केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

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

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

KAMRUP DISTRICT, ASSAM

उत्तर पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

REPORT ON

AQUIFER MAPPING AND MANAGEMENT PLAN OF KAMRUP DISTRICT, ASSAM

ANNUAL ACTION PLAN, 2022-23

R. K. Kalita, Scientist D (Hg.)

Miss Mophi Mili, Scientist C (Hg.)

North Eastern Region

Guwahati

Table of Content

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

1.0 Introduction

1.1 Objectives

The objective of the study is to prepare aquifer map of the area in 1:50,000 scale, identify the groundwater contaminated area and prepare a groundwater management plan.

1.2 Scope of the study

The part of the Kamrup district has vast groundwater and surface water resources. However, the agro based economy of the area has no irrigation facility. Moreover, the groundwater of the area is contaminated with iron and fluoride which possesses serious health hazard to the general public. Proper hydrogeologic 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 aquifers and to conceptualize the aquifer system. This will help to formulate an aquifer management plan. Finally, the scientific knowledge will be disseminated to farmers, 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 10.3) using Projection category longitude/latitude (WGS 84). 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, besides detailed hydrogeological surveys.

Aquifer Map Preparation: It is a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are 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 falls under Survey of India Toposheet No. 78J/16, 78N/4, 78N/7, 78N/8, 78N/9, 78N/10, 78N/11, 78N/12, 78N/15, 78O/1, 78O/5 and 78O/9 bounded by $25^{o}43'00''$ and $26^{o}51'00''$ northern latitude and $90^{o}36'00''$ and $92^{o}12'00''$ east longitude.

Administrative set up of the study area:

Kamrup Rural district which is situated at the plains of the Brahmaputra Valley is located between 25°43’00” and 26°51’00” N Latitude and 90°36’00” and 92°12’00” E Longitude. At present, Kamrup district consists of two sub- divisions. They are namely Kamrup Sadar Sub-division and Rangia sub-division. Kamrup district comprises 12 revenue Circles with 1068 villages. It has 14 Community Development Blocks within the district. The total area in the district is 3105 Sq.Km

Total population of the district is 15, 17,542 souls (as per 2011 census) with average population density of 489 persons/sq.km. The decadal variation of population for 2001-2011 is 15.69percent. There are total 33 Mouzas, in the district.

Table 1.1 Administrative Division

No Of Civil Subdivision	No Of Blocks	No Of Revenue Circles	No Of Gram Panchayats	No Of Villages (Inhabited)	Uninhabited Villages
2	14	12	139	1068	31

Data Source: District Census Handbook, Kamrup

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

Civil Subdivision	Blocks	No of Panchayat	Area (sq.km)	Population
Kamrup Sadar Sub-Division:	Bongaon Dev. Block	4	85.37	54651
	Bezera Dev. Block	7	149.82	83860
	Boko Dev. Block	11	308.59	111880
	Chaygaon Dev. Block	7	106.63	79282
	Chayani Barduar Dev. Block	11	138.93	97406
	Chamaria Dev. Block	15	164.11	204884
	Hajo Dev.Block	16	251.17	193980
	Sualkuchi Dev.Block	8	99.28	68551
	Rani Dev. Block	3	78.59	38986
	Rampur Dev.Block	10	128.16	97709
	Goroimari Dev. Block	8	162.73	122082
Rangia Sub-Division :	Kamalpur Dev. Block	12	143.44	91 056
	Rangia Dev. Block	15	186.98	132000
	Bihdia Jajikona Dev. Block	12	161.59	108401

#Data source: Census Handbook 2011

The district has a good network of roads, train and air connections. Guwahati, the earlier Headquarter of the district and state capital can be termed as the Gateway of North Eastern Region and other parts of the country.

Kamrup district is basically agrarian, where more than 50 percent of the population is engaged in agriculture and allied activities. Out of the total population, 30 percent population is involved in agriculture as a main source of income and livelihood. Around 16 percent of the total population is agricultural labourers. Moreover, males are predominantly involved in agriculture and allied activities with 44.56 percent, while women share is 10.06 percent of the total population of district. However, women are overwhelmingly in manufacturing and production in household, small scale industry, rearing of livestock etc. Like elsewhere, women are also engaged in agricultural labour. Like the trend in the country, men predominate the main worker category both in rural and urban, women outweigh men in marginal workers category. The working females in rural Kamrup are mostly marginal workers.

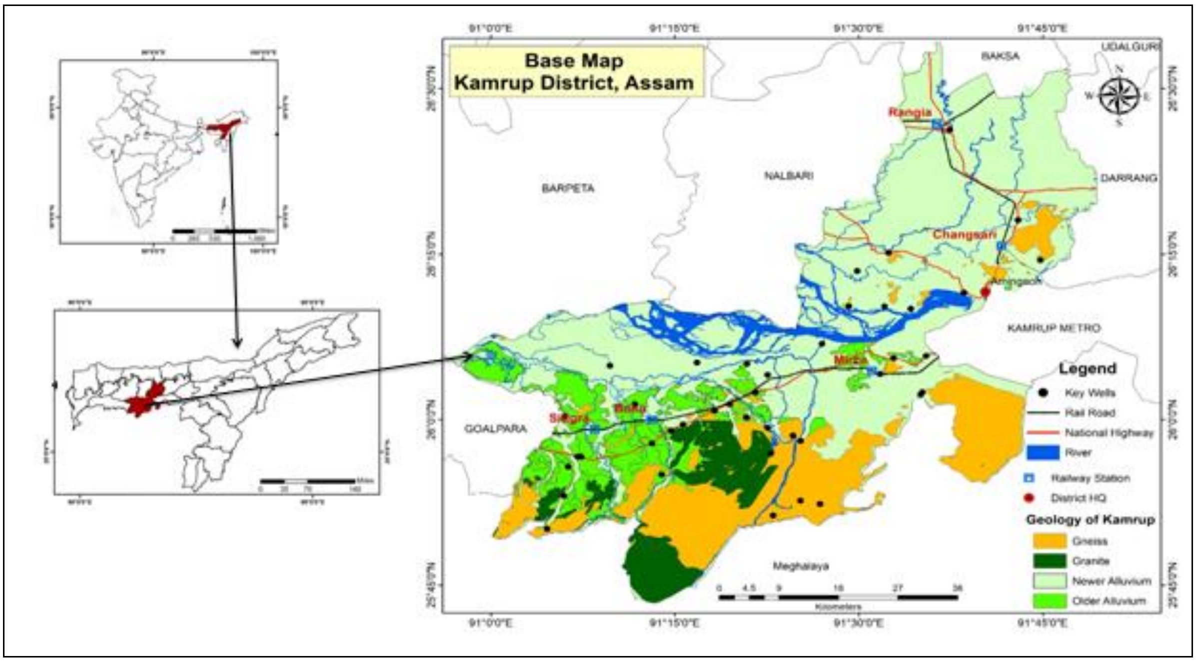

Fig.1.1: Index Map of the study area

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

The preliminary works consisted of collection and review of all existing hydrogeological and exploration data of CGWB. All data were plotted in base map on GIS Platform (MapInfo-11.0 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 Kamrup district, Assam

SN	Theme	Type	Data available	Data gap	Data generation	Total	Remarks
1	Borehole Lithology Data		35	13	5	40	
2	Geophysical data		24	20	Nil	24	
3	Groundwater level data	Dug well	12	20	32	44	
		Piezometer Aquifer-I	Nil	13	2	2	
4	Groundwater quality data	Dugwell-Aquifer-I	12	20	32	44	
		Piezometer Aquifer-I	Nil	13	2	2	
5	Specific Yield		Nil	6	Nil	Nil	
6	Soil Infiltration Test		8	4	3	10	

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

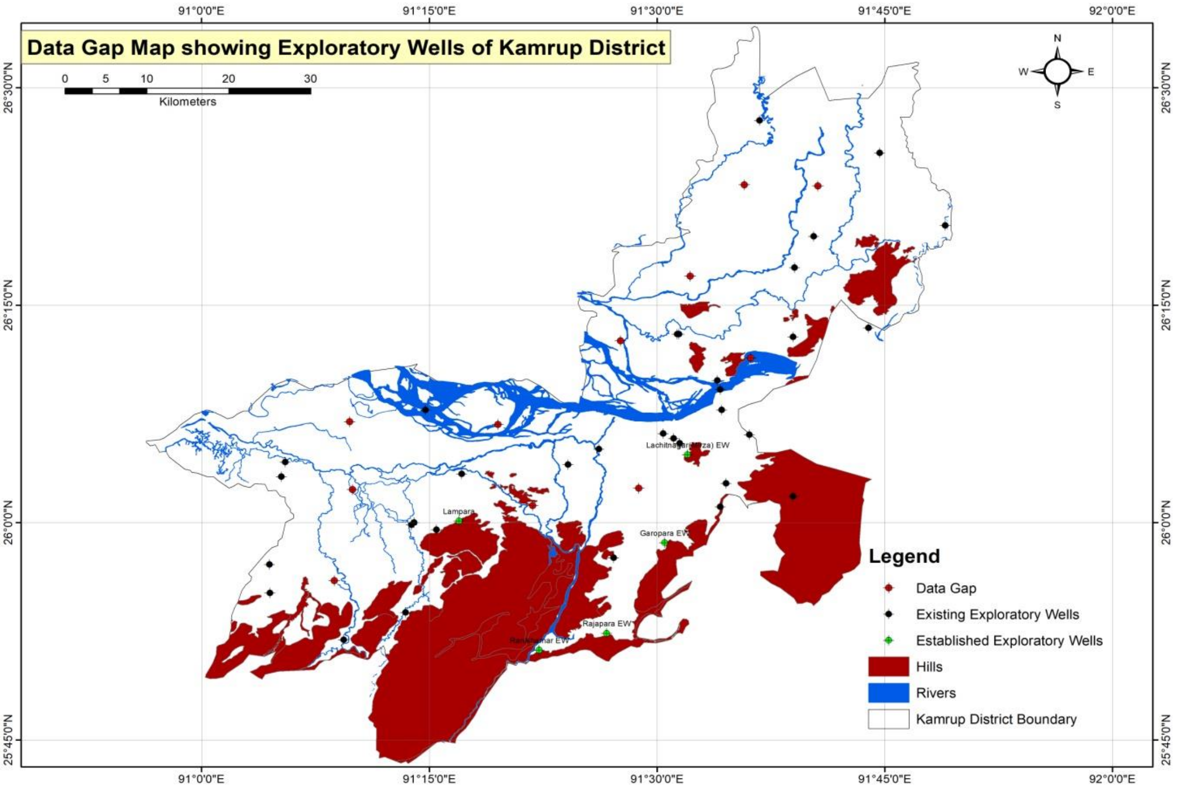

Fig. 1.2: Available data and data generation of exploration in the study area

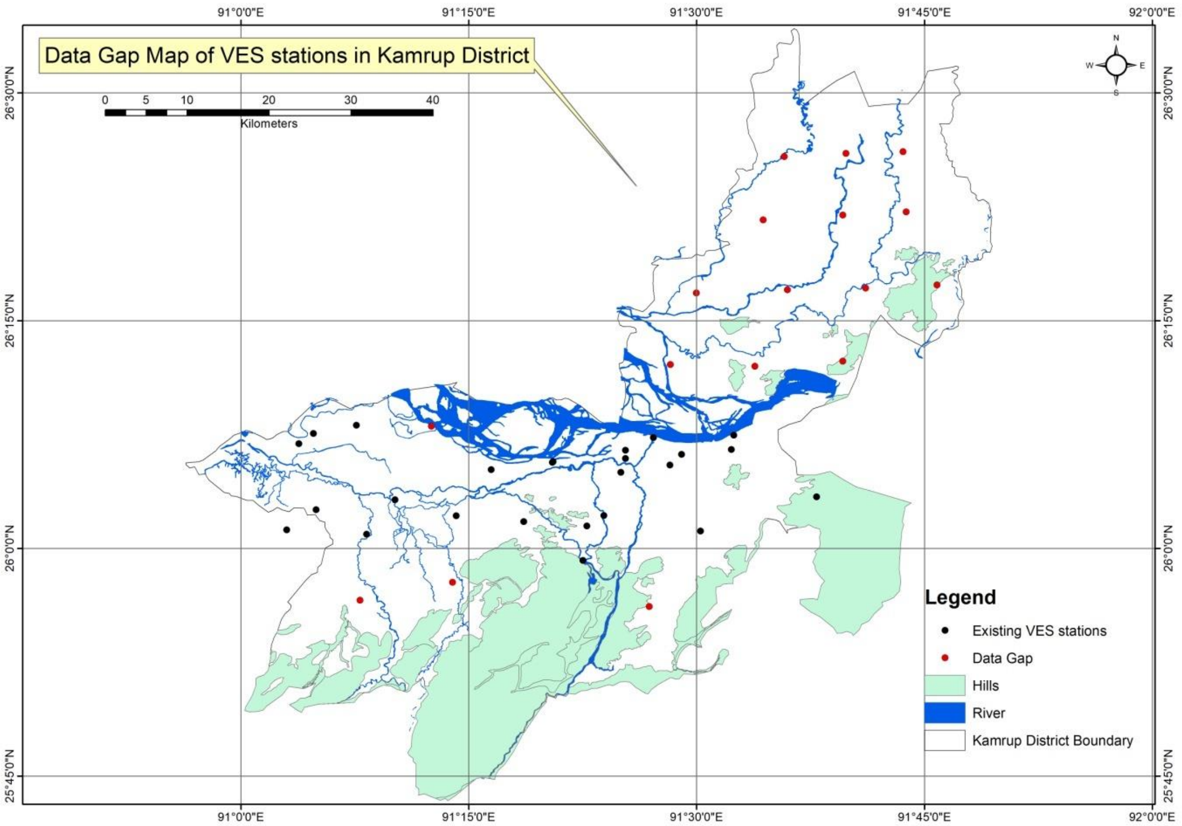

Fig. 1.3: Available data and data generation of VES in the study area

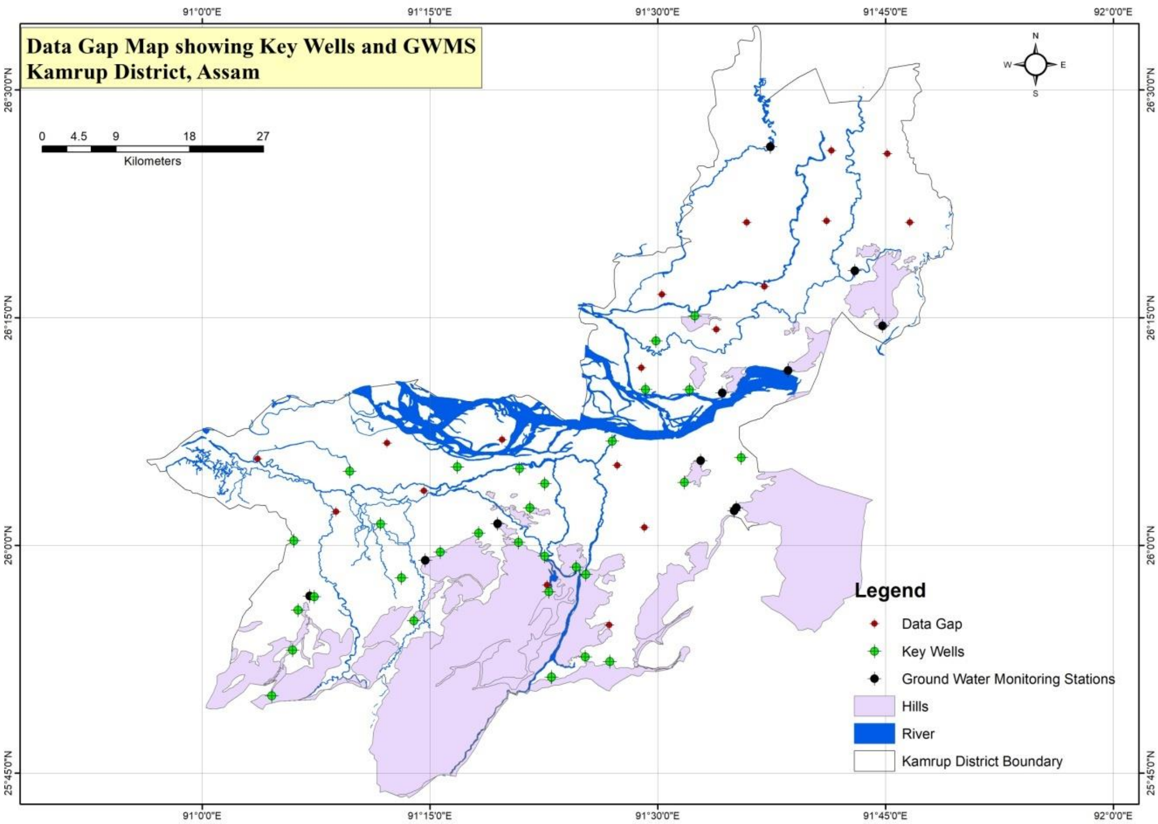

Fig. 1.3: Available data and data generation of ground water level

1.6 Rainfall distribution

The average annual rainfall recorded from 2011 to 2020 of I.M.D is 1749.46 mm. Rainfall during January to April contributes nearly 16.61% to the total rainfall whereas the rainy season which commences from May and continues up to September contributes 79.18%. October to December rainfall is 4.1%. December receives least rainfall and maximum rainfall occurs during May and June. (Table- 1.4)

State / Dist	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Total
Kamrup (R)	2011	9.3	23.4	53.6	101.4	224.5	88.4	373.4	204	255.5	0.3	15.3	1.3	1350.4
Kamrup (R)	2012	5.2	7.6	23.3	382.2	181.4	396.4	343.7	309.7	180.2	57.7	0.2	4.7	1892.3
Kamrup (R)	2013	0	13.5	48.2	124	227.4	209.8	190.2	287.1	210.7	114.3	0	2.9	1428.1
Kamrup (R)	2014	0	26.2	16.1	85.6	362.1	442.5	122	278.3	349.5	40.7	0	0.5	1723.5
Kamrup (R)	2015	13.9	20.8	23.1	175.1	508.8	350.4	196.4	418	137.6	40.7	14.4	21.1	1920.3
Kamrup (R)	2016	1.7	4.8	58.5	542	316.9	276.6	348.5	105.8	142.5	34.5	0	0	1831.8
Kamrup (R)	2017	0	35.6	23	404.4	272.3	366	333.8	199.6	207.7	100.4	15.8	0	1958.6
Kamrup (R)	2018	0	16.9	86.9	86	165.8	254	126	261.6	204.9	46.8	23.7	22.7	1295.3
Kamrup (R)	2019	0.1	6.2	55.2	272.2	483.6	184.5	319.9	228.9	210.1	100.4	0.2	0	1861.3
Kamrup (R)	2020	16.6	8.5	9.6	126.9	466.9	693.6	426.9	131.4	277.2	75.4	0	0	2233
Average		4.68	16.35	39.75	229.98	320.97	326.22	278.08	242.44	217.59	61.12	6.96	5.32	1749.46

The average monthly rainfall from 2011 to 2020 and also yearly rainfall distribution of Kamrup district are illustrated in Fig.1.4 and Fig 1.5

