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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

KARBI ANGLONG DISTRICT, ASSAM

उत्तर पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

MINISTRY OF JAL SHAKTI

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Department of Water Resources, River Development and Ganga Rejuvenation

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विभाग

GOVERNMENT OF INDIA

भारतसरकार

REPORT ON
AQUIFER MAPPING AND MANAGEMENT PLAN OF GROUND WATER RESOURCES OF KARBI ANGLONG DISTRICT, ASSAM

ANNUAL ACTION PLAN 2022-23

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March 2023

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INTRODUCTION

1.0 Introduction

1.1 Objectives

With dwindling ground water resource in the country it is dire need of the hour to quantify and qualify the ground water in all parts of the country and give a sustainable management plan keeping future demands in mind. The objective of the current study is to prepare aquifer map of the area in 1:50,000 scale, asses the ground water resource of the area, identify the groundwater contaminated area and prepare a groundwater management plan.

1.2 Scope of the study

The Karbi Anglong district have vast groundwater and surface water resources. The agro based economy of the area has ample scope for irrigation facility. Moreover, the groundwater of the area is contaminated with iron and fluoride which possesses serious health hazard to the general public. Proper hydro-geologic knowledge of the area can be helpful to prepare a sustainable management plan for groundwater utilization.

1.3. Approach and methodology

The approach is to identify the principal aquifer types and to conceptualize the aquifer system. This will help to formulate an aquifer management plan. Finally, the scientific knowledge will be disseminated to state government and stake holders. The methodology can be illustrated as follows:

Data compilation and data gap analysis: The preliminary works consisted of collection and review of all existing hydrogeological and exploration data of CGWB, and State Groundwater Departments. All data were plotted in base map on GIS Platform (ArcGIS 10.8) using both Geographic and Projected category longitude/latitude (WGS 1984). On the basis of available data, Data Gaps were identified.

Data Generation: Efforts were made to fill the data gaps by multiple activities such as exploratory drilling, geophysical techniques, hydro-geochemical analysis, soil infiltration tests, besides detailed hydro-geological surveys.

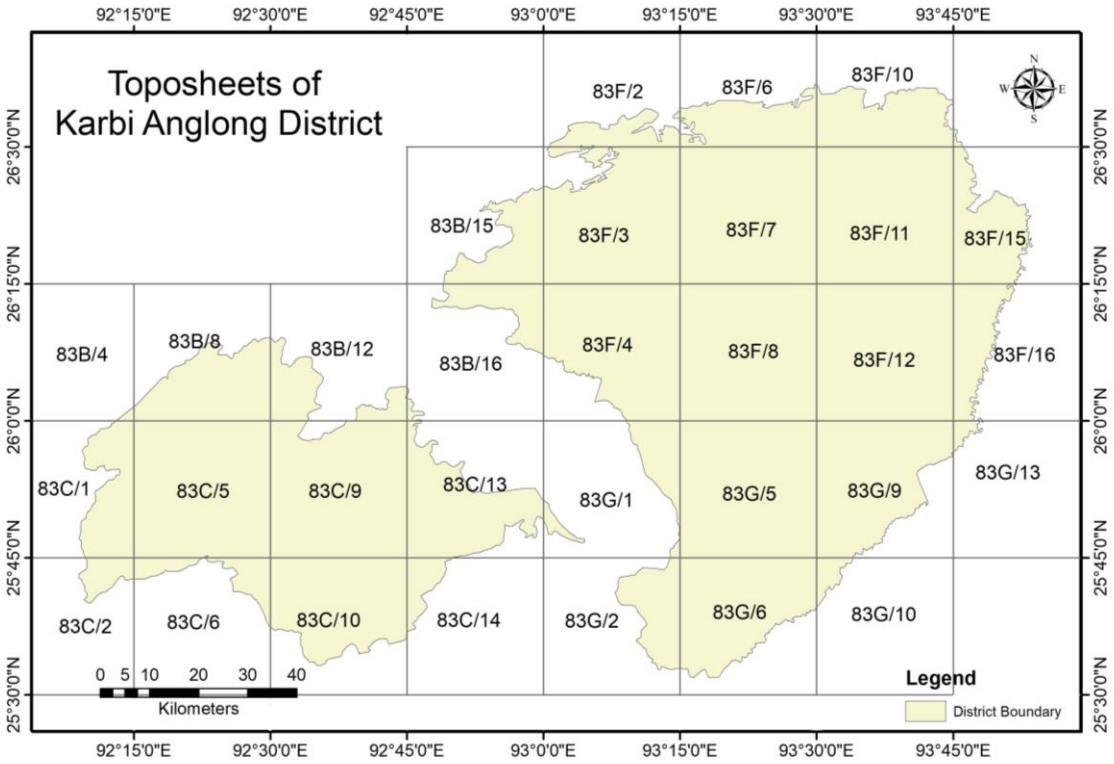
Aquifer Map Preparation: It is a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses applied to characterize the quantity, quality and sustainability of ground water in aquifers. On the basis of integration of data generated from various studies of hydrogeology and geophysics, aquifers have been delineated and characterized in terms of quality and ground water potential. Various maps have been prepared to delineate the lateral and vertical disposition of aquifers and their characterization on 1: 50,000 scale.

Aquifer Management Plan Formulation: Based on aquifer map and conceptual model a sustainable development plan of the aquifer is formulated.

1.4 Area Details

The area chosen for aquifer mapping is divided into East Karbi Anglong and west Karbi Anglong districts. The West Karbi Anglong district falls under Survey of India Toposheet No.s 83B/4,83B/8, 83B/12, 83C/1, 83C/5, 83C/9, 83C/13, 83C/2, 83C/8, 83C/10

and 83C/14 bounded by 25°30’00” and 26°15’00” northern latitude and 92°10’00” and 93°02’00” east longitude. The East Karbi Anglong district is falls under toposheet numbers of 83B/15, 83B/16, 83F/2, 83F/3, 83F/4, 83F/6, 83F/7, 83F/8, 83F/10, 83F/11, 83F/12, 83F/15, 83F/16, 83G/1, 83G/2, 83G/5, 83G/6, 83G/9, 83G/10 and 83G/13. This district is bounded by 25°30’00” and 26°45’00” north latitude and 92°45’00” and 93°45’15” east longitude.



Administrative set up of the study area:

Karbi Anglong District is situated at the central part of Assam. It is surrounded by the district Golaghat and Nagaland State in the east, by Meghalaya state and Morigaon in West, by Nagaon district in the North and by Dima Hasao district and in parts by Nagaland in the South. Districts of East Karbi Anglong and West Karbi Anglong is separated by Hojai district.

At present, Karbi Anglong district has three civil subdivisions and 04 Revenue Circles viz., Donka, Diphu, Phuloni and Silonijan. It has 11 Community Development Blocks within the district with 2712 numbers of inhabited villages. There 7 town committees present in district viz; Hamren, Donkamokam, Diphu, Bokajan, Lahorijan, Howraghat and Dokmoka.

Table 1.1 Administrative Division

No. of Civil Subdivision	No. of Revenue Circles	No. of CD Blocks	No. of Gram Panchayats	No. of Villages (Inhabited)	Uninhabited Villages
3	4	11	-	2712	-

The district has total geographic area of 10434.00 km2, out of which 3873.09 km2 area is hilly.

District	*Total Geographical Area (Ha)	*Hilly Area (Ha)	*Total Recharge Worthy Area (Ha)			
			***Command**	***Non Command**	***Poor Quality**	**Total**
Karbi Anglong	1043400	387309	8602	647489	0	656091

Total population of the district is 956313 souls (as per 2011 census) with 843347 people in rural area and 112966 people in urban area. The average population density of the district is 92 persons/sq.km. The decadal variation of population for 2001-2011 is 17.58 percent.

sl no.	Tehsil	Rural	Urban	Total
1	Donka	2,77,495	17,863	2,95,358
2	Diphu	2,05,668	84,182	2,89,850
3	Phuloni	2,68,927	10,921	2,79,848
4	Silonijan	91,257	0	91,257
	Total	8,43,347	1,12,966	9,56,313

Table 1.2 Block Level Geographical Area (in sq.km) and Population of Karbi Anglong District:

Sl No.	CD Block	Total number of inhabited villages	Total rural population		
			Persons	**Male**	**Female**
1	Amri	132	45,573	23,027	22,546
2	Chinthong	138	46,553	24,080	22,473
3	Rongkhang	201	158035	81,054	76,981
4	Socheng	76	27,334	14,002	13,332
5	Lumbajong	417	93,914	48,847	45,067
6	Bokajan	419	142409	73,610	68,799
7	Howraghat	334	127673	64,733	62,940
8	Samelangso	304	63,869	32,189	31,680
9	Langsomepi	235	55,157	27,918	27,239
10	Rongmongwe	176	32,773	16,694	16,079
11	Nilip	280	50,057	25,770	24,287
	Total	**2712**	**843,347**	**431,924**	**411,423**

#Data source: District Census Handbook 2011

The district has a good network of roads, train and air connections.

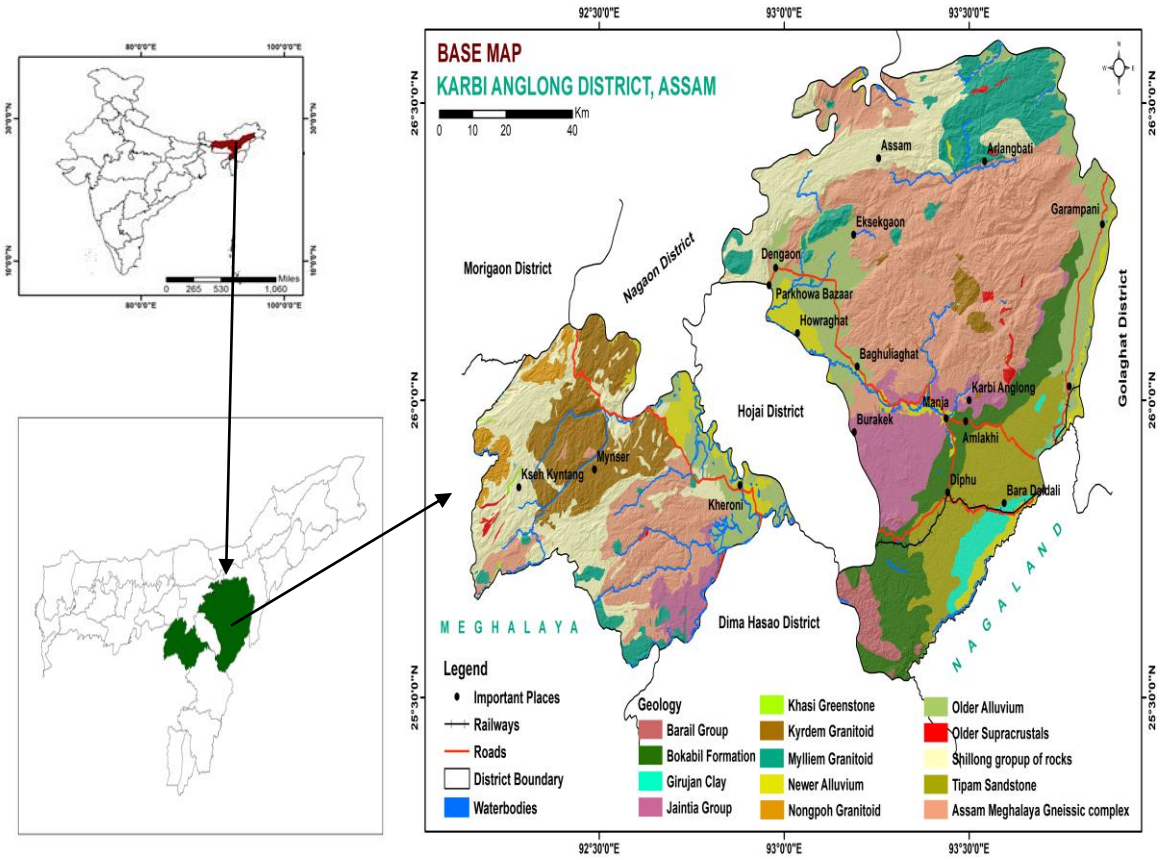


Fig.1.1: Index Map of the study area

1.5 Data availability, data adequacy, data gap analysis and data generation

The preliminary works consisted of collection and review of all existing hydrogeological, geophysical and exploration data of CGWB. All data were plotted in base map on GIS Platform (ArcGIS 10.3) using Projection category longitude/latitude (WGS 84).

The available data, data gap and data generation work is tabulated in Table: 1.3

Table 1.3: Data availability, data gap and data generation in Karbi Anglong district, Assam

SN	Theme	Type	Data available	Data gap	Data generation	Total	Remarks
1	Borehole Lithology Data		56	04	03	59	
2	Geophysical data		00	6			
3	Groundwater level data	Dug well	40	03	03	43	
		Piezometer Aquifer-I					
4	Groundwater quality data	Dug well-Aquifer-I					
		Piezometer Aquifer-I					
5	Specific Yield						
6	Soil Infiltration Test						

The available data and data generation points are shown in following figures.

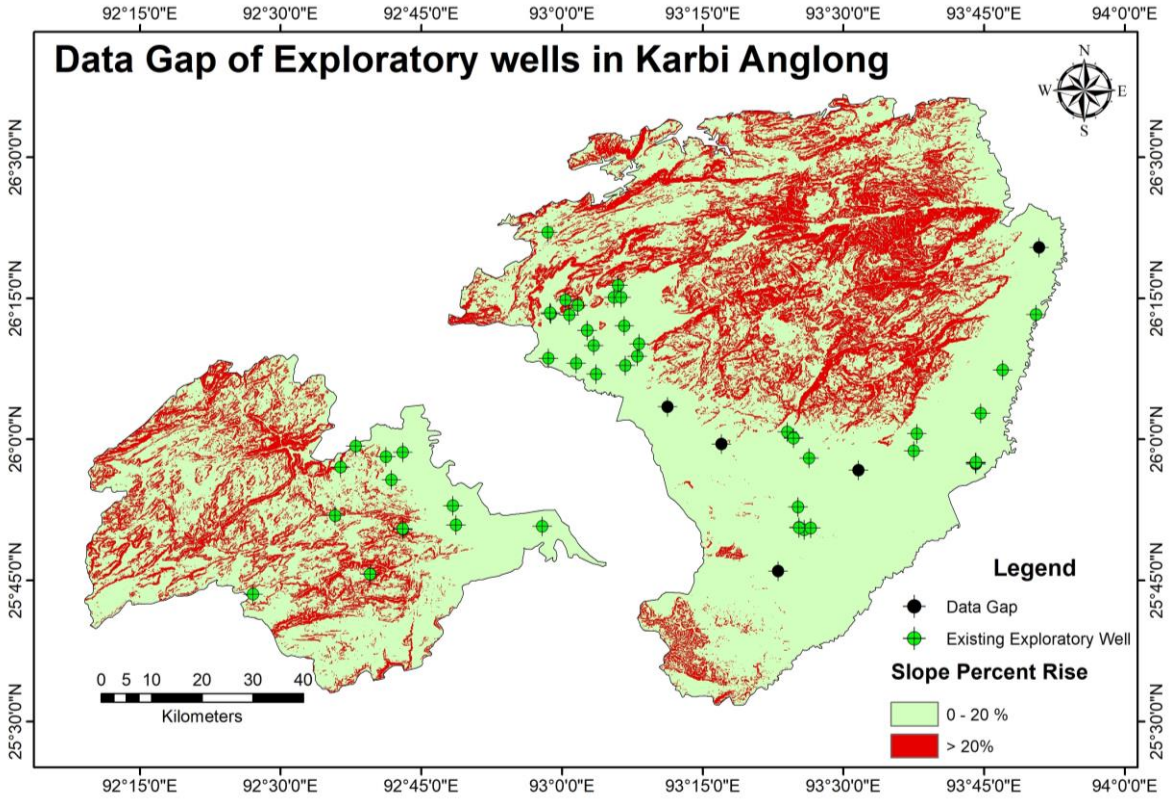


Fig. 1.4: Available data and data generation of exploration in the study area

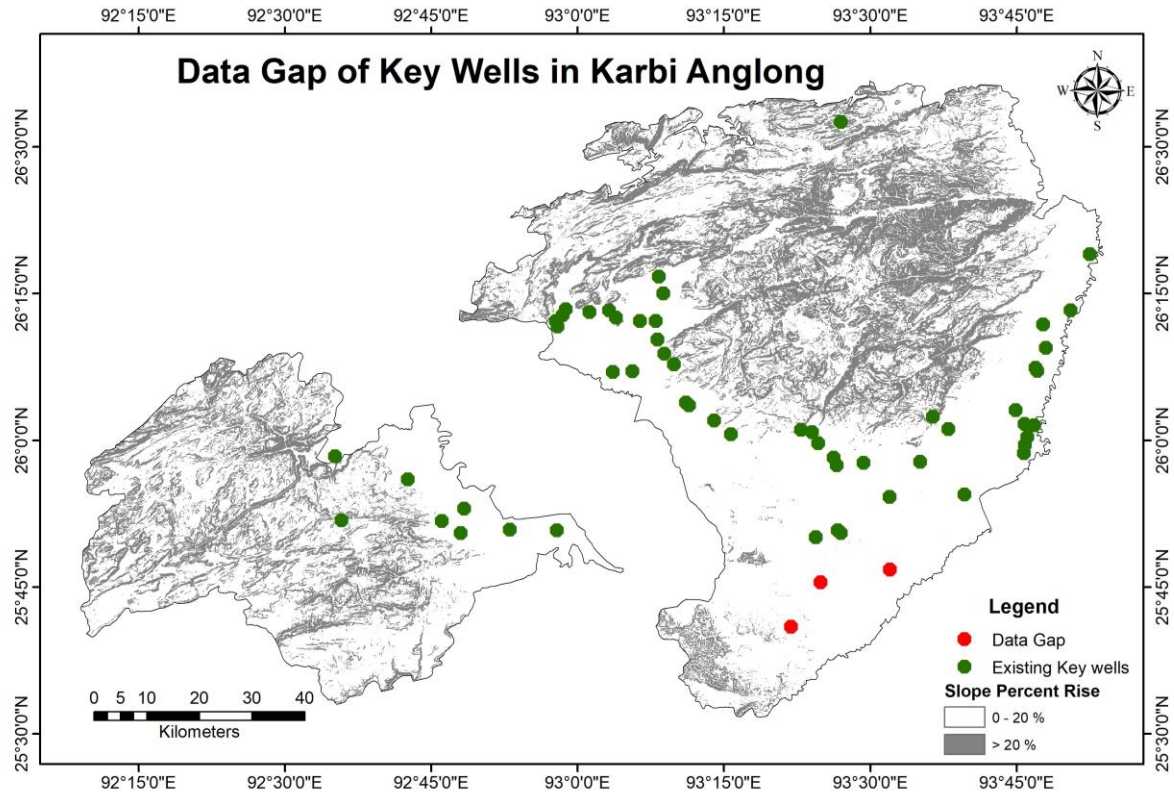


Fig. 1.5: Available data and data generation of geophysical investigation in the study area

1.6 Rainfall distribution

The average annual rainfall recorded from 2011 to 2022 of I.M.D is 1235.29 mm. Rainfall during January to April contributes nearly 12.3% to the total rainfall whereas the rainy season which commences from May and continues up to October contributes 86.2%. November to December rainfall is only 1.5%. December receives least rainfall. (Table- 1.4)

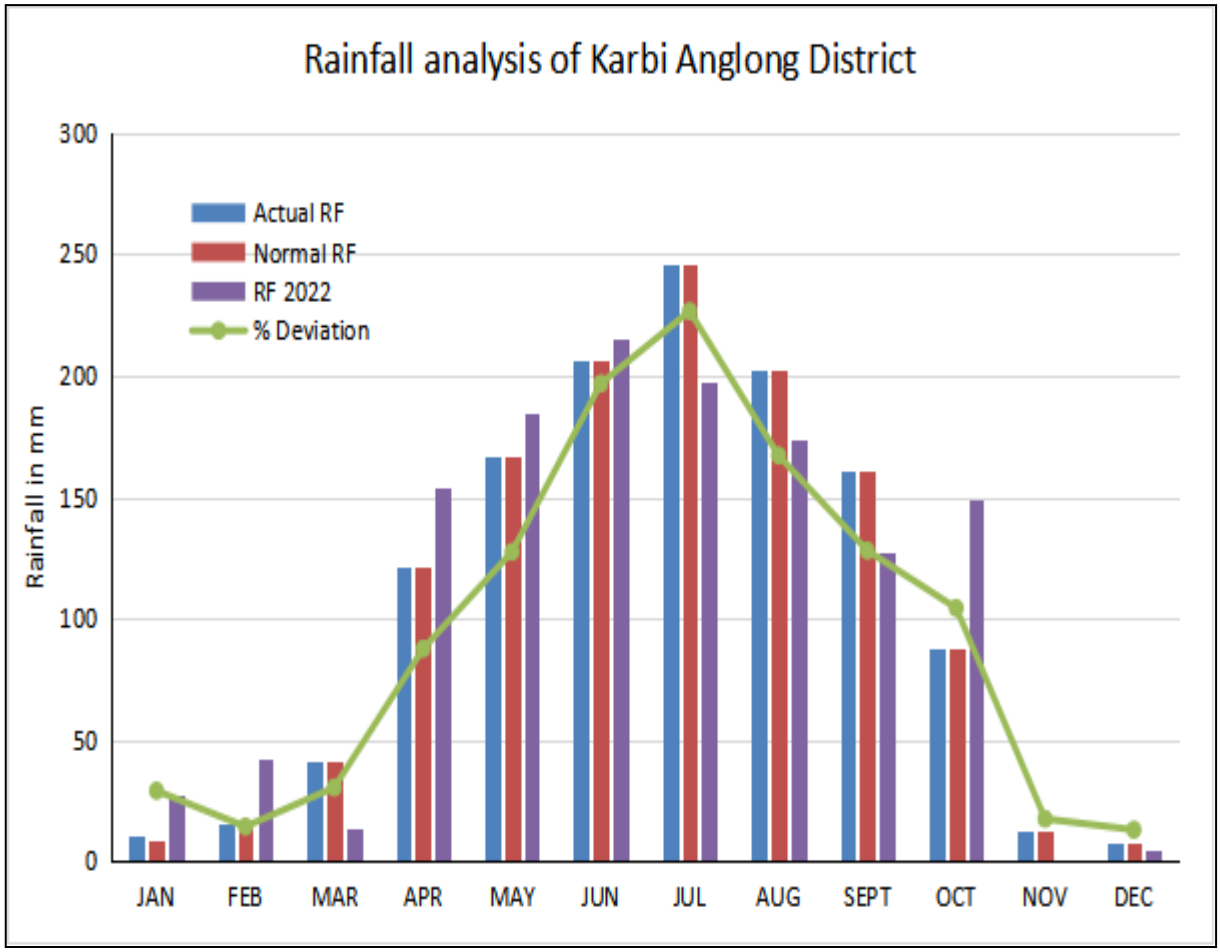


Table 1.4: Monthly rainfall distribution of Karbi Anglong district, Assam

When Actual monthly rainfall of last 10 years was compared with normal rainfall, it was found that there was no major changes in the rainfall pattern and quantity. But during 2022, rainfall was slightly less than the Actual rainfall. As such, the month of May to October receives highest average rainfall whereas November and December month received least rainfall during the year 2022. During October of 2022 there was a heavy pouring due to late monsoon. Annual average rainfall of Karbi Anglong district ranges from 844.2mm to 1572.2mm.

