartzites, Intrusives, sandstone and Alluvium.
Total area of Groundwater Assessment Unit	390600
Hilly area	225356
Command area	0
Non-command area	165244
Poor ground water quality area	0
Area considered for groundwater recharge	165244

b) Ground Water Resource Potential in West Khasi Hills district during 2016-17 (in ham)

Assessment Unit / District	West Khasi Hills
Command/ Non-Command/ Total	Total
Recharge from rainfall during monsoon season	28913.66
Recharge from other sources during monsoon season	122.90
Recharge from rainfall during non-monsoon season	4374.25
Recharge from other sources during non- monsoon season	29.63
Total Ground Water Recharge	33440.44
Natural discharge during non-monsoon season	3344.04
Annual Extractable Ground Water	30096.40

c) Balance Ground Water Resources Available and Stage of Groundwater Development in West Khasi Hills District 2016-17 (in ham)

Resource Estimation Parameters	2017-18
Annual Extractable Ground Water	30096.40
GW draft for irrigation	0
GW draft for domestic and industrial supply	14.00
Gross GW extraction	14.00
Provision for domestic, and industrial requirement supply to 2025	28.00
Net Ground Water Availability for future development	30068.40
Stage of GW Extraction	0.05%

d) Categorization for Ground Water Development of West Khasi Hills district during 2016-17

Assessment Unit/ District	West Khasi Hills
Stage Of Ground Water Development (%)	0.05%
Is there a significant decline of pre-monsoon water table levels (Yes / No)	No
Is there a significant decline of post-monsoon water table levels (Yes / No)	No
Categorization For Future Ground Water Development (Safe / Semi-Critical/ Critical/ Over-Exploited)	Safe

FIELD PHOTOGRAPHS

1. Spring Monitoring

2. Spring Rejuvenation Scheme, Govt. Of Meghalaya

3. Water Level Monitoring

4. Water Sample Collection

5. Agriculture

6. Surface Water Body/ Kynshi River