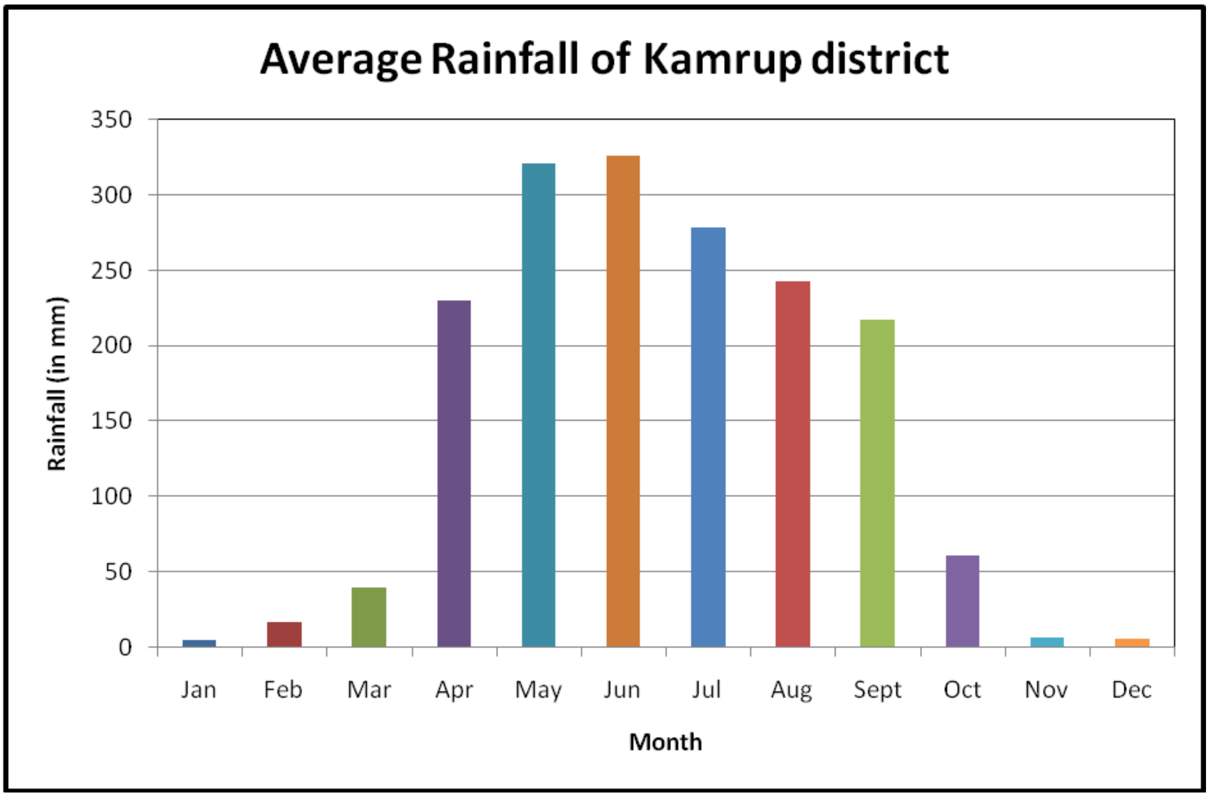

Fig. 1.4 Average monthly rainfall variations of Kamrup district

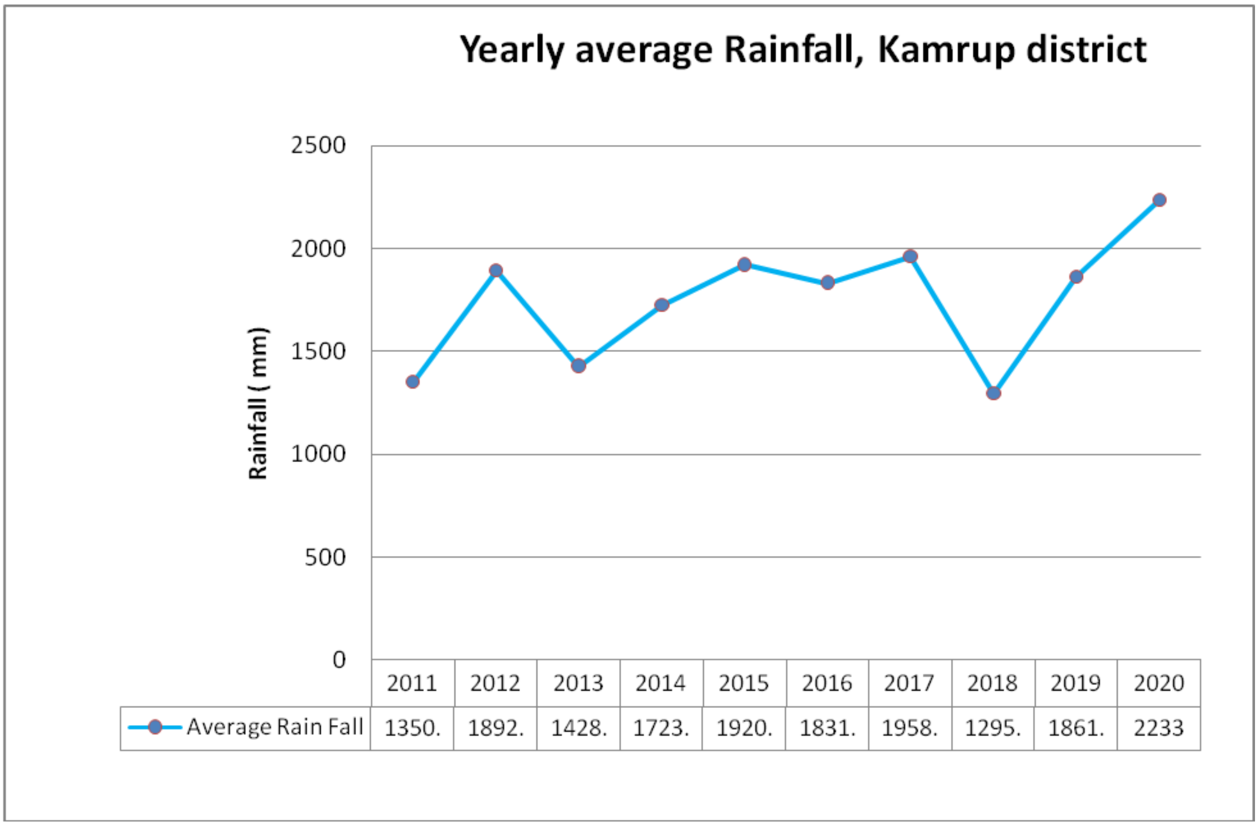

Fig.1.5: Annual variation of rainfall as recorded I.M.D rain gauge stations of Kamrup district

1.7 Temperature

The climate of the district is predominantly sub tropical humid climate with heavy rainfall, hot summer and high humidity. Average temperature ranges from 12 to 38^{o}C during the year. In winter, temperature ranges from 15 to 25^{o}C during day and 8 to 15^{o}C during night. The summer temperature ranges from 25 to 38^{o}C during day and 15 to 25^{o}C during night. Monsoon usually starts from April and continue till end of September. Prevalence of Relative Humidity is generally high (78-80%) particularly during the summer months. Winter months are cool and start from November to February.

1.8 Physiographic set up

The district is situated in the western part of the state, surrounded by Darrang and Morigaon district on the east, Nalbari and Goalpara on the west, Baksa on the North and Meghalaya state on the west. The mighty river Brahmaputra bifurcates the district into nearly equal parts. The river thus has a lot of influence in the physiography of the entire district. In the immediate neighborhood of the Brahmaputra the land is low, and exposed to annual inundation. In this marshy tract reeds and canes flourish luxuriantly, and the only cultivation is that of rice. At a comparatively short distance from the river banks the ground begins to rise in undulating knolls towards the mountains of Bhutan on the north, and towards the Khasi hills on the south. The hills south of the Brahmaputra in some parts reach the height of 800 feet (240 m). The middle portion of the district, being part of the Brahmaputra valley is characterized by an almost plain topography (Fig.1.6).

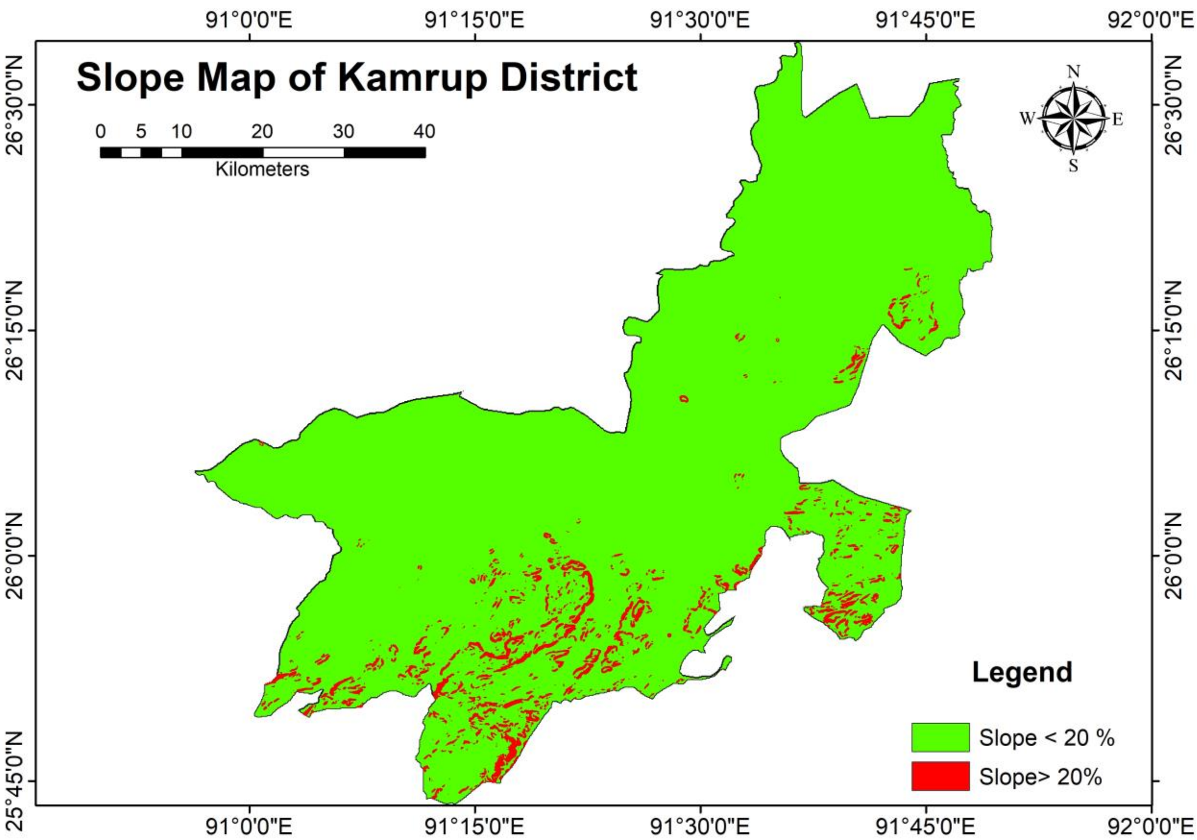

Fig.1.6: Slope map of the study area

1.9 Drainage and Morphometric Features

The Brahmaputra is the main river, which passes through the district. There are a number of tributaries of the Brahmaputra, which are the major natural water resources. The northern tributaries viz., Bornadi, Puthimari, Sessanoi, Borolia etc. originating from Bhutan hills subsequently flow southwards into Brahmaputra. The southern tributaries viz., Kulsi, Kukurmara, Boko and Singra originating from Meghalaya hills subsequently flow northwards into the Brahmaputra. Most of these rivers carry huge volumes of water during monsoon and overflow due to heavy rainfall during the monsoon season causing flood hazard in the district every year. There are number of small streams, channels and sizeable area under marshy lands in the district of Kamrup.

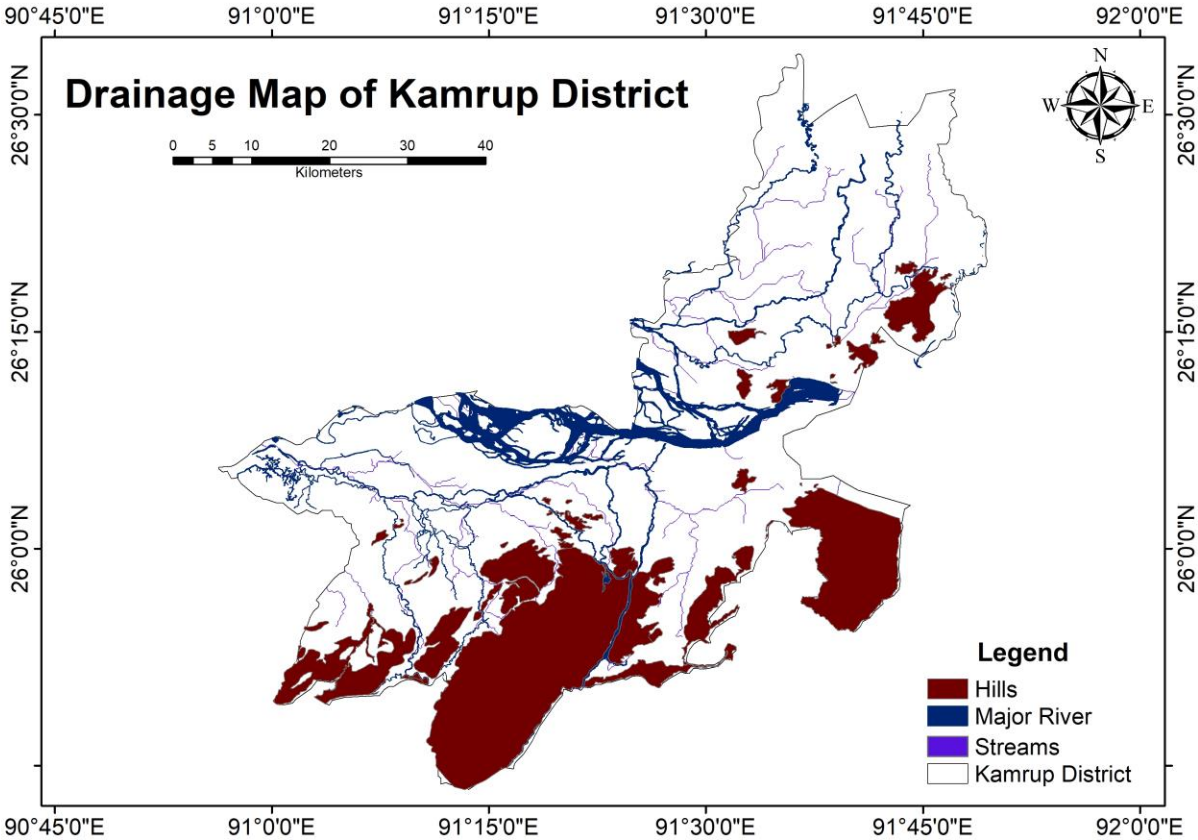

Fig. 1.7: Drainage Map of Kamrup District, Assam

1.10 Geology

The area consists of two broad hydrogeological units – 1) Pre-Cambrian consolidated rocks and 2) Quaternary alluvium consisting of unconsolidated sediments (Fig 1.8).

Pre-Cambrian consolidated rocks are confined to hilly areas and inselbergs. The oldest formation is composed of Gneisses and schist, which are extensively intruded by granites occurring as small basses. Later pegmatitic and quartz veins intruded both.

In Hilly area ground water occurs in shallow weathered zone and this can be developed through open wells. The joints and fractures developed due to tectonic activities form potential water bearing zones and suitable for development through construction of bore wells. The district has a more or less plain topography, some hillocks are found here and there. It has a gentle slope from northern side towards south direction.

A general geological sequence is given below:

Group	Formation	Lithology
Quaternary	Recent Alluvium	Clay, Silt, Sand and Gravel.
	Older Alluvium	Sand, Gravel, Boulder and Clay
Pre-Cambrian	Shillong Group	Pegmatite, quartzite, feldspar and epidote vein, fine grained granite, grey porphyritic granite, pink granite, Migmatitic Amphibolite, granulite, Schists and gneisses etc

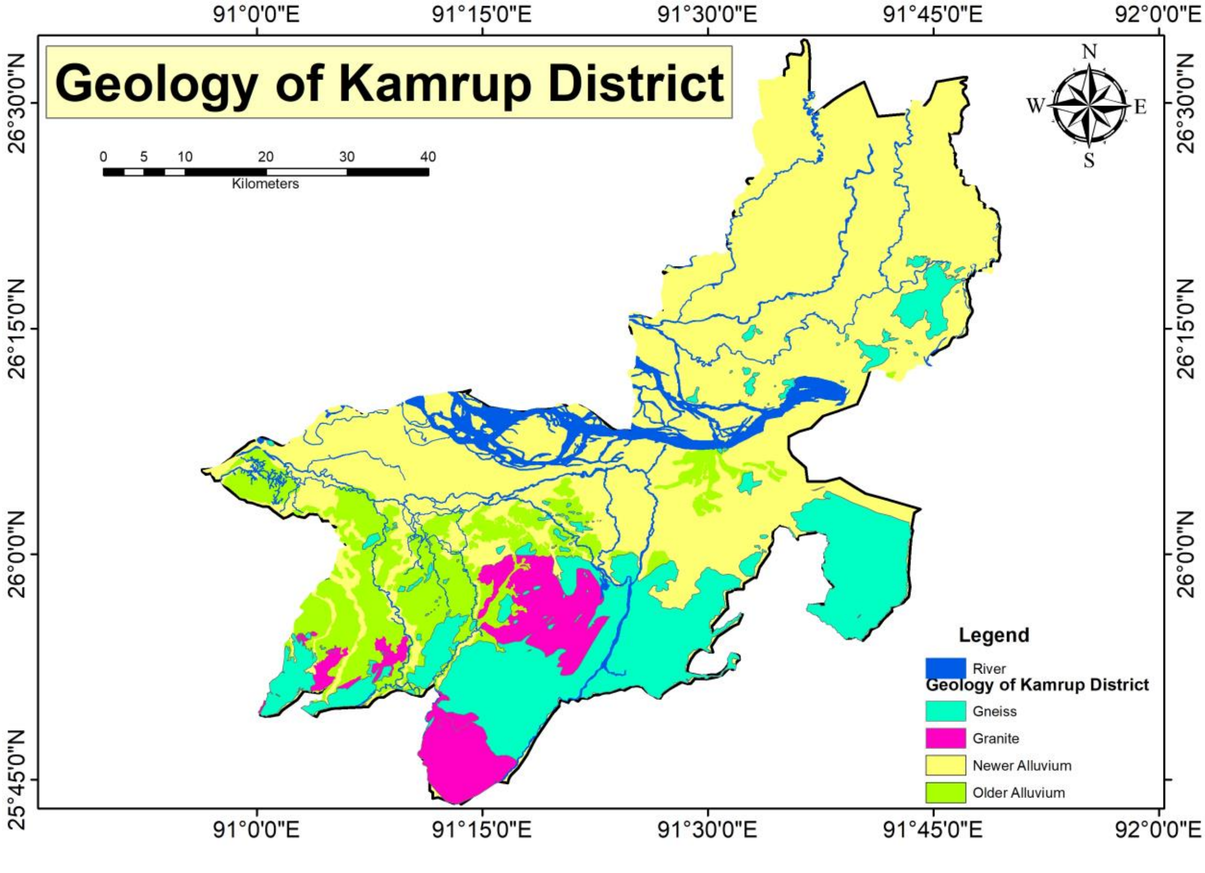

Fig 1.8: Map showing Geology of Kamrup District

1.11 Geomorphology

Geomorphologically the area can be classified into ten divisions: active flood plain, younger alluvial plain, Pediment alluvial plain, Pediment pediplain complex, older flood plain, older alluvial plain, low dissected denudational hills and valleys, moderately dissected denudational hills and valleys, highly dissected denudational hills and valleys and moderately dissected structural hills and valleys.

The flood plain areas are restricted to flood plain of river Brahmaputra and its tributaries consisting of unconsolidated material like gravel, sand, silt and clay. Due to seasonal floods the different depositional environment like paleo channel, natural levees, back swamps wetlands and channel bars are common features of flood plain area. These areas are good for ground water development in shallow depth.

The major part of the district is occupied by younger and older alluvial plain. The elevation of the younger alluvial plain is slightly higher than the flood plain areas, consisting of gravel, sand, silt and clay. These areas are also good for ground water development in shallow depth.

In Hilly area and Inselbergs ground water occurs in shallow weathered zone and this can be developed through dug wells. The joints and fractures developed due to tectonic activities form potential water bearing zones and suitable for development through construction of bore wells. (Fig. 1.9).

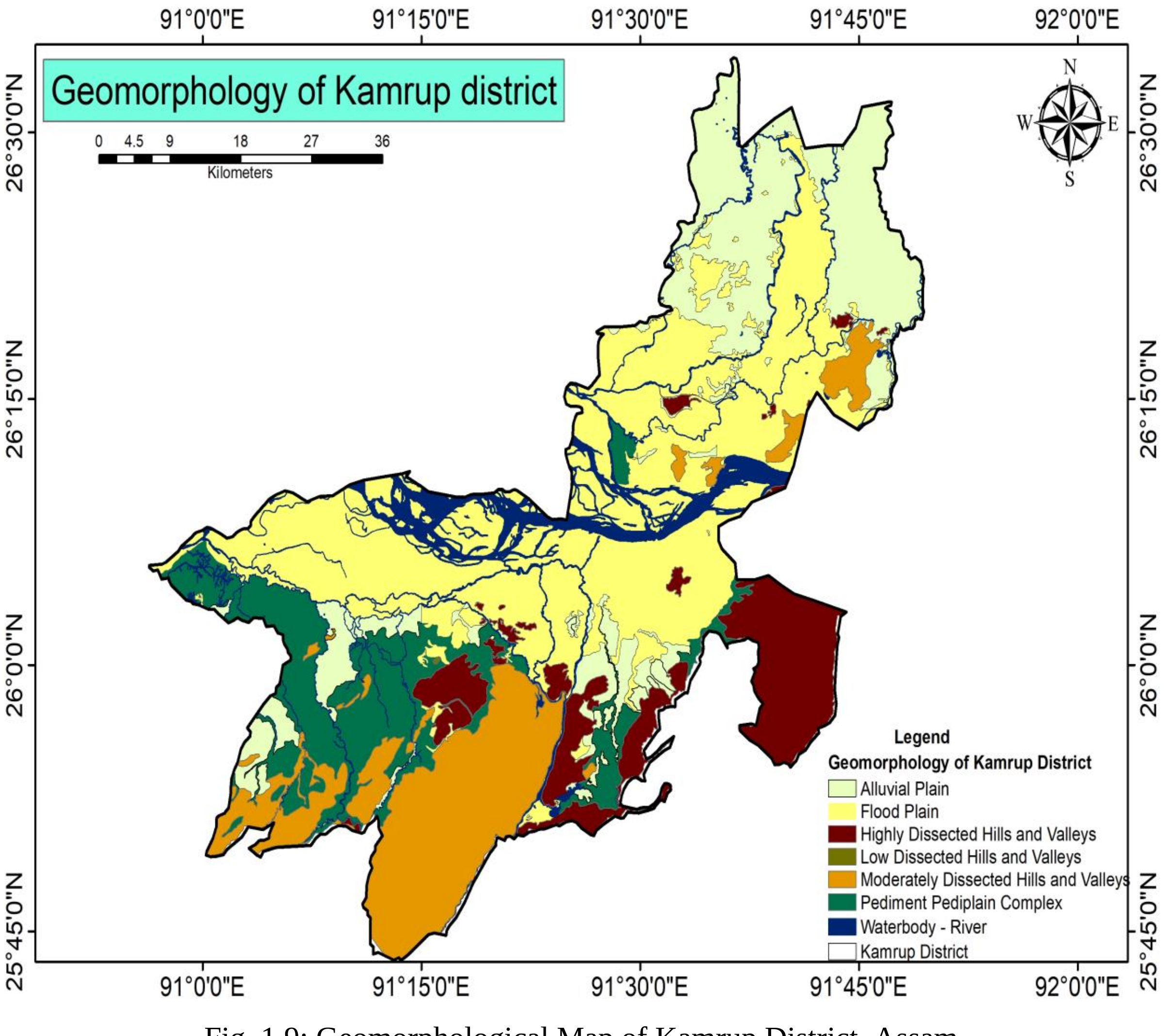

Fig. 1.9: Geomorphological Map of Kamrup District, Assam

1.12 **Land use Pattern**

The net sown area of the district is 100264 ha which accounts for 32.29 percent of the total geographical area (310500ha) of the district & the land utilization pattern in the district

The gross cropped area of the district is 169666 ha with cropping intensity of 114% percent. Out of the total cropped area, 69402 ha and that is 40.91 percent are cropped more than once.