State / Dist	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
		*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)
Karbi Anglong	2011	7.6	12	43.4	41.3	55.1	260.3	207.3	144.5	49.2	23.3	0.2	0
Karbi Anglong	2012	3	0	0.1	107.9	64.2	246.4	131.4	159.5	167.8	142	8.2	0
Karbi Anglong	2013	0	4	42.3	68.2	244.9	226.3	255.4	129.9	202.2	78.6	0	0.5
Karbi Anglong	2014	5.2	19.1	33.3	18.5	108	153.4	349.4	177.4	258.6	32.5	0	0.4
Karbi Anglong	2015	19	3.8	27.4	145.6	123.4	234.4	173	222.7	185.1	70.7	10.5	0.5
Karbi Anglong	2016	28.9	4.9	28.9	176.1	135.8	221.5	303.2	268.9	202.6	105.3	85	11.1
Karbi Anglong	2017	0	6.3	67.6	101.4	119.7	179	268.6	171.4	163.9	137.8	7.6	5.7
Karbi Anglong	2018	9.3	1.4	49.7	55.6	79.3	240.9	367.5	545.2	118.1	20.6	1.4	42.6
Karbi	2019	4.74	25.8	49.08	134.19	227.66	215.59	261.06	191.85	224.18	167.61	11.7	0.72

State / Dist	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
		*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)	*Actual (mm)
Anglong													
Karbi Anglong	2020	11.27	9.63	11.23	129.34	184.52	218.69	118.46	143.14	216.58	163.58	18.19	0.32
Karbi Anglong	2021	5.96	2.47	35.26	34.79	107.54	134.63	225.91	159.86	148.74	95.87	3.72	7.29
Karbi Anglong	2022	27.39	42.4	13.83	154.03	184.67	215.23	197.67	173.81	127.65	149.51	0	4.51

The average monthly rainfall from 2011 to 2022 and also yearly rainfall distribution of Karbi Anglong district are illustrated in Fig.1.4 and Fig 1.5

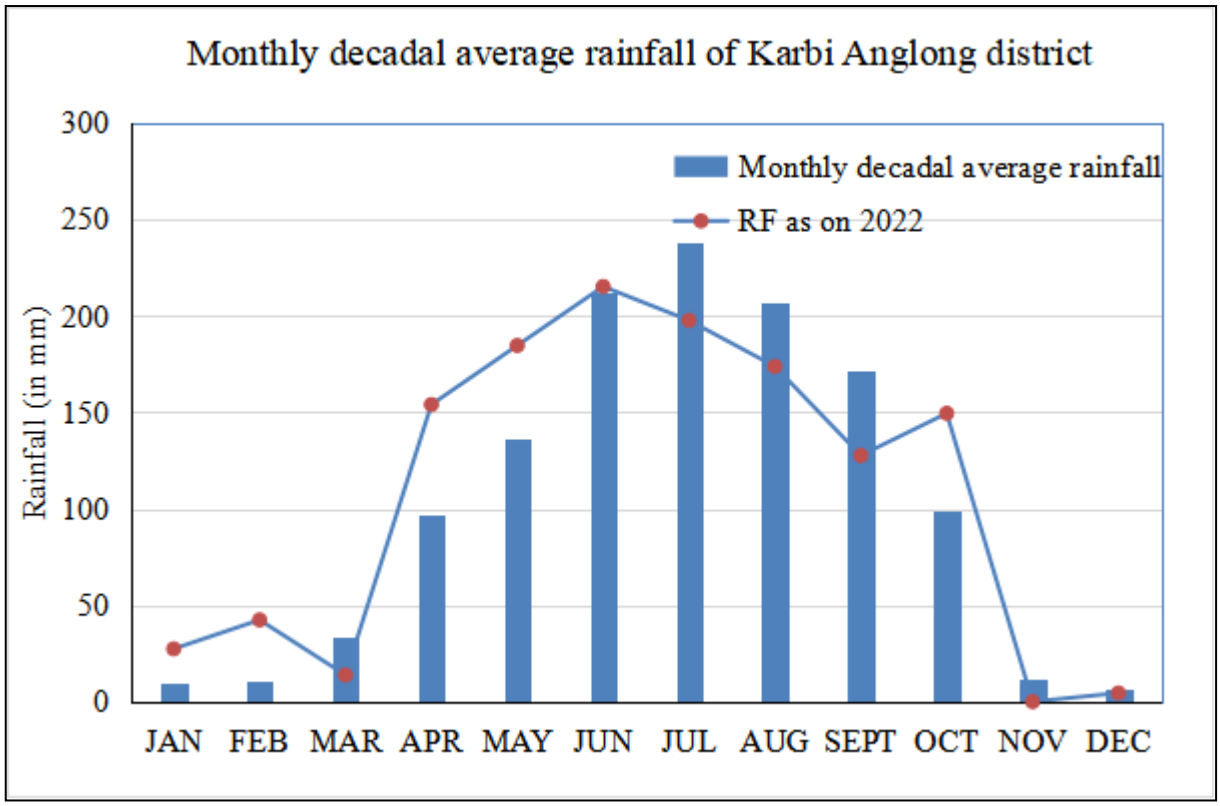


Fig. 1.4 Average monthly rainfall variations of Karbi Anglong district

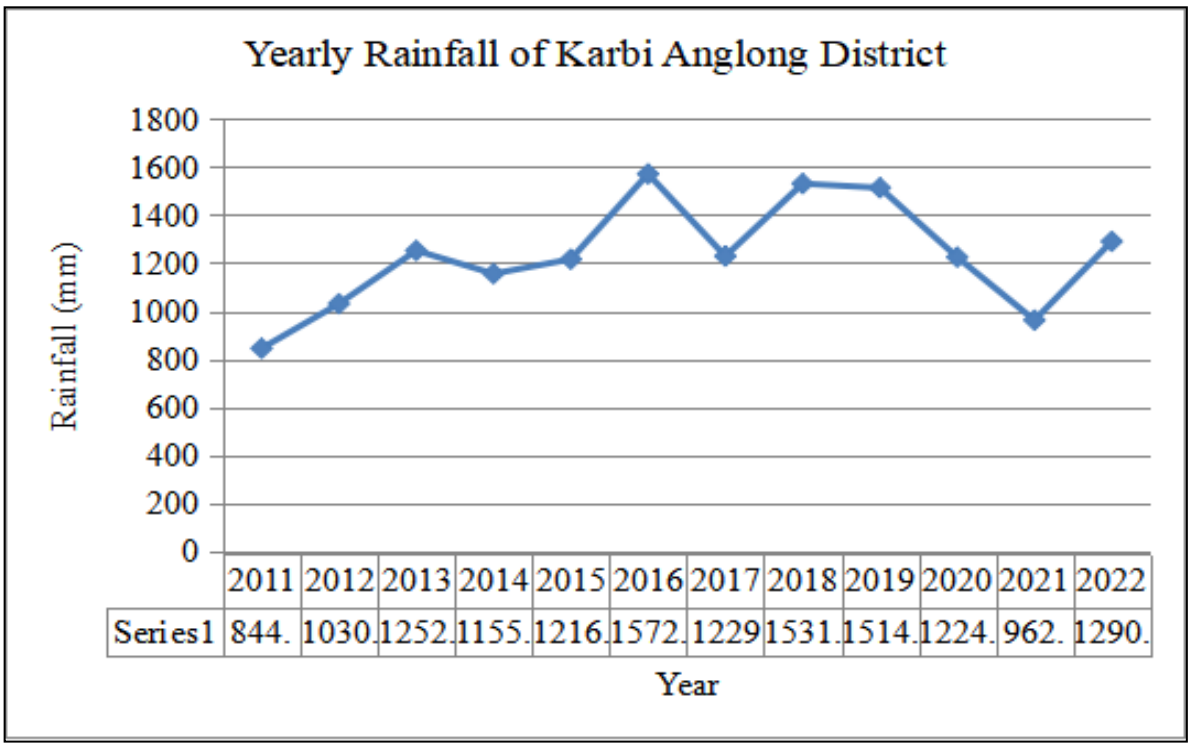


Fig.1.5: Annual variation of rainfall as recorded I.M.D rain gauge stations of Karbi Anglong district

1.7 Temperature

The climate of the district is predominantly sub-tropical humid climate with heavy rainfall, hot semi dry summer and cold winter. The district experiences a maximum temperature of 6 to minimum temperature of 12°C in winter and minimum of 23°C to maximum of 32°C in Summer. Average temperature ranges from 12 to 32^{O}C during the year. Monsoon usually starts from April and continue till end of September. The average rainfall is about 2416 mm. Prevalence of Relative Humidity is generally high (78-80%) particularly during the summer months. Average humidity of the state is 76%. During summer, the atmosphere becomes sultry. The winter commences from October and continues till February.

Due to variation in the topography, this hill zone experiences different climates in different parts. The climate of the region is controlled by the same factors that apply to other parts of Northeast India. The Cherra-Dawki escarpment of Meghalaya and the Barail range obstruct to some extent the south-west monsoon winds coming from the south into the heart of the region. This provides a rain-shadow effect to the northwestern portion of Dimasa plateau and the Hojai-Lumding area of Nagaon district which constitute the southern part of the Karbi inhabited area, lofty ranges of Arunachal Pradesh protect the Brahmaputra Valley from the cold air masses of the Tibetan region in winter, and in summer they provide a congenital condition for relief rainfall from the south-west monsoon in the Brahmaputra Valley.

1.8 Physiographic set up

The district is situated in the central part of the state and majority of the district is hilly.

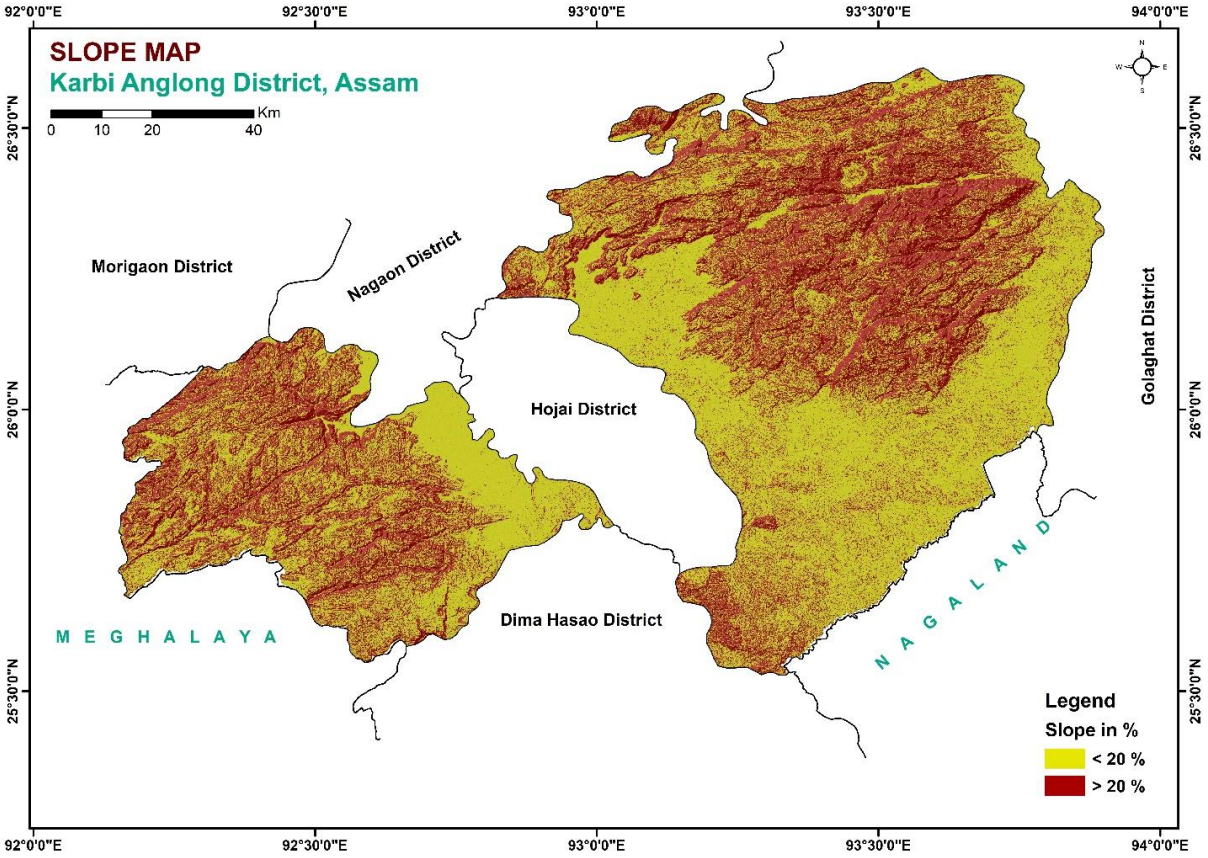


Fig.1.6: Slope map of Karbi Anglong District

1.9 Drainage and Morphometric Features

Drainage pattern of Karbi Anglong district appears to be of radial dendritic pattern. It develops in regions underlain by homogeneous material. That is, the subsurface geology has a similar resistance to weathering so there is no apparent control over the direction the tributaries take. Major rivers flowing across the district are Diyung, Borpan and Panimur in West Karbi Anglong which meets at Kopili river along Hojai-Karbi Anglong West district boundary. Frequency of rivers at East Karbi Anglong is less dense than west Karbi Anglong. Major river is Dhansiri which flows along Assam- Nagaland Boundary towards South- East corner of the district.

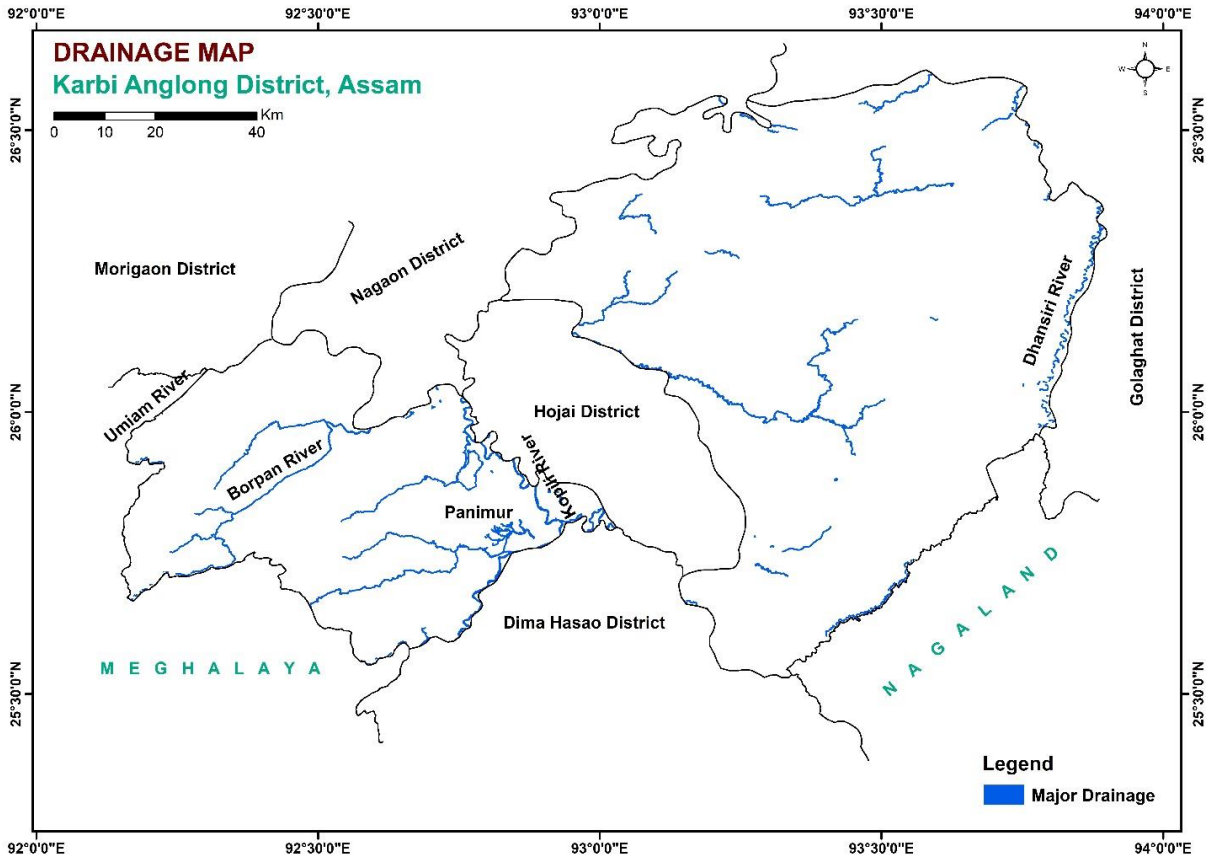


Fig. 1.7: Drainage Map of Karbi Anglong District, Assam

1.10 Geology

Geologically Karbi Anglong plateau is known as the oldest landform in Assam. It is pear-shaped and has an area of about 7000 km2.

It has been subjected to extreme weathering and denudation and as a result, resistant sandstones of the Surma series which underlie them have contributed to the characteristic rugged topography with a number of hills purely of relic type.

To the south lie the young folded ranges of North Cachar Hills and to the surrounding lowlands on all sides. The plateau has developed a radial drainage pattern.

However, the central part still remains high with the Rengma Range reigning the east-central landscape.

The highest peak is Dambusho (1363m) lies in this region.

Generalised geology of Karbi Anglong:

Age	Formation	Description
Recent to Sub-recent	Alluvium	Clay, Silt and Gravel
~~unconformity~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		
Miocene Oligocene Eocene	Tipam/Surma Barail Jaintia/ Disang	Feldspathic browinsh Sandstone, Clay and Shale Ferrufenous thinly bedded fine to medium grained sandstone and shale Fine to medium grained sandstone, limestone and shale.
~~unconformity~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		
Precambrian	Shillong	Granite, pegmatite, metadolerite intrusive, aletrnate horizons of quartzite, phyllite and conglomerate.
~~unconformity~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		
Archean	Gneissic Complex	Gramite, pegmatite, metadolerite intrusive, biotite-hornblende gneiss, sillimanite schist, pyorxene-hornblende granulite

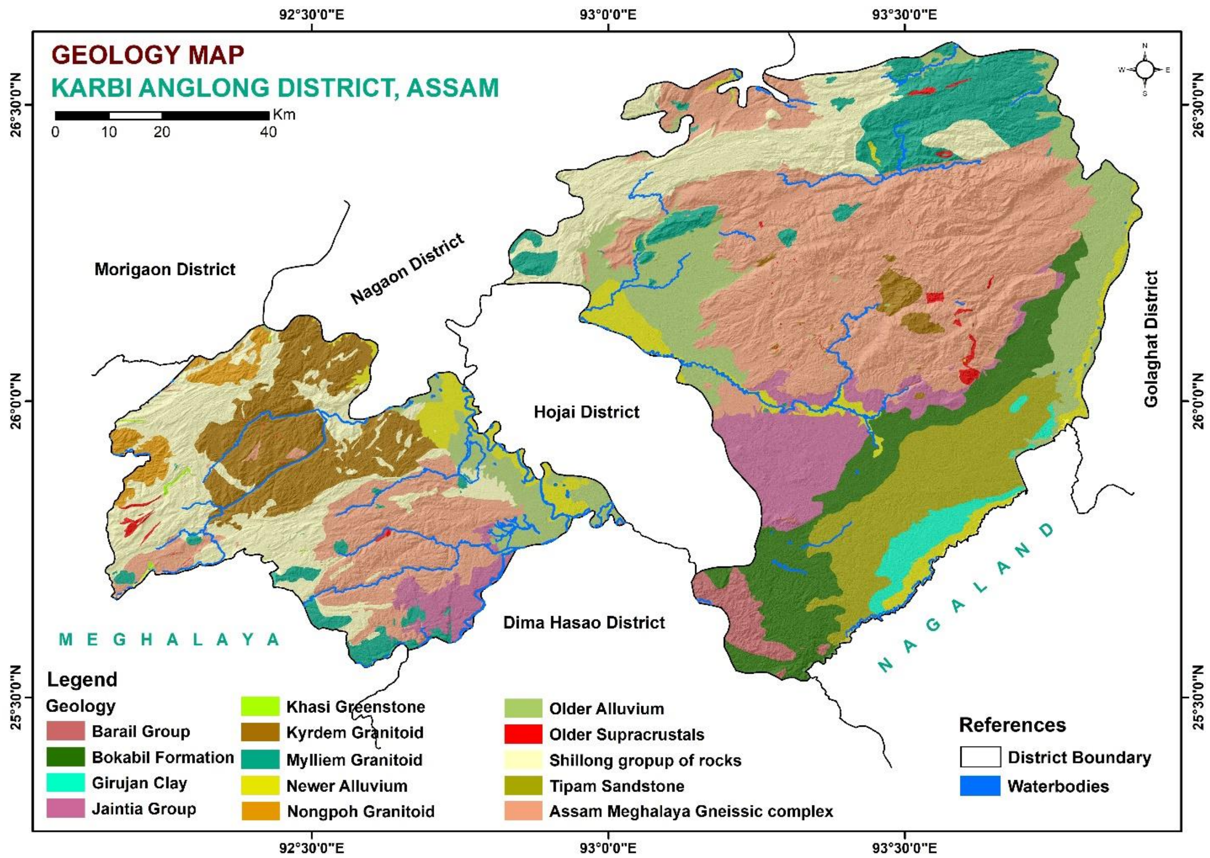


Fig 1.8: Map showing Geology of Karbi Anglong District

1.11 Geomorphology

Karbi Anglong is one among the two hilly districts of Assam State, the other being the Dima Hasao district. Karbi Anglong East is geomorphologically divided into Moderate to Highly Dissected hills and Valley and Pediment Pediplain complex. Alluvial plains are only confined along the banks of Dhansiri river and towards Dokomoka-Langing area.

Karbi Anglong West consist of Moderate to Highly dissected plateau and flood plains along the bank of river Kopili, Panimur and Borpan. Area between hills and flooad plain is covered by Pediment pediplain complex.

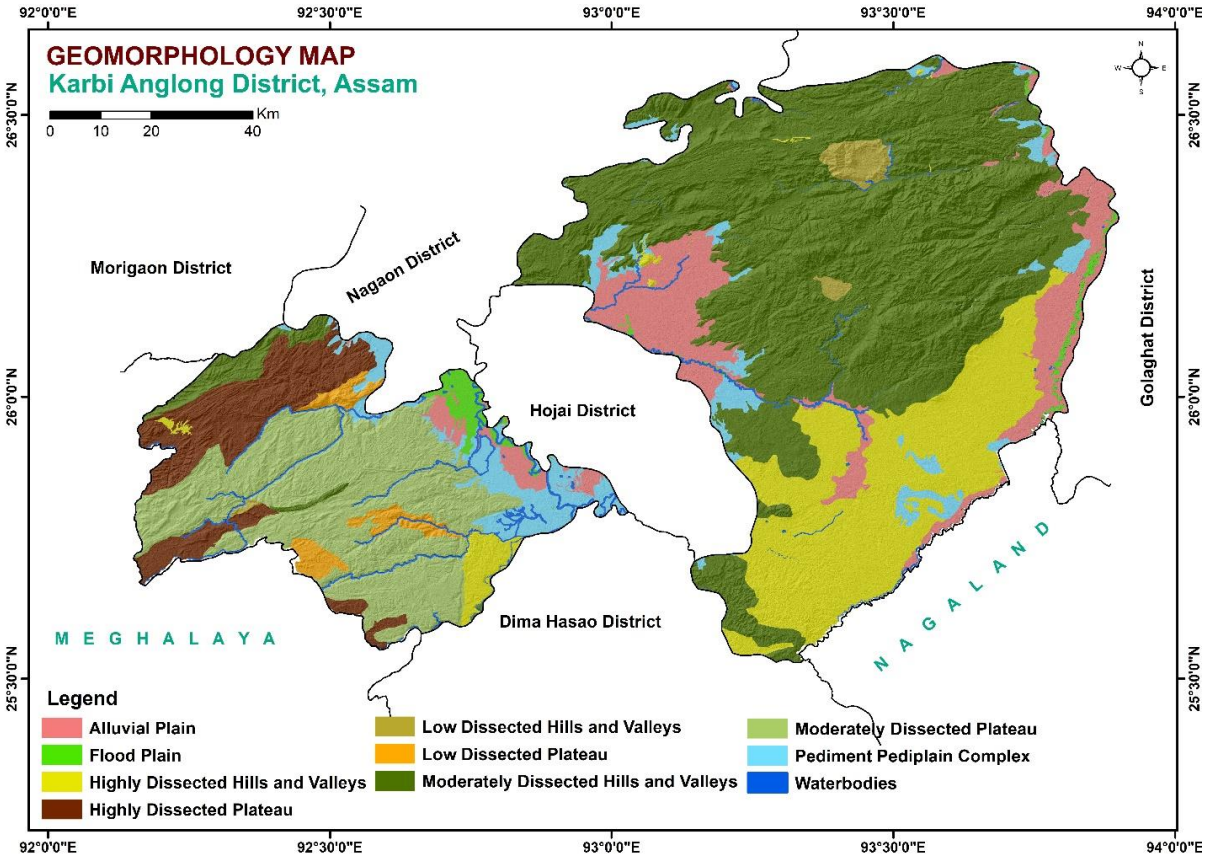


Fig. 1.9: Geomorphological Map of Karbi Anglong District, Assam

1.12 Land use Pattern

The total geographic area of the study area is 133200 ha but reporting area for land utilisation statics is 1043400 ha. The net sown area of the district is 127476 ha which accounts for 12.21 percent of the total area for land utilisation statics of the district.

The gross cropped area of the district is 209075 ha with cropping intensity of 129% percent. Net sown area is 127476 ha.

The district is covered in open and moderately Dense to Highly Dense Forest area covering mainly the hilly portion (slope >20% rise) of the district. Patches of Scrub Land is found in Western Karbi Anglong district. Forest area in the district accounts for 320840 ha i.e. 30.75% of total area for land utilisation statics. Area under non-agricultural uses is 134853 ha. Barren and Uncultivable Land comes to be around 460231 ha. Separate

classification of **Permanent Pastures and other Grazing Land, Land under Misc. Trees groves not including in Net Area Sown, Cultivable Waste Land, Fallow Land other than Current Fallow and Current Fallow** is not available for hills district.