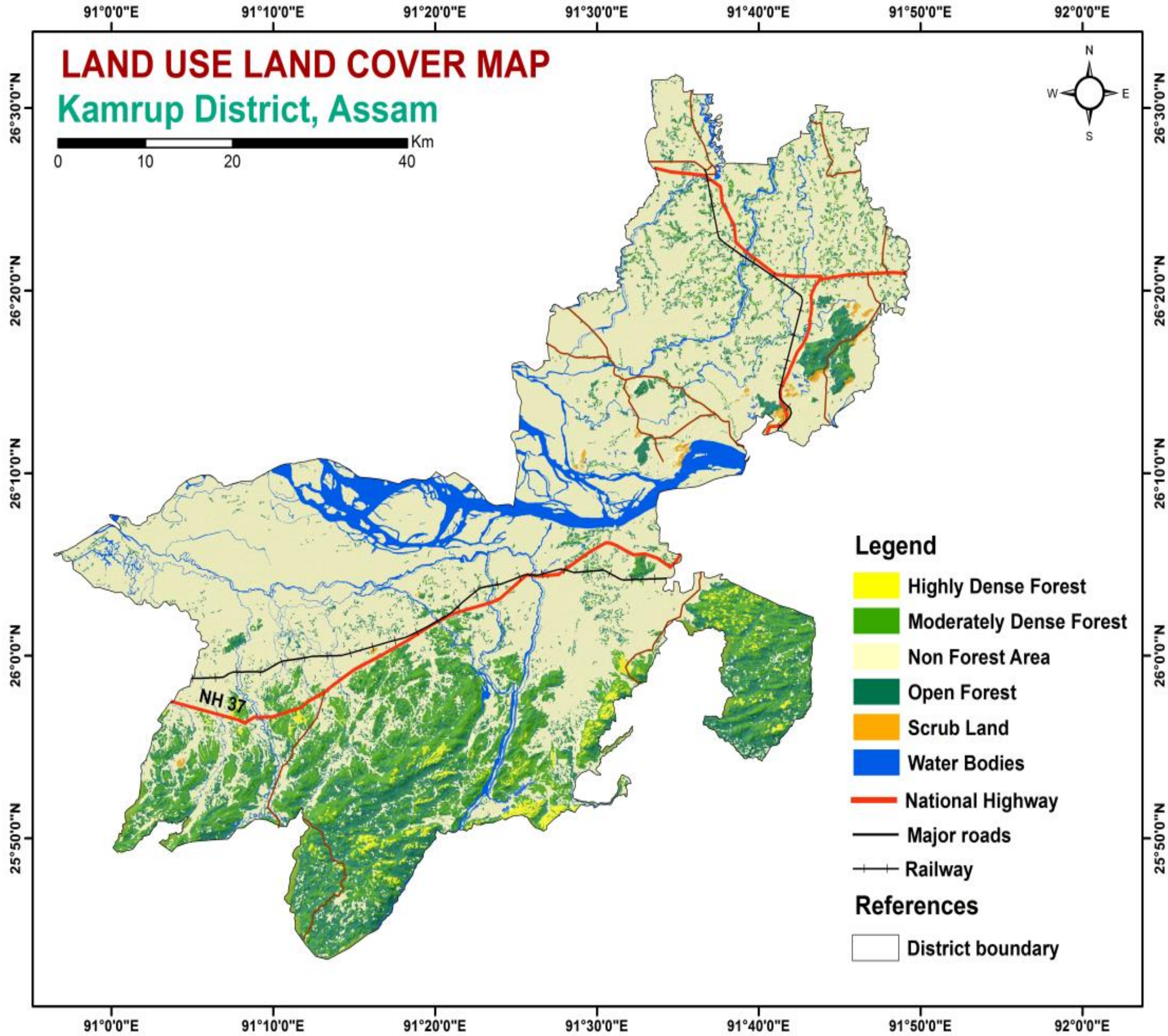

Fig 1.10: Map showing Land Use and Land Cover, Kamrup District.

Forest area in the district accounts for 87424 ha i.e. 28.15% of total Geographic area. Area under non-agricultural uses is 49120 ha. Barren and Uncultivable Land comes to be around 18593ha. Grazing land of the district is around 13591 ha. Cultivable waste land is around 16130ha.

Total Area and Classification of Area, 2018-19: *(Area in Hectare)*

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 Uncultivable 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			
Kamrup	**318850**	**87424**	**49120**	**18593**	**13591**	**17950**	**16130**	**7665**	**8113**	**100264**	**169666**	**69402**

Source: Ministry of Agriculture, Govt. of India.

Table 1.5 Land Use Pattern in Kamrup District

1.13 Soil

The major groups of soils identified in the district are recent riverine alluvial soils (Entisols), old riverine alluvial soils (Inceptisols), mountain valley alluvial soils (Ultrasols) and laterite red soils (ultisols). 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. The northern part of the district lying at the foothills of Bhutan is built up of old mountain valley alluvial soils, which are heavy textured soils. In the laterite red soils, iron and aluminum are found along the southern hilly tracts of the district. These are fairly well drained coarse textured soils. The district usually faces heavy losses in agricultural production due to recurring occurrence of flood. It not only causes damage to the standing crops but also to the soil due to long duration inundation and deposition of sand particles over a large area in varying depth.

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 2.42% , alluvial soil 26.14% , sandy soil 18.08%, sandy loam soil 39.28% and clay loam soil 14.08%. 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.

Soil erosion is one of the major threats in the district; however its severity varies across the blocks. Mild severity persists in 7 blocks and very severe in 2 blocks namely Chaygaon and Goroimari blocks. Soils of, Hajo, Rangia and Goroimari are also affected by sand deposition.

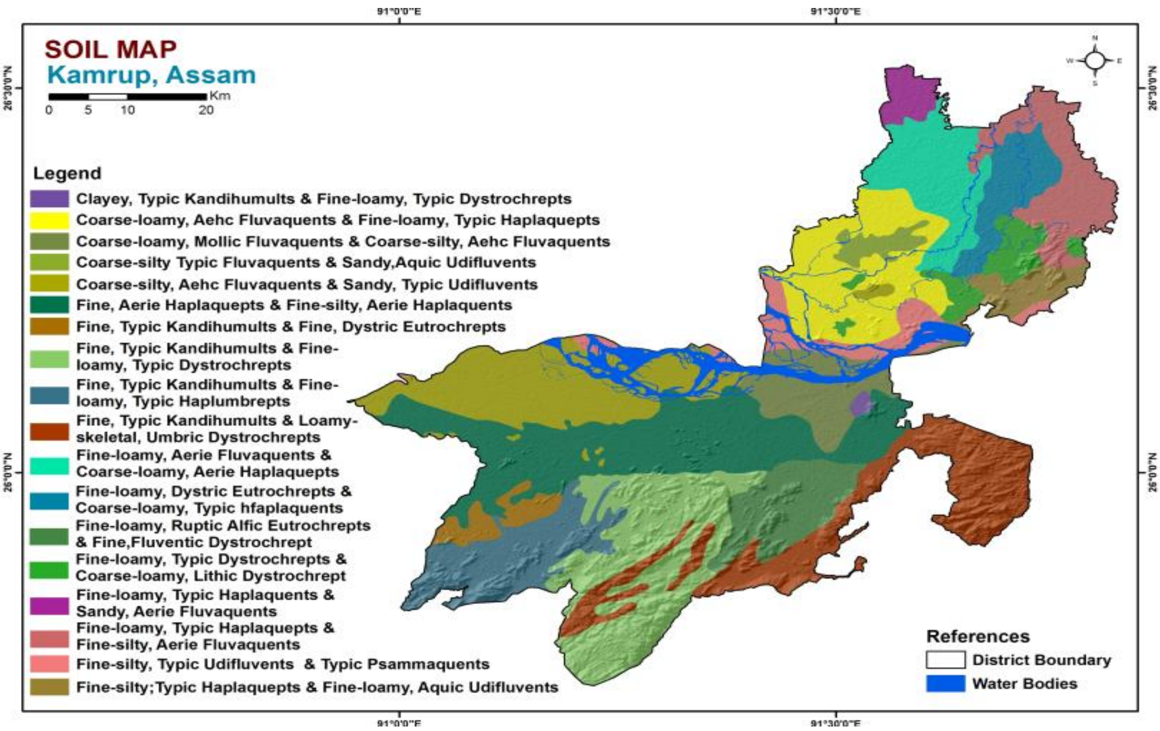

Fig. 1.11: Soil Map of Kamrup District, Assam

1.14 Hydrology and surface water

Surface water bodies are mainly observed in the flood plain area where south and north flowing rivers loses its gradient. Waterlogged and marshy lands are observed.

The area covered by the surface water bodies are shown in the following Table 1.7

Table: 1.7 Water bodies in Kamrup District

Sl no	Water bodies	Area in ha
1	Ponds and tanks	4576.20
2	Paddy cum fisheries	5040
3	Derelict water bodies	643.36
4	Beel fisheries	3817.9
5	River fisheries	453
6	Eco hatchery	-
7	Magur hatchery	-
8	Others (**Forest Fisheries)**	27.5
Total		14557.96

Source: Statistical Handbook Assam 2019

1.15 Agriculture

The Economy of the district is mainly agricultural. The alluvial soil of the district is fertile and suitable for agricultural production. The district is self-sufficient in food grains. However, due to increasing population, a great strain on the districts food resources is being noticed. The emphasis was laid on various schemes in Five year plans for increased agricultural production.

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 crops which are being grown are rice, mustard, pulse, cereals, wheat and tea. Jute is also grown in the district. 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.

The district is not very much important for growing fruits. Only a few kinds of fruits are growing in the district. An important garden crop of the district is banana. Mangoes, Jack fruits, Lemons, areca nuts, coconuts etc. are also common production of the district.

It has been observed from records of Revenue department in the district that the Gross Cropped Area is 176824 hectare out of which 28948 hectare and 23438 hectare i.e. around 16.4% and 13.3% of the area falls in Boko and Chamaria Blocks respectively. Boko and Hajo Blocks record for the maximum net sown area of 28348 hectare and 20975 hectares i.e. around 18.2% and 13.5% of the net sown area of the district respectively. The cropping intensity in Chayani block is 143% which is highest among other blocks in the district. For rest of the blocks, the average cropping intensity is 114 %.).

The total geographical area of Kamrup Rural District is 310500 hectare. The largest Block of the district is Boko which comprises of a total Geographical area of 33475 hectare i.e. about 10.8% of the total Geographical area of the district. The season wise area covered and production of Rice are shown in the following Table 1.8

Table 1.8. Season wise area covered and production of Rice in Kamrup district Area, Production and Yield of Rice, 2018-19:

District	Season	Area (Hectare)	Production (Tonnes)	Yield (Tonnes/Hectare)
Kamrup	Autumn	7232	7938	1.1
	Summer	29608	84606	2.86
	Winter	70465	191534	2.72
	Total	107305	284078	2.65

Source: Ministry of Agriculture and Farmers Welfare, Govt. of India

Agriculture in Kamrup is characterized by small holdings operated by family labour, both men & women with average land holding size of 1.25 ha in the district. Around 0.46% are very large farmers who possesses 1.86% of the total area, 6.21% are large farmers are occupying 18.03% area, 12.13% are medium farmers and are holding 25.53% area, 25.46% are small farmers and are possesses 32.60% area, 31.57% are marginal farmers who are holding 16.68% area and 24.17% are landless farmers and are having access to only 5.30% area. The district has a very distinguishable land ownership distribution pattern where 18.80% resource rich farmers (very large, large and medium) having access to 45.42% area on the other hand there are 81.20% resource poor farmers (small, marginal and landless) having access to only 54.58% area. Thus it indicates that the district has enormous scope for both diversification and intensification with higher technology in addition to the low cost technology to address existing problems of large section of resource poor farmers. Small farmers are occupying 31.20 % of area, marginal 18.02%, medium 13.90%, large 11.51% and very large 1.65%.

The net sown area of the district is 100264 ha which accounts for 32.29 percent of the geographical area of the district & the land utilization pattern in the district.

Paddy is the principal crop grown in the district and *autumn paddy*, *winter paddy* and *summer paddy* are the three main types of paddy grown in the district. Winter paddy is the most important crop in the district. Winter paddy occupies 65.66 % followed by summer paddy 27.59% and autumn paddy 6.73% of the total annual paddy area. In the district summer rice cultivation has received more attention to avoid flood and other natural calamities to make the district self-sufficient in rice production. About 30-40% area of the total geographical area of the district is flood affected area.

IRRIGATION:

Agricultural activities in the district are predominantly rain fed as out of the total cultivated area only 19% area is under irrigation. However, rainfed areas across the blocks vary from 35.45% in Chamaria block to highest 95.65% in Rani Block. Principal crops under irrigated are summer paddy (Boro paddy) and Vegetables during rabi season. In addition, Wheat, Potato, Pulse & oilseeds and flowers are also irrigated in sporadic /isolated places during rabi. Major source of irrigation in the district is Shallow Tube Well that contributes 86.90% out of total irrigated area of 48036 ha. Shallow tube well irrigation existed in all blocks with varying degree of coverage of 3.04% area under Rani block and as high as 56.37% area under Chamaria block. Other irrigation schemes of the district are "Flow irrigation scheme" contributes only 3.65% and confined in 4 blocks namely Boko, Chaygaon, Goreswar and Rani. Likewise "Lift irrigation scheme" contributes 2.12% and is confined in Hajo, Kamalpur, Rangia and Chamaria blocks. Besides above, the rapid growth in irrigation status seems difficult under the present situation and therefore, it is necessary to re-looked and redefined the package of practices based on rainfed agriculture on a holistic approach.

a. Existing Type of Irrigation

The Net irrigated and gross irrigated area of the district is 11737 ha and 15566 ha respectively. As per District Agriculture Department, a total of 54 irrigation canals, 7319 tube wells, 632 bore wells and a total of 8288 irrigation sources are operating in the district. Bongaon block has the maximum number of sources of irrigation, i.e. 6004 out of 8288 irrigation sources in the district. In terms of the command area, Bihdia-Jajikona block has the largest command area with 5895 ha (44.8%) out of a total command area of 13137.9 ha. The areas covered by the irrigation are shown in the following Table 1.9.

Table 1.9 a. Source and Net Irrigated Area, 2018-19 *(Area in Hectare)*

District	Canal			Tank	Well			Other Source	Total
	Govt.	Private	Total		Tube well	Other Well	Total		
Kamrup	517	1061	1578	707	3244	2949	6193	3289	11767

Source: Ministry of Agriculture, Govt. of India.

Table 1.9 b. Source and Gross Irrigated Area, 2018-19: (Area in Hectare)

District	Canal			Tank	Well			Other Source	Total
	Govt.	Private	Total		Tube well	Other Well	Total		
Kamrup	788	1314	2102	941	4046	3548	7594	8929	15566

Source: Ministry of Agriculture, Govt. of India.

Table 1.9 c. Season-wise Irrigation of Rice, 2018-19: (Area in Hectare)

District	Autumn	Winter	Summer	Total
Kamrup	-	3001	9359	12360

Source: Ministry of Agriculture, Govt. of India.

Table 1.9 d. Irrigation of Food grains, 2018-19: (Area in Hectare)

District	Cereals and Millets	Pulses	Total Food Grains
Kamrup	12568	1232	13800

Source: Ministry of Agriculture, Govt. of India.

Table 1.9 e. Irrigation of Condiments and Spices, Fruits & Vegetables and Oilseeds, 2018-19: (Area in Hectare)

District	Condiments and Spices	Fruits & Vegetables	Oilseeds
Kamrup	-	1085	86

Source: Ministry of Agriculture, Govt. of India.

Table 1.9 f. Sector wise Irrigation Potential Created, 2018-19 (Cumulative): (Area in Hect.)

District	Irrigation potential created up to 31st March, 2019			
	Minor Irrigation	Major/Medium Irrigation	Total	Grand Total
Kamrup	32305	0	32305	32305

Source: Statistical Handbook Assam 2019

Table 1.9 g. Gross Area Irrigated under Govt. Irrigation Facilities, 2018-19: (Area in Hect.)

District	Irrigation Scheme				Source		
	Surface Lift	Surface Flow	Ground Water Lift	Total	Canals	Tube Wells	Total
Kamrup	226	5408	611	6245	5634	611	6245

Source: Statistical Handbook Assam 2019

Table 1.9 h. Length of Irrigation Canals/ Channels Constructed upto 2017-18: (In Km.)

District	Constructed	Lined	Pipe
Kamrup	303.874	183.369	30.962

Source: Statistical Handbook Assam 2019

Table 1.9 i. Target and achievement of additional irrigation potential created, 2018-19: (Area in Hect.)

District	Achievement		
	Minor Irrigation	Total M.I & M/M Irrigation	Total (AP+RLP)
Kamrup	2293	2293	2293

N.B: A- Additional, P- Potential, R- Revival, L- Lost

Source: Statistical Handbook Assam 2019

CHAPTER 2.0

2.0 Data Collection and Generation

2.1 Data collection

Data collection includes collection of rainfall data from state government, litholog collection from state groundwater departments, compilation of CGWB's earlier survey data, exploration and geophysical data. Population data is collected from Census of India website. Agriculture data are taken from District Irrigation Plan, 2016-2021, Kamrup, Assam prepared by NABARD.

CGWB had constructed 35 exploratory wells in this area earlier. Public Health Engineering Department and Directorate of Geology and Mining, Govt. of Assam had constructed number of tube wells in the area and the department provided lithology and chemical analysis data. However, all the wells are not incorporated in the present study due to lack of coordinate data. Details of the wells are given in Table 2.4.

Rainfall data was collected from Indian Meteorological Department.

2.2 Data Generation

2.2.1 Hydrogeological data

The entire study area is covered by regular monitoring of existing 12 GWMS and another 31 key wells have been established. All these wells are under monitoring after establishment (Table 2.1).

2.2.2 Soil Infiltration studies: Infiltration test

Three soil infiltration tests were conducted during the field season in the study area. The salient features of the test sites are provided in **Table 2.2**. The test has been conducted only in barren land and the soil types encountered in the sites are sand admixtures.

2.2.3 Water Quality

During Pre monsoon period 35 numbers and post monsoon period 36 water samples were collected from dug wells and hand pumps of the study area for analysis of detail, iron, heavy metals and arsenic.

2.2.4 Geophysical survey

During AAP 2011-12, 24 numbers of VES survey was conducted with maximum current electrode separation of around 200m and 800m using schlumberger configuration. Generally H, K, KH type multilayered VES curves was recorded. The interpretation of VES curves was done by matching the field curves with master curves (Orellana & Moony) to obtain the true resistivity's and thickness of different geo-electrical layers. The results were correlated with the hydrogeological data of the boreholes located near the location of VES taking ground water quality data into account. The location details of these VES survey is shown in Table 2.3.