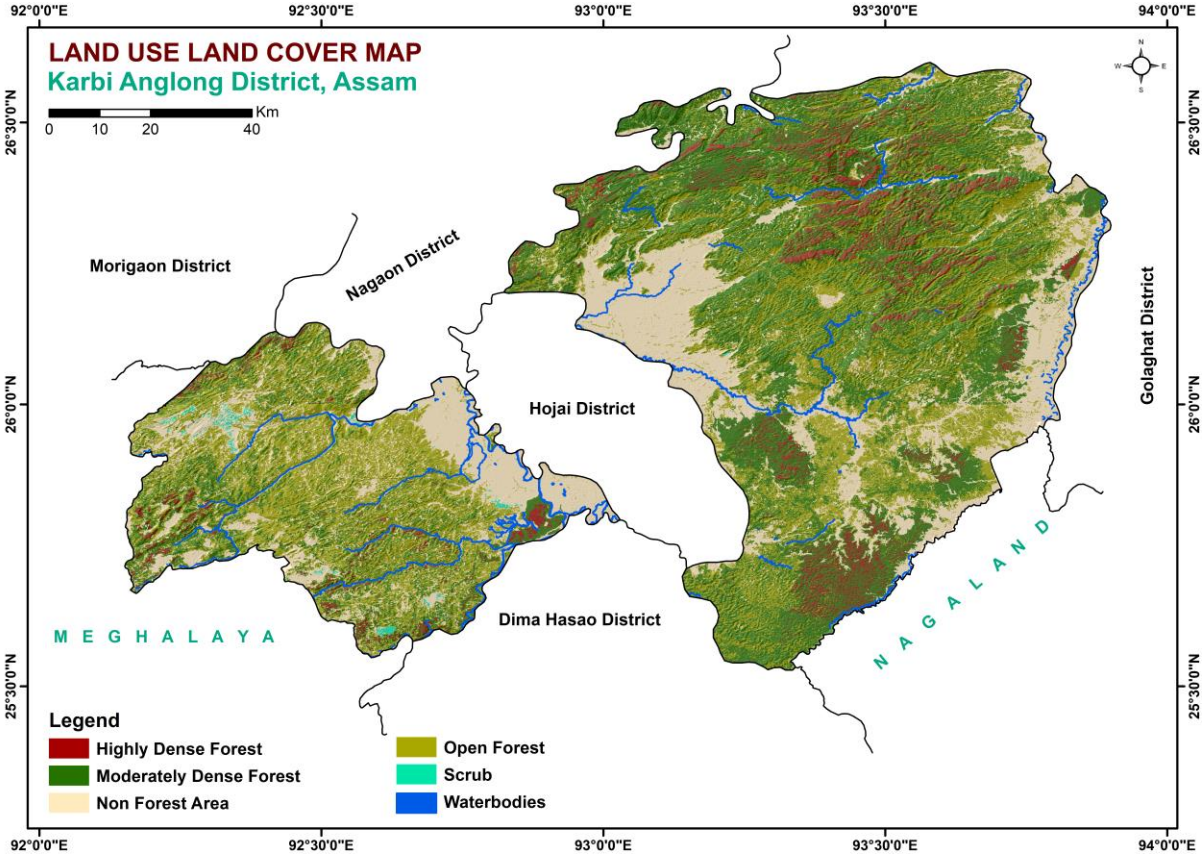


Fig 1.10: Map showing Land Use and Land Cover, Karbi Anglong District.

Total Area and Classification of Area, 2020-21: *(Area in Hectare)*

Table 1.5 Land Use Pattern in Karbi Anglong District

Reporting Area for land utilization	Forests	Not available for cultivation		Other Uncultivated Land excluding Fallow Land			Fallow Land		Net Area Sown	Total Cropped Area	Area Sown more than once
		Area under non-agricultural uses	Barren and Unculturable Land	Permanent Pastures and other Grazing Land	Land under Misc. Trees groves not including in Net Area Sown	Cultivable Waste Land	Fallow Land other than Current Fallow	Current Fallow			
1043400	320840	134853	460231	#	#	#	#	#	127476	209075	81599

Source: Assam Statistical Handbook, Assam 2021

Separate classification of area for Hill Districts are not available. All included under Barren & Unculturable Land

1.13 Soil

The major groups of soils identified in the district are recent riverine alluvial soils (Entisols), old riverine alluvial soils (Inceptisols), laterite red soils (Ultisols) and moderately leached (Alfisols). The flood plain of Brahmaputra is built up with riverine alluvial soils. The valleys soils are characterized sandy loam to clay, which are not affected by the flood.

Entisols: Also known as recent soil. These soil types occur mainly in flood plain areas. These type of soil occurs on river levees to nearly levelled active flood plain and on stable river islands having sandy surface. Ground water table is usually below one metre below ground level and are associate with very severe flooding. Two types of fluvaquents occure in the study area; Mollic Fluvaquents and Aeric Fluvaquents. Mollic Fluvaquents are Entisols with aquic moisture regimes that occur on floodplains and that have thick dark surface layers. Aeric Fluvaquents are Entisols that occurs on floodplains. They have an aquic moisture regime that are not so wet. They are better aerated in the "upper" part of the soil.

Ultisols: These soil type forms as the ultimate of leaching. Ultisols are strongly leached, acid forest soils with relatively low native fertility. They usually occur on hill tops. Ultisols that are more or less freely drained and humus-rich. These soils are mainly in mountainous areas that have high rainfall but also have a moisture deficit during some season. They are found primarily in humid temperate and tropical areas. Occurs in older, stable landscapes. Intense weathering of primary minerals has occurred, and much Ca, Mg and K has been leached from these soils. Strong yellowish or reddish colors resulting from the presence of Fe oxides. Kandihumults are the Humults that have a kandic horizon and they occur on top of hillocks in the district.

Inceptisols: These are the young soil or inception soil confined to old riverine regimes. They form quickly through alteration of parent material. They are more developed than Entisols. They have no accumulation of clays, iron oxide, aluminium oxide or organic matter. They have an ochric or umbric horizon and a cambic subsurface horizon. Types of inceptisols are dystrochrepts, eutrochrepts and haplaquepts.

Alfisols; These type of soil is composed of aluminum and iron oxides and charecterised by the presence of ochric (thin, light colored, low in organic matter) diagnostic horizon, an argillic horizon, and moderate to high base saturation level. Hapludalf alfisol is present towards the eastern boundary of the district and it is characterized by humid, udic (wet) moisture regime.

Various factors like heavy rainfall, floods, soil erosion and undulating terrain have affected the soil formation process which gave diverse textural classification of soils in the district. As per textural classifications, red soil is 17.7%, younger alluvial soil 32.88%, old alluvial soil 48.89%, and alfisols of 0.53%. On the whole the district is having light to medium textured soils suitable for growing the wide range of crops successfully without being influenced by other inhibiting parameters for growth and development.

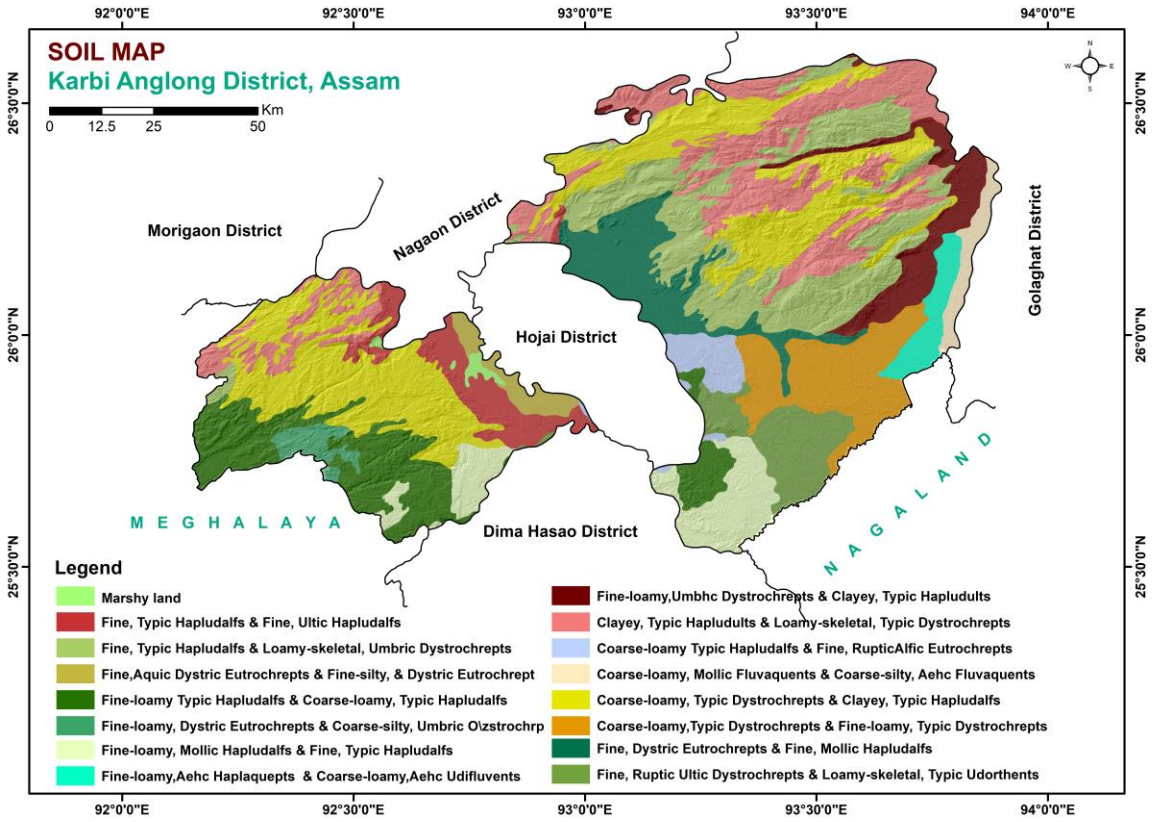


Fig. 1.11: Soil Map of Karbi Anglong District, Assam

1.14 Hydrology and surface water

The water drainage in the north of the district is the mighty Brahmaputra. Among the rivers, Dhansiri in the north east, the Kapili, the Doiang and the Jamuna in the west constitute the main drainage of the district. In Karbi Anglong proper the water drainage shows a radical pattern with the rivers and streams flowing south into the Jamuna valley, west into Kapili valley and in north into the Brahmaputra. The other important rivers of this district are Alioni. flowing to east-north and the east is crossed the north eastern part. The river Diphu flows towards northern slopes, Deopani, Kaipani towards north-western slopes of the district. The Langkangtang along with the tributaries of river Nonoi flows towards western slopes. Then Bar Dikharu ,Horaghati, Chelabor flows through south-western slopes. Some other important rivers of Karbi Anglong are Nambar, Doigrung, Kalanga, Horguti, and Harina, Among these Nambar, Doigrung and Kalioni are the tributaries of river Dhansiri. The river Kalonga flows into Kapili after passing through Rongkhang area. The Horguti river arising from Singahasan hill crossing plains meets Dikharu river and ultimately falls into Jamuna The river Diphu is also a tributary of Jamuna. The river Harina originating from north-west of Karbi Anglong also joins with Jamuna.

Number of beels, tanks and ponds and fisheries in the district are as tabulated below:

Types	Beel Fisheries	Pond & Tank	Derelict Water Bodies/Swampss	River Fisheries	Forest Fisheries	Others (paddy filed, canals etc)
Numbers	19	11350	106	4	5	1550
Area (in ha)	186	3283	332	450	0.9	1062

Source: Statistical Hand Book Assam, 2021

1.15 Agriculture

Major Agricultural Products of the district are paddy, maize, mustard, sugarcane, sesame, wheat, jute, arhar, cotton and pulses. Major plantation is Arecanut and Coconut. Major horticulture product cultivated in the district is Pineapple, Banana, Orange, Lime & lemon and Papaya. Vegetables and spices grown in the district are Ginger, Rabi vegetables, Kharif vegetables, Turmeric, Potato, Chilli and Onion.

The alluvial soil of the block is very fertile and suitable for agricultural production.

Field crops	Total area (Ha)	Irrigated (Ha)	Rainfed (Ha)
Rice	133565	3682	**129883**
Rape & Mustard	19110	1519	17591
Maize	12165	600	11565
Sugarcane	8100	-	8100
Sesame	3255	-	3255
Wheat	1560	450	1110
Jute	1520	-	1520
Arhar	1293	-	1293
Cotton	912	-	912
Black gram	883	-	883
Pea	725	100	625
Green gram	670	-	670

Agricultural land use	Area (ha)
Net sown area	176433
Area sown more than once	51165
Net irrigated area	5052
Gross irrigated area	8246
Rainfed area	**171381**
Gross cropped area	227598

Source: District Agriculture Contingency Plan

The stable food of this district is rice. Paddy namely autumn (Ahu), winter (Sali) and summer (Boro) are raised in the district. The alluvial soil, humid atmosphere and enough rains are favorable for growing agricultural crops in the district.

The important paddy crops which are being grown are rice, mustard, pulse, cereals, wheat and tea. Lahi rice is grown in high fields which is an important production of the district. The Joha is the finest variety of rice commonly grown in the district. Boradhan is also produced particularly to prepare chira and pitha (cake). Ahu and Bao are other varieties of rice grown in the district. Wheat is also gaining popularity and is supplementing rice in diet. Wheat is cultivated as a rabi crops. The varieties are Sonalika and Kalyan Sona. Rape and mustard are often grown along with Ahu rice. Pulses like Mati Kalai, Masur, Mung are also grown in the area. Arhar is also another pulse grown in the district. The vegetables of different kinds are grown in the district. The most common of them are cauliflower, cabbage, brinjal, lady's finger, pumpkin, tomatoes, peas, radish, turnip etc. These vegetables are

mostly grown in rural areas and are exported to the commercial centers of the district and also to other districts of the state.

IRRIGATION:

There is a separate Department of Irrigation is set up to meet the general need in the district. Under this, few projects are being taken up for surface water irrigation in the district namely Jamuna Irrigation Project, Langparpan Irrigation Project, Borjan, Harina, Patradisha, Horguti, Kanjukpather, Hongkram, Donka, Deohari, Sarihajan, Irrigation Projects which take major role in development of Agricultural economy of the district and side by side improves the standard of living of the people.

Irrigation from ground water is done through various abstraction structures as mentioned below

Source of irrigation	Number	Area (ha)	% area
Tanks	495	388	7.68
Bore wells	20	225	4.45
Lift irrigation	8	3568	70.62
Other sources	-	0871	17.24
Total	**-**	**5052**	**100.00**

Agricultural activities in the district are predominantly rain fed as out of the net sown area of 176433 ha, only 5052 ha (2.86%) area is under irrigation.

CHAPTER 2.0

2.0 Data Collection and Generation

2.1 Data collection

Various data for NAQUIM report was needed to be generated and compiled together. First of all existing data of CGWB's earlier survey data, exploration and geophysical data were compiled and based on that data gap was analysed and accordingly generation of those proceeded. Data collection also includes acquiring data from various state government organisations such as collection of rainfall data from state government, litholog collection from state groundwater departments, Population data is collected from Census of India website. Agriculture data are taken from Assam statistical Handbook and NEDFI databank for Kamrup (M) district.

So far CGWB had constructed 59 exploratory wells in this area of Karbi Anglong district earlier. However, all the wells are not incorporated in the present study. Details of the wells are given in Table 2.4.

Rainfall data was collected from official website of Indian Meteorological Department; the Customized Rainfall Information System (CRIS).

2.2 Data Generation

2.2.1 Hydrogeological data

The entire study area is covered by regular monitoring of existing 33 Ground Water Monitoring Stations and another 05 key wells have been established. All these wells were under monitoring after establishment (Table 2.1). There were 35 dug wells and 2 tube wells.

Table 2.1: GWMS and Key wells details

District	Location	Well Type	MP	RL	Mar-22	Jan-22	Nov-22	Aug-22
East Karbi Anglong	Adarakha Tiniali	Dug Well	0.87	120.00	3.00	1.16	0.42	2.14
East Karbi Anglong	Amlokhi	Dug Well	1.35	144.00	1.60	1.89	0.54	1.21
East Karbi Anglong	Balipathar	Dug Well	0.90	117.00	4.89	2.11	1.12	3.04
East Karbi Anglong	Bokajan I	Dug Well	0.75	127.00	11.40	11.59	8.75	12.15
East Karbi Anglong	Bokajan II	Dug Well	0.60	127.00		3.40	3.05	3.48
East Karbi Anglong	Bokoliaghat	Dug Well	1.00	74.00	3.51	3.97	2.43	3.10
East Karbi Anglong	Bokulia	Dug Well	0.69	104.78	2.50	1.02	2.36	0.75
East Karbi Anglong	Dengaon	Dug Well	0.93	68.00	3.00	3.50	1.02	1.57
East Karbi Anglong	Deopani	Dug Well	1.05	120.00	11.48	11.68	10.80	5.66
East Karbi Anglong	Dillai	Dug Well	0.69	145.00	8.65	3.86	1.65	7.41
East Karbi Anglong	Diphu	Dug Well	0.79	182.00	23.09	20.34	19.03	23.47
East Karbi Anglong	Diphu (matibung	Dug Well	1.17	166.00	3.10	3.89	2.16	1.98

District	Location	Well Type	MP	RL	Mar-22	Jan-22	Nov-22	Aug-22
	Road)							
East Karbi Anglong	Dishobai	Dug Well	0.67	97.00	2.12	1.48	1.41	2.62
East Karbi Anglong	Dokmoka	Dug Well	1.2	80.35	0.73	1.23	1.12	1.92
East Karbi Anglong	Donka Bey	BH	0.5	112	25.98	26.96	23.3	22.66
East Karbi Anglong	Ghouria Dhubi	Dug Well	0.80	168.00	3.63	3.86	2.32	2.68
East Karbi Anglong	Hapjan	Dug Well	0.82	148.35	6.27	4.14	4.10	3.30
East Karbi Anglong	Hidipi	Dug Well	0.80	169.00	3.87	8.06	2.23	2.52
East Karbi Anglong	Khatkhati	Dug Well	0.79	143.00	4.19	3.99	3.32	3.21
East Karbi Anglong	Khatkhati (Matipul Namgarh)	Dug Well	0.54	143.00	5.81	3.78		4.12
East Karbi Anglong	Lahorijan	Dug Well	0.75	154.00	6.66	7.37	6.91	4.67
East Karbi Anglong	Lakhijan	Dug Well	0.99	135.00	5.77	5.79	4.13	5.02
East Karbi Anglong	Langhing	Dug Well	0.84	82.00	3.76	3.66	1.90	1.33
East Karbi Anglong	Manikpur	Dug Well	0.87	98.64	3.80	1.30	1.11	0.73
East Karbi Anglong	Manja Bus Stand	Dug Well	0.20	129.00	3.60	3.05	2.10	3.10
East Karbi Anglong	Manja OW	BH	0.50	80.00	2.44	2.06	1.32	1.16
East Karbi Anglong	Mohendijua	Dug Well	1.00	132.00	12.50	5.86	4.12	2.42
East Karbi Anglong	Phonglangso	Dug Well	0.92	119.00	4.38	5.14	3.82	3.35
East Karbi Anglong	Phuloni	Dug Well	0.94	90.56	8.40	2.10	0.84	0.82
East Karbi Anglong	Saphapani	Dug Well	0.89	109.00	6.01	3.99	3.24	4.03
East Karbi Anglong	Silanijan	Dug Well	0.80	103.00	6.01	5.49	5.49	6.30
East Karbi Anglong	Swarghati	Dug Well	0.63	82.00	4.28	2.67	1.62	1.47
East Karbi Anglong	Terangaon	Dug Well	1.00	120.00	2.80	2.33	1.73	
West Karbi Anglong	Boithalangsu	Dug Well	0.97	69.30	4.68	3.81	3.45	
West Karbi Anglong	Donkamokam	Dug Well	0.95	74.89	2.28	1.09	5.68	0.21
West Karbi Anglong	Kalonga	Dug Well	0.77	91.92	5.59	4.65	5.45	2.57
West Karbi Anglong	Kheronighat	Dug Well	0.88	79.87	10.61	9.13	12.32	8.45

2.2.3 Water Quality

During Pre monsoon and post monsoon period 48 numbers of samples were collected from dug wells and hand pumps of the study area for analysis of basic parameters, fluoride, iron, heavy metals and arsenic.

For each station, 1000ml for Basic Parameters, 500ml of sample preserved in HNO_3 acid for Heavy Metal, 250ml of sample preserved with HCL acid for Arsenic and Iron, and

250ml of Refrigerated samples were collected. For pre-monsoon, Sample for Uranium analysis were collected in 60ml sample bottles after preserving HCL acid.

Parameters such as Temperature, pH, Electrical Conductivity, Salinity, Total Dissolved Solid, Dissolved Oxygen and Oxygen Reduction Potential were tested at location using Water Testing Tool.

2.2.4 Exploratory Drilling

During AAP 2022-23, 3 exploratpry wells and 2 piezometers were drilled in the study area by CGWB. A list of existing exploratory wells constructed in the area are prepared incorporating location, well designs, etc (Table 2.2). Details of 2 exploratpry wells and 2 piezometers constructed in current AAP is given in Table 2.3.

Table 2.2: Details exploratory wells and piezometers in Karbi Anglong District, Assam.

Location	Longitude	Latitude	Type of Well	Depth of Drilled (mbgl)	Depth of constr. (mbgl)	Source
Ampukhuri-EW	93.0558	26.166	Tube Well	207.90	185.00	CGWB
Baghpani-EW	93.0922	26.251	Tube Well	39.50	39.50	CGWB
Beptlong-EW &OW	92.8061	25.883	Tube Well	82.50	79.81	CGWB
Borjan-EW	93.4000	26.013	Bore Hole	22.30		CGWB
Central Bazar-EW	93.1339	26.148	Tube Well	99.90	99.90	CGWB
CRPF Campus, Khatkhati-I-DW	93.7353	25.956	Tube Well	225.60	219.00	CGWB
CRPF Campus, Khatkhati-I-DW	93.735	25.958	Tube Well	252.00	252.00	CGWB
CRPF Campus, Khatkhati-II-DW	93.7347	25.958	Tube Well	251.54	250.00	CGWB
Dengaon-EW	92.9800	26.222	Tube Well	151.00	133.00	CGWB
Dengaon-PZ	92.9742	26.367	Tube Well	85.20	73.00	CGWB
Deopani-EW&OW	93.8417	26.221	Tube Well	237.00	145.00	CGWB
Dighaliati-EW	92.976	26.144	Tube Well	154.83	49.00	CGWB
Diphu -EW	93.4300	25.840	Tube Well	247.60	227.00	CGWB
Doloni-EW	92.6869	25.969	Tube Well	39.40	30.00	CGWB
Donkamukang-EW	92.6967	25.928	Tube Well	236.10	156.00	CGWB
Eradighai Pani- EW	93.0247	26.135	Tube Well	171.80	158.00	CGWB
Hamren-EW &OW	92.5969	25.865	Tube Well	67.00	67.00	CGWB
Haraguti-EW	93.1106	26.201	Tube Well	214.05	214.00	CGWB
Hawaipur-EW	92.965	25.846	Bore Hole	214.66		CGWB
Hidipi-EW	93.6300	26.010	Tube Well	149.00	149.00	CGWB
Jirikending-EW	92.6589	25.761	Tube Well	46.20	46.20	CGWB
Kauripathar-EW	93.0125	26.220	Tube Well	34.10	32.00	CGWB
Kendriya Vidayalaya -EW,Diphu	93.4208	25.844	Tube Well	104.00	98.00	CGWB
Kendriya Vidayalaya -OW,Diphu	93.4208	25.844	Tube Well	104.00	95.00	CGWB
Khanajan - EW	92.7169	25.977	Tube Well	222.61	215.00	CGWB
Khanajan OW	92.7167	25.840	Tube Well	220.87	211.00	CGWB
Khanajan-EW	92.7169	25.842	Tube Well	222.61	156.00	CGWB
Khanduli-EW	92.4508	25.726	Tube Well	43.45	43.45	CGWB

Location	Longitude	Latitude	Type of Well	Depth of Drilled (mbgl)	Depth of constr. (mbgl)	Source
Khatkhati-OW	93.7353	25.959	Tube Well	255.06	218.95	CGWB
Lakhijan-I-EW	93.7436	26.046	Tube Well	227.75	215.40	CGWB
Linchika-EW	92.6333	25.988	Bore Hole	85.30		CGWB
Longkai Bey-EW	93.4114	26.003	Tube Well	68.00	61.00	CGWB
Longkai Bey-OW	93.4114	26.002	Tube Well	64.00	64.00	CGWB
Manikpur-EW	93.0058	26.247	Tube Well	88.00	85.00	CGWB
Manja-OW	93.4384	25.967	Tube Well	91.87	46.00	CGWB
Matikhola-EW	93.1122	26.131	Tube Well	180.00	156.00	CGWB
Nambor Adarsha-EW&OW	93.7825	26.123	Tube Well	254.83	209.77	CGWB
Okkerang (Kalaigaon)-EW	93.9333	26.151	Tube Well	200.00	197.00	CGWB
Ongone -EW&OW	93.0606	26.116	Tube Well	228.27	217.17	CGWB
Pachim Deodak -EW	93.0994	26.273	Tube Well	50.30	36.00	CGWB
Phuloni-EW	92.9783	26.224	Tube Well	50.60	33.00	CGWB
Phuloni-OW	93.1367	26.169	Tube Well	105.45	91.00	CGWB
Pigobasti-EW	93.6250	25.979	Bore Hole	270.66		CGWB
Rangkat Haikhola-EW	93.1122	26.131	Tube Well	177.00	157.42	CGWB
Rangkhelleng-EW	93.4417	25.843	Tube Well	247.60	227.42	CGWB
Rangkhelleng-EW	93.442	25.843	Tube Well	247.60	227.42	CGWB
Sarsobay-EW	93.1050	26.251	Bore Hole	96.00		CGWB
Tanglok gaon-EW	93.0278	26.238	Tube Well	40.60	32.30	CGWB
Taralangso-EW	93.4194	25.880	Tube Well	103.00	86.00	CGWB
Taralangso-OW	93.4194	25.880	Tube Well	92.00	84.00	CGWB
Tekegaon- II-PZ	93.0447	26.193	Tube Well	164.70	164.70	CGWB
Tekegaon-EW	93.0447	26.193	Tube Well	201.20	59.00	CGWB
Tekegaon-I-PZ	93.0447	26.193	Tube Well	99.04	87.00	CGWB
Thapliaram-EW	92.8117	25.848	Tube Well	40.10	40.10	CGWB
Tika -EW	92.6067	25.951	Tube Well	85.00	85.00	CGWB
Dillai	93.92278	26.64333	Bore Hole	129.9		CGWB
Phutuni			Tube Well	50.6	33	CGWB
Mirdan			Bore Hole	200		CGWB

Table 2.3: Details of exploratory wells constructed in Karbi Anglong District during AAP 2022-23

Location	Block	Topo sheet No	Long	Lat	Type of Well (DW/ BW/ TW)	Depth Drilled	Depth of construction (m)
Bokulia	Langsomapi	83F/8	25.0564	93.199	Tubewell	86	51
Kovebir Langso	Langsomapi	83F/8	25.9352	93.538	Tubewell	76	37
Hojaipur	Hojaipur	83G/5	25.7717	93.3296	Tubewell	71	

CHAPTER 3.0

Data Interpretation, Integration and Aquifer Mapping

3.1 Data Interpretation

Exploration and Aquifer Disposition

Central Ground Water Board, North Eastern Region, Guwahati has drilled numbers of exploratory wells in the district. But for the sake of this report, only 27 wells will be considered. During aquifer mapping, in the district 3 exploratory wells and 3 piezometers were drilled down to the depth of 200m through DTH Rig. The litholog of all the exploratory wells were used to identify the major aquifer in the district. The lithologs of all the exploratory wells and piezometers are dominated by Quarternary alluvium sediments like grey coloured clay and sand which indicate deposition in riverine environment and underlain by Pre-Cambrian Gneissic and Quartzite rocks. The principal alluvial aquifer is further categorized as younger alluvium. The deeper aquifer present in the district is fracture zones of granite gneiss and quartzites.

Aquifer Disposition

To understand the disposition of aquifer, 2D sections and 3D panel diagrams are constructed using the lithologs of the exploratory wells.

2D Aquifer Disposition:

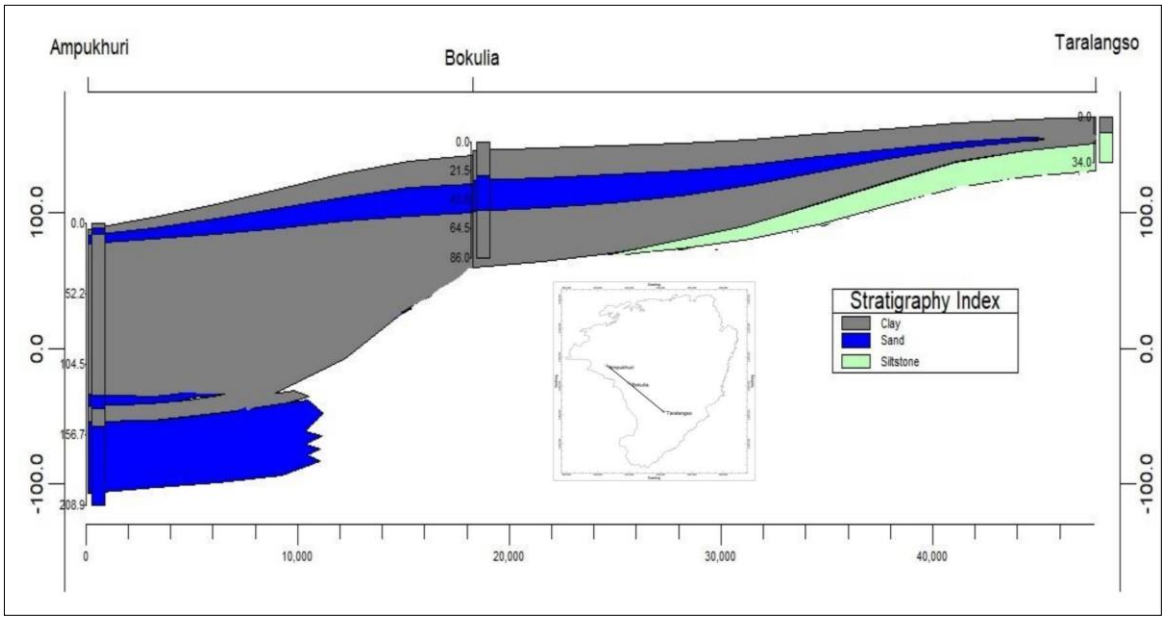
Two-dimensional aquifer disposition of East Karbi Anglong and West Karbi Anglog were prepared separately for better visualisation of the aquifer.

In East Karbi Anglong four sections were drawn along NW-SE direction from Ampukhuri to Taralangso via Bokulia, another section from Bokulia to Khatkhati via Pigobasti, another from Dillai to Manja via Taralanso and another section in NE-SW from Deopani to Khatkhati via Nambor Adarsha.

a. Section from Ampukhuri to Taralangso via Bokulia:

Exploratory wells drilled at Ampukhuri, Taralangso and Bokulia reveals two aquifer system in the area. Three layers of sand is prominent in Ampukhuri. First layer is encountered within 100mbgl at a depth of 3mbgl and has a thickness of nearly 5m. second layer is encountered at a depth of 127mbgl and the third layer is encountered at a depth of 150mbgl. Thickness of these layers ranges from 9.5m to as high as 58m respectively. In Bokulia, one sand layer of 25m is encountered at 25mbgl. Towards Taralangso this sand layer is absent and here the major aquifer type is Siltstone.

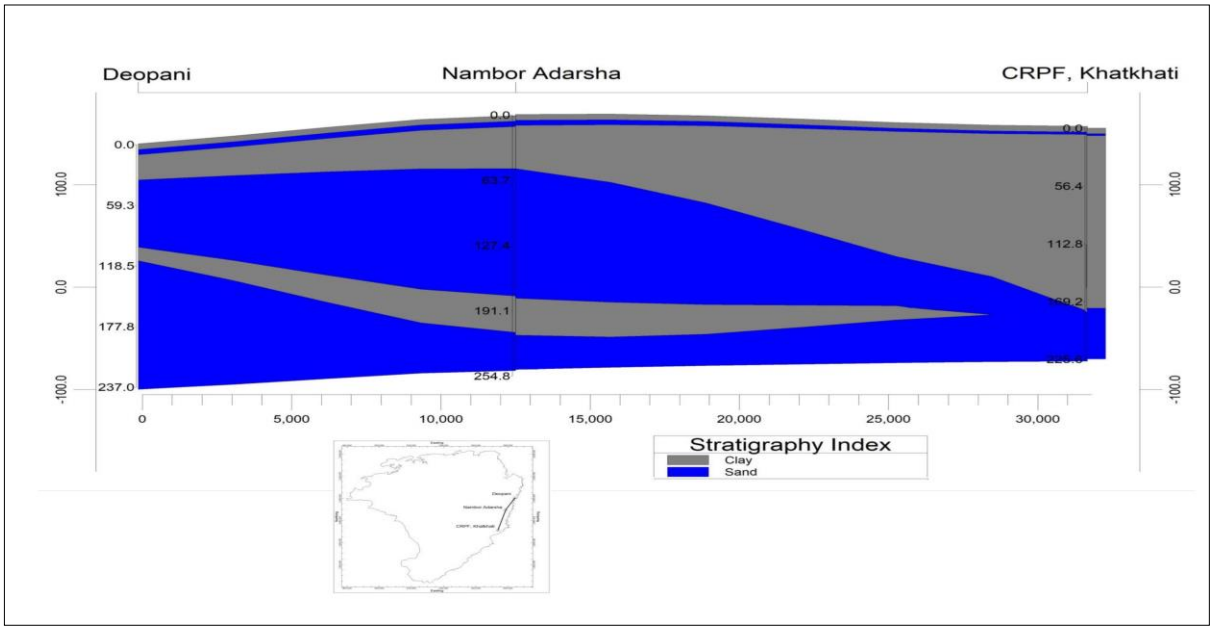
Discharge in the sand aquifer ranges from 7 to 45m3/hr and in the siltstone aquifer a discharge of 200m3/hr was encountered.



b. Section from Deopani to Khatkhati via Nambor Adarsha:

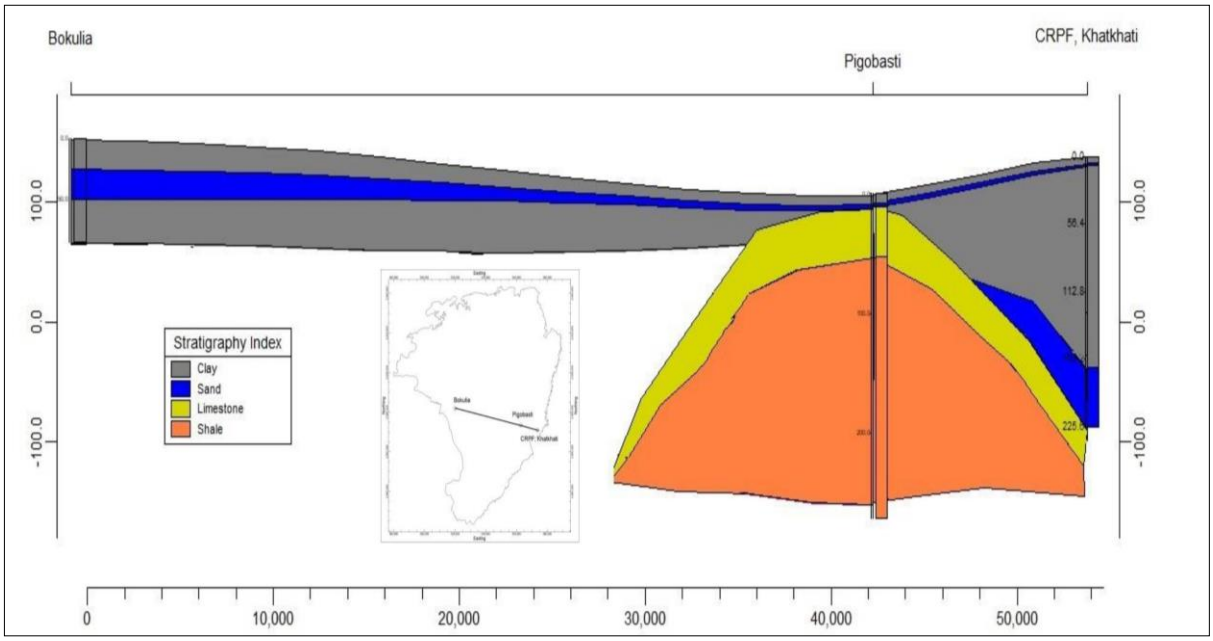
In these areas, aquifer is an monoaquifer of Alluvium composing of Sand and Clay. The first layer of sand is encountered at as shallow as 5mbgl and has an average thickness of 5m. the second layer of sand is encountered at a depth of 30mbgl in Deopani and at 46mbgl in Nambar Adarsha. This sand layer has a thickness ranging from 50 to 100s of meter. The third layer of sand is encountered at depths >100mbgl. Both these layers taper into a single lense in Khatkhati area.

Discharge of this aquifer ranges from 16.7 to as high as 163.7m3/hr.



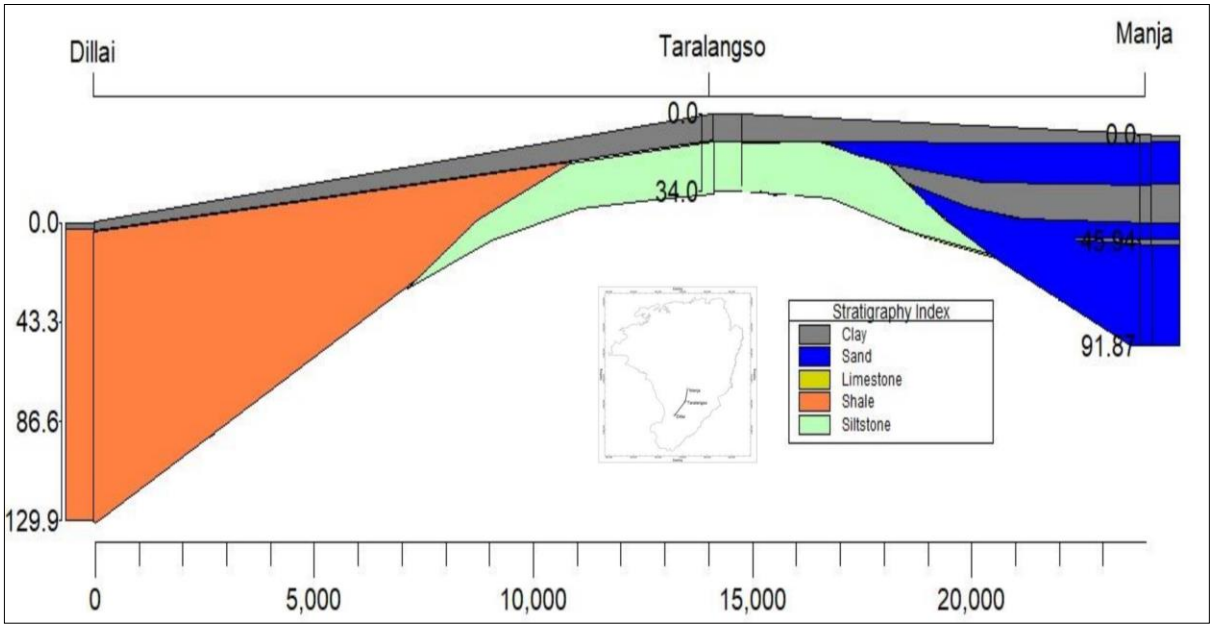
c. Section from Bokulia to Khatkhati via Pigobasti

In the Dillai-Pigobasti area sand, limestone and shale aquifers encountered. The layer of sand is encountered at a depth of 7.5mbgl immediately after top soil. Limestone occurs at a depth of 12mbgl and its thickness on an average is 40m. Shale occurs at a depth beyond 53mbgl



d. Section from Dillai (towards Nilapur) to Manja via Taralanso:

Towards Dillai, in Nilapur, shale is encountered immediately below the top Clay layer. Fractures in these shales are encountered at depths of 54mbgl, 84mbgl and 115mbgl. Towards Manja, three layers of Sandy aquifers are encountered at various depths of 3mbgl, 38mbgl and 48mbgl. Average thickness of this sand layer is 20m and discharge is 33.33m3/hr.

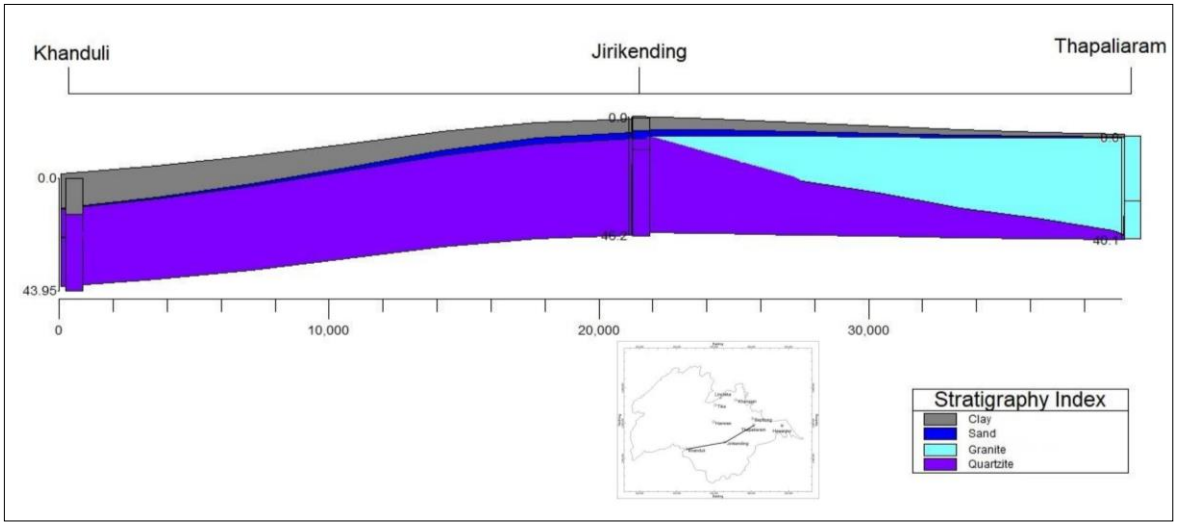


In West Karbi Anglong three sections were drawn along NE-SW direction from Thapliaram to Khanduli, another section in NW-SE from Khonajan to Hawaipur via Baptalong and another section in N-S direction from Khanduli to Linchika.

a. Section Thapliaram to Khanduli:

In Khanduli and Jirikinding area the aquifer type is Quartzite. Fractures are encountered at depths of 14mbgl, 16mbgl 19mbgl and 35mbgl. Discharge is quite low from these fractures and ranges from 0.0427 to 0.175m3/hr.

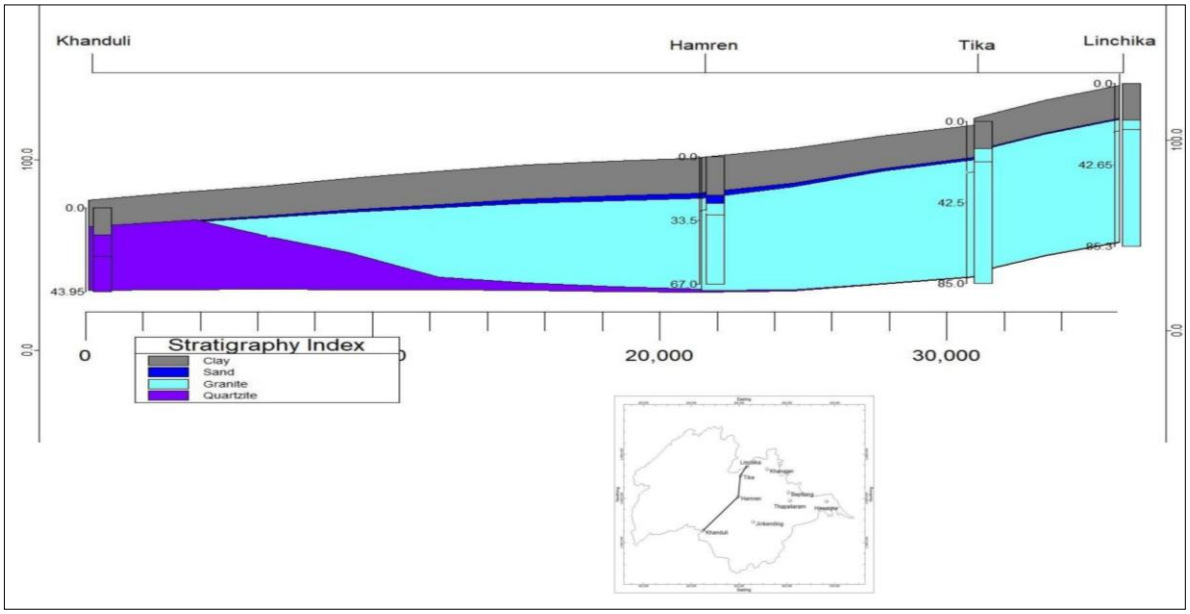
In Thapliaram, Granite Gneiss is the major aquifer. Fractures encountered at depths of 25mbgl and 32mbgl produces a discharge of 40m3/hr.



b. Section from Khanduli to Linchika:

Section from Khanduli to Linchika via Hamren and Tika again reveals two aquifer system of Quartzite and Gneissic rock. In gneissic rocks fractures area encountered at depths of 31mbgl at Hamren, 44 to 52mbgl in Tika, and at 66mbgl, 69mbgl and 76mbgl in Linchika Exploratory well. Discharge in Gneissic rock ranges from 1 to 3.6m3/hr.

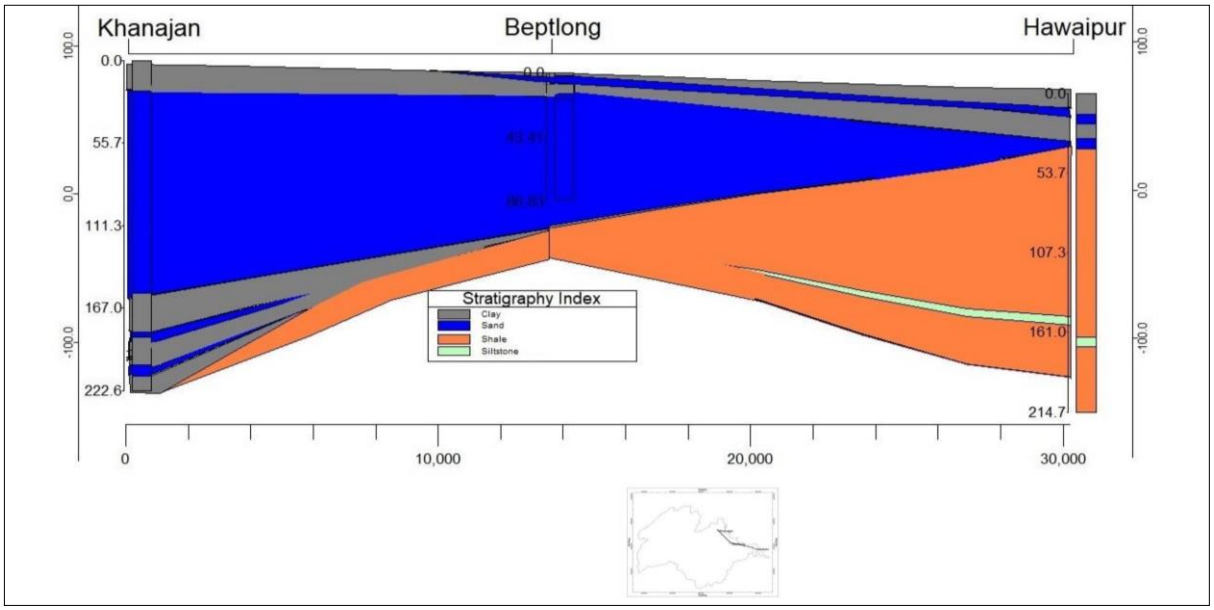
A small sand lens of 4m is also encountered at Hamren at a depth of 20mbgl.



c. Section from Khonajan to Hawaipur via Baptalong:

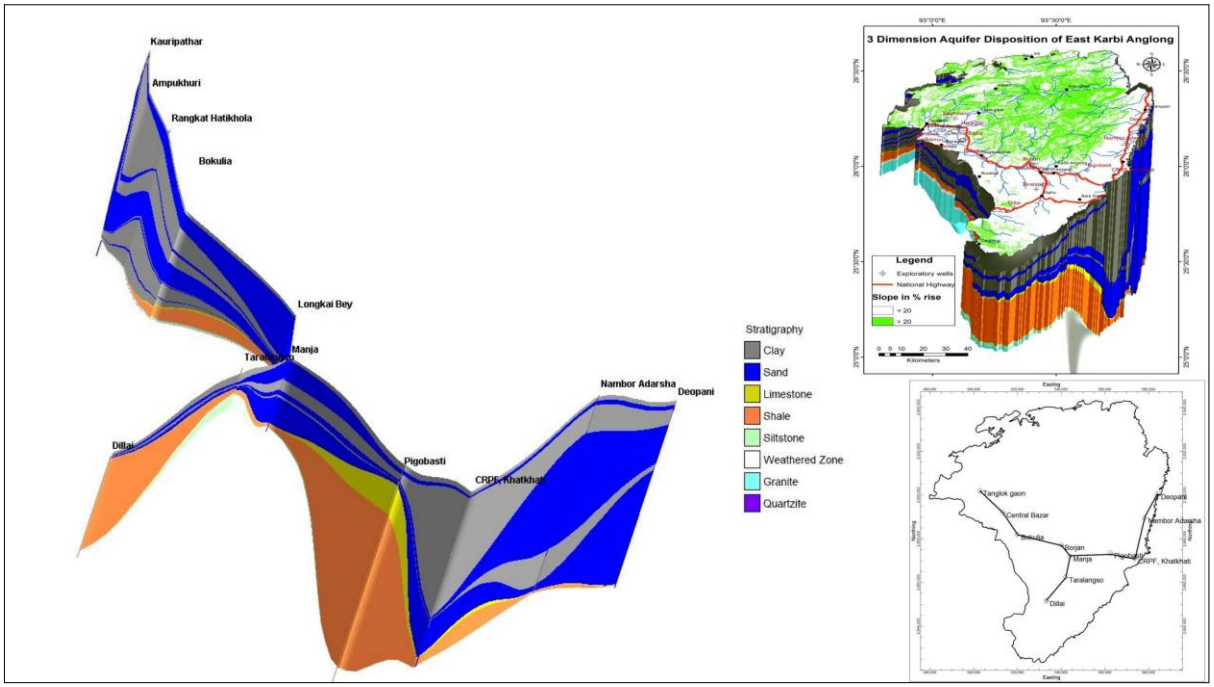
This section runs parallel to the river Kopili and Foothills of West Karbi Anglong. Two aquifer types of Sand and Shale is encountered. Apart few very small lenses of sand, a large thickness of sand is encountered at depths varying from 17mbgl to 20mbgl is encountered in Khanajan and Baptalong. Thickness of this sand layer is in 100s of meters. Towards Hawaipur two small sand lenses are encountered at depths of 14 and 30mbgl respectively. Shale is encountered beyond the depth of 36mbgl. A small lens of 6.8m siltstone occurs at depth of 164mbgl in Hawaipur.