Table 2.3 Details of VES, Kamrup district

Sl. No.	**Block /Tehsil etc.**	**Location**	**Coordinate**		**Depth of major Aquifer layers (m)**		**Thickness of Aquifer layer (m)**	**Resistivity Ohm m**	**Remark**
1	Chhaygaon	Banshar	26º06´27"	91º 25´19"	0	1.3	1.3	10	Top soil with clay etc.
					1.3	7.5	6.2	35	sands with clays etc.
					7.5	39	31.5	84	Sands with gravel, pebbles and clays etc.
					Below 39m			50	Intercalations of clays with sands etc.
2	Chhaygaon	2 no. Jaikur Village	26º05´55"	91º 25´19"	0	1	1	190	Top soil with clay etc.
					1	7.6	6.6	38	sands etc.
					7.6	62	54.4	105	Hard clays with Sands etc.
					Below 62m			38	Intercalations of sands with clays etc.
3	Rani	Rani	26º03´23"	91º37´54"	0	10	10	80	Top soil with clay etc.
					10	70	60	160	Hard clays with sands etc.
					Below 70m			350	Consolidated formation
4	Chhaygaon	1no. Jaikur	26º05´00"	91º 25´00"	0	12	12	42	Top soil with clay etc.
					12	120	108	105	Hard clays with sands etc.
					Below 120m			46	Intercalations of Sands with clays etc.
5	Chhaygaon	Gumi I	26º05´42"	91º 20´33"	0	3	3	32	Top soil with clay etc.
					3	6	3	26	Sands etc.
					6	7.8	1.8	90	Hard clays etc.
					7.8	38	30.2	66	Intercalations of sands with clays etc.
					Below 38m			245	Hard clays with sands etc.
6	Rani	Bholagaon	26º01´08"	91º 30´15"	0	1.8	1.8	110	Top soil with clay etc.

Sl. No.	Block /Tehsil etc.	Location	Coordinate		Depth of major Aquifer layers (m)		Thickness of Aquifer layer (m)	Resistivity Ohm m	Remark
					1.8	7.9	6.1	34	Sands with clays etc.
					7.9	63	55.1	21	clays with sands etc.
					Below 63m			36	Intercalations of sands with clays etc.
6	Chhaygaon	Badekuchi	26º01´28"	91º 22´46"	0	6	6	78	Top soil with clay etc.
					6	14.4	8.4	195	Hard clays with sands etc.
					14.4	25.6	11.2	120	clays etc
					25.6	161	135	36	sands with clays etc.
					Below161m			450	Consolidated formation
7	Chhaygaon	Hathigarh	26º59´12"	91º 22´31"	0	1.6	1.6	88	Top soil with clay etc.
					1.6	25.6	24	220	Hard clays with sands etc.
					25.6	114	88.4	48	Intercalations of sands and clays etc
					Below114m			290	Consolidated formation
8	Chhaygaon	1 no. Balasidhi	26º02´09"	91º 23´53"	0	2	2	30	Top soil with clay etc.
					2	16	14	60	sands with Clays etc.
					16	67	51	220	Sands with hard clays etc
					Below 67m			110	Clays with sands etc.
9	Rampur	Simina	26º02´08"	91º 14´10"	0	1.4	1.4	540	Top soil with clay etc.
					1.4	7.4	6	162	sands with hard Clays etc.
					7.4	44	36.6	70	Sands etc
					Below 44m			23	Intercalations of clays with sands
10	Boko	Chamaria	26º03´12"	91º 10´08"	0	1	1	100	Top soil with clay etc.
					1	11	10	60	sands with Clays etc.
					11	36	25	140	hard clays with sands etc
					36	58.6	22.6	88	sands with clay etc.
					58.6	92	33.4	127	hard clays with sands etc

Sl. No.	Block /Tehsil etc.	Location	Coordinate		Depth of major Aquifer layers (m)		Thickness of Aquifer layer (m)	Resistivity Ohm m	Remark
					Below 92m			72	Intercalations of sands with Clays etc.
11	Boko	Hafshapara	26º08´06"	91º07´35"	0	3.2	3.2	135	Top soil with clay etc.
					3.2	17.6	14.4	83	sands with Clays etc.
					17.6	34	16.4	165	hard clays with sands etc
					Below 34m			85	sands with clay etc.
12	Boko	1 no. Rangapani	26º07´34"	91º 04´45"	0	3.7	3.7	33	Top soil with clay etc.
					3.7	10	6.3	66	sands with Clays etc.
					10	60	50	157	hard clays with sands etc
					Below60m			55	Intercalations of sands with Clays etc.
13	Boko	Rongeshwari	26º06´53"	91º 03´48"	0	5	5	40	Top soil with clay etc.
					5	40	35	60	sands with Clays etc.
					40	60	20	84	hard clays with sands etc
					Below 60m			32	Intercalations of sands with Clays etc.
14		Rajapukhari	26º06´11"	91º 29´00"	0	3.5	3.5	130	Top soil with clay etc.
					3.5	18.5	15	65	sands with Clays etc.
					18.5	49	30.5	108	hard clays with sands etc
					Below 49m			38	Intercalations of sands with Clays etc.
15	Chhaygaon	Chapathuri	26º07´17"	91º 27´09"	0	11	11	35	Top soil with clay etc.
					11	63	52	122	sands with hard Clays etc.
					Below 63m			266	Semi consolidated / consolidated formation
16	Rampur	Rampur	26º05´29"	91º 28´14"	0	1.3	1.3	100	Top soil with clay etc.
					1.3	13.5	12.2	200	hard Clays with sands etc.
					13.5	96	82.5	49	sands with clays etc

Sl. No.	Block /Tehsil etc.	Location	Coordinate		Depth of major Aquifer layers (m)		Thickness of Aquifer layer (m)	Resistivity Ohm m	Remark
					Below 96m			145	Intercalations of sands with Clays/ hard clays etc.
17	Chayani	Mirza city	26º06´30"	91º 32´17"	0	6.2	6.2	130	Top soil with clay etc.
					6.2	52.9	46.7	162	Hard clays with sands etc.
					52.9	105	51.8	212	Hard clays with gravel , sands etc
					105	225	120	114	Intercalations of sands with clays / hard Clays etc.
					Below 225m			70	Intercalations of clays with sands etc.
18	Rani	Palasbari	26º07´27"	91º 32´27"	0	5	5	26	Top soil with clay etc.
					5	33	28	52	sands with Clays etc.
					33	57	24	168	hard clays with sands etc
					Below 57m			52	Intercalations of sands with Clays etc.
19	Chhaygaon	Lakhadubi	26º01´45"	91º 18´36"	0	6.6	6.6	250	Top soil with clay etc.
					6.6	27.7	21.1	375	hard clays with sands etc
					27.7	65	37.3	136	Sands with hard clays, gravel etc.
					Below 65m			36	Intercalations of sands with Clays etc.
20	Chhaygaon	Hatipara	26º05´11"	91º 16´28"	0	5	5	32	Top soil with clay etc.
					5	20	15	64	sands with Clays etc.
					Below 57m			92	Intercalations of sands with Clays/ hard clays etc.
21	Chhaygaon	Gumi II	26º05´39"	91º 20´30"	0	0.5	0.5	94	Top soil with clay etc.
					5	16.5	11.5	38	sands with Clays etc.
					Below 16.5m			95	Intercalations of Clays / hard

Sl. No.	Block /Tehsil etc.	Location	Coordinate		Depth of major Aquifer layers (m)		Thickness of Aquifer layer (m)	Resistivity Ohm m	Remark
									clays with sands etc.
22	Boko	Tarabari	26º00´55"	91º 08´16"	0	1	1	170	Top soil with clay etc.
					1	21	20	85	hard Clays with sands etc.
					21	85	64	41	sands with clays etc
					Below 85m			90	Intercalations of sands with Clays / hard clays with sands etc.
23	Boko	Jugipara	26º02´32"	91º 04´56"	0	2.3	2.3	370	Top soil with clay etc.
					2.3	13.8	11.5	56	hard Clays with sands etc. sands with clays etc
					13.8	76	62.2	231	hard Clays with sands etc
					Below 76m			55	Intercalations of sands with Clays with sands etc.
24	Boko	Chaplai	26º01´13"	91º 03´00"	0	4.2	4.2	270	Top soil with clay etc.
					4.2	38	33.8	36	sands etc.
					Below 38m			68	Intercalations of sands with Clays / hard clays , gravel with sands etc.

Due to lack of geophysicist in the Region geophysical could not be carried out during this study.

2.2.5 Exploratory Drilling

During AAP 2020-21, five exploratory drilling and two observatory wells were drilled in the study area by CGWB. A list of wells constructed in the area are prepared incorporating location, well designs, etc (Table 2.4).

Table 2.1: GWMS and Key wells details

S. N	District*	Village	Lat*	Long*	Well* Type	Depth of well	Dia (m)	MP	RL	WL (mbgl), Aug, 20	WL (mbgl) Jan 2021	WL(mbgl) November 2020	WL(mbgl) March 2021
Key Wells, Kamrup district, Assam													
1	Kamrup	Rajapara (Chandubi)	25.87236111	91.44736111	Dug well	10.52	0.9	0.82	80	6.77	7.47	7.28	8.18
2	Kamrup	Chandubi	25.87736111	91.42061111	Dug well	7.58	0.9	0.8	50		3.45	3.2	4.38
3	Kamrup	Baroigaon	25.85522	91.38361	Dug well	8.69	0.81	0.88	67	0.78	3.65		
4	Kamrup	Ranikhamar	25.8552	91.38353	Dug well	8.77	0.88	0.95	62			2.07	5.5
5	Kamrup	Kulshi_forest	25.96786111	91.421	Dug well	6.11	0.78	0.87	88	2.17	2.58	2.4	2.99
6	Kamrup	Kulshi	25.975914	91.410587	Dug well	7.03	0.73	0.97	49	1.48	2.48	1.97	3.13
7	Kamrup	Maniori Tinali	26.06886111	91.52922222	Dug well	8.47	0.76	0.6	46	1.3	2.34	1.93	
8	Kamrup	Simina (Sulikata)	26.11427778	91.45	Dug well	6.85	0.92	0.8	48	0.86	3.75	1.8	4.6
9	Kamrup	Natun Jarabari	26.06758	91.37608	Dug well	1.22	0.8	0	49	0.17	0.68	0.5	Dry
10	Kamrup	Gumi	26.08422222	91.34827778	Dug well	7.9	0.85	1.02	50	0.99	3.28	1.98	5.55
11	Kamrup	Hatipara	26.08602778	91.28013889	Dug well	5.33	0.8	0.63	43	0.81		1.54	Dry
12	Kamrup	Howli	26.08133333	91.16188889	Dug well	6.5	0.9	0.8	50	2.56	3.94	3.2	4.85
13	Kamrup	Narenga Kaithpara	26.02352778	91.19580556	Dug well	4.94	0.8	0.68	37	1.01	2.24	2.02	2.92
14	Kamrup	Bhurkibari	26.01336111	91.30361111	Dug well	5.36	0.85	0.83	46	1.27	2.11	1.59	3.17

S. N	District*	Village	Lat*	Long*	Well* Type	Depth of well	Dia (m)	MP	RL	WL (mbgl), Aug, 20	WL (mbgl) Jan 2021	WL(mbgl) November 2020	WL(mbgl) March 2021
15	Kamrup	Bullarpar (Bhuban Nagar)	26.09625	91.59161	Dug well	5.1	0.88	0.7	64	0.86		1.47	4.16
16	Kamrup	Gobardhan	26.04094444	91.35972222	Dug well	6.55	0.84	0.94	56	1.96	4.46		
17	Kamrup	Chaikata	25.92886111	91.10511111	Dug well	5.86	0.93	0.86	59	2.21	3.41	2.84	4.57
18	Kamrup	Gangrapara	25.88480556	91.09933333	Dug well	7.61	0.98	0.77	65	1.41	5.23	2.64	5.37
19	Kamrup	Gosanipara	25.83477778	91.07652778	Dug well	3.62	0.85	0.86	87	1.37	2.2	1.84	2.62
20	Kamrup	Dhopguri	25.94352778	91.12297222	Dug well	5.6	1.12	0.76	55	1.68	3.26	2.04	4.64
21	Kamrup	Damalchos	26.00494444	91.10063889	Dug well	4.92	0.8	0.92		0.5	1.71	0.78	2.28
22	Kamrup	Hatigarh	25.98783333	91.37602778	Dug well	5.92	1	0.72	53	1.6	4.22	2.57	5.18
23	Kamrup	Malini than	25.94897222	91.38047222	Dug well	3.23	0.83	0.84	49	1.02	1.26	1.19	4.96
24	Kamrup	Borjhar Chowk	26.00313889	91.34725	Dug well	5.64	0.91	0.87	44	2.49	3.06	2.76	4.03
25	Kamrup	Dimakhuli	25.91702778	91.23227778	Dug well	5.38	0.89	0.88	60	1.96	2.61	2.3	3.3
26	Kamrup	Jarapara	25.96419444	91.21888889	Dug well	5.4	0.79	0.86	47	1.19	1.84		
27	Kamrup	Agchia	25.99261	91.26142	Dug well	12.95	0.95	0.88	43	2.06	4.12	3.47	11.85
28	Kamrup	Hajo New	26.251899	91.540708	Dug well	12	0.83	0.8	53.72		0.65	0.31	1.33

S. N	District*	Village	Lat*	Long*	Well* Type	Depth of well	Dia (m)	MP	RL	WL (mbgl), Aug, 20	WL (mbgl) Jan 2021	WL(mbgl) November 2020	WL(mbgl) March 2021
29	Kamrup	Sualkuchi 1	26.170797	91.534904	Dug well	15	1.5	0.93	44.95		3.37	2.47	4.22
30	Kamrup	Bamundi	26.171184	91.486601	Dug well	9.8	0.97	0.82	50.71		2.63	2.03	3.39
31	Kamrup	Ramdia	26.224346	91.498055	Dug well	12	0.69	0.97	41.6			3.2	4.36
GWMS Wells, Kamrup district, Assam													
1	Kamrup	Bamunigaon	26.02361	91.32444	Dug well	5.9	0.8	0.7	50	0.74	2.48	1.6	3.84
2	Kamrup	Rajapara	25.94417	91.11806	Dug well	12.5	0.8	0.8	64	1.28	1.7	1.1	
3	Kamrup	Rani II	26.04129	91.586327	Dug well	6.55	0.8	0.9	76	1.1	1.94	1.58	2.05
4	Kamrup	Boko	25.98333	91.24500	Dug well	9.4	0.8	0.75	54	2.2	4.65	4.13	5.7
5	Kamrup	Chhaygaon	26.04111	91.35972	Dug well	6.6	0.9	0.9	38	4.5	4.5	2.77	4.6
6	Kamrup	Mirza	26.09306	91.54722	Dug well	9.3	0.9	0.8	70	2.59	4.7	3.3	6.44
7	Kamrup	Rani	26.0377	91.5839	Dug well	5.2	0.8	0.85	272	1.03	2.23	1.72	2.25
8	Kamrup	Agyathuri	26.19181	91.64300	Dug well	9	0.8	0.85	49.80		4.75	3.35	
9	Kamrup	Dirgheswari	26.240935	91.746847	Dug well	5.2	1.2	0.7	49	0.63	1.94	1.08	4.95
10	Kamrup	Rangia	26.43759	91.62364	Dug well	5	0.9	0.42	27	1.81	4.28	4.03	4.45
11	Kamrup	Sualkuchi	26.16744	91.57083	Dug well	7.4	0.78	0.87	38	0.58	1.42	0.88	1.69
12	Kamrup	Dora Kahara	26.30148	91.71640	Dug well	8	1	0.62	35	3.98	4.98	4.18	4.98

Table 2.2: Summary of Infiltration Test Results of Kamrup district, Assam

SI No	Location	Latitude	Longitude	Infiltration Rate (mm/hour)	Infiltration factor
1	Chamaria	26˚03′58″	91˚10′11″	16	21.52
2	Lachitpur	26⁰11'11"	91°38'56"	21	5.91
3	Alegjari	26°02'10"	91°11’37”	12	4.59
4	Sontali	26°08'47"	91°06'24"	27	7.3
5	Palashbari	26°7' 46"	91°34'16"	09	3.16
6	Abhayapuri	26°12'42"	91°42'28"	09	3.28
7	Bhalukjuli	26˚01′15″	90˚56′42″	17	15.38
8	Sarpara	26˚01′03″	90˚49′52″	36	11.25
9	Rajapara	25°52'21"	91°26'40"	30	5.718
10	Garopara	25°58'35"	91°30'30"	06	04

Table 2.3: Details of exploratory wells in Kamrup District, Assam

Sl No	Location	Block	Toposheet No	Longitude	Latitude	Type of Well (DW/ BW/ TW)	Depth	Depth of construction (m)	Source
1	Dumnichauki-EW		78/15	91.817	26.342	TW	291.45	168.00	CGWB
2	Changsari- II-DW			91.672	26.329	TW	192.90	187.00	CGWB
3	Boko-DW			91.233	26.000	TW	106.70	31.80	CGWB
4	Muktapur-EW			91.744	26.425	TW	183.70	167.00	CGWB
5	Jugipara-EW			91.088	26.053	TW	189.10	93.00	CGWB
6	Chaikata-EW			91.0744	25.952	TW	101.90	98.00	CGWB
7	Chhaygaon Balapukhuri-EW			91.402	26.067	TW	201.30	158.00	CGWB
8	Rani-EW			91.576	26.045	TW	200.25	200.00	CGWB
9	Hajo-EW			91.522	26.217	TW	18.00		CGWB
10	Hajo, Fakirtala-EW			91.524	26.217	TW	94.00	81.00	CGWB
11	Rangamati-EW			91.507	26.102	TW	189.45	98.00	CGWB
12	West suailkuchi-EW			91.5694	26.018	TW	92.00	62.50	CGWB
13	Sakhati-EW			91.075	25.919	TW	181.30	143.00	CGWB
14	West Sualkuchi-EW			91.569	26.153	BH	62.50	62.00	CGWB
15	Siddheswar Dewalaya, Suwalkuchi-I &II-EW			91.566	26.163	BH	113.00		CGWB
16	IIT complex-Amingaon, Ghy.-EW			91.732	26.224	BH	187.20		CGWB
17	Kahikuchi south Colony-EW			91.750	26.146	BH	169.00		CGWB
18	Hahim-EW&OW			91.156	25.865	BH	90.00		CGWB
19	Rangia College-EW		ASKM54	91.613	26.463	TW	306.69	156.00	CGWB
20	Deochar-EW		78N/08	91.246	26.129	TW	120.00	52.00	CGWB
21	Agchia-EW		78/N/12	91.649	26.030	TW	194.30	94.00	CGWB
22	Chamaria-EW		78/N/08	91.092	26.069	TW	200.00	122.00	CGWB
23	Palashbari-EW		78/ N/12	91.571	26.129	TW	104.00	90.00	CGWB

Sl No	Location	Block	Toposheet No	Longitude	Latitude	Type of Well (DW/ BW/ TW)	Depth	Depth of construction (m)	Source
24	Borjhar-EW			91.601	26.101	TW	104.10	100.00	CGWB
25	Sarpara-EW			91.518	26.097	BH	251.30		CGWB
26	Madanpur-EW			91.453	25.959	TW	196.00	123.50	CGWB
27	Jambari-EW			91.286	26.056	TW	89.55	64.00	CGWB
28	Bamunigaon-EW			91.258	25.992	TW	87.85	81.00	CGWB
29	Dhupguri (Sukunia)-EW			92.119	26.108	TW	92.70	89.00	CGWB
30	Gohalkona-EW			91.224	25.896	TW	53.10	53.00	CGWB
31	Dakhin Sakhedari-EW			91.525	26.091	TW	92.35	81.00	CGWB
32	Agchia (Palasbari)-EW		78/N/12	91.649	26.213	TW	194.45	90.00	CGWB
33	Panitema-EW			91.165	26.293	TW	200.00	181.70	CGWB
34	Raipara-EW			91.230	25.997	TW	80.15	80.00	CGWB
35	Bar Tezpur-EW			91.436	26.084	TW	100.00	94.00	CGWB
36	Ranikhamar EW			91.37061	25.85317	BH	119.74	31.1	CGWB
37	Rajapara EW			91.44478	25.87261	BH	180.6	84	CGWB
38	Lachitnagar(Mirza) EW			92.53341	26.07794	BH	136.4	19	CGWB
39	Garopara EW			91.50849	25.97661	BH	171.1	66	CGWB
40	Lampara			91.2825	26.00163	BH	99.05		CGWB

CHAPTER 3.0

Data Interpretation, Integration and Aquifer Mapping

3.1 Data Interpretation

3.1.1 Geophysics and aquifer Characterization:

The surface geophysical study was carried out during the AAP 2011-2012 in the south bank of Kamrup district. Based on the analysis of interpreted data of geophysical studies it is confirm that the study area consist of two broad hydrogeological unit viz., Pre Cambrian consolidated formation (resistivity ranging from 250 to 450 Ωm in the study area) and Quaternary formation consisting of intercalation of unconsolidated sediments of sand and clay resistivity ranging from 21 to 231 Ωm in the study area.

Based on the geological unit two aquifer systems are identified one being the younger alluvium (Quaternary) and the other is banded gneissic complex (BG 01). Pre Cambrian consolidated rocks are confined to hilly areas and inselbergs (south of NH-37 to Meghalaya). In deeper depths, the joints and fractures developed due to tectonic activities.