Discharge in Sand aquifers ranges from 16.3 to 106.8 m3/hr.



3D Aquifer Disposition:

A three dimensional model of Aquifer system was prepared for better visualization of aquifers in the district. In East Karbi Anglong district, four aquifer types are encountered. Towards Ampukhuri and Deopani, Sand aquifer is prominent. Limestone is found in the Pigobasti-Dilai-Bokajan area. Shale is found towards Pugobasti and Nilapur area. General trend of the foramtions is that unconsolidated sediments overlie the consolidated ones.



In West Karbi Anglong, four aquifer system of Alluvium, Shale, Gneissic rock and Quartzite is found. Shale is found towards Hawaipur, Sand towards Khanajan, Gneissic rock in Linchika-Hamren-Khanduli area and Quartzite towards Jirikinding-Khanduli is found.

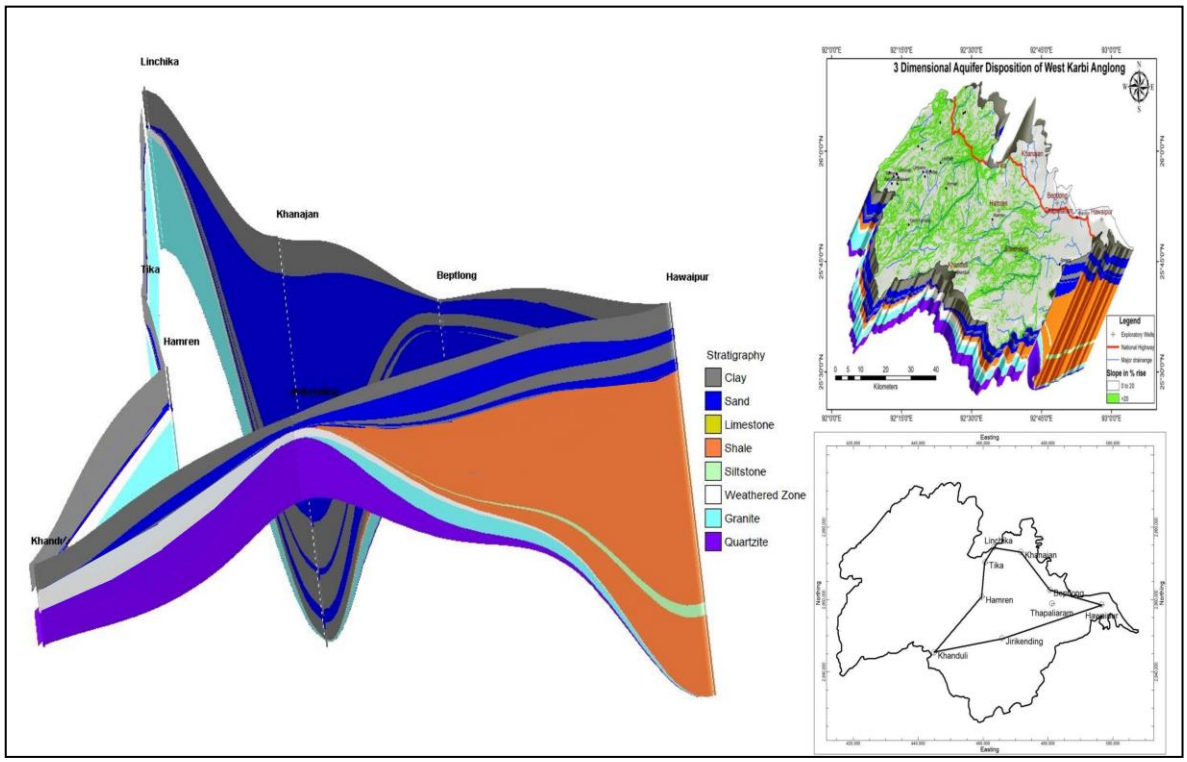

Linchika
Khanajan
Tika
Beptlong
Hawaipur
Hamren
Khandi
Stratigraphy
Clay
Sand
Limestone
Shale
Siltstone
Weathered Zone
Granite
Quartzite
3 Dimensional Aquifer Disposition of West Karbi Anglong
Legend
Slope in % rise
Linchika
Khanajan
Tika
Beptlong
Hamren
Thapaliagan
Hawaipur
Jirikending
Khanduli
Easting
Northing

Table 3.1: Aquifer parameters:

Location	Depth of Drilled (mbgl)	Depth of constr. (mbgl)	Length of casing lowered with dia (m)	Zones / Fractured encountered			Static Water level (mbgl)	Discharge (m^3/hr)	Draw Down (m)	T (m2/ day	Permeability (m/day)	Specific Capacity
				From 0.00 to 50.00 m.bgl	From 50 to 100 m.bgl	From 100 to 300 m.bgl						
Ampukhuri-EW	207.90	185.00		13-16, 19-22, 24-27			3.9	45.65	4.62	401.2		13.39
Beptlong-EW &OW	82.50	79.81		30-32	51-57, 66-78		9.84	1.63	8.2	573.4		198.96
CRPF Campus, Khatkhati-I-DW	225.60	219.00				179-191, 209-215	11.55	163.521	2.25	107	4.78	46.35
CRPF Campus, Khatkhati-I-DW	252.00	252.00				232-250	8.53	16.70	36.00	245.00	13.60	84.60
CRPF Campus, Khatkhati-II-DW	251.54	250.00				179-191	8.53	16.698	3.29	245	13.6	84.6
Deopani-EW&OW	237.00	145.00			49-73, 84-93,	104-113, 133-142	0.71	138.06	13.98	331.01		164.59
Hamren-EW &OW	67.00	67.00	31.4	31-54.8			3.12	1	13.3			1.13

Location	Depth of Drilled (mbgl)	Depth of constr. (mbgl)	Length of casing lowered with dia (m)	Zones / Fractured encountered			Static Water level (mbgl)	Discharge (m^3/hr)	Draw Down (m)	T (m2/ day	Permeability (m/day)	Specific Capacity
				From 0.00 to 50.00 m.bgl	From 50 to 100 m.bgl	From 100 to 300 m.bgl						
Hawaipur-EW	214.66											
Jirikending-EW	46.20	46.20	12.4				10.15	0.0427				
Khanajan - EW	222.61	215.00			62.5-55.5, 72-78,	110-116, 150-157, 183-186,	1.27	106.08	6.43	510.57		273.72
Khatkhati-OW	255.06	218.95				179-198, 208-214	11.55	6.8	2.45	107		46.26
Linchika-EW	85.30		24.1		66-67, 69.1-70, 76.2-77.2		28.3	3.60				
Manja-OW	91.87	46.00		38-55			2	33.33				
Nambor Adarsha-EW&OW	254.83	209.77			92.08-80.52,	109.11-121.51, 186-191.97,	4.66	63.12	24.56	102.62		42.83
Pigobasti-EW	270.66											
Taralangso-EW	103.00	86.00			65-84		20	200				
Taralangso-OW	92.00	84.00			62-93		16					

Location	Depth of Drilled (mbgl)	Depth of constr. (mbgl)	Length of casing lowered with dia (m)	Zones / Fractured encountered			Static Water level (mbgl)	Discharge (m^3/hr)	Draw Down (m)	T (m2/ day	Permeability (m/day)	Specific Capacity
				From 0.00 to 50.00 m.bgl	From 50 to 100 m.bgl	From 100 to 300 m.bgl						
Thapliaram-EW	40.10	40.10	24.05	25.4-28.4, 32.5-36.5			6.2	40	4.9	23.37		152.9
Tika -EW	85.00	85.00	21.2	44.4-52.5	54.1-56.6, 58.6-69.95		6.74	1.03	30.0			0.57
Dillai	129.90				54-55, 84-85, 115-117							
Bokulia EW	86	51	31.5	25.1-51.0			11.02	15	3.5	132.52		
Kovebir Langso EW & Pz	76	37	24.5	**2**4.32-33.44								
Hojaipur	71			Abandoned due to lack of zones								

3.1.2 Ground water level

To study ground water regime, depth to water level from 34 monitoring stations in East Karbi Anglong and 4 monitoring stations in West Karbi Anglong district were measured periodically during the months on August 2022, November 2022, January 2023 and March 2023. Variations in water level is discussed:

In East Karbi Anglong, during Pre-Monsoon i.e. on March 2023, 4 (12.9%) key wells show depth-to-water level of less than 2m bgl, 51.61% (16) key wells show water level in the range from 2 to 5 mbgl and 22.58% (7) key wells have water level from 5 to 10mbgl and four wells show water level above 10 mbgl. Minimum water level of 1.14mbgl was recorded at Amlokhi dug well and maximum water level recorded is 22.98 mbgl was recorded at Diphu dug well. Areas such as Deopani, Bokajan and Diphu have deeper water level usually more than 10mbgl.

In West Karbi Anglong, out of the four monitoring stations except Kheronighat, rest shows water level within 5mbgl (Fig. 3.5).

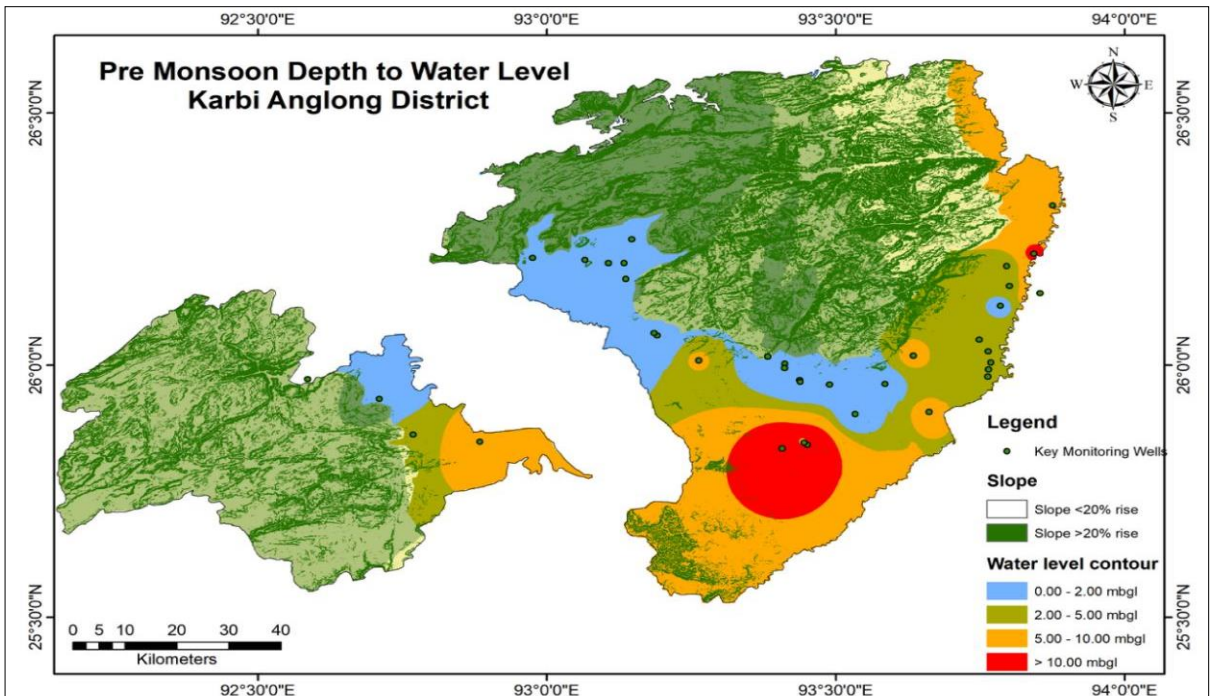


Fig. 3.5: Pre-monsoon DTW level contour of Karbi Anglong district, Assam

In East Karbi Anglong, during Post-monsoon (November 2022), depth to water level data of dugwells in Karbi Anglong district ranges from a minimum of 0.42m bgl recorded at Adarakha Tiniali to maximum 19.03m bgl at Diphu and in pizometers ranges from 1.32m in Manja OW to 23.3m in Lonkai Bey OW. The overall post monsoon water level of the district is shallow. About 35.29% well (12 numbers) shows water level less than 2mbgl, 38.24% (13) wells records water level of 2 to 5 mbgl, 11.76% (4) stations show water level from 5 to 10 mbgl and 14.71% (5) key wells water level is above 10mbgl. Water level >10mbgl in dug wells is recorded in Deopani and Diphu area.

In West Karbi Anglong except the dugwell in Kheronighat, rest of the dug wells have water level within 5mbgl. (Fig. 3.6).

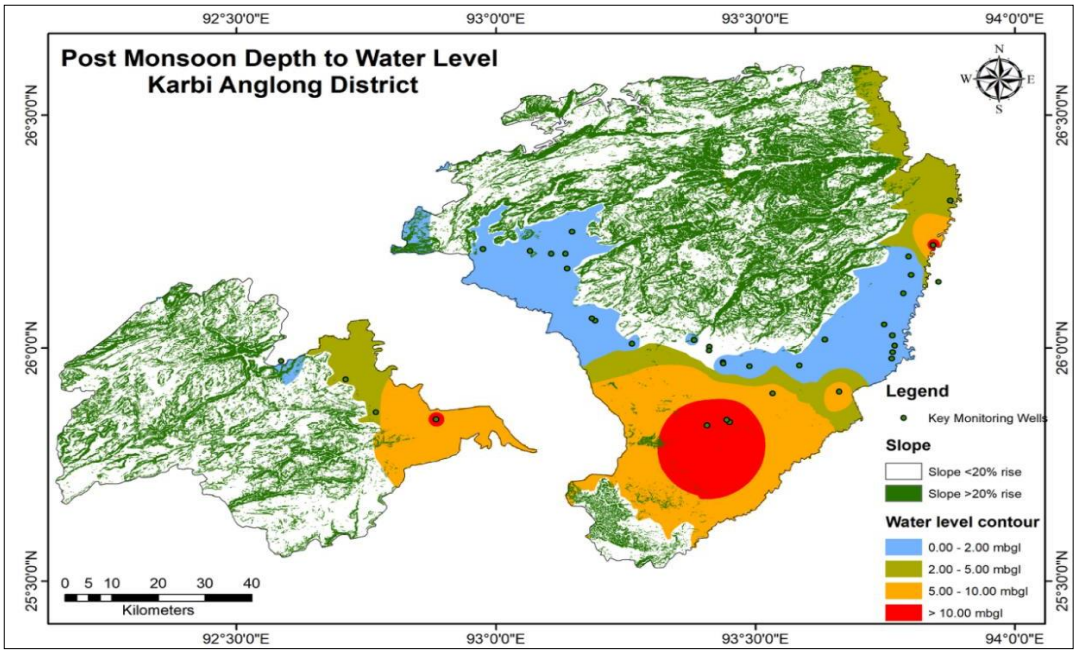


Fig. 3.6: Post-monsoon DTW contour of Karbi Anglong district, Assam

During Monsoon (August 2022) in East Karbi Anglong, 34 wells were monitored out of which 29.41% (10) wells have water level less than 2mbgl, 50.0% (17) wells have water level 2 to 5 mbgl, 8.82% (3) wells have water level in the range from 5 to 10mbgl and 4 well has water level >10mbgl. Maximum water level of 23.47 and minimum water level of 0.73 is recorded in Diphu and Manikpur dug wells respectively. In Pizometers, minimum of 1.16mbgl and maximum of 22.66mbgl is recorded in Manja and Lonkai Bey OW respectively.

In West Karbi Anglong, except in Kheronighat all the stations show water level within 5mbgl. (Fig. 3.7)

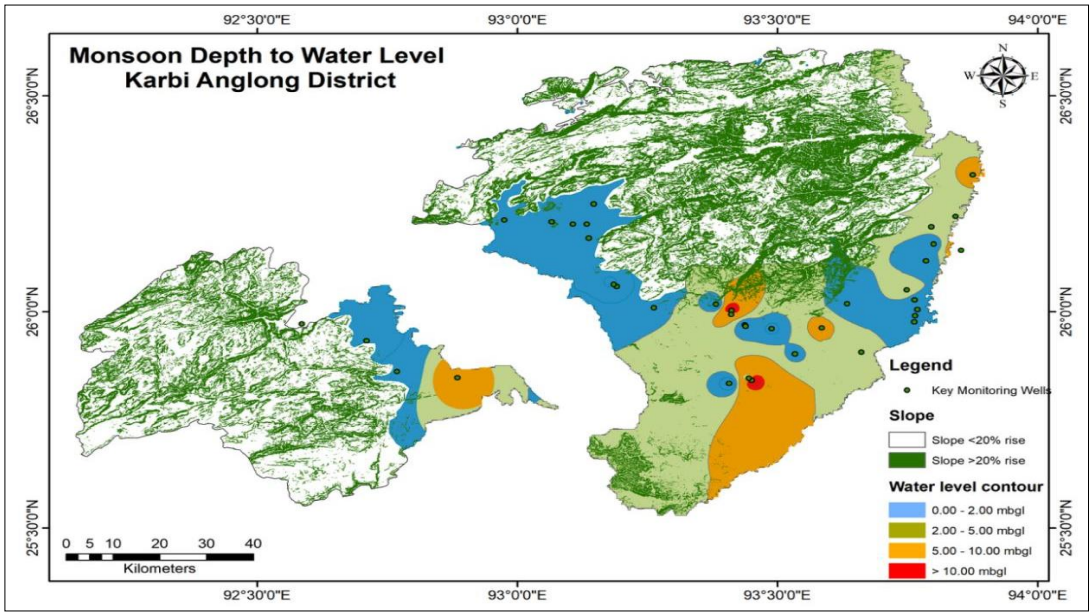


Fig. 3.7: Monsoon DTW contour of Karbi Anglong district, Assam

Fluctuation of water level in pre and post monsoon water level was compared for East and West KArbi Anglong districts. In East Karbi Anglong, fluctuation difference ranges from

0.0 to 1 m in 32.35% (11 wells) of the key wells, 44.12% (15 wells) in 1 to 2m, 11.76% (4 wells) each in 2-3m and >3m range is observed in the monitored wells of the district. Minimum fluctuation of 0.04m and maximum of 5.07 m is recorded in Bokulia and Hidipi dugwells respectively.

In West Karbi Anglong district, all the 4 wells show fluctuation in the range within 2m. (Fig. 3.7)

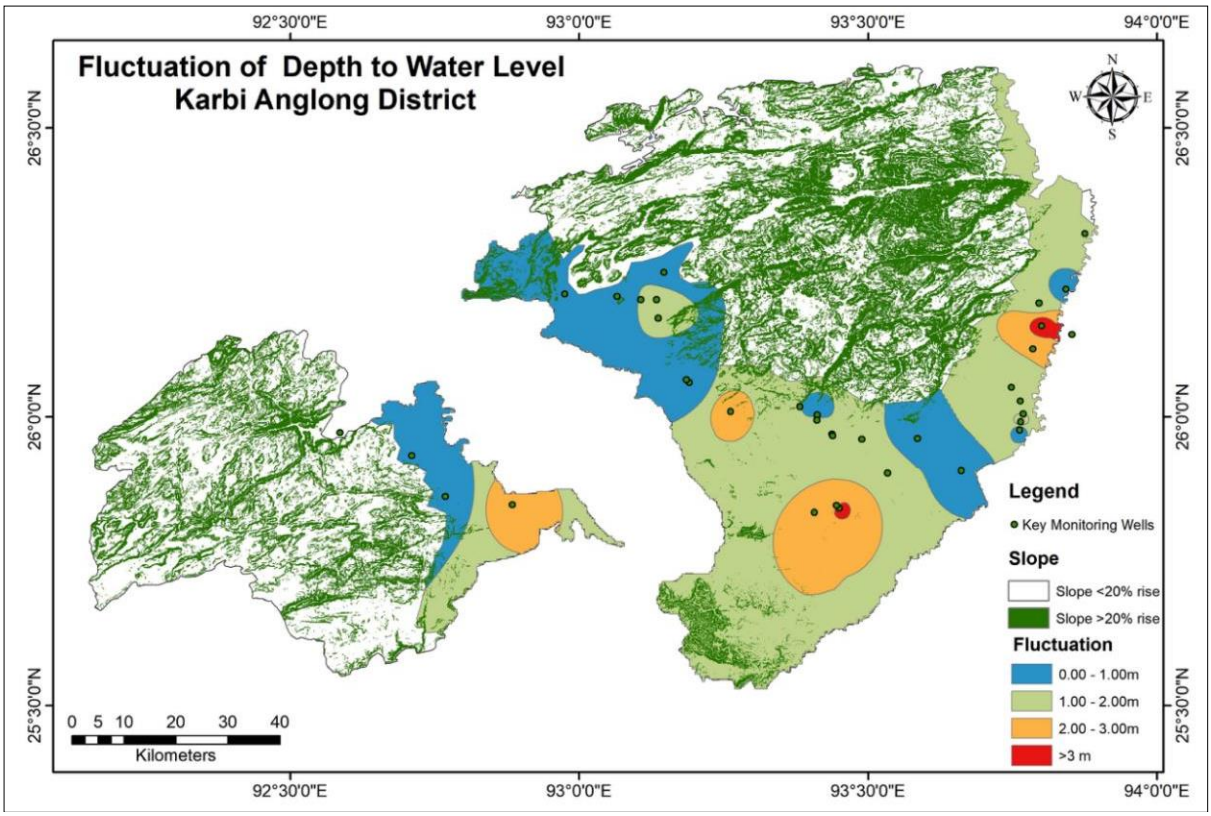


Fig. 3.8: Water Level Fluctuation map of the study area

3.1.3 Ground Water Movement

The water table contour has been prepared based on water level of ground water monitoring stations (Fig.3.8). The ground water flow direction is from the higher elevation in south-eastern side to north-western direction towards the Brahmaputra river and Southwest to Northeastern side in Manja-Deopani area. The highest water table is 150 m above mean sea level.

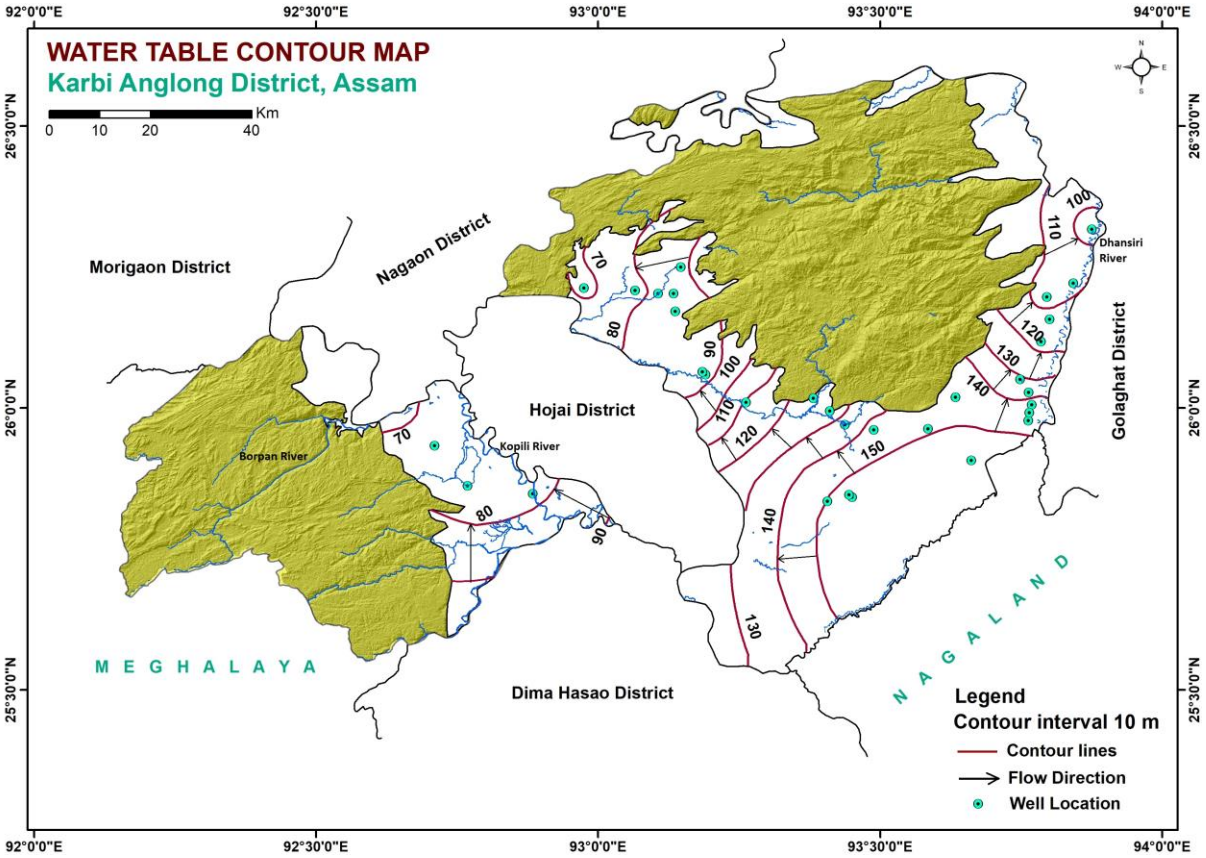
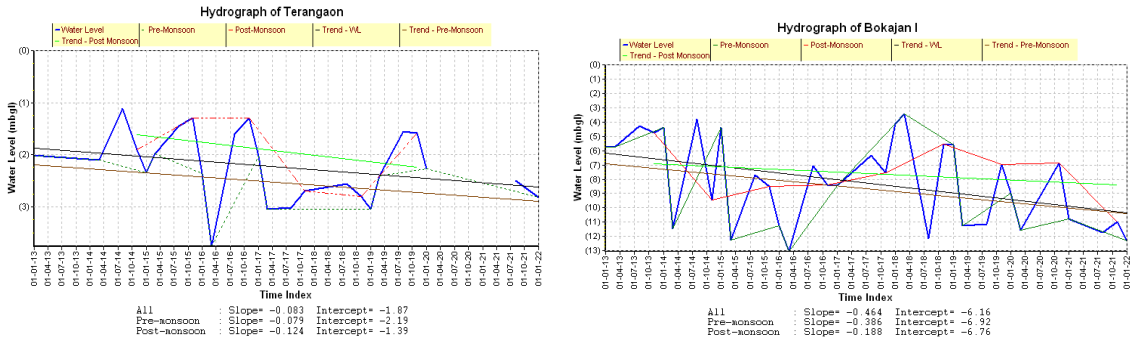


Fig. 3.9: Water table contour of the study area

3.1.4 Water level trend analysis

For analysis of long-term behavior of ground water level, data from Ground Water Monitoring Stations (GWMS) are utilized. Historical depth-to-water level data (in m bgl) are plotted as individual hydrographs and are given in Figure 3.9 which shows the overall trend of water levels in GWMS wells.

In East Karbi Anglong, except the monitoring stations of Bokajan, Diphu, Dillai and Terangaon, rest of the area shows overall rising trend. During pre-monsoon, falling in water level ranges from 6.3cm/year in Bokajan to 85.1 cm/year in Diphu, likewise in post monsoon, falling ranges from 7.9cm/year in Terangaon to 72.7cm/year in Diphu. Overall fall in dug wells ranges from a minimum of 0.4cm/year recorded in Dillai to 48.5cm/year in Diphu.



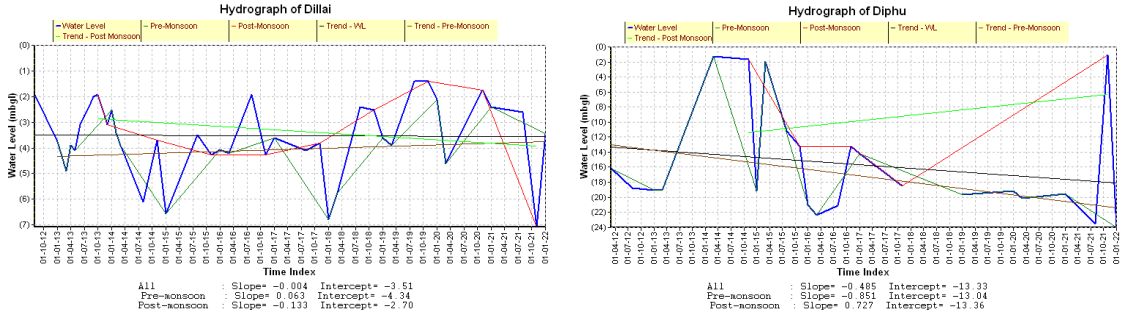


Fig.3.10: Hydrographs of GWMS in East Karbi Anglong showing falling trend

Rising trend is recorded in 87.5% of the monitoring stations in East Karbi Anglong. During pre-monsoon rising water level ranges from 4cm/year to 65.3cm/year in Phonglangsho and Manja dug wells respectively. During post-monsoon, rise in water level ranges from 7.3cm/year to 44.8cm/year in Adarakha tiniali and Phonglasho dug well respectively. Overall rise in water in the district ranges from 2.0cm/year to 64.4 cm/year.

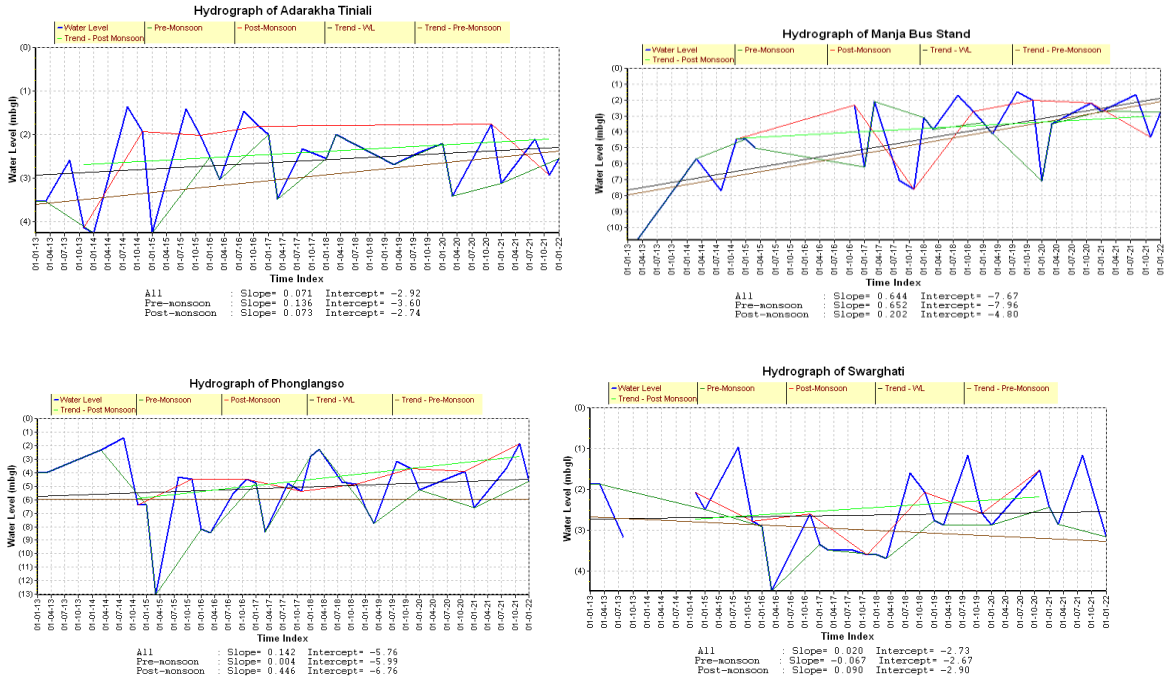


Fig.3.11: Hydrographs of GWMS in East Karbi Anglong showing rising trend

In West Karbi Anglong, out of the four monitoring stations, only Donkamokam show rising trend in pre-monsoon, postmonsoon as wells in over all trend. The monitoring station at Boithalsho though show rising trend over all but have declining trend in both pre-monsoon and post monsoon. Dug wells at Kolonga and Kheronighat have declining trend in pre-monsoon, post-monsoon and over all water level.

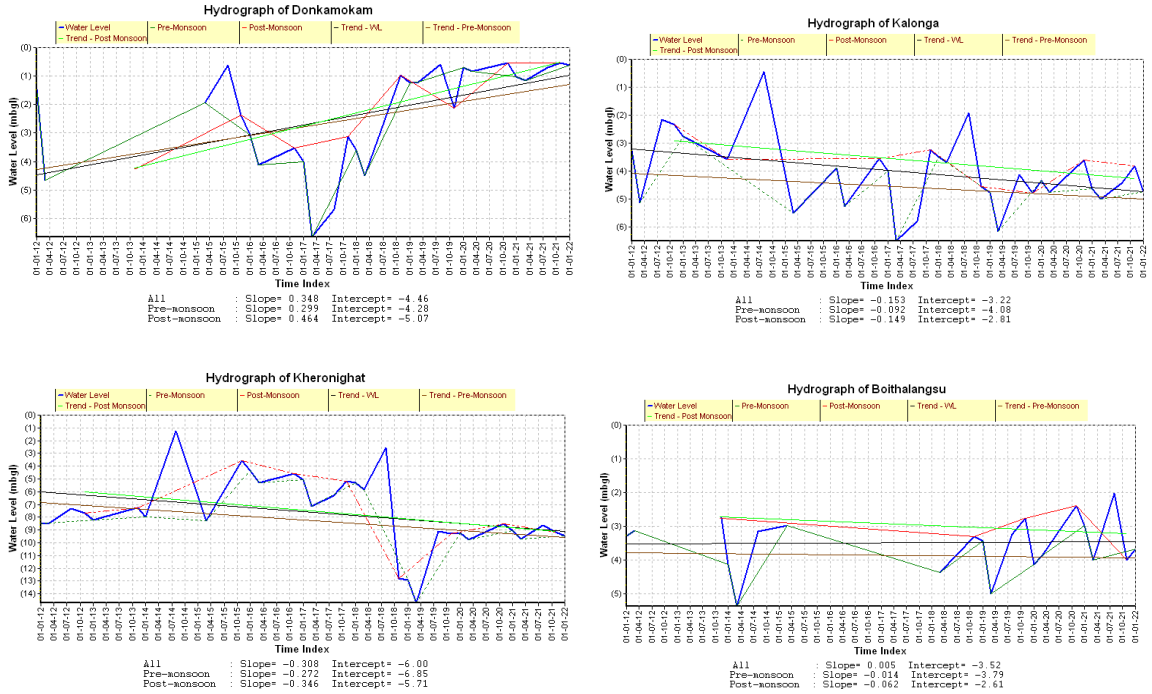


Fig.3.12: Hydrographs of GWMS in West Karbi Anglong

3.1.5 Ground water quality

A total of 48 samples were collected for Pre-Monsoon and Post monsoon for chemical analysis of ground water. Chemical analysis of ground water samples are carried out by regional chemical laboratory of Central Ground Water Board, North Eastern Region, Guwahati.

Most of the chemical constituents are within permissible limit except in few locations. The summarized results are given below.

Table 3.3. Summarized result of Chemical Quality in Karbi Anglong district

Parameter		Values		IS 10500:2012	
		Min	Max	Acceptable limit	Permissible limit*
pH		4.076	7.602	6.5-8.5	6.5-8.5
Turbidity, NTU		0.00	1.8	1	5
Electrical conductivity (µS/cm)		1.41	828.8	-	-
TDS	mg/L	0.93	547.01	500	2000
Carbonate alkalinity as $CaCO_3$		0.0	39	-	
Bicarbonate alkalinity as $CaCO_3$		12.209	720.37	-	
Total alkalinity as $CaCO_3$		12.209	759.37	200	600
Chloride		10.635	145.345	250	1000
Sulphate		0.21	74	200	400
Nitrate		0.697	22.90	45	No relaxation
Fluoride		0.0	2.2	1	1.5
Calcium (as Ca)		8.00	126.10	75	200
Magnesium (as Mg)		1.20	94.64	30	100

Parameter		Values		IS 10500:2012	
		Min	Max	Acceptable limit	Permissible limit*
Total Hardness (as $CaCO_3$)		30.00	495.00	200	600
Sodium		4.1	107.31	-	
Potassium		1.17	61.89	-	
Iron		Data under process		1	No relaxation
Arsenic	ppb			10	
Uranium	(µg/L)	BDL	9.29	30	-

pH and Turbidity:

pH analysis of samples collected from Karbi Anglong shows value in the range from 4.076 to 7.602 in i.e. acidic to mildly alkaline in nature. Areas of Bokajan, Manja, Khatkhati, Dengaon, Baghpani, Ghouria Dhubri, Diphu (Lumding road), Safapani, Silanijan, Hamren, Domkamukam, Hamren and Diphu (Matibung road) have pH less than the permissible limit of 6.5.

Turbidity measures the haziness or cloudiness of water due to presence of suspended solids. High turbidity in drinking water can shield bacteria or other organisms so that chlorine cannot disinfect the water as effectively. Some organisms found in water with high turbidity can cause symptoms such as nausea, cramps, and headaches. In the study area turbidity ranges from 0.0 to 1.8 NTU, hence well within permissible limit of 1 to 5 NTU BIS standards for drinking water (IS 10500:2012).

Total Hardness:

Total hardness is measured as sum of calcium and magnesium concentrations, expressed both as calcium carbonate. Based on total hardness, water is classified into soft, moderately hard, hard and very hard water. Minimum total hardness of 30 and maximum of 495 mg/L was recorded in the samples. All the samples are well within permissible limit of 600 mg/L.

Total Dissolved Solids:

TDS is the total concentration of organic and inorganic substance present in water in molecular, ionized or micro-granular suspended form. Based on TDS, water can be classified as Fresh, Brackish, Saline and hypersaline or Brine. Minimum TDS of 0.93 mg/l and maximum TDS of 547 mg/l was recorded.

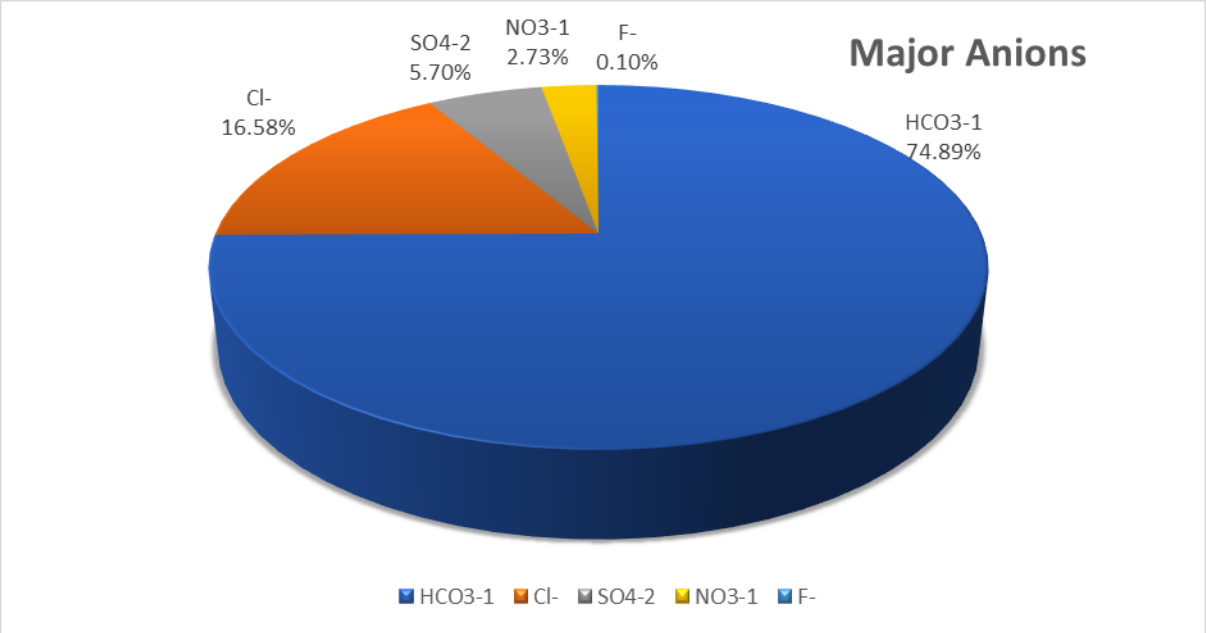
TDS (mg/L)	Water Class	% Sample	
		Post Monsoon	Pre-Monsoon
0-1000	Fresh	100%	100%
1000-10000	Brackish	Nil	Nil
10000-35000	Saline	Nil	Nil
>35000	Brine	Nil	Nil

Electrical Conductivity:

EC is the measure of water's ability to pass electrical flow which depends on the concentration of ions in water. Increase in concentration of dissolved solids increase the electrical conductivity of the water. In Karbi Anglong, EC ranges from 1.41 to 828.8 micro S/cm.

Major Anions (F^-, Cl^-, HOC_3^-, SO_4^{2-} and NO_3^-):

Major anions present in water are composed of Fluoride, Chloride, Bicarbonate, Carbonate, Sulphate and Nitrate. Majority of the anion is contributed by Bicarbonate and Chloride in the samples. A distribution of major anions in the samples is shown in the pie chart below:



Bicarbonate (HCO_3^{2-}) contributes highest (74.89%) to the total anion concertation in the samples. A minimum of 12.21 mg/L and maximum of 720.37 mg/L was recorded in the district. Bicarbonate comes to water from oxidation of CO_2 in water forming carbonic acid. Presence of Bicarbonate raises the pH value of water.

Chloride (Cl^-) contributes upto 16.58% of total anion concentration. BIS standard for Cl^- in water is 250 to 1000mg/L. In the samples, concentration of Cl^- has a minimum of 10.635 mg/L and maximum of 145.345 mg/L. The entire district is within permissible limit of Cl^- in water.

Sulphate (SO_4^{2-}) concentration in the ground water samples constitute 2.73% of total anions and its value ranges from 0.21 to 110.74 mg/L. BIS standard for Sulphate in drinking water has acceptable limit of 200mg/L and permissible limit of 400mg/L. so it is safe to say that the entire district very well within Acceptable limit. Drinking the water with high Sulphate concertation can cause diarrhea and dehydration. Sulphate may also cause corrosion of metals in the distribution system, particularly in water having low alkalinity.

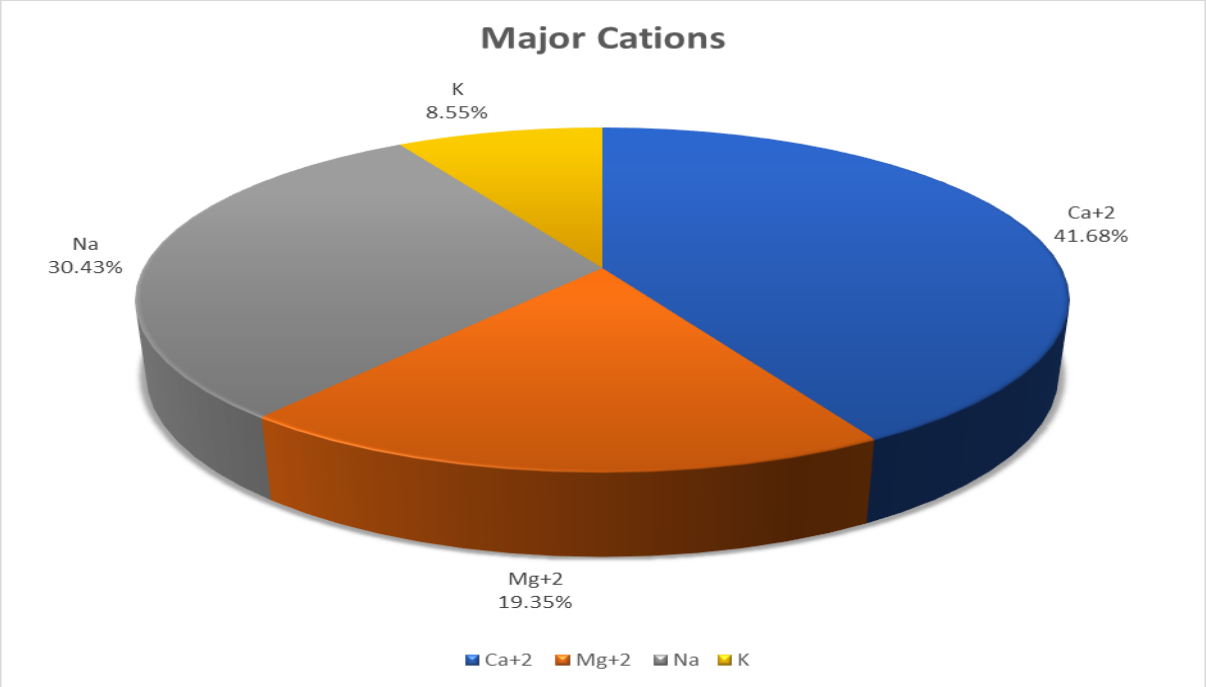
Nitrate (NO_3^-) in water can come from use of fertilizers, discharge from sewage system and animal waste etc. BIS acceptable limit for nitrate in drinking water is 45mg/L and there is no

permissible limit or relaxation. In the study area, nitrate concentration ranges from 0.697 mg/L to 22.90 mg/L in the monitoring stations. Consuming too much nitrate can affect how blood carries oxygen and can cause methemoglobinemia (also known as blue baby syndrome).

Fluoride (F^-) is an essential element which prevents tooth decay, ensuring a healthy tooth and strengthens our bones. Standard for fluoride in drinking water has acceptable limit of 1.0mg/L and permissible limit of 1.5mg/L according to BIS standard for drinking water. F^- concentration ranges from 0.04 to 2.2 mg/L. Concentration of F^- more than permissible limit is being reported at Phuloni, Khor Singh Rang Hang and Dentaghat area. Fluoride occurs naturally in public water systems as a result of runoff from weathering of fluoride-containing rocks and soils and leaching from soil into groundwater.

Major Cations (Ca, Mg, Na, K):

Major cations contributing to ground water are Calcium, Sodium, Potassium and Magnesium. Karbi Anglong district is dominated by alkali earth metals (Ca+Mg) as compared to Alkali Metals (Na+K).



Sodium (Na) concertation in the ground water samples ranges from a minimum of 4.1 to a maximum of 107.31 mg/L. It contributes about 30.43% of the total cationic concentration. Sodium in ground water comes from sodium bearing rocks and soil from which sodium is being dissolved. Sodium is an essential nutrient and adequate levels of sodium are required for good health. However, too much sodium is one risk factor for hypertension (high blood pressure).

Calcium (Ca) concentration during Pre-monsoon ranges from 8.0 to 126.1 mg/L. It is the highest contributor (41.68%) to concentration of Cations in the water. BIS standard for Calcium in drinking water ranges from an acceptable limit of 75mg/L to permissible limit of 200 mg/L. All the monitoring stations have calcium well within the permissible limit of 200 mg/L.

Magnesium (Mg) concentration according to BIS standard has a acceptable limit of 30mg/L and permissible limit of 100mg/L. Magnesium concentration ranges from a minimum of 1.20 to a maximum of 94.64 mg/L. All the samples show Mg^{+2} values well within permissible limit.

Potassium (K) contributes 19.35% to the cation concentration in the ground water of that area. Its value ranges from 1.17 to 61.89 mg/L. Potassium occurs in various rock forming minerals such as feldspar, clay, sylvite etc., from which it may be dissolved into ground water through weathering processes. Potassium is a dietary requirement. Potassium shortages are relatively rare, but may lead to depression, muscle weakness, heart rhythm disorder and confusion.

Water Type and Hydro-chemical Facies:

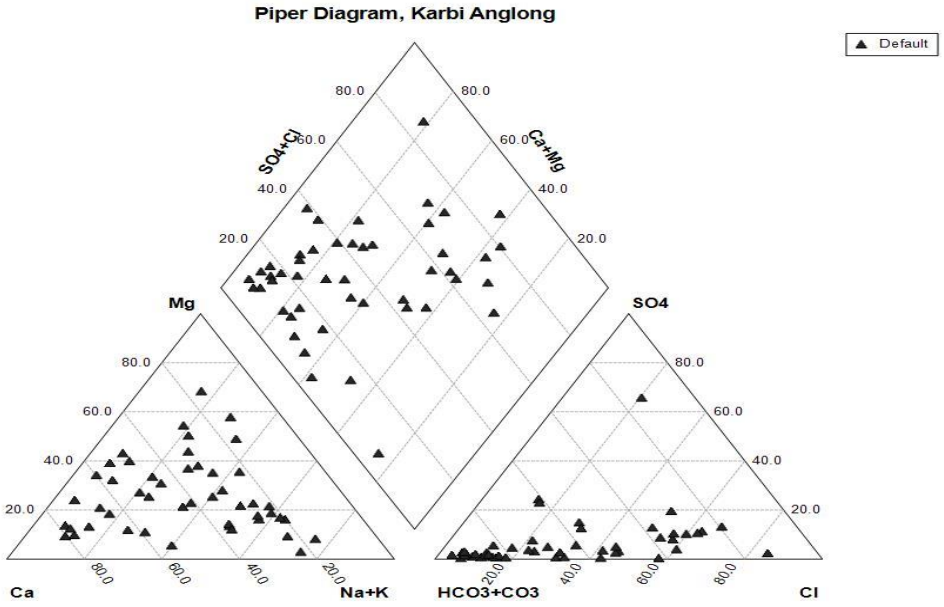
The Hill and Piper plot of ground water samples in Karbi Anglong is shown in the diagram below. The Hill and Piper plot is very useful in determining relationships of different dissolved constituents and classification of water based on its chemical characters. The triangular cationic field of Piper diagram reveals that the groundwater samples fall into Ca Type, no dominant and Na+K type, whereas in anionic triangle majority of the samples fall into bicarbonate and no dominant fields.