In alluvial plain (North of NH-37 to the river Brahmaputra) ground water occurs in regionally extensive aquifers down to depth of 305m. The aquifers are consisting of sands of various grades with gravel.

3.1.1a Soil infiltration Test

Infiltration is important in view of ground water recharge, transportation of ground water contamination, irrigation and ecosystem viability. Ten soil infiltration tests were carried out to determine soil type in Kamrup District at Chamaria, Lachitpur, Alegjari, Sontali, Palashbari, Abhayapuri, Bhalukjuli, Sarpara, Rajapara and Garopara village.

Basic infiltration factor for various soil type are

Soil type	Basic infiltration factor (mm/hour)
Sand	less than 30
Sandy Loam	20 - 30
Loam	10 - 20
Clay Loam	5 - 10
Clay	1 - 5

The infiltration rate in the study area ranges from a minimum of 3.16mm/hr to 15.38 mm/hr. Three types of soil were found in the district namely, clay, Loam and Clay loam (Table 3.1).

Table 3.1: Infiltration rate of at different locations of Kamrup District, Assam

SI No	Location	Latitude	Longitude	Infiltration Rate (mm/hour)	Infiltration factor	Soil Type
1	Chamaria	26°03′58″	91°10′11″	16	9.97	Clay Loam
2	Lachitpur	26°11'11"	91°38'56"	21	5.91	Clay Loam
3	Alegjari	26°02'10"	91°11’37”	12	4.59	Clay Loam
4	Sontali	26°08'47"	91°06'24"	27	7.3	Clay Loam

SI No	Location	Latitude	Longitude	Infiltration Rate (mm/hour)	Infiltration factor	Soil Type
5	Palashbari	26°7' 46"	91°34'16"	09	3.16	Clay
6	Abhayapuri	26°12'42"	91°42'28"	09	3.28	Clay
7	Bhalukjuli	26˚01′15″	90˚56′42″	17	15.38	Loam
8	Sarpara	26˚01′03″	90˚49′52″	36	11.25	Loam
9	Rajapara	25°52'21"	91°26'40"	30	5.718	Clay Loam
10	Garopra	25°58'35"	91°30'30"	1	04	Clay

Percentage of sand, silt and clay determines the infiltration of rainfall into ground. Infiltration in Clay rich soils depends on moisture content and compaction. If clayey rich soils dry it develops cracks due to shrinkage and acts as conduit for water to move. When the clayey soil is moist, the cracks are closed and porosity thus created is diminished.

Loam soil is composed of sand, silt and small amount of clay in 40:40:20 ration respectively. Loams can retain water while still allowing excess water to drain away. This type of soil is very ideal for agricultural as it can retain nutrients as well.

3.1.1b Data Integration

Central Ground Water Board, North Eastern Region, Guwahati has drilled 35 exploratory wells in the district. Public Health Engineering Department has also drilled number of wells in the area. During aquifer mapping, in the district five exploratory wells were drilled down to the depth of 180m through DTH Rig. The litholog of all the exploratory wells are used to identify the major aquifer in the district. The lithologs of all the exploratory wells are dominated by grey colour sand and discontinuous grey colour clay bands with gravel which indicate deposition in riverine environment. The principal alluvial aquifer is further categorized as younger alluvium. There is another aquifer present in the district is weaker zones of granite gneiss and schist.

3.1.1c Aquifer Disposition

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

2D disposition: Six sections are constructed to visualize the aquifer disposition

(a) a north east - south west section from Rajapara to Borjhar in the hardrock-alluvial formation parallel to the River Brahmaputra (Fig. 3.1)

(b) an east - west section from Chamaria to Garigaon in the alluvial formation parallel to River Brahmaputra(Fig. 3.2)

(c) a north west to south east section from Jambari to Garopara, i.e., Perpendicular to flood plain (Fig. 3.3).

(d) a section in the North Eastern Border of the district from Rangia to Dumnichoki in alluvial formation (Fig. 3.4).

(e) A section in the hard rock formation of the district in its Southern boundary from Ranikhamar to Lachitnagar (Fid 3.5).

Rajapara to Borjhar :

Banded gneissic aquifer is comprised of weathered and un-weathered portions. Fractures are encountered at Gneissic rocks at 97 to 103m in Garopara EW having discharge of 7.66m^3/hr and two fractures are observed at Rajapara EW; first one from 98.3m to 113.5m and the second one from 122.7m to 180.6m. Both the fractures give a cumulative discharge of 7.66m^3/hr. Weathered portion also acts as an unconfined aquifer which can be developed with the help of dug wells.

Presence of thick layers of sand and clay in the alluvial portion towards the Brahmaputra River is prominent. The clay layers acts as confining layer for the sand.

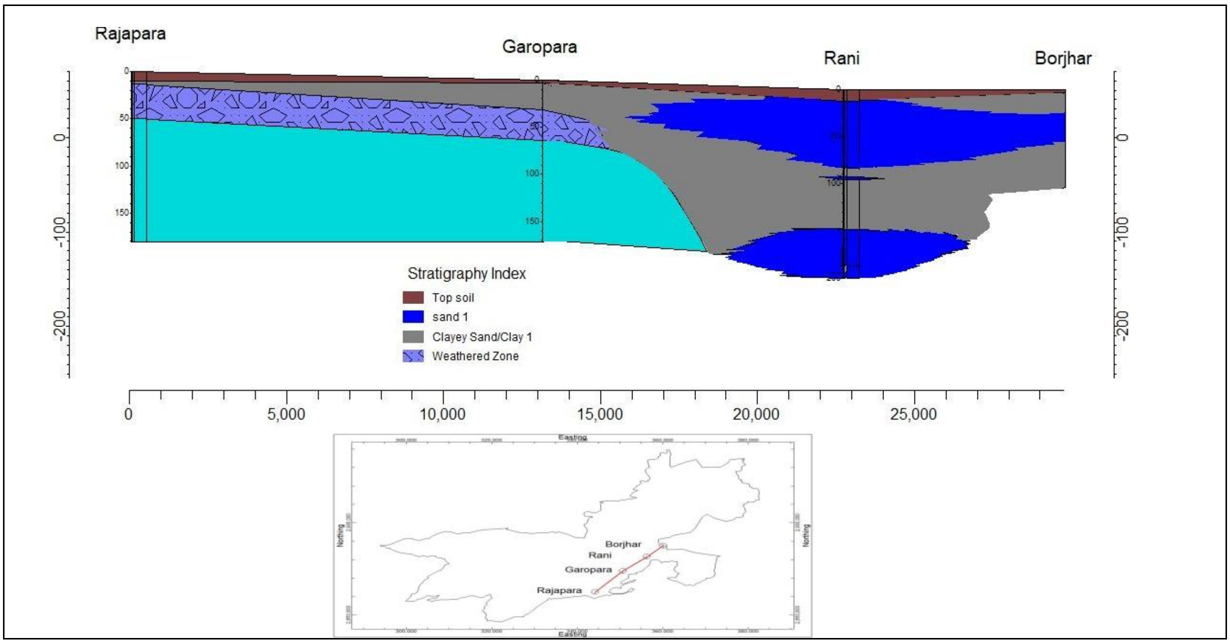

Figure 3.1: North East - South West Section showing aquifer disposition along southern border of the district.

The first Sand layer starts immediately after top soil at 12m depth and continues upto 90m. This layer has a discharge of 27m^3/hr the layer quite extensive and it reaches till Borjhar EW.

The clay layer at 90m is nearly 71m thick and it acts as lower confining layer for the first sand layer and lower confining layer for the second sand layer.

The second sand layer occurs at depth of 150m and it has a discharge of 38m^3/hr.

Chamaria to Garigaon :

This E-W section along the River Brahmaputra shows presence of younger alluvial aquifer down to a depth of 200m. The first sand layer is observed throughout the section but its thickness is not consistent decreases from nearly 90 m in Agchia to nearly 10m in Chamaria in West and in Borjhar in East. Apart from this sand layer, a second layer of sand layer nearly of 10m thickness is consistently found at 100n depths (except at Deochar) which will also act as an excellent source of ground water. Discharge of these wells ranges from 17m3/hr to 45.64m^3/hr.

There are numbers of clay layers are observed within the sand layer throughout the section.

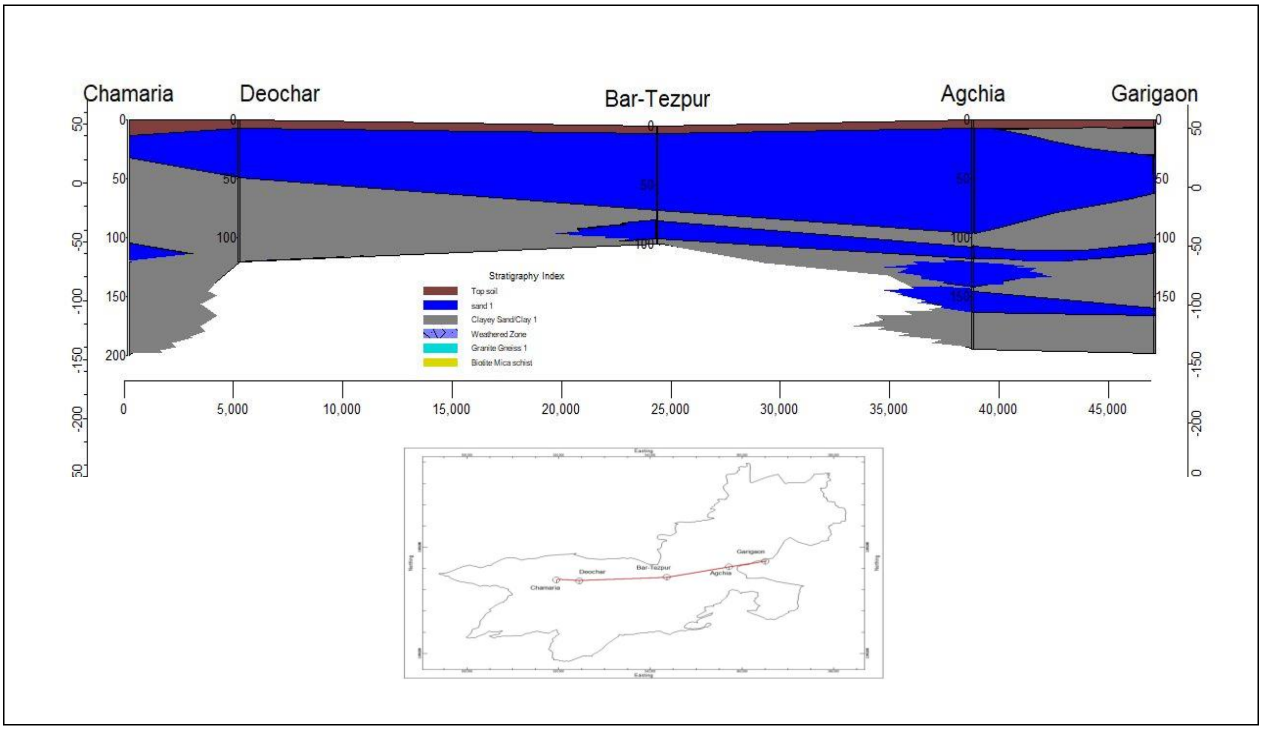

Figure 3.2: Section showing aquifer disposition along central part of the District.

Jambari to Garopara:

Inorder to know about the behavior of litholgical formations as we move from hill to valley, a section was drawn from Garopara to Jambari (Fig. 3.3). The gneissic rock formation dips towards North-West and pinches out just after Badekuchi VES station. Presence of a large clay layers (30 to 100m) is prominent in the section. As usual fracture acts as source of ground water in hardrock and sand layer in the alluvial formations.

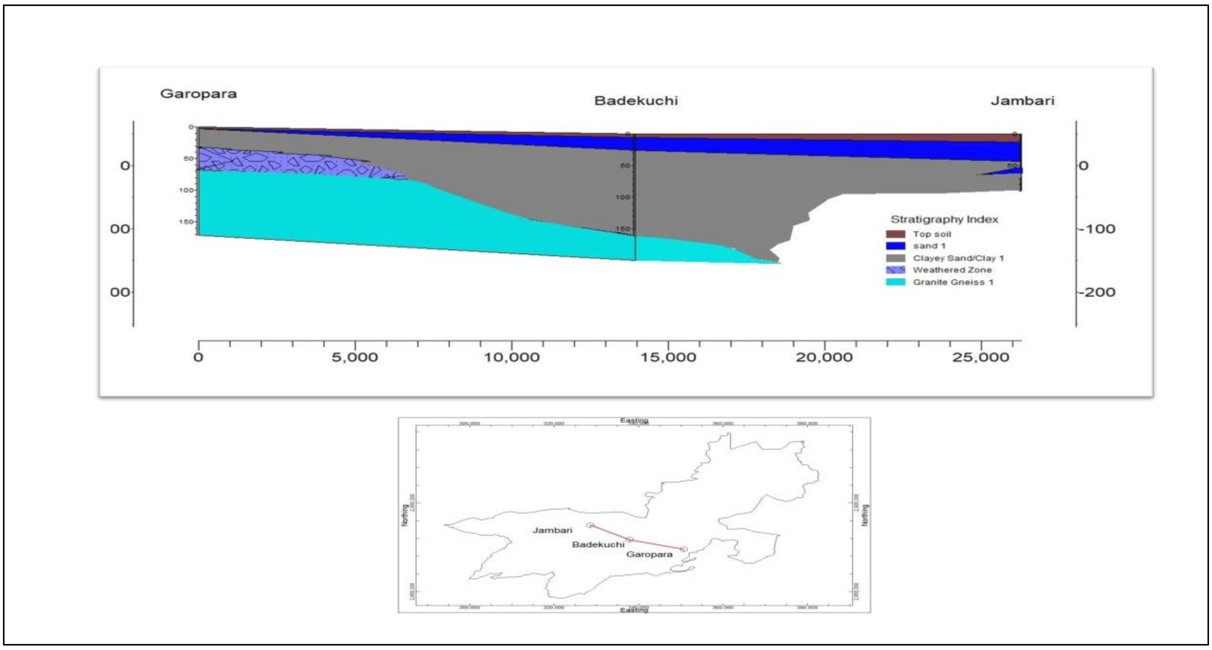

Figure 3.3: Section showing aquifer disposition from hills to flood plain (Brahmaputra river)

Rangia to Dumnichoki:

This section is a representative of the northern bank of the district. Alternate layers of thick sand and clay typical of flood plain is distinctive in the section. This area shows a huge yield of ground water and has a discharge in range from 54.24 m^3/hr to 194.36 m^3/hr.

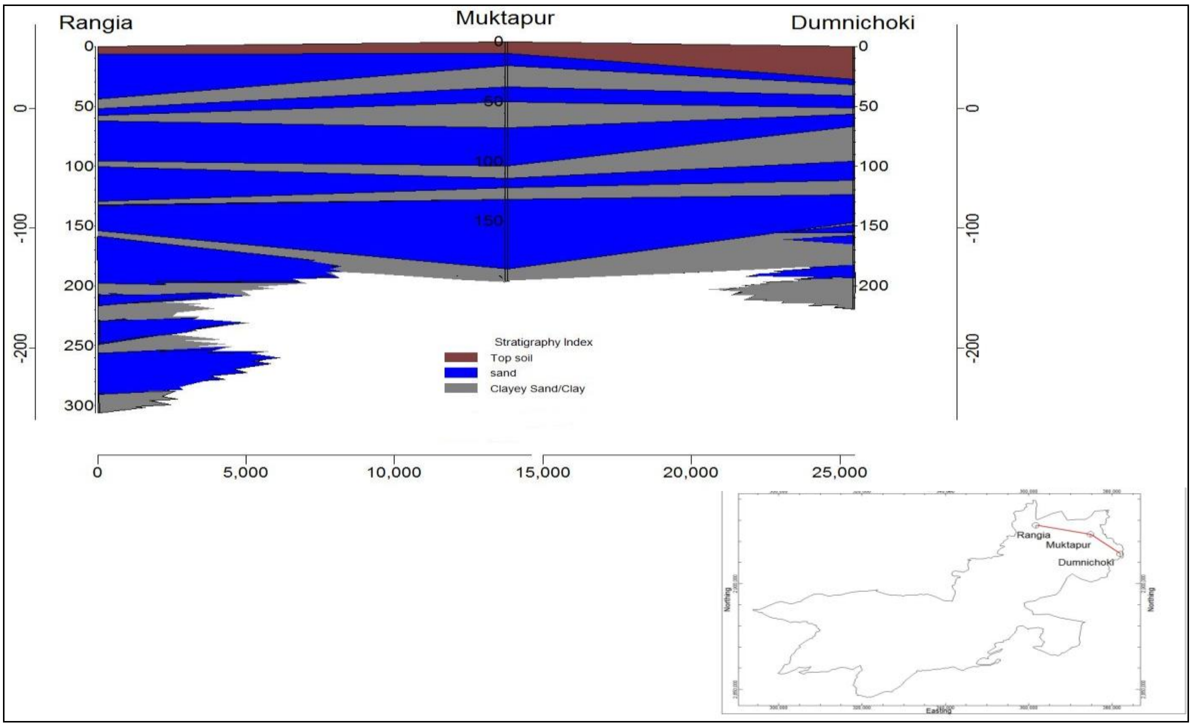

Figure 3.4: Section in the North Eastern Border of the district from Rangia to Dumnichoki in alluvial formation.

Ranikhamar to Lachitnagar:

The consolidated formation of this area consists of Gneissic rock and Mica schist. This section lies at the foothills of Shillong Plateau at Assam-Meghalaya border. Primary source of ground water is fractures encountered at various depths and the shallow weathered zone running consistently along the section.

Discharge of these wells ranges from 10.8m3/hr to 7.66m3/hr. on an average atleast two sets of fractures are encountered at a depth from 40m to 70m and a deeper fracture from 100m to 180m depth.

In Ranikhamar EW, fractures are encountered at 47.2m to 53.3m, 56.4m to 62.5m, 93.0m to 99.1m, 114.0m to 120.4m and from 124.0m to 129.6m depth. In Rajapara EW fracture encountered are at a depth of 98.3m to 113.5m and 122.7m to 180.6m. Lachitnagar EW has a total of 4 fractures respectively at depths of 65.3m to 68.4m, 98.9m to 108.0m, 117.2m to 123.3m and 129.4m to 132.4m.

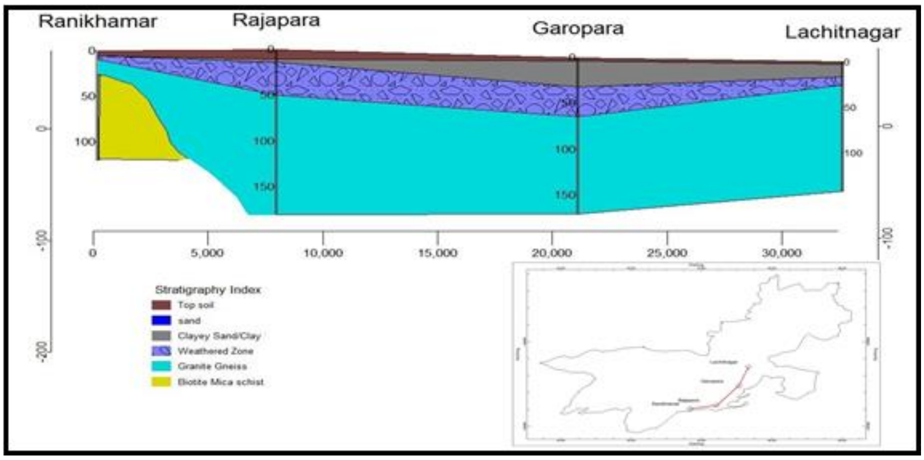

Figure 3.5: A section in the hard rock formation of the district in its Southern boundary from Ranikhamar to Lachitnagar.

3D Disposition of aquifer: The alluvial aquifer is sand dominated and it is evident from the 3D fence diagram.