The plot of chemical data on diamond shaped central field, which relates the cation and anion triangles revealed that the major water types were Mixed Type (Ca-Mg-Cl-SO4, Na-K-HCO3-Cl) and Magnesium-Bicarbonate type.

In majority of the ground water samples, alkaline earth metals (Ca^{2+}+Mg^{2+}) are slightly exceeding the alkali metal cations (Na^{+}+K^{+}).

In general, the groundwater exhibits the dominance of weak (HCO_3^{-}) acid over strong (SO_4^{2-}+Cl^{-}) acid.

The facies mapping approach applied to the present study shows that Ca-Mg-HCO3, Na-K-Cl, Ca-Mg-Cl-SO4 and Na-K-HCO3-Cl are the dominant hydrogeochemical facies in the groundwater.



Concentration range of different chemical elements in ground water in the study area is given in Annexure-1.

3.1.6 Ground Water Quality for Irrigation:

A total of 48 samples were collected and analysed from dugwells and tubewells covering the entire district of Karbi Anglong district. To check the suitability of water for irrigation purpose following indices are analysed, namely

1. Sodium Absorption Ratio (SAR)
2. Residual Sodium Carbonate (RSC)
3. Sodium Percentage (Na%), and
4. Kelly Ratio (KR)

These indices were calculated using Aquachem 10.0 software and MS excel.

3.1.6a Sodium Absorption Ratio (SAR):

It is the ratio of sodium ion with respect to calcium ion and magnesium ion in ground water determined by following formula. If the SAR value is within 0 to 10meq/L then the water is considered Excellent, 10 to 18 meq/L is considered Good, 18 to 26 meq/L is considered Fair and beyond 26 meq/L the water is considered Poor for Irrigation. From risk point of view, > 18meq/L is considered medium to high risk.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}\ meq/L$$

where the ion concentrations are in meq/L.

In the study area, samples from ground water (Fig 3.1.6a) shows that all the samples are within 18meq/L.

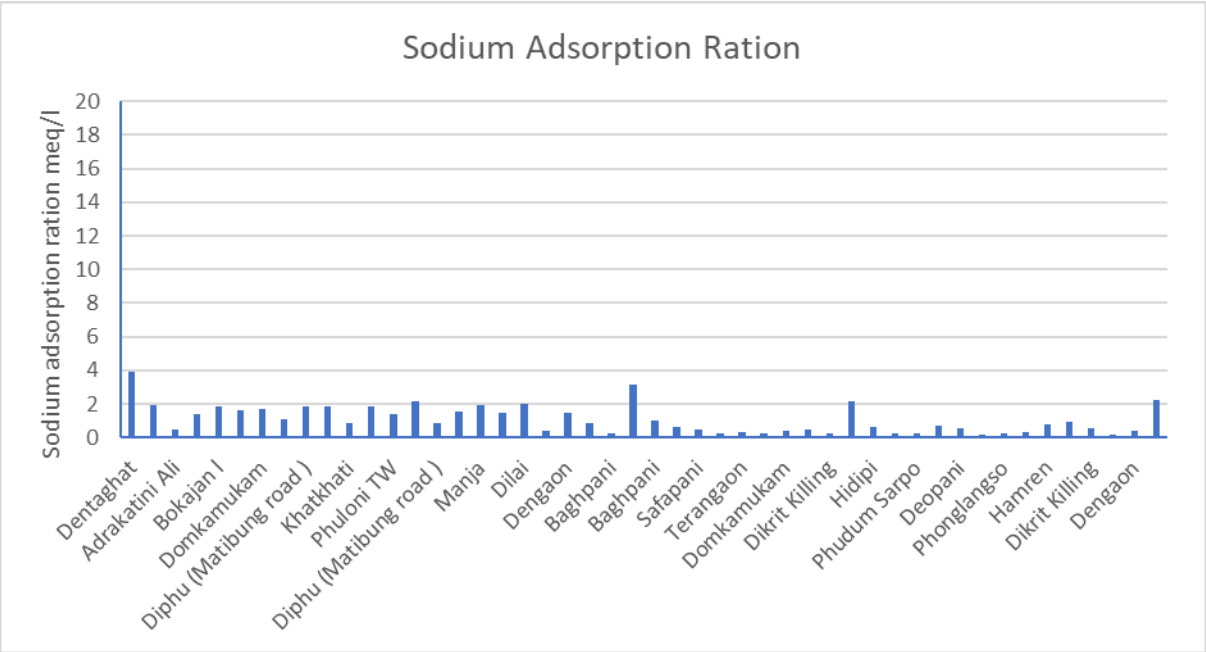


Fig 3.1.6a: Sodium Adsorption Ratio.

Moreover US Salinity plot of SAR vs Electrical Conductivity (Wilcox Plot) also deems that water to be safe for irrigation in that area.

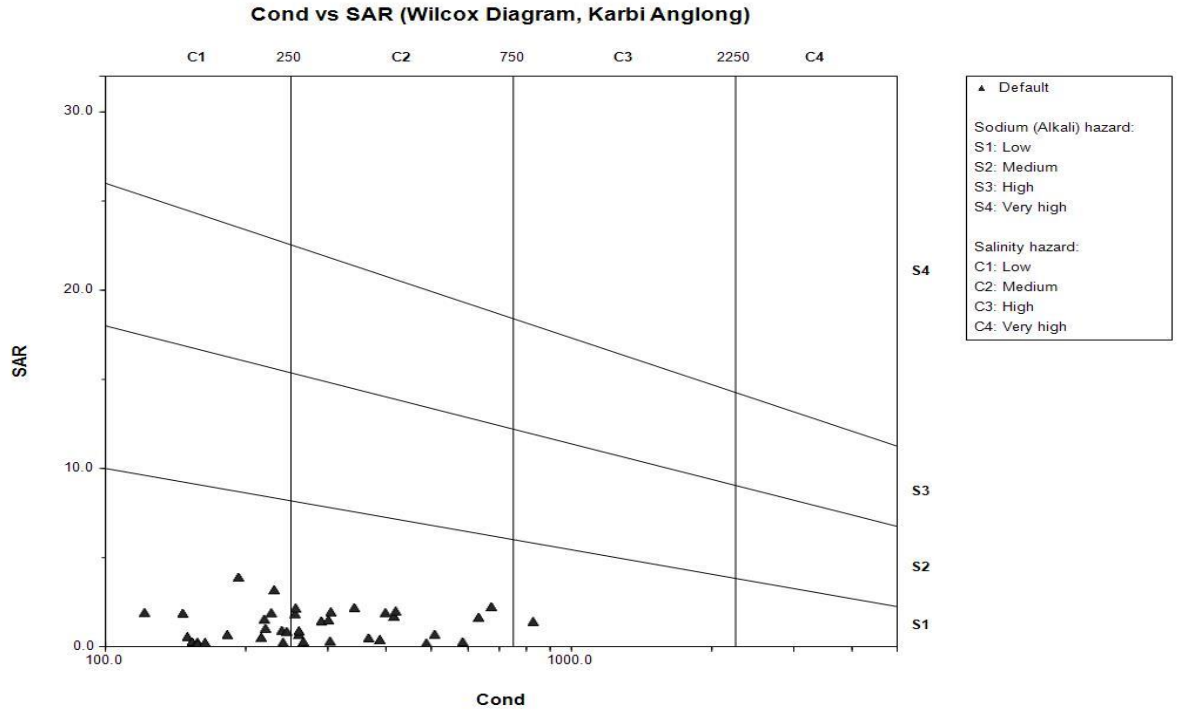


Fig 6.4.1b: Wilcox Plot

From the Wilcox plot it is very clear that Sodium Alkali Hazard is “low” and Salinity Hazard is “low” to “medium” for all the samples.

3.1.6b Residual Sodium Carbonate (RSC)

This indices is used to indicate the alkalinity hazard in irrigation water. It can be calculated by the following formula.

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) meq/L$$

If RSC value is less than 1.25 meq/L then it is considered excellent with no risk, 1.25to 2.5 meq/L is Good with low risk and more than 2.5meq/L RSC value is considered Poor quality with High Risk factor.

All the samples show RSC value less than 2.5meq/L except in the areas of Dentaghat, Khor Singh Rang Hang and Phuloni, where the RSC is >2.5 meq/l. Hence the area safe from any residual sodium carbonate hazard and is suitable for irrigation.

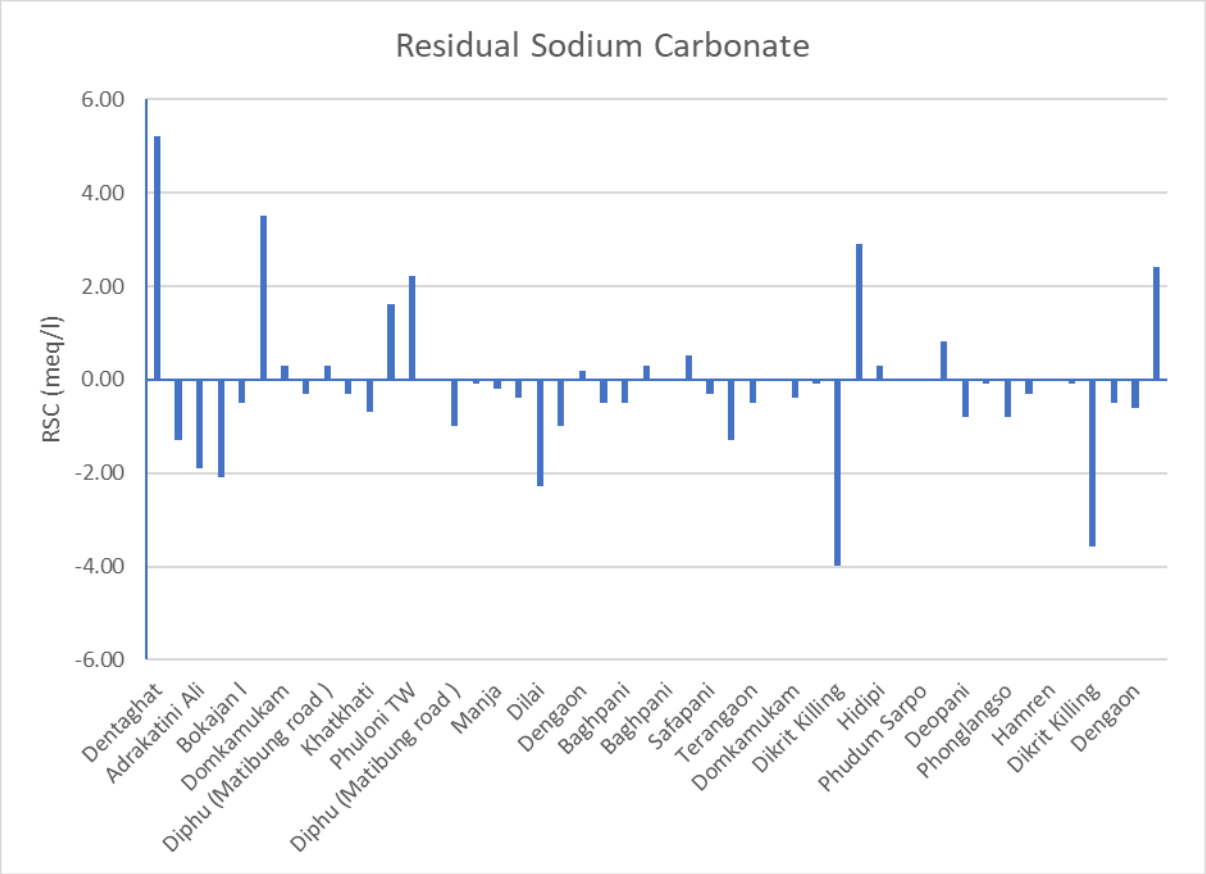


Fig 3.1.6c: Residual Sodium Carbonate

3.1.6c Sodium Percentage (Na%):

It is the amount of monovalent cations with respect to total cations. All the ion concentrations are expressed in meq/L. Na% less than 40 is considered good for irrigation. Sodium percentage between 40 to 60 is poor and more 60 is considered doubtful and unsuitable for irrigation.

$$Na\% = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \times 100$$

From all the samples analysed, few samples from Diphu (Lumding road), Dentaghat, Manja, Bokajan, Gharial Dhubi, Dengaon, Silanijan, Diphu (Matibung road), Hamren, Domkamukam, Khatkhati and Phuloni, shows Na% between 40 to 80 i.e. in “poor” and “doubtful” category.

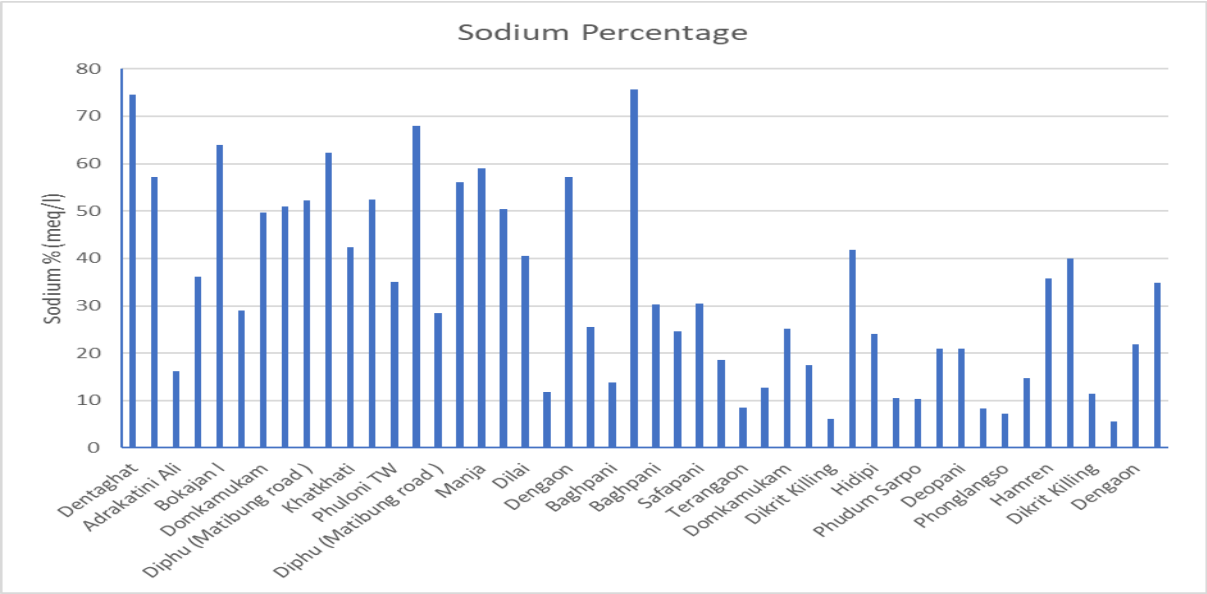


Fig 3.1.6d: Sodium Percentage

3.1.6d Kelly Ratio (KR):

It is the ration of sodium cation with respect to divalent cations, Ca^{2+} and Mg^{2+}. It can be calculated using following formula

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}\ meq/L$$

If KR value is <1 meq/L, then water is suitable for irrigation and if KR value is >1meq/L it is unsuitable for irrigation.

Areas of Khor Singh Rang Hang, Hamren, Dilai, Phuloni, Khatkhati, Domkamukam, Silanijan, Diphu (Matibung road), Dentaghat, Bokajan, Dengaon, Manja, Gharial Dhubi and Diphu (Lumding road) have Kelly ratio >1 meq/l.

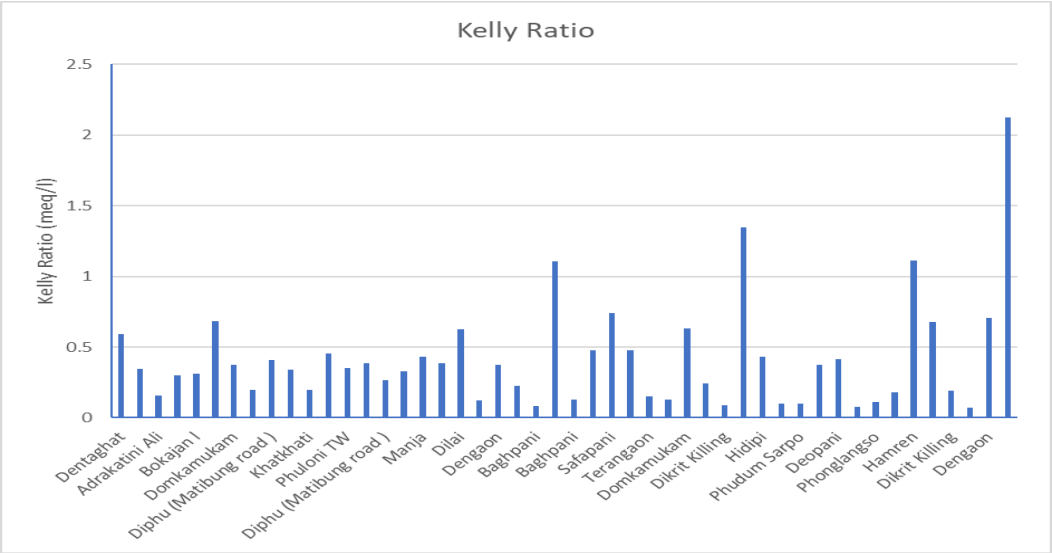


Fig: 3.1.6e: Kelly Ratio

CHAPTER 4.0

Ground Water Resources

The computation of ground water resources available in the district has been done using GEC 2015 methodology. The dynamic resource estimation is done district wise due to paucity of block-wise data. In this present report the same calculation is used but resource for Karbi Anglong East and Karbi Anglong West is assessed together. The resource is further proportionately divided among blocks based on their geographical areas.

Data and assumptions used in the assessment: Following data and assumptions are used in the assessment:

1) Rainfall recharge has been computed by both RIF and WLF methods. In RIF method, rainfall infiltration factor has been taken as 0.22 for major aquifer like valley fill. In WLF method, specific yield has been taken as 0.12.

2) Last ten years rainfall data is considered for groundwater resource calculation.

3) Water level data has been considered for 2021-22. Water level fluctuation based on data of March (Pre monsoon) and November (post monsoon) has been considered since deepest water levels are recorded during the month of March.

The average pre- and post-monsoon water level of Karbi Anglong is 2.38 mbgl and 2.11 mbgl respectively.

4) The population figures were collected from Census, 2011and projected to 2022. The per capita domestic requirement for the rural population has been considered as 55 lpcd for rural population and for urban population, it is 135 lpcd.

5) The dependency on ground water resource for domestic and industrial water supply in the district is calculated to be 83%.

6) In order to calculate the canal seepage, the data on length of the drainage channels are taken from the Irrigation Department, Govt. of Assam. The factor for return flow from surface water irrigation has been taken as 0.50 (paddy) and 0.30 (non-paddy) and for Ground water irrigation it has been taken as 0.45 (paddy) and 0.25 (non-paddy). Recharge from tanks and ponds are calculated based on the norms suggested in GEC'2015.

7) Recharge from water conservation structure has been taken as nil.

The total replenish able ground water resources available in the study area have been computed using the average water level fluctuations in observation wells and specific yield of aquifers. These have been normalised using normal rainfall data to eliminate variations in recharge due to excess or deficit rainfall. The monsoon recharge arrived at is then compared with the recharge computed using rainfall infiltration method. In cases where the difference between the two is more than 20 percent, the recharge is computed using ad hoc method.

4.1 Ground Water Resources of Karbi Anglong District

Karbi Anglong has a Total Geographic area of 10434.00 sq. km. Of which Hilly area having slope more than 20% is 3873.09sq.km. The remaining area is taken up for Aquifer Mapping which is around 6560.91sq.km which is also the total rechargeable area. Further, the

district divided into command, Non Command and poor quality areas. But Karbi Anglong has no poor quality area. Therefore resource for Command and Non-Command area is assessed.

Assessment Unit	*Total Geographical Area (ha)	*Hilly Area (ha)	*Total Recharge Worthy Area (ha)			
			*Command	*Non Command	*Poor Quality	Total
Karbi Anglong	1043000	387309	8602	647489	0	656091

4.2 Recharge

The aquifers of the study area are recharged through a) infiltration of rainfall on the outcrop, b) seepage from the tanks and ponds, c) subsurface inflow across the up dip margin d) recharge from surface water irrigation and ground water irrigation. The study area experiences south-east monsoon. Monsoon rainfall contributes approximately 79.74 percent of total rainfall (May, June, July, August, September) while share of post and pre monsoon rainfall are approximately 16.7 and 5.8 percent each.

Previous records show that the rainfall occurs almost in every month of a year. The month November to December has the minimum number of rainy days in any year and the period May to September has maximum number of rainy days.

4.2.1 Recharge from Rainfall:

Seasonal i.e., Monsoon and Non-Monsoon, Ground water recharge is estimated both by rainfall infiltration and water table fluctuation or water balance method for Monsoon season and by rainfall infiltration method for non-monsoon season as per guidelines. The monsoon recharge computed by WLF method is normalized for the current year rainfall.

Sl. No.	District	Rainfall Recharge (Ham)			
		Command	Non Command	Poor Quality	Total
1	Karbi Anglong	1698.96	127884	0	129582.7

4.2.2 Recharge from Other sources:

Recharge from other sources means recharge through return flow from tanks and ponds, canals, water conservation structures, surface and ground water irrigation. Existing area of tanks and ponds are from Statistical Hand Book, Assam 2021. Recharge from return flow, Irrigated area during Kharif and Rabi-Pre-Kharif seasons are taken as per 5th MI Census. Recharge from Canal and Water conservation structure is zero for Karbi Anglong.

Surface Water Irrigation				Ground Water Irrigation			
Command	Non Command	Poor Quality	Total	Command	Non Command	Poor Quality	Total
4530.05	342.086	0	4872.14	0	480.06	0	480.06

Tanks and Ponds				Canals				Total from other sources
Command	Non Command	Poor Quality	Total	Command	Non Command	Poor Quality	Total	
0	1235.63	0	1235.63	153.44	0	0	153.44	13,329.14

Total Recharge from Other sources is 13,329.14 ham

4.3 Ground Water Extraction

The ground water extraction of unconsolidated aquifer is created by natural discharge like seepages and draft created by human interference, viz., (a) withdrawals for irrigation and industry and (b) public-supply wells.

Ground Water Extraction for all uses (ha.m)				
Domestic	Industrial	Irrigation	Non Command	Total extraction from all uses
Non Command	Non Command	Non Command		
1909.09	2.4	1066.8	2978.29	2978.29

Total irrigation extraction in Karbi Anglong is 1066.8 ham, for industry 2.4 ham and extraction for domestic uses is 1909.09 ham. Total groundwater extraction for all uses is only 2987.29 ham.

The water trend analysis shows that there is no significant change in the water level for both pre and post-monsoon periods.

4.4 Total annual G.W. Recharge/ accumulation (in ham)

Total annual ground water recharge is the sum-total of monsoon and non-monsoon recharge from rainfall and other sources minus the resultant flows such as evaporation, transpiration, baseflow etc.

District	Rainfall Recharge	Recharge from other source	Resultant Flows (Evapotranspiration Loss) in ham	Total annual G.W. Recharge/ accumulation (in ham)
Karbi Anglong	129582.7	13,329.14	-2653.6	133670.37

4.5 Annual extractable ground water resource:

Environmental flow subtracted from total Ground Water Recharge gives the Annual Extractable Ground Water Resource. An allowance is kept for Environmental Flow (nu-accounted natural discharge as per GEC’97) in the non-monsoon season by deducting 5% of total annual ground water recharge, where WLF method is employed to compute rainfall recharge during monsoon season and 10% of total annual ground water recharges where RIF method is employed before getting the annual extractable ground water resource.

District	Total Annual Ground water Recharge (ham)	Environmental Flows (ham)	Annual Extractable Ground water Resource (ham)
Karbi Anglong	133670.37	13632.4	120037.97

4.6 Allocation of resources up to 2025 for domestic use

The net ground water resource is allocated for domestic sector.

Assessment Unit	Annual extractable Ground Water Resource (ham)	Current annual gross G.W. Extraction for irrigation (ham)	Current annual gross G.W. Extraction for industrial (ham)	Annual Allocation of G.W. for Domestic water supply as on 2025 (in ham)	Net G.W. Availability for future Use (in ham)
Karbi Anglong	120037.97	1066.8	2.4	2051.09	116917.68

4.7 Stage of Ground Water Extraction

The area has very little irrigation facilities. Similarly industrial development in the area is practically less. Groundwater is mainly utilized for domestic purposes. However, Public Health Engineering & Water Supply Department has supplied water mainly through surface water sources. The stage of groundwater extraction in the district is 28.39%.

Assessment Unit	Annual extractable Ground Water Resource (ham)	Current annual gross G.W. Extraction for all uses (ham)	Stage of GW Extraction (%)
Karbi Anglong	120037.97	2978.29	2.48

Table 4.1: Tabulation of Ground Water Resource of Karbi Anglong district as on March 2022.