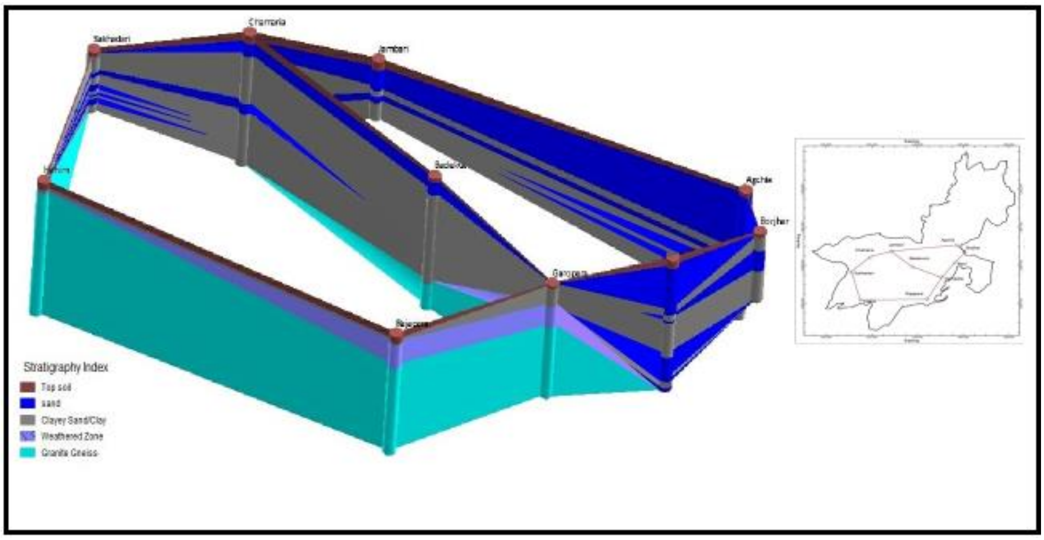

Fig. 3.6: 3D disposition of aquifer in the study area

The banded gneissic aquifer which is encountered at shallow depth in the southern part of the district bordering Meghlaya is dipping NW beneath the flood plain of the Brahmaputra. The sand and clay layers are pinching out towards the southern part of the district. Their lateral continuity is extensive along the flood plains. The top soil layer is generally observed in all the exploratory wells in the district. Presence of clay layers, their extent and their thickness in the central part of the district i.e. close to river Brahmaputra, evident from Agchia and Borjhar EWs, is less compared to the distal part of the district.

3.1.1d Aquifer Characteristics

The younger alluvial aquifer of Kamrup district can be divided into two, viz, shallow and deeper, based on the subsurface geology deciphered from drilling and prevailing ground water conditions.

Shallow aquifers: The water bearing horizons occur within 30-50mbgl is considered to constitute shallow aquifer system. Ground water in this aquifer occurs under unconfined to semi-confined conditions. The aquifer materials comprises of sands. The upper surface of the shallow aquifer is bounded by top soil layer and its thickness is nearly homogenous in the entire district. Clay layer immediately follows the top sand layer and this layer is continuous throughout the study area. Thickness of sand is maximum (100m) towards the Brahmaputra river at agchia and Garigaon. State Government has constructed number of shallow tube wells. Discharge of the shallow tube wells is generally $30m^3$/hr.

Deeper Aquifers: In the deeper aquifers, ground water occurs under semi-confined to confined conditions. The upper confining layer is generally 3 to nearly 50m thick and is not regionally extensive. The aquifer materials are composed of sands of different size grade. In this district, CGWB, NER had explored the subsurface down to the depth of 306m in Rangia area.

Table 3.1: Aquifer parameters:

SN	Location	Depth (m)	Zones tapped up to 50	Zones tapped up to 100 m	Zones tapped up to 200 m	Zones tapped up to 300 m	SWL (mbgl)	Discharge (m^3/hr)	Draw Down (m)	T (m2/ day	Permeability (m/day)	Storativity
1	Dumnichauki-EW	291.45		57-66, 85-91, 98-110	125-143,150-153,159-165		0.60	194.36	8.95	7427.88	137.5533	2.17*10-3
2	Changsari- II-DW	192.90			145-151		0.54	0.173	10.3	4.2		
3	Boko-DW	106.70	20.3-29.3				3.17	10.395	1.75	1354.75	150.5278	
4	Muktapur-EW	183.70	34-37	72-96,	128-146, 158-164		0.34	54.24	2.84	5962.8	116.9176	3.38*10-4
5	Jugipara-EW	189.10	32-38, 44-50	70-82, 87-90			3.67	44.94	1.91	2139	79.22222	3.1*10-3
6	Chaikata-EW	101.90	42-52	57-59, 61-67, 76-85, 90-96			7.025	23.62	11.538	4091	123.9697	
7	Chhaygaon Balapukhuri-EW	201.30		68-80, 86-92, 98-101,	106-112, 117-120, 123-126, 133-145, 151-155		2.12	13.5	2.225	866.25	17.67857	
8	Rani-EW	200.25	46-58	78-81, 83-94, 148-157, 170-182, 194-197			3.50	38.00				
9	Hajo-EW	18.00										

SN	Location	Depth (m)	Zones tapped up to 50	Zones tapped up to 100 m	Zones tapped up to 200 m	Zones tapped up to 300 m	SWL (mbgl)	Discharge (m^3/hr)	Draw Down (m)	T (m2/ day	Permeability (m/day)	Storativity
10	Hajo, Fakirtala-EW	94.00	48-54	60-78			1.14					
11	Rangamati-EW	189.45	39-47,	77-95			4.33	11.82	0.34	2022.7	77.79615	
12	West suailkuchi-EW	92.00		54.5-61.5			4.53	2				
13	Sakhati-EW	181.30		70-76, 80-86,	110-116, 119-125, 140-143		5.92	7.20	2.76	40.9		
14	West Sualkuchi-EW	62.50		54.5-61.5			4.53	1.82				
15	Siddheswar Dewalaya, Suwalkuchi-I &II-EW	113.00			102.1-113		9.53	113.00				
16	IIT complex-Amingaon, EW	187.20		48-60	168-178, 185-188		3.40	9.12	15.66	2.64		
17	Kahikuchi south Colony-EW	169.00	33.3-34.3		110.5-118, 130.5-131.5, 145-146, 164.5-165.5		11.43	28.35	12.91	10.30		
18	Hahim-EW&OW	90.00			128.8-129.3, 137.9-138.5,	231-231.2	5.82	46.00				

SN	Location	Depth (m)	Zones tapped up to 50	Zones tapped up to 100 m	Zones tapped up to 200 m	Zones tapped up to 300 m	SWL (mbgl)	Discharge (m^3/hr)	Draw Down (m)	T (m2/ day	Permeability (m/day)	Storativity
					185.9-186.4,							
19	Rangia College-EW	306.69	30-42	65-71, 79-85,	101-107, 120-16, 135-154		0.92	150.0	4.28	89.3		
20	Deochar-EW	120.00	37-49				3.5	33.15	4.12	124.42		
21	Agchia-EW	194.30	45-51	75-87			2.76	45.64	6.00	572		
22	Chamaria-EW	200.00		105-120			5.18	37.92	3.59	808.62	161.724	
23	Palashbari-EW	104.00	45-51	75-87			4	30.63054				
24	Borjhar-EW	104.10	42-54				3.78	27.00				
25	Sarpara-EW	251.30			128.8-129.3, 137.9-138.5, 185.9-186.4,	231-232.5	6.24	3.00				
26	Madanpur-EW	196.00		112-124								
27	Jambari-EW	89.55	34-43, 55-61				1.60	29.52				
28	Bamunigaon-EW	87.85	32-44	53-57, 73-77			1.64	29.52				
29	Dhupguri (Sukunia)-EW	92.70	46-49	67-76			8.00	23.00				
30	Gohalkona-EW	53.10	32-41, 44-50				2.10	23.00				
31	Dakhin	92.35	33-37	52-58,			12.00	26.00				

SN	Location	Depth (m)	Zones tapped up to 50	Zones tapped up to 100 m	Zones tapped up to 200 m	Zones tapped up to 300 m	SWL (mbgl)	Discharge (m^3/hr)	Draw Down (m)	T (m2/ day	Permeability (m/day)	Storativity
	Sakhedari-EW			72-78								
32	Agchia (Palasbari)-EW	194.45	45-51	75-87			2.76	111.0	6.00	227.9		2.21*10-4
33	Panitema-EW	200.00		90-96,	14-151, 166-178		3.61	46.35				
34	Raipara-EW	80.15	47-53	65-77								
35	Bar Tezpur-EW	100.00	42-51	63-72, 82-91			4.03	17				
36	Ranikhamar EW	119.74	34.1-43.3	52.4-64.6			4.44	10.8	4.66	56.28		
37	Rajapara EW	180.6		93.2-95.20	98.3-101.3, 134.9-137.9, 162.3-168.4,		10.53	11.16	6.38	21.449		
38	Lachitnagar(Mirza) EW	136.4	43.6-46.6, 132.3-136.4				7.38	9.576	5.31	28.49		
39	Garopara EW	171.1	97.6-100.70 (Fract)				5.46	7.66	29.94	5.09		
40	Lampara	99.05	-	-	-	-	-	-	-	-		Abandoned

3.1.2 Ground water level

To study ground water regime, depth to water level from 43 monitoring stations (Ground Water Monitoring Stations 12, new Key well established 31) were measured seasonally durig the months on August 2020, November 2020, January 2021 and March 2021. Variation in water level can be discussed as below.

During Pre-Monsoon i.e. on March 2021, only two key wells (about 5.7%) show depth-to-water level of less than 2m bgl, 88.57% wells i.e. 25 key wells show water level in the range from 2 to 5 mbgl and 22.85% (around 8) key wells have water level above 5 mbgl. Minimum water level of 1.33mbgl at Hajo and maximum water level recorded is 11.85mbgl at Agchia (Fig. 3.5)

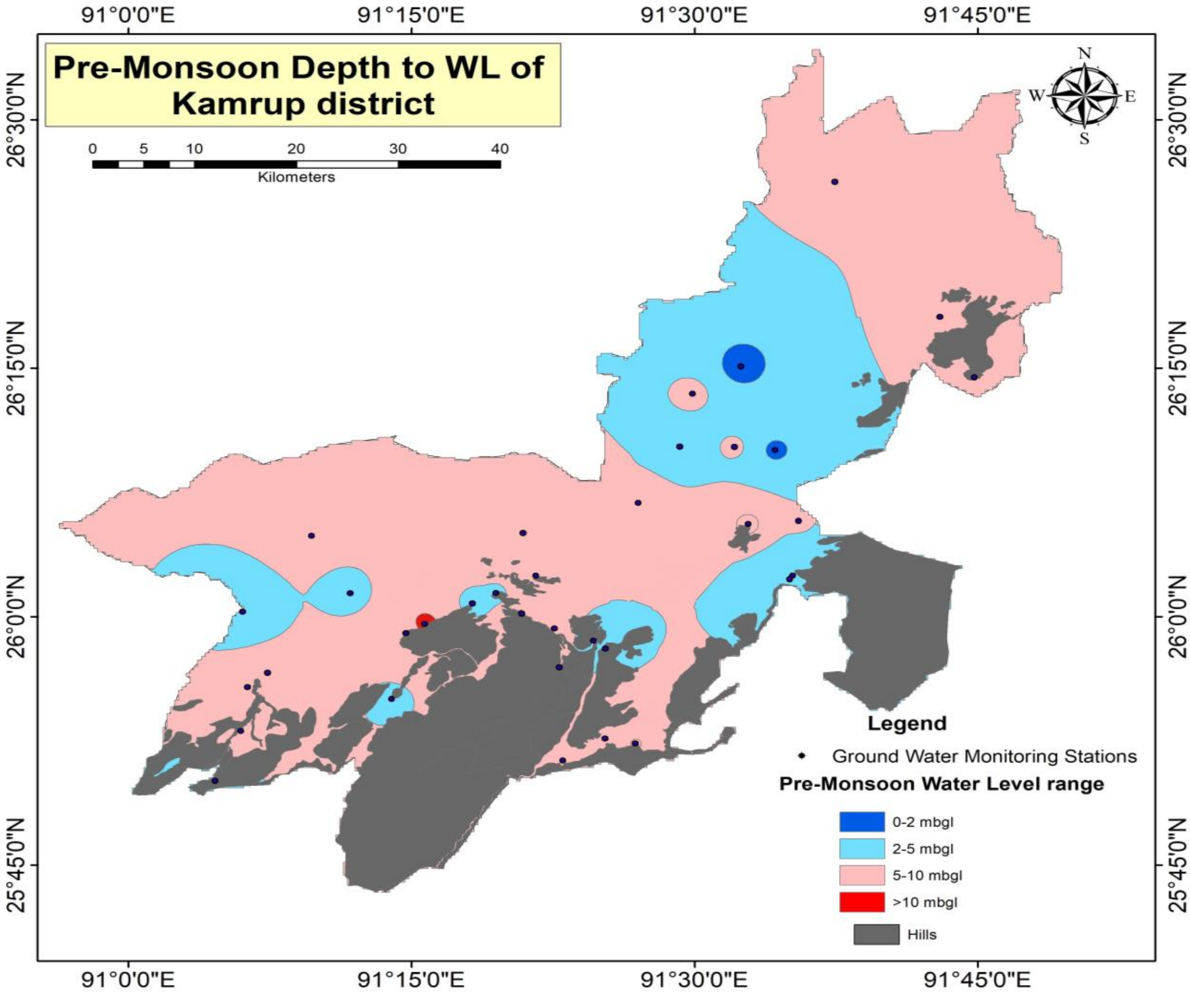

Fig. 3.5: Pre-monsoon DTW level contour of Kamrup district, Assam

Post-monsoon water level data of Kamrup district ranges from a minimum of 0.31m bgl at Hajo to maximum 7.28m bgl at Rajapara. The overall post monsoon water level of the district is shallow. About 45% well (18 numbers) shows water level less than 2mbgl, 52.5% (21) wells record water level of 2 to 5 mbgl and only in key well water level is above 5mbgl. (Fig. 3.6).

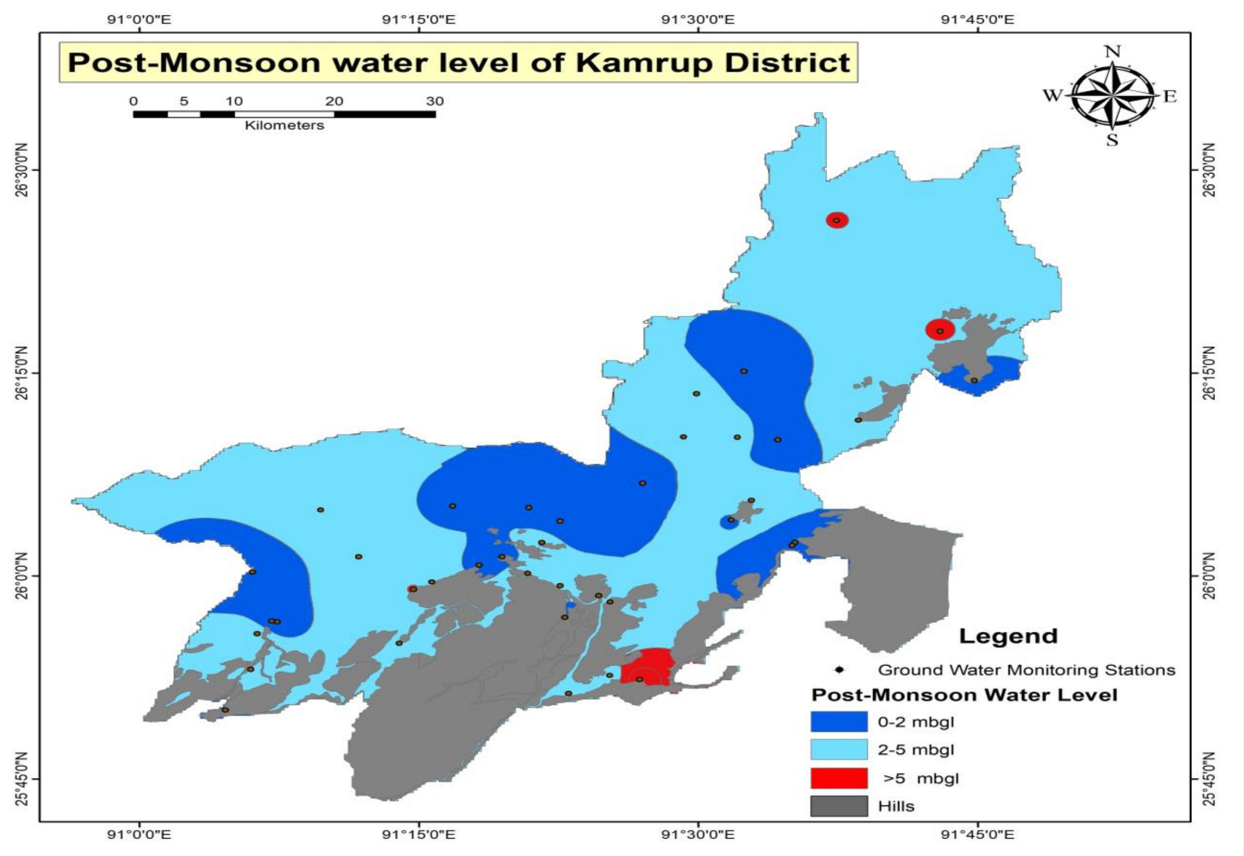

Fig. 3.6: Post-monsoon DTW contour of the study area

Fluctuation of water level in pre and post monsoon water level, difference ranges from 0.0 to 2.0 m in 65.7% (23 wells) of the key wells, 2.0 to 4.0 m in 31.4% (11) wells and only in one well (Agchia) water level fluctuation above 4 m is observed in the monitored wells of the district. Minimum fluctuation of 0.42m and maximum of 8.38m is recorded in Rangia and Agchia respectively. (Fig. 3.7)

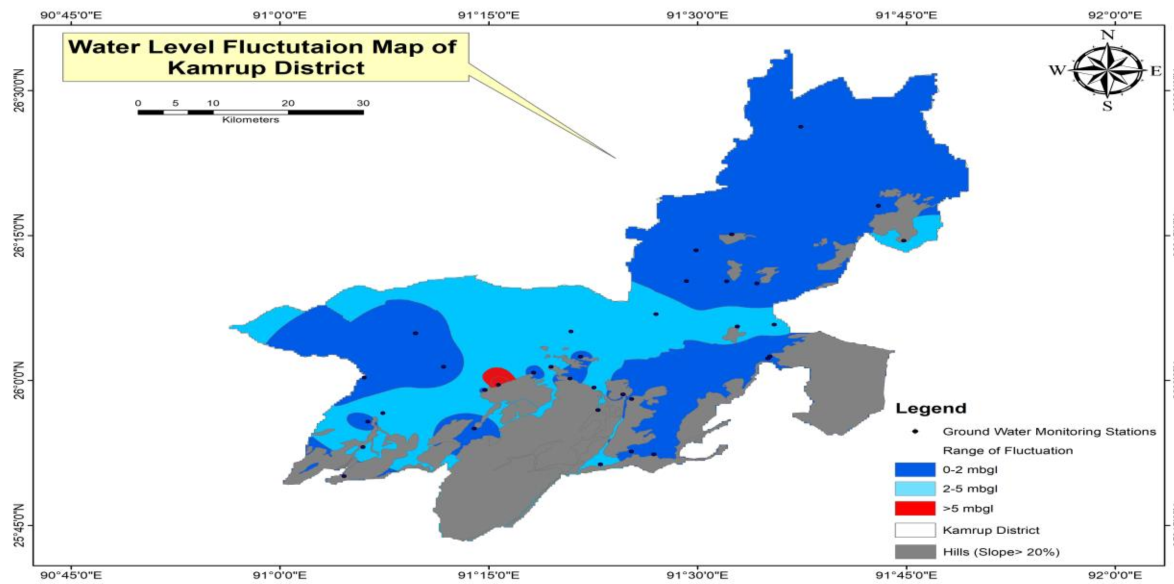

Fig. 3.7: Water Level Fluctuation map of the study area

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 northwestern side to towards the Brahmaputra river in the south eastern side. The highest water table is 80 m above mean sea level.

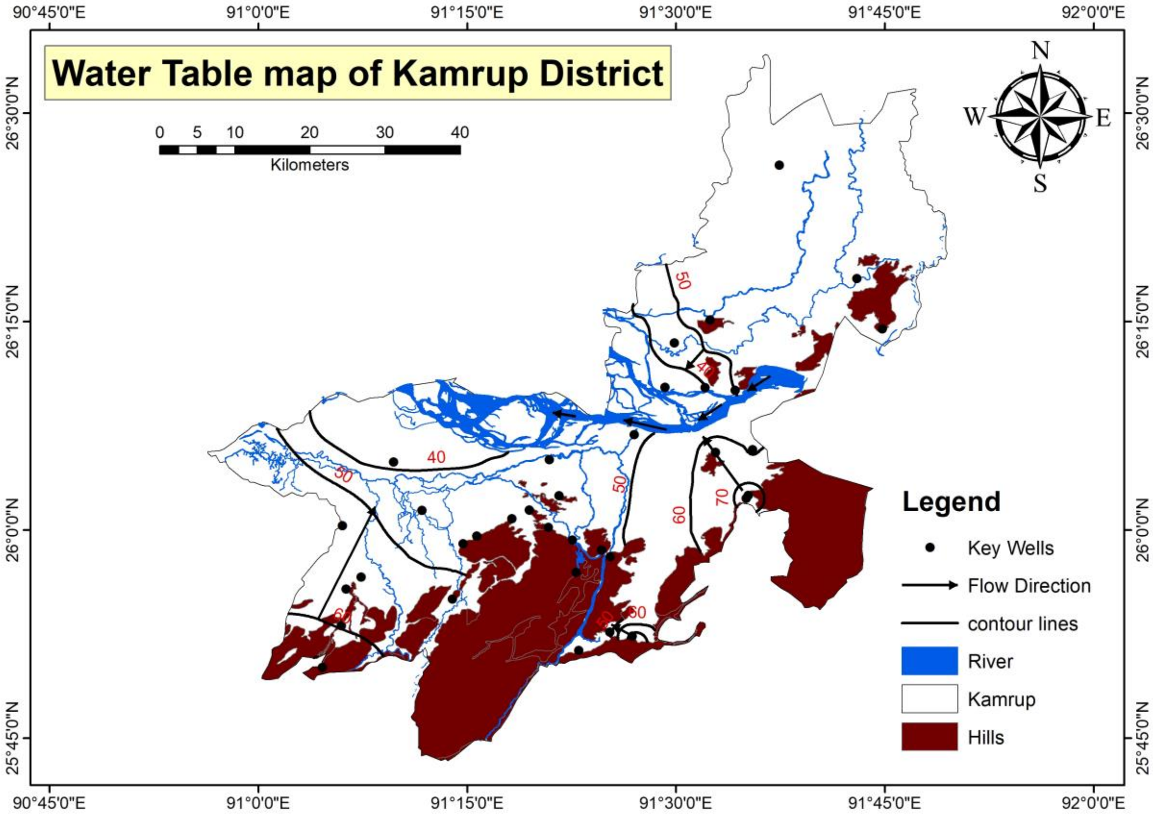

Fig. 3.8: Water table contour of the study area

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 and Table 3.2 shows the overall trend of water levels in GWMS wells.

Table 3.2 Trend of Water levels in GWMS Wells

SN	Locality/Name	No. of years	Water Level Trend	
			Post-monsoon	Pre-monsoon
1	Dirgheswari	10	Rise	Fall
2	Agyathuri	10	Rise	Rise
3	Chhaygaon	10	Rise	Rise
4	Bamunigaon	10	Rise	Fall
5	Dora Kahara	8	Fall	Fall
6	Hajo	10	Rise	Rise
7	Mirza	8	Rise	Rise
8	Sualkuchi	10	Rise	Rise

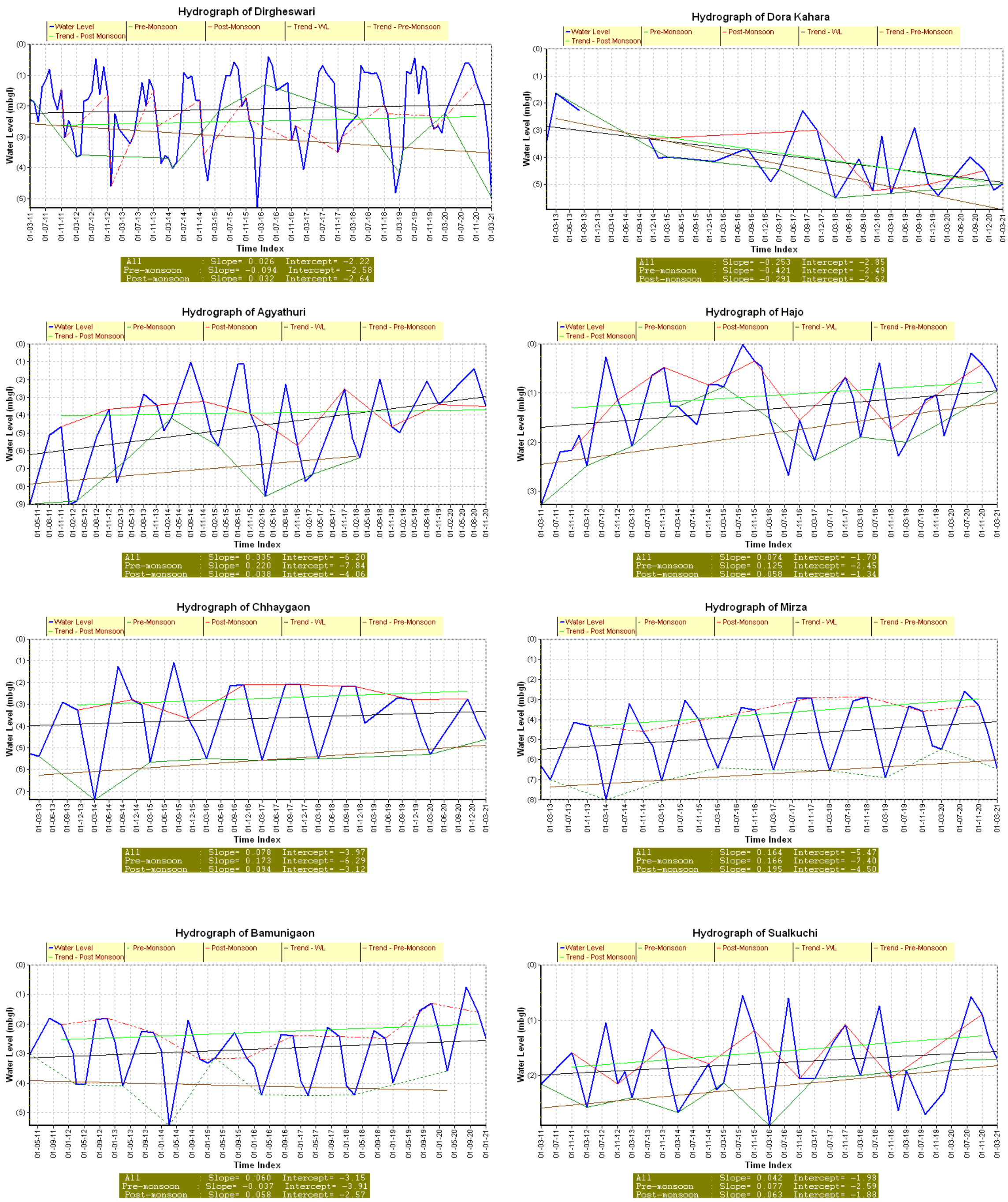

Fig.3.9: Hydrograph of GWMS wells

3.1.5 Ground water quality

Chemical analysis of ground water samples are carried out by regional chemical laboratory of Central Ground Water Board, North Eastern Region, Guwahati.

Both in pre and post monsoon period 35 samples were collected and submitted to regional chemical laboratory, Guwahati for analysis. Most of the chemical constituents are within permissible limit except in few locations. The summarized results are given below. Table -3.3

Table 3.3. Post monsoon Chemical Quality of Kamrup district

Parameter	Unit	Post Monsoon		Pre Monsoon	
		Range	Place	Range	Place
pH		6.05-8.19		6.62-8.848	
EC (µs/cm) 25C		30.34- 1702	Sualkuchi area EC is high 1368 -1702	34.41-1655	Sualkuchi area EC is high 1207 - 1655
Turbidity (NTU)		BDL-0.40		BDL-0.20	
TDS	mg/L	15.51 - 880.8	Sualkuchi area TDS is high 713 -880.8	18.08-870.9	Sualkuchi area TDS is high 636.1-870.9
CO3-2		BDL		BDL-18.0	
HCO3-1		24.42 -744		18.31-488.39	
Cl-		7.09 - 145.35		17.725-209.155	
SO4-2		4.34 - 62.92		2.22- 212.6	
NO3-1		0.42 - 8.02		0.165- 10.76	
F-		0.05 -0.56		0.33- 1.7	Gumi 1.6, Dirgheswari 1.7
Ca+2		4 -76.06		4.0- 110.0	
Mg+2		1.19 - 69.14		2.42-50.93	
TH (as CaCO3)		25 - 475		20-385	
Na		1.74 - 100		3.89-95.87	
K		0.63 - 230.78		1.43-181.46	
Fe		0.29- 2.95	Natun Jarabari, Saikata, Damalchos, Agyathuri, Boko, Bamunigaon, Gumi, Dorakohra, Rajapara, Chhay gaon, Hatipara, Mirza, Maniori Tinali Fe is more than permissible limit.	0.197-2.311	Mirza, Gangrapara, Kulshi, Boko, Rajapara (Chandubi), Bamunigaon, Hatipara, Bullarpar (Bhuban Nagar), Gumi, Chaikata, Hatigarh, Dora Kahara and Agchia Fe is more than permissible limit.
As		0.08-4.16			Result awaited

Pre-monsoon pH value ranges from 6.62 at Dimakhuli to 8.845 at Kulshi and in the post-monsoon pH value ranges from 6.05 at Malini Than to 8.19 at Simina indicating wide variation in pH which shows that pH value is well within BIS limit.

Pre-monsoon iron concentration ranges from 0.19mg/L at Dimakhuli to 2.311mg/l at Agchia. Locations such as Mirza, Gangrapara, Kulshi, Boko, Rajapara (Chandubi), Bamunigaon, Hatipara, Bullarpar (Bhuban Nagar), Gumi, Chaikata, Hatigarh, Dora Kahara and Agchia shows iron concentration more than BIS permissible limit of 1mg/L. In post monsoon water samples iron concentration is ranges from 0.299mg/L in Agchia to 2.953mg/l in Rajapara (Chandubi) Key well. In general most of the samples i.e. around 62.85% of samples, have Iron concentration is within permissible limit. Locations such as Natun Jarabari, Chaikata, Borjhar Chouk, Damalchos, Agyathuri, Boko, Bamunigaon, Gumi, Dora Kahara, Hatipara, Mirza, Chhaygaon, Maniori Tinali and Rajapara (Chandubi) show iron concentration more than 1mg/L. In pre monsoon samples also 62.85% of key wells show iron concentration within permissible limit.

Fluoride in high concentration in water can cause skeletal and/or dental fluorosis which can damage bones and joints. Fluoride above 1.5mg/L is not permissible in drinking water. In Kamrup district during pre-monsson, only in two locations high concentration of Fluoride was found. In Gumi Key well fluoride was 1.6mg/L and in Dirgheswari, it was 1.7mg/L. in Post monsoon samples, fluoride concentration is within permissible limit in all the samples.

Electrical conductivity of all the samples is within BIS permissible limit of 1000μS/cm except in Sualkuchi area. Samples from Rangia (829μS/cm) in pre-monsoon and Howli (934μS/cm) in post monsoon, also marginal high value of electrical conductivity.

For remaining parameters such as Ca, Mg, Cl, SO_4, TDS and hardness as $CaCO_3$, it is observed that both in pre and post-monsoon groundwater samples, are within permissible limit. So ground water of Kamrup district is potable for other constituent except iron and fluoride. **Annexure-1**(Table 1d) and shown in the Fig 3.10a and 3.10b.

Arsenic in groundwater:

During aquifer mapping pre and post monsoon ground water samples were collected and submitted in NABL accredited Regional Chemical Laboratory of Central Ground water Board, Guwahati. Both Pre- and Post-monsoon arsenic concentration is within permissible limit.

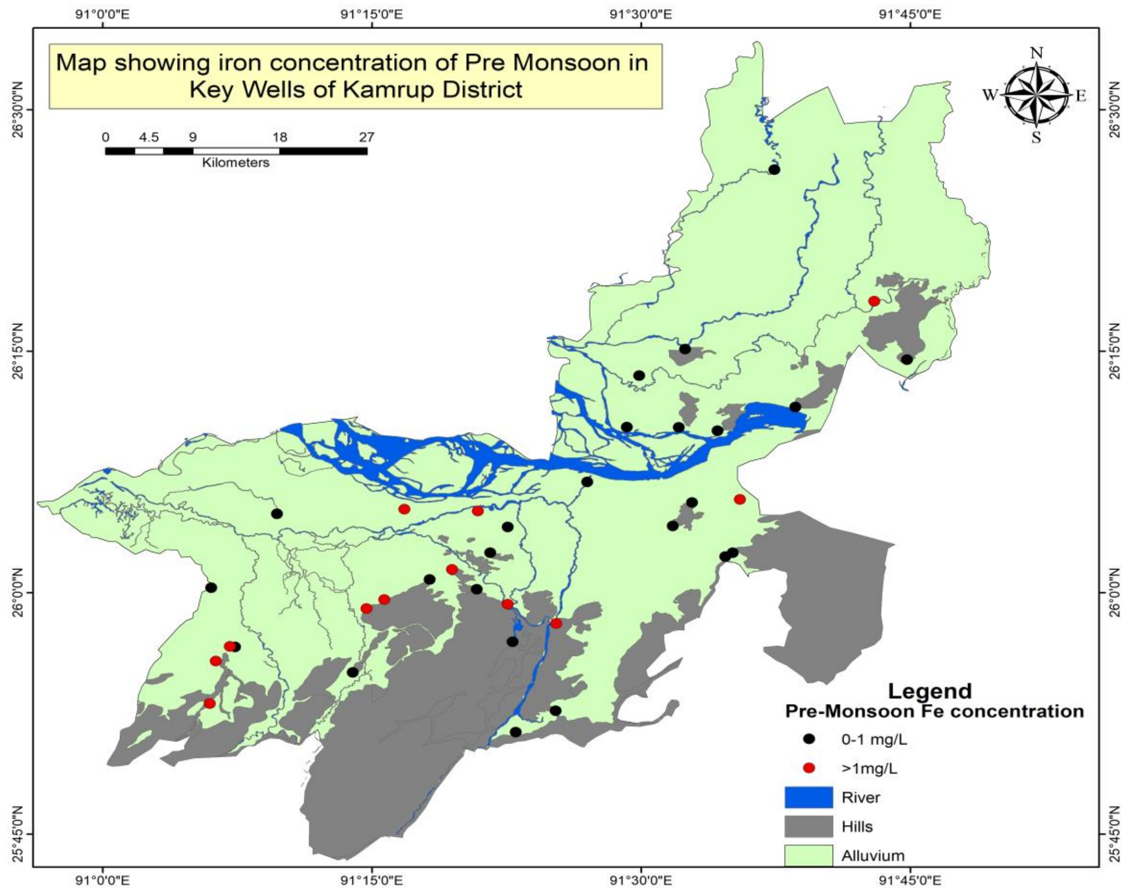

Fig. 3.10 a : Pre monsoon Iron Concentration map of Kamrup District

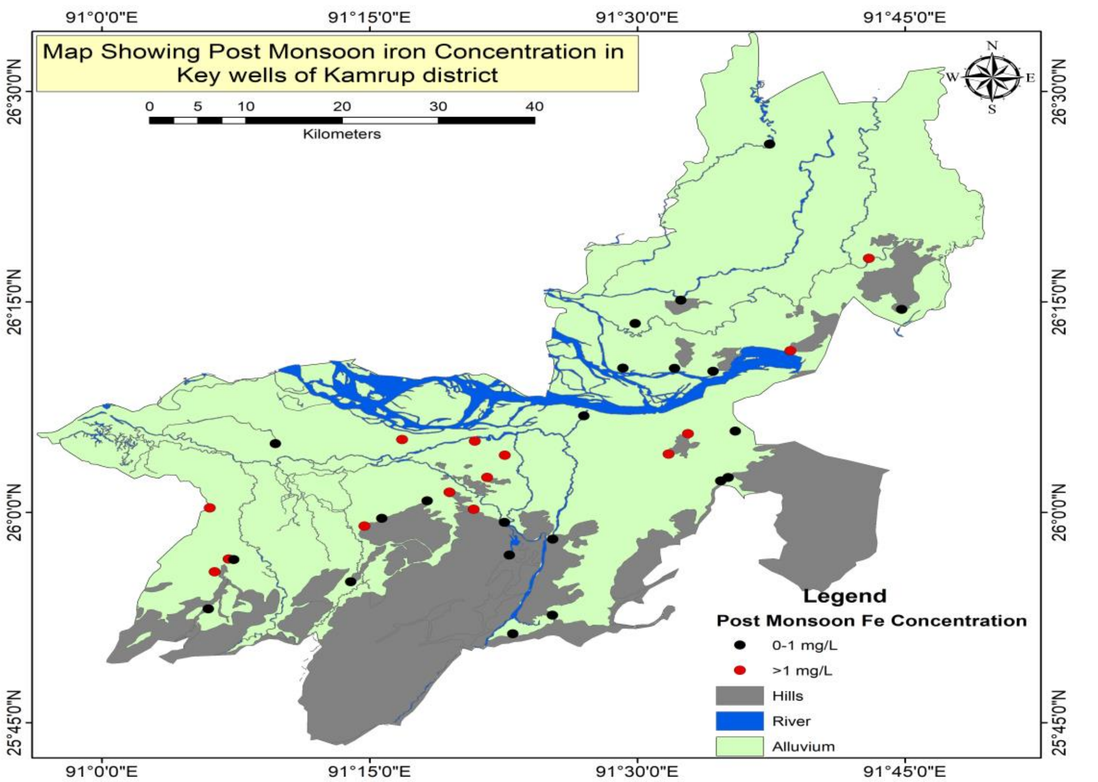

Fig. 3.10 b : Post monsoon Iron Concentration map of Kamrup District

Concentration range of different chemical elements in ground water during pre- and post monsoon in the study area is given in **Annexure-1**(Table 1 a, b)

3.1.6 Ground Water Quality for Irrigation:

A total of 35 samples were collected and analysed in Pre-monsoon (March2021) and Post Monsoon (November 2020) from dugwells covering the entire district of Kamrup. To check for suitability of water for irrigation purpose following indices are analysed, namely

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

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

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, 35 samples from dugwells analysed for both Pre-monsoon and Post-monsoon (Fig 3.1.6a) shows that all the samples are within 10meq/L. Hence the water quality is excellent for irrigation with no risk at all.

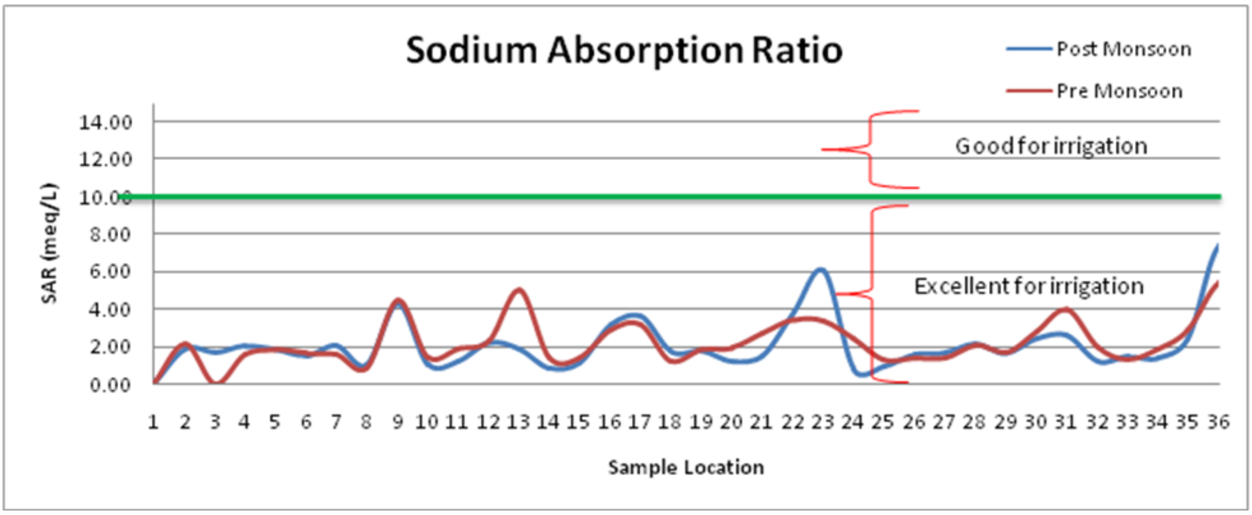

Fig 3.1.6a: Sodium Absorption Ratio.

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

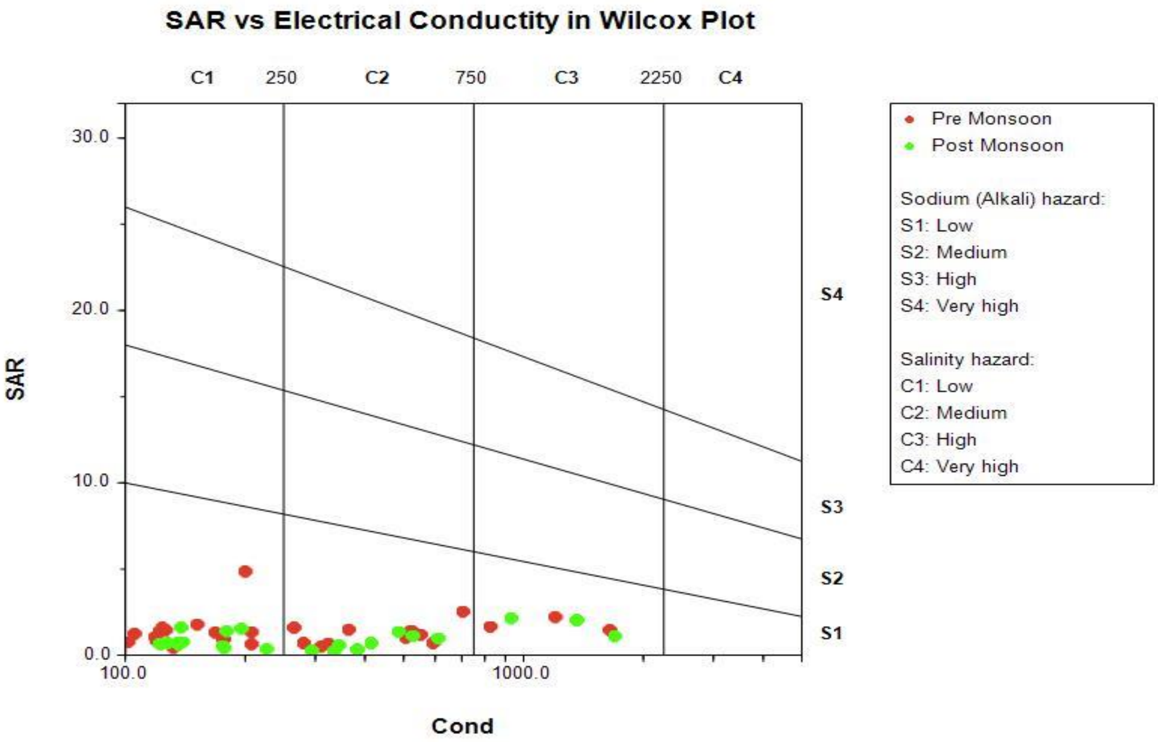

Fig 6.4.1b: Wilcox Plot

From the Wilcox plot it is very clear that Sodium Alkali Hazard is low (below S1 line) for all the samples in both Pre-Monsoon and Post Monsoon. In terms of salinity hazard, except three samples from Rangia, Sualkuchi and Nartun Jarabari, all the remaining ones are within low to medium risk (within C1 and C3 line). There is no case of very high salinity hazard in the area.