PARAMETER	Value
Total geographical area (Ha)	104300
Recharge worthy area (Ha)	656091
Rainfall Recharge (monsoon) (Ham)	102594.00
Rainfall Recharge (non-monsoon) (Ham)	26988.70
Annual Recharge from Other Sources (monsoon) (Ham)	2415.10
Annual Recharge from Other Sources (non- monsoon) (Ham)	4326.19
Annual G. W. Recharge (Ham)	136323.99
Ecological Flow (Ham)	2653.57
Total Natural discharge (Ham)	13632.40
Annual extractable Ground Water Resource (Ham)	120038.02
Current annual gross G.W. Extraction for domestic use (Ham)	1909.0854
Current annual gross G.W. Extraction for industrial (Ham)	2.4
Current annual gross G.W. Extraction for irrigation use (Ham)	1066.8
Current annual gross G.W. Extraction for All uses (Ham)	2978.29
Annual G.W. Allocation for Domestic water supply as on 2025 (Ham)	2051.09
Net Annual G.W. availability for future use (Ham)	116917.68
Stage of GW Extraction (in %)	2.48
Quantity Categorisation for Future GW extraction (Safe/Semi-Critical /Critical /Over Exploited)	Safe

CHAPTER 5.0

Groundwater Related Issues

Based on various scientific studies that being carried out at the study area like exploratory drilling, establishing and periodic monitoring of Key Wells, and Ground water quality analysis for Pre-monsoon and Post Monsoon issues relating to ground water has been identified in Karbi Anglong area. Those issues have been addressed in this chapter.

Problems to be addressed are as follows:

5.1 low stage of ground water exctraction

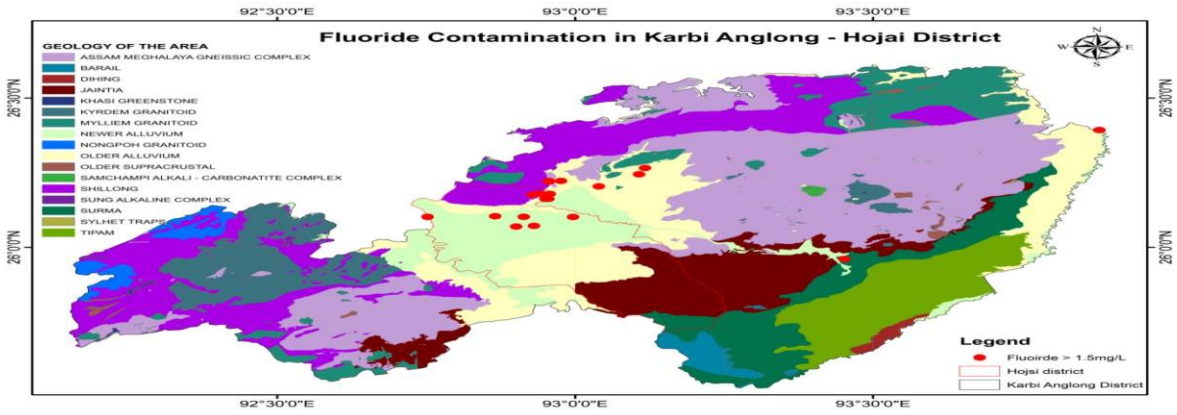
5.2 Water Quality Issue

Chemical parameters exceeding the permissible limit are fluoride and iron concentration. In most of the samples of Dug wells all the other basic parameters are within permissible limit. Iron contamination is more or less spread throughout the district owing to the underlying geologic condition of Gneissic complex.

5.2.1 High Fluoride Concentration:

Presence of fluoride in ground water in Karbi Anglong was confirmed by CGWB, NER office during investigations in 1999, 2000 and further, during the year 2001-2002. CGWB, NER identified certain pockets of fluoride in ground water beyond permissible limit in the areas Ramsapathar-Longnit and Baghpani-Dentaghat areas of Karbi Anglong and Ratiagaon-Haldiati area of Hojai bordering Karbi Anglong district. A maximum of 10.64mg/l and 12.5mg/l of fluoride concentration was reported from these areas during the study time.

From the study it was noted that, fluoride was found almost exclusively occurring in Older and younger Alluvium of Quaternary age in Lumbijan, Samelangso and Howraghat blocks of Karbi Anglong district. The concentration of fluoride varies both in space and depth. It was found that dug wells within the depth of 15m bgl have Fluoride within permissible limit. Higher concentration of Fluoride (>1.5mg/l) in the areas of Ramsapathar-Longnit and Baghpani-Dentaghat area of Diphu Sub-Division occurs in dug wells having depth beyond 15m bgl. Maximum concentration of fluoride was found to occur within the range of 20-50m bgl. Further, the concentration of fluoride is less in the deeper zones except at a few places.



Map 5.1.1: Locations of areas with high Fluoride Concentration

CHAPTER 6.0

Management Strategy

6.1 Quality issues:

The aquifer system in the study area is a dual aquifer System. The first aquifer is of Quaternary sediments composing of Sand, Sandy Clay, Silt and Clay.

Table 6.1: Division of study area based on geomorphology and its characteristic features

Geomorphology	Lithology	Chemical Quality	WL condition	Population density
Alluvial plain and flood plain	Sand and Clay	High Fe Fluoride	Shallow water level	Low
Hilly area	Granite gneiss and Schist	High Fe	Shallow to Deep Water level	Low

To mitigate the fluoride issue in ground water different methods can be used such as dilution of water, installation of defluoridisation plant, use of alternate source of drinking water etc. On experimental basis one defluoridisation plant was installed at Baghpani L. P. School, Tekejangjun, Karbi Anglong district back in October 2001. This plant works on adsorption method where granular Ferric Hydroxide has been used to remove excess fluoride in ground water. The plant removes fluoride by reverse osmosis after the suspended solids are removed by special cartidge filter and bacteria by a UV unit.

CGWB in collaboration with PHED, Karbi Anglong has also taken up steps to create awarenedd among the people. Tubewells with hig fluoride water have been identified and painted red cautioning people not to use of such water.

6.2 Low stage of ground water extraction:

Currently Karbi Anglong has a very low stage of ground water extraction of 2.48%. In order to increase this low stage, future demand of ground water for irrigation is calculated and number of abstraction structures to be constructed is worked out.

Future demand for agriculture

The major crops of Karbi anglong district are Paddy, Oil seed, Maize, Sugarcane, sesame and seasonal vegetables. Autumn paddy, winter paddy and summer paddy are the three main types of paddy are grown in the district.

Future demand of water for agriculture is estimated in the present analysis by projecting the cropping intensity to 200%. As per data from District Agriculture Contingency plan of Karbi Anglong, the net unirrigated paddy area is 129883 ha.

Table 6.2: Season wise cropping pattern of Karbi Anglong district

S N	Main Crop	Sowing season					
		Kharif		Summer		Rabi	
		Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
1	Paddy	June to July	June to July	March to May	March to April	-	Nov to Dec
2	Rape seed Mustard		-	-	-	October to November	October to Dec
3	Maize	April to May	-	-	-	-	August to sept
4	Sugarcane	March to April	-	-	-	-	-
5	Sesame	July to August					
6	Pulse			August to September			

Since stage of ground water development is only 2.48%, there is ample scope for ground water extraction for irrigation purpose which will bring unirrigated mono cropped area to double cropped area. To use groundwater for irrigation purpose a cropping plan has been designed for the district by using CROPWAT model developed by FAO (Food & Agricultural Organisation). CROPWAT 8.0 for Windows is a computer program for the calculation of crop water demand/requirements and irrigation demand/requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. FAO defined water requirements of various crops as the depth (or amount) of water needed to meet the water loss through evapotranspiration. The present season wise cropping pattern of Karbi Anglong is shown in Table 6.2.

The crop water need can be calculated using the following formula.

$$ETcrop = ETo * Kc$$

Where: ETcrop= Crop water need (mm/unit time)

ETo = Reference crop evapotranspiration (mm/unit time) [Influence of climate]

Kc = Crop factor [Influence of crop type and growth stage]

6.3 Cropping Plan

The intention of the proposed plan is to bring this fallow land under assured irrigation during Rabi season which will help to increase gross cropped area to 259,766 ha and thereby increase cropping intensity up to 200%. This can be achieved by growing maize, pulse, potato, wheat and vegetables in rice fallow with the support of irrigation. Present cropping pattern, proposed cropping pattern, intended increase in cropping intensity were shown in tabular form (Table 6.3)

Table 6.3: Cropping pattern, proposed cropping pattern, intended cropping intensity

Cropping pattern (s)				
Summer Rice- Autumn Rice-Winter Rice-Winter Rice	Present Cultivated area	Area to be cultivated	Area to be cultivated (**ha**)	Irrigation requirement (**ha m**)
Winter Vegetables-Summer Vegetables-Pulses--Potato-Oilseed	(**ha**)	(**%**)		
Cultivated Area	**129883**			
	1	2 (= % of 1)	3	4
Rice (main crop)	129883	100	129883	21589.80
Summer Rice		25	32470.75	16667.24
Vegetables		15	19482.45	2881.45
Wheat		15	19482.45	5116.09
Maize		**15**	19482.45	2834.70
Pulses		15	19482.45	2583.37
Oil seed		15	19482.45	3304.22
Net cultivated area	129883		129883	54976.88
Gross cultivated area (Paddy/+Wheat+Pulses)	259766			
Total irrigation requirement (70% irrigation efficiency)				**78538.39**

Based on available groundwater resource and subsurface condition, the approximate numbers of tube wells that can be constructed in the area is worked out.

Currently as per GWRE 2022, Karbi Anglong has extraction by all uses of 2978.29 ham and 120037.97 ham extractable resource, resulting in a Stage of ground water development of 2.48%. In extracting additional requirement of 78538.39 ham of water, stage of development in Karbi Anglong area will increase from 2.48 % (safe category) to 70% (safe category). Further to not put all the stress on ground water alone, consumptive use of surface water from ponds, rivers and streams in the nearby area may be implemented to increase the efficiency of irrigation. Moreover as per GWRE 2022, Karbi Anglong has an additional Potential Resource of 16925.14 ham under Specific Conditions of Waterlogged and Shallow Water Table Areas. This additional potential can also be utilised to increase the cropping intensity up to 200%.

Groundwater draft is calculated for well discharge of $30m^3$/hr. If the well is allowed to run 8 hrs a day for 120 days of a year then a tube well having discharge will create a draft of 2.88 ham. To meet irrigation demand of 78538 ham, 27270 numbers of shallow TW can be constructed to cover unirrigated area of 18508 ha area.

Numbers Of Tube Wells To Be Constructed	
Well Discharge	$30m^3$/hr
Running Time Of Well	8 hrs a day for 120 days a year
Groundwater Draft created	2.88 ham
To Meet Irrigation Demand of 78538 Ham	27270 STW to be constructed
Method of drilling	Direct Rotary Rig in alluvial area DTH Rig for foothill area

Drilling: Direct Rotary Rig is useful for drilling in the Flood plain and alluvium area down to depth of 200 m. A tube well tapping 6 to 60m granular zone can expected to yield 20 to 50m3 /hr. Tube wells can be constructed by using 8" dia.

Shallow Tube wells can be designed within a depth of 50m. A tube well tapping 12m granular zone can expected to yield 10 to $20m^3$ /hr.

In consolidated formation DTH Rig useful for drilling. In foothill area where ground water occurs in shallow weathered zone and this can be developed through open wells. The joints and fractures developed due to tectonic activities from potential water bearing formation suitable for development through construction of bore wells.

The pump test data of CGWB has indicated that the drawdown of the tube wells is 2 to 16 m in the flood plain area.

Table 6.4 : Crop-wise and month-wise precipitation deficit (IWR) from CROPWAT 8

Precipitation deficit (in mm)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Winter Rice	0	0	0	0	147.9	52.3	0	0	0	6.1	0	0
Winter Rice	0	0	0	0	50.5	98	0	0	0	0	0	0
Winter Rice	0	0	0	0	48.5	98	0	0	0	0	0	0
Winter Rice	0	0	0	0	0	147	0	0	0	14	2.6	0
Summer Rice	58.9	57.8	82.4	22.5	0	0	0	0	0	0	65.3	226.4
Vegetables	36.7	46.7	48.5	0	0	0	0	0	0	0	0	16
Wheat	36.4	35.5	61.1	57.2	8.8	0	0	0	0	0	20.2	43.4
Maize	19.8	0	0	0	0	0	0	0	1	0.8	53	70.9
Pulses	12.7	0	0	0	0	0	0	0	3.8	0	47.1	69
Oil seed	51	54	35.7	0	0	0	0	0	0	0	2.5	26.4

Table 6.5 : Actual monthly water requirement for different crops in Karbi Anglong, Assam

Actual monthly water requirement for different crops in Karbi Anglong district, Assam																	
Crop	**Net sown area**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Cropwise Total IWR (Ham)**	**Total(Ham)**	**Gross irr. Requirement with 70% irr. Efficiency**	**Crop**
Winter Rice	32471	0	0	0	0	4802.42	1698.22	0	0	0	198.07	0	0	6698.72	**21589.8**	**30842.6**	Rice
Winter Rice	32471	0	0	0	0	1639.77	3182.13	0	0	0	0	0	0	4821.91			
Winter Rice	32471	0	0	0	0	1574.83	3182.13	0	0	0	0	0	0	4756.96			
Winter Rice	32471	0	0	0	0	0	4773.2	0	0	0	454.59	84.42	0	5312.21			
Summer Rice	32471	1912.53	1876.81	2675.59	730.59	0	0	0	0	0	0	2120.34	7351.38	16667.24	16667.24	23810.34	Rice
Vegetables	19482	715.01	909.83	944.90	0	0	0	0	0	0	0	0	311.72	2881.45	2881.45	4116.36	Vegetables
Wheat	19482	709.16	691.63	1190.38	1114.40	171.45	0	0	0	0	0	393.55	845.54	5116.09	5116.09	7308.70	Wheat
Maize	19482	385.75	0	0	0	0	0	0	0	19.48	15.59	1032.57	1381.31	2834.70	2834.70	4049.57	Maize
Pulses	19482	247.43	0	0	0	0	0	0	0	74.03	0	917.62	1344.29	2583.37	2583.37	3690.53	Pulses
Oil seed	19482	993.60	1052.05	695.52	0	0	0	0	0	0	0	48.71	514.34	3304.22	3304.22	4720.32	Oil seed
Total area	**259766**										**Gross irr. Requirement with 70% irr. Efficiency**					**78538.39**	

Annexure I

Concentration range of chemical constituents in groundwater

Location	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO3-2	HCO3-1	TA (as CaCO3)	Cl-	SO4-2	NO3-1	F-	Ca+2	Mg+2	TH (as CaCO3)	Na	K	Fe	As (in ppb from AAS)	U from Fluorimeter)
Dentaghat	7.02	193.30	0.13	127.58	0.00	427.34	427.34	17.73	1.19	10.23	1.00	32.03	2.41	90.00	84.66	61.89	Data in process	Data in process	0.31
Bokajan I	4.08	305.10	0.16	201.37	0.00	30.52	30.52	116.99	4.26	16.87	0.00	18.01	10.91	90.00	42.10	22.03	Data in process	Data in process	0.27
Adrakatini Ali	7.29	367.70	0.19	242.68	0.00	311.35	311.35	70.90	17.34	11.99	0.51	26.02	69.16	350.00	20.48	17.85	Data in process	Data in process	2.00
Dilai	6.65	828.80	0.00	547.01	0.00	128.20	128.20	131.17	67.24	1.16	0.09	54.04	18.18	210.00	46.23	14.47	Data in process	Data in process	BDL
Bokajan I	5.75	146.80	0.03	96.89	0.00	24.42	24.42	49.63	13.01	22.90	0.06	10.01	4.85	45.00	28.60	13.55	Data in process	Data in process	0.00
Khor Singh Rang Hang	7.60	633.00	0.08	417.78	39.00	720.38	759.38	35.45	15.58	17.65	1.80	36.03	94.64	480.00	82.04	13.47	Data in process	Data in process	3.24
Domkamukam	6.51	416.80	BDL	275.09	0.00	146.52	146.52	46.09	30.90	9.33	0.21	24.02	10.91	105.00	39.74	13.09	Data in process	Data in process	0.24
Hamren	6.32	86.67	0.03	57.20	0.00	48.84	48.84	39.00	0.21	13.35	0.07	16.01	3.63	55.00	18.55	12.96	Data in process	Data in process	BDL
Diphu (Matibung road)	6.39	227.30	BDL	150.02	0.00	140.41	140.41	46.09	24.52	19.39	0.19	30.02	6.05	100.00	43.20	11.72	Data in process	Data in process	0.13
Ghouria Dhubri	5.96	255.50	BDL	168.63	0.00	36.63	36.63	53.18	12.71	15.16	0.06	10.01	4.85	45.00	28.13	10.13	Data in process	Data in process	BDL
Khatkhati	5.67	260.60	0.02	172.00	0.00	36.63	36.63	49.63	11.26	15.43	0.06	10.01	9.70	65.00	16.10	10.04	Data in process	Data in process	0.06
Dentaghat	7.06	399.40	BDL	263.60	0.00	213.67	213.67	17.73	4.99	9.08	0.79	20.02	10.91	95.00	42.27	9.82	Data in process	Data in process	0.86
Phuloni TW	7.19	291.10	0.12	192.13	0.00	396.82	396.82	17.73	4.93	2.67	1.60	58.05	16.96	215.00	47.93	8.67	Data in process	Data in process	7.26
Manja	6.39	256.40	0.72	169.22	0.00	42.73	42.73	49.63	11.33	1.50	0.12	10.01	2.42	35.00	29.20	8.38	Data in process	Data in process	0.09
Diphu (Matibung road)	6.57	239.50	0.13	158.07	0.00	152.62	152.62	67.36	7.32	9.42	0.26	34.03	21.83	175.00	27.16	8.30	Data in process	Data in process	0.19
Silanijan	6.43	219.60	BDL	144.94	0.00	54.94	54.94	42.54	14.73	4.54	0.18	12.01	4.85	50.00	24.79	7.72	Data in process	Data in process	BDL
Manja	5.67	121.50	0.29	80.19	0.00	54.94	54.94	46.09	9.97	2.16	0.06	12.01	6.06	55.00	32.30	6.97	Data in process	Data in process	0.09
Silanijan	6.23	301.50	0.03	198.99	0.00	61.05	61.05	60.27	5.18	17.63	0.15	20.02	4.84	70.00	28.51	6.93	Data in process	Data in process	0.14
Dilai	6.58	420.30	0.08	277.40	0.00	146.52	146.52	145.35	35.80	1.10	0.11	54.04	24.25	235.00	69.71	6.66	Data in	Data in	0.09

Location	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO3-2	HCO3-1	TA (as CaCO3)	Cl-	SO4-2	NO3-1	F-	Ca+2	Mg+2	TH (as CaCO3)	Na	K	Fe	As (in ppb from AAS)	U from Fluorimeter)
																	process	process	
Diphu (Lumding road)	7.23	388.60	0.05	256.48	0.00	317.45	317.45	28.36	4.98	17.26	0.27	68.05	33.95	310.00	15.30	6.47	Data in process	Data in process	0.50
Dengaon	5.88	84.72	0.90	55.92	0.00	61.05	61.05	31.91	2.92	3.44	0.06	10.01	3.64	40.00	20.91	6.09	Data in process	Data in process	0.10
Phuloni	6.92	245.30	0.05	161.90	0.00	201.46	201.46	35.45	16.72	7.15	0.32	64.05	7.25	190.00	26.33	5.92	Data in process	Data in process	1.30
Baghpani	5.88	266.30	0.07	175.76	0.00	146.52	146.52	28.36	4.82	6.63	0.23	44.04	8.47	145.00	7.20	5.81	Data in process	Data in process	0.04
Diphu (Lumding road)	6.07	230.50	0.15	152.13	0.00	54.94	54.94	53.18	9.89	2.89	0.04	8.01	2.42	30.00	39.95	4.94	Data in process	Data in process	0.05
Baghpani	6.96	220.90	0.12	145.79	0.00	195.36	195.36	53.18	6.11	8.78	0.30	54.04	6.04	160.00	29.25	4.64	Data in process	Data in process	0.21
Hidipi	6.75	182.90	BDL	120.71	0.00	195.36	195.36	21.27	0.97	2.37	0.22	32.03	13.33	135.00	17.54	4.43	Data in process	Data in process	1.04
Safapani	6.21	57.88	1.80	38.20	0.00	48.84	48.84	24.82	1.82	1.64	0.05	10.01	7.28	55.00	8.48	4.41	Data in process	Data in process	0.48
Garam Pani	6.53	57.95	0.06	38.25	0.00	12.21	12.21	10.64	45.85	16.10	0.05	10.01	12.13	75.00	5.47	4.03	Data in process	Data in process	BDL
Terangaon	7.04	303.90	0.29	200.57	0.00	384.61	384.61	14.18	8.75	1.26	0.46	72.06	38.80	340.00	12.43	3.53	Data in process	Data in process	1.10
Boithalangsu	6.90	153.70	0.01	101.44	0.00	164.83	164.83	21.27	0.81	4.79	0.22	48.04	3.62	135.00	6.97	3.44	Data in process	Data in process	1.06
Domkamukam	6.33	70.65	0.04	46.63	0.00	48.84	48.84	21.27	0.25	12.51	0.05	10.01	8.49	60.00	7.23	3.39	Data in process	Data in process	BDL
Phuloni	7.33	216.30	0.09	142.76	0.00	213.67	213.67	28.36	9.72	1.92	0.50	56.04	9.68	180.00	15.49	3.31	Data in process	Data in process	1.79
Dikrit Killing	7.23	585.20	0.13	386.23	0.00	360.19	360.19	53.18	105.35	6.58	0.31	126.10	43.63	495.00	13.09	3.13	Data in process	Data in process	1.39
Phuloni TW	7.03	342.70	0.09	226.18	0.00	470.08	470.08	10.64	6.14	2.77	2.20	50.04	27.89	240.00	77.22	3.12	Data in process	Data in process	9.29
Hidipi	6.70	260.50	0.05	171.93	0.00	183.15	183.15	14.18	1.02	1.67	0.25	36.03	10.90	135.00	17.89	3.07	Data in process	Data in process	0.07
Boithalangsu	6.95	157.80	0.06	104.15	0.00	177.04	177.04	17.73	1.21	5.73	0.19	52.04	3.62	145.00	6.08	3.03	Data in process	Data in process	0.97
Phudum Sarpo	6.90	163.90	0.03	108.17	0.00	177.04	177.04	10.64	1.43	2.91	0.21	50.04	4.83	145.00	5.89	3.01	Data in process	Data in process	1.20
Phonglangso	6.99	509.50	0.00	336.27	0.00	280.82	280.82	17.73	4.71	2.82	0.54	50.04	15.75	190.00	21.40	2.81	Data in process	Data in process	0.06
Deopani	7.08	150.20	0.05	99.13	0.00	109.89	109.89	35.45	7.83	6.40	0.17	30.02	13.33	130.00	14.22	2.74	Data in process	Data in process	0.21

Location	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO3-2	HCO3-1	TA (as CaCO3)	Cl-	SO4-2	NO3-1	F-	Ca+2	Mg+2	TH (as CaCO3)	Na	K	Fe	As (in ppb from AAS)	U from Fluorimeter)
Phudum Sarpo	6.88	157.80	0.01	104.15	0.00	158.73	158.73	17.73	1.88	3.25	0.20	46.04	4.83	135.00	4.10	2.69	Data in process	Data in process	1.10
Phonglangso	7.17	240.90	0.09	158.99	0.00	299.14	299.14	24.82	3.86	1.26	0.84	66.05	29.09	285.00	8.52	2.66	Data in process	Data in process	0.08
Lakhijan	7.33	81.31	0.07	53.66	0.00	140.41	140.41	24.82	5.27	4.05	0.13	44.04	4.83	130.00	9.03	2.23	Data in process	Data in process	0.21
Hamren	6.38	79.66	0.11	52.58	0.00	67.15	67.15	17.73	0.44	12.86	0.09	10.01	7.28	55.00	12.77	2.13	Data in process	Data in process	BDL
Domkamukam	6.37	77.11	0.07	50.89	0.00	61.05	61.05	17.73	0.48	12.82	0.07	20.02	1.20	55.00	15.62	1.98	Data in process	Data in process	BDL
Dikrit Killing	7.21	1.41	0.02	0.93	0.00	354.08	354.08	49.63	110.74	5.42	0.30	120.10	41.20	470.00	26.48	1.94	Data in process	Data in process	1.06
Terangaon	7.23	489.10	0.00	322.81	0.00	354.08	354.08	14.18	8.73	0.70	0.36	94.08	19.37	315.00	7.55	1.83	Data in process	Data in process	0.60
Dengaon	5.98	68.24	1.19	45.04	0.00	48.84	48.84	24.82	3.72	3.25	0.07	10.01	10.92	70.00	8.12	1.50	Data in process	Data in process	0.03
Khor Singh Rang Hang	7.53	674.10	0.00	444.91	0.00	683.75	683.75	60.27	35.59	15.44	1.60	44.04	80.08	440.00	107.31	1.17	Data in process	Data in process	3.42