3.1.6b Magnesium Hazard (MH)

This gives us an idea about the Magnesium content in respect to total divalent cations in irrigation water. Excess of magnesium can cause serious health hazards. Thus, Mg:Ca below 50% is considered suitable for irrigation. (The ion concentrations are in meq/L)

$$MH\% = \frac{Mg^{2+}}{(Ca^{2+} + Mg^{2+})} * 100$$

Fig 3.1.6b shows that except few, most samples of both Pre-Monsoon and Post Monsoon show MH % less than 50. If we look at the Pre monsoon curve, location of Bamunigaon, Bullarpur and Chandubi show MH% is more than 50 but their Post Monsoon counterpart is <50. On contrary, Post monsoon MH% of Dhupguri, Dora Kohora, Kulshi and Mirza are above 50% and their pre monsoon MH% is less than 50. Hence it can be said that overall water of study area is suitable for irrigation.

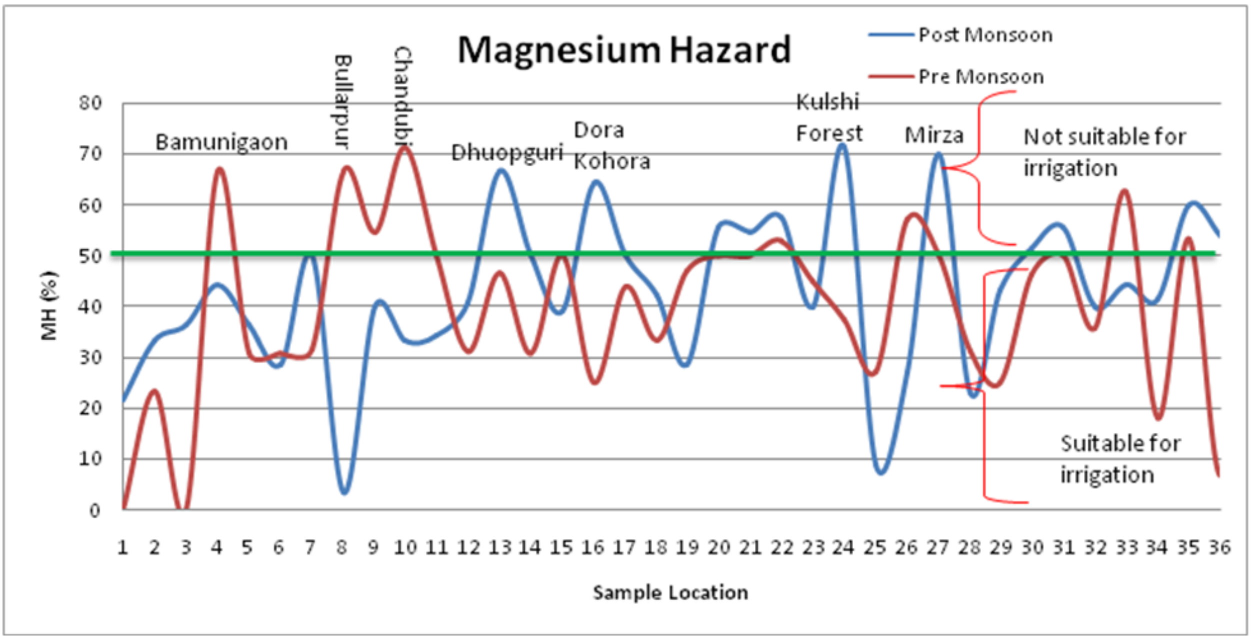

Fig 3.1.6b: Magnesium Hazard

3.1.6c 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. Hence the area safe from any residual sodium carbonate hazard and is suitable for irrigation.

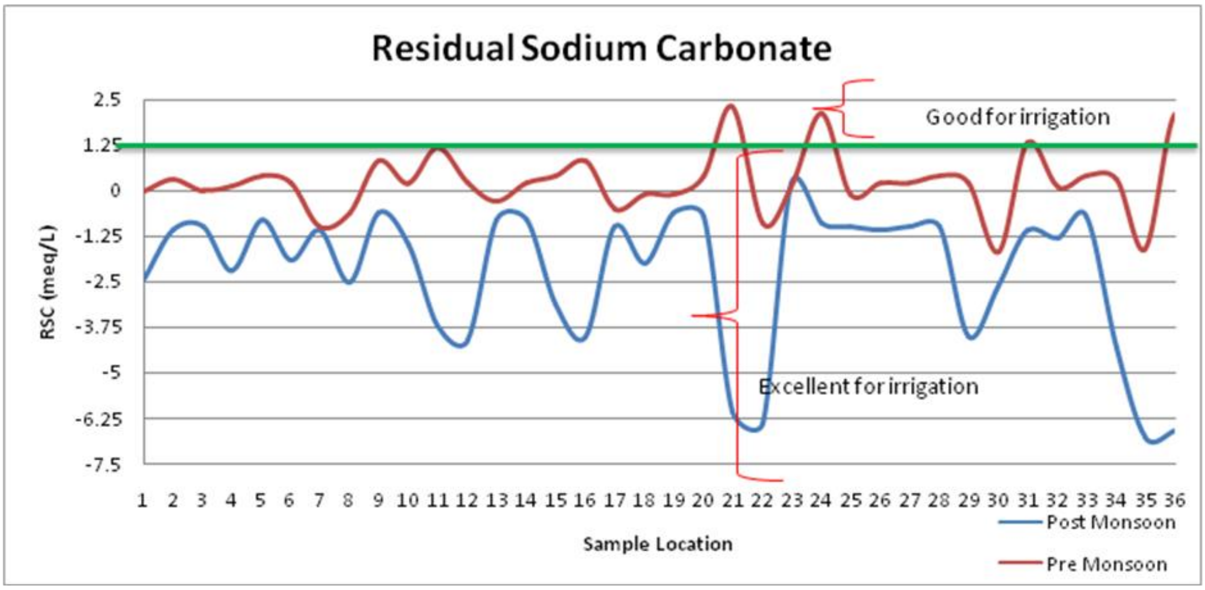

Fig 3.1.6c: Residual Sodium Carbonate

3.1.6d Sodium Percentage (Na%):

It is 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, samples from Dhupguri, Dirgheswari, Hatipara and Malini Than during Pre Monsoon show Na% between 60 to 80 i.e. in “doubtful” category. But Post Monsoon data shows these samples to be in “Good” category. Hence the study area can be considered suitable for irrigation.

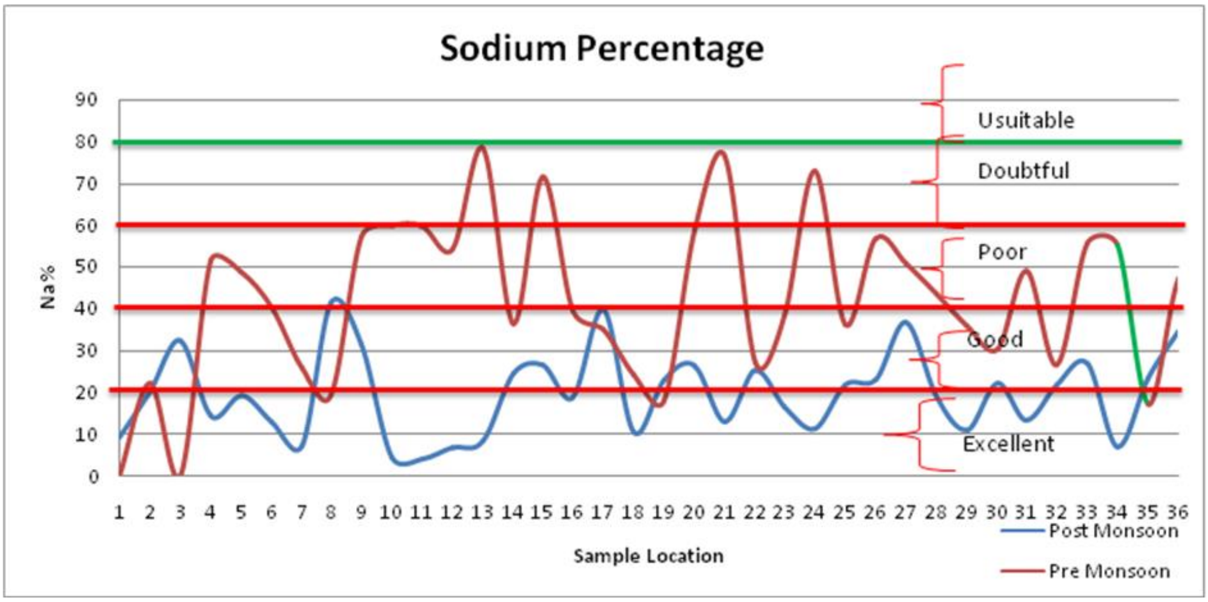

Fig 3.1.6d: Sodium Percentage

3.1.6e 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.

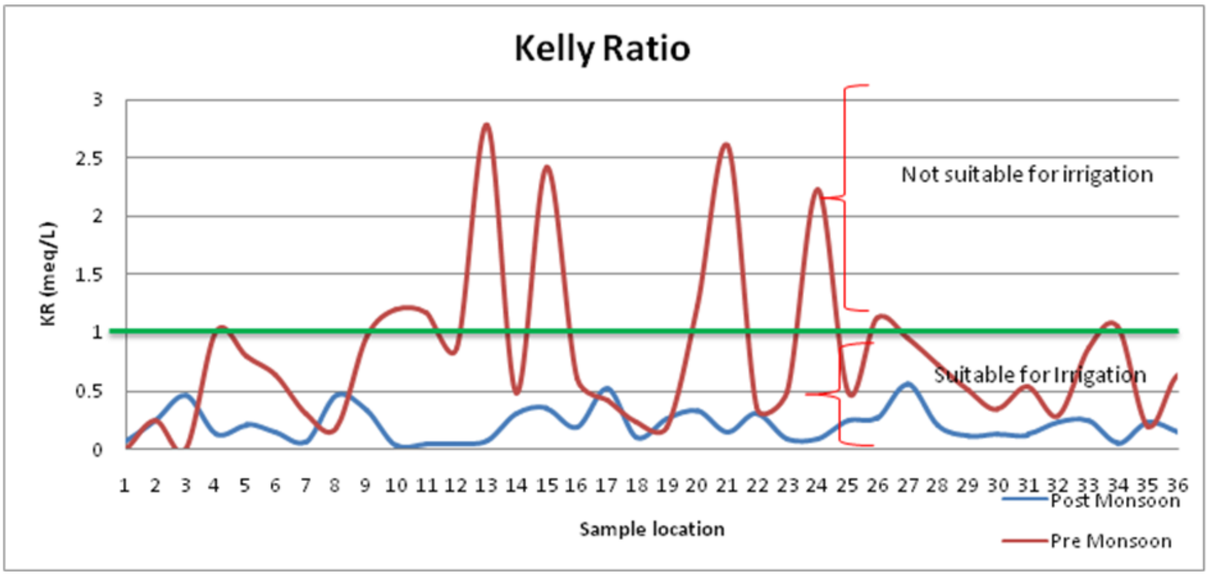

Fig: 3.1.6e: Kelly Ratio

Pre Monsoon analysis of samples from Dhopguri, Dirgheswari, Hatipara and Malini Than show KR value >1meq/L. But their Post Monsoon KR value is within suitable condition. So the study area can be said to be suitable for irrigation.

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 the present report the same calculation is used and the resource is 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 2020-21. 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 Kamrup district is 4.46 mbgl and 2.71 mbgl.

4) The population figures were collected from Census, 2011and projected to 2019. The per capita domestic requirement for the rural population has been considered as 60 lpcd and for urban population, it is 135 lpcd.

5) The dependency on ground water resource for domestic and industrial water supply in rural areas is considered as 81%.

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 replenishable 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 Kamrup District

Kamrup has a Total Geographic area of 3105 sq.km. of which Hilly area having slope less than 20% is 474.76 sq.km. Hence, area taken up for Aquifer Mapping was 2630.24 sq.km which is the total rechargeable area. Further the district divided into command, Non

Command and poor quality areas. But Kamrup has no command and poor quality area. Therefore resource assessment for only Non-Command area is done.

Assessment Unit	Total Geographical Area (ha)	Hilly Area (ha)	Total Recharge Worthy Area (ha)			
			Command	Non Command	Poor Quality	Total
Kamrup	310500	47476	0	263024	0	263024

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 area experiences south-east monsoon. Monsoon rainfall contributes approximately 79 percent of total rainfall (May, June, July, August, September) while share of post and pre monsoon rainfall are approximately 16.7 and 4.3 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.

Rainfall Recharge (Ham)			
Command	Non Command	Poor Quality	Total
0	82821	0	82821

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 2018. 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 Kamrup.

Ground water irrigation		Tanks & Ponds		Surface Water Irrigation		Recharge from other source
Non Command	Total	Non Command	Total	Non Command	Total	
8477.63	8477.63	2130.24	2130.24	45.23	45.23	10653.1

Total ground water recharge from all sources is 93475.63ham.

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.

In the district natural discharge is 6609.48 ham. Total irrigation extraction created is 20144.88ham, for industry 124.6ham and extraction for domestic uses is 3064.53ham. Total groundwater extraction for all uses is only 23334.02ham.

Domestic	Industrial	Irrigation	Extraction from all source
3064.536 Ham	124.6 Ham	20144.88 Ham	23334.02 Ham

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

4.4 Annual ground water recharge:

Annual ground water recharge is the sum-total of monsoon and non-monsoon recharge. An allowance is kept for Environmental Flow (un-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.

Annual Ground water Recharge (ham)	Environmental Flows (ham)	Annual Extractable Ground water Resource (ham)
86864.62	4673.7	82190.92

4.5 Allocation of resources up to 2025

The net ground water resource is allocated for domestic and industrial and irrigation sector. 3412.23ham of resource is allocated for domestic use in future. Annual extractable Ground Water Resource for the district is 82192.36(ham). Net G.W. Availability for future Use is 58510.66 ham.

4.6 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%.

Table 4.1: Tabulation of Ground Water Resource of Kamrup district as on March 2020.

PARAMETER	VALUES
Total geographical area (Ha)	310500
Recharge worthy area (Ha)	263024
Rainfall Recharge (monsoon) (Ham)	54794.90
Rainfall Recharge (non-monsoon) (Ham)	28027.63
Annual Recharge from Other Sources (monsoon) (Ham)	5666.45

PARAMETER	VALUES
Annual Recharge from Other Sources (non- monsoon) (Ham)	4986.65
Annual G. W. Recharge (Ham)	93475.63
Ecological Flow (Ham)	4673.7
Total Natural discharge (Ham)	4673.7
Annual extractable Ground Water Resource (Ham)	82190.92
Current annual gross G.W. Extraction for domestic use (Ham)	3064.54
Current annual gross G.W. Extraction for irrigation (Ham)	20144.9
Current annual gross G.W. Extraction for industrial use (Ham)	124.6
Current annual gross G.W. Extraction for All uses (Ham)	23334.02
Annual G.W. Allocation for Domestic water supply as on 2025 (Ham)	3412.23
Net Annual G.W. availability for future use (Ham)	58509.2
Stage of GW Extraction (in %)	28.39
Quantity Categorisation for Future GW extraction (Safe/Semi-Critical /Critical /Over Exploited)	Safe

CHAPTER 5.0

Groundwater Related Issues

Identification of issues: The main groundwater issue in this area is vulnerability issue. The vulnerable areas generally include areas vulnerable to water logging and polluted areas.

5.1 Area vulnerable to water logging

Permanently water logged areas are identified by preparing depth-to-water level contour for both pre- and post-monsoon seasons. The permanently water logged areas are those which are water logged both in pre- and post-monsoon seasons in the range of 0-2 mbgl.

GROUNDWATER CONDITION

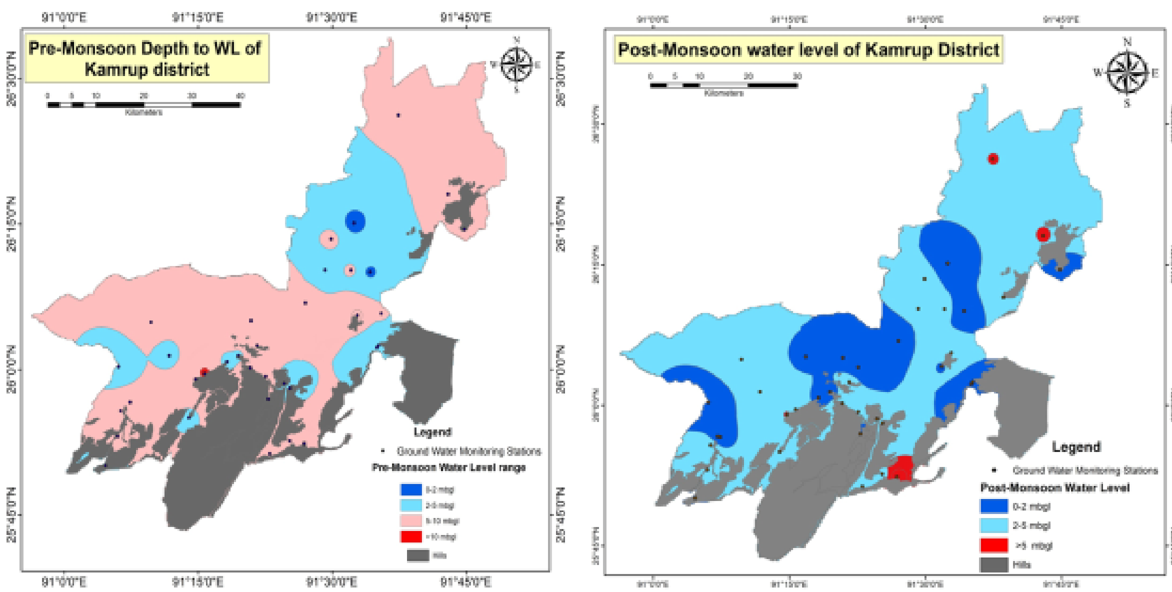

Fig. 5.1 Water logged area map of Kamrup distict

Permanently water logged areas are found in Hajo key well and Sualkuchi key well area where depth to water level is 0-2 mbgl throughout the year. The post monsoon depth-to-water level in these areas is shallow. Water logged areas are found in the alluvial plain, flood plain.

5.2 Water Quality Issue

In most of the samples of Dug wells, except iron, fluoride and electrical conductivity other basic parameters are within permissible limit.

Electrical conductivity more than 1000µS/cm is considered not suitable for drinking according to BIS 2012 standard. High electrical conductivity in water is due high concentration of dissolved salt such as sodium, chloride, calcium, and magnesium. They increase the salinity of water. In the study area, high EC is recorded in Sualkuchi area where EC ranges from 1207 to 1655 µS/cm in pre-monsoon and from 1368 µS/cm to 1702 µS/cm in post monsoon. These areas also show high value of Total Dissolved Solid ranging from 636.1mg/L to 870.9mg/L in Pre monsoon and from 713mg/L to 880.8mg/L in post monsoon.

Acceptable BIS standard for TDS in drinking water is 500mg/L but it is permissible upto 1000mg/L. Remaining locations have electrical Conductivity within permissible limit.

High concentration of Fluoride (more than 1.5mg/L) in drinking water is the main cause of dental and skeletal fluorosis in young children affecting their bone and teeth. In Kamrup District, during pre-monsoon high concentration of fluoride is found from Dirgheswari (1.7mg/L) dug well and Gumi (1.6mg/L) dug well. But in post monsoon period all the locations have fluoride value within permissible limit.

Map below shows dug wells having chemical parameters in range above permissible limit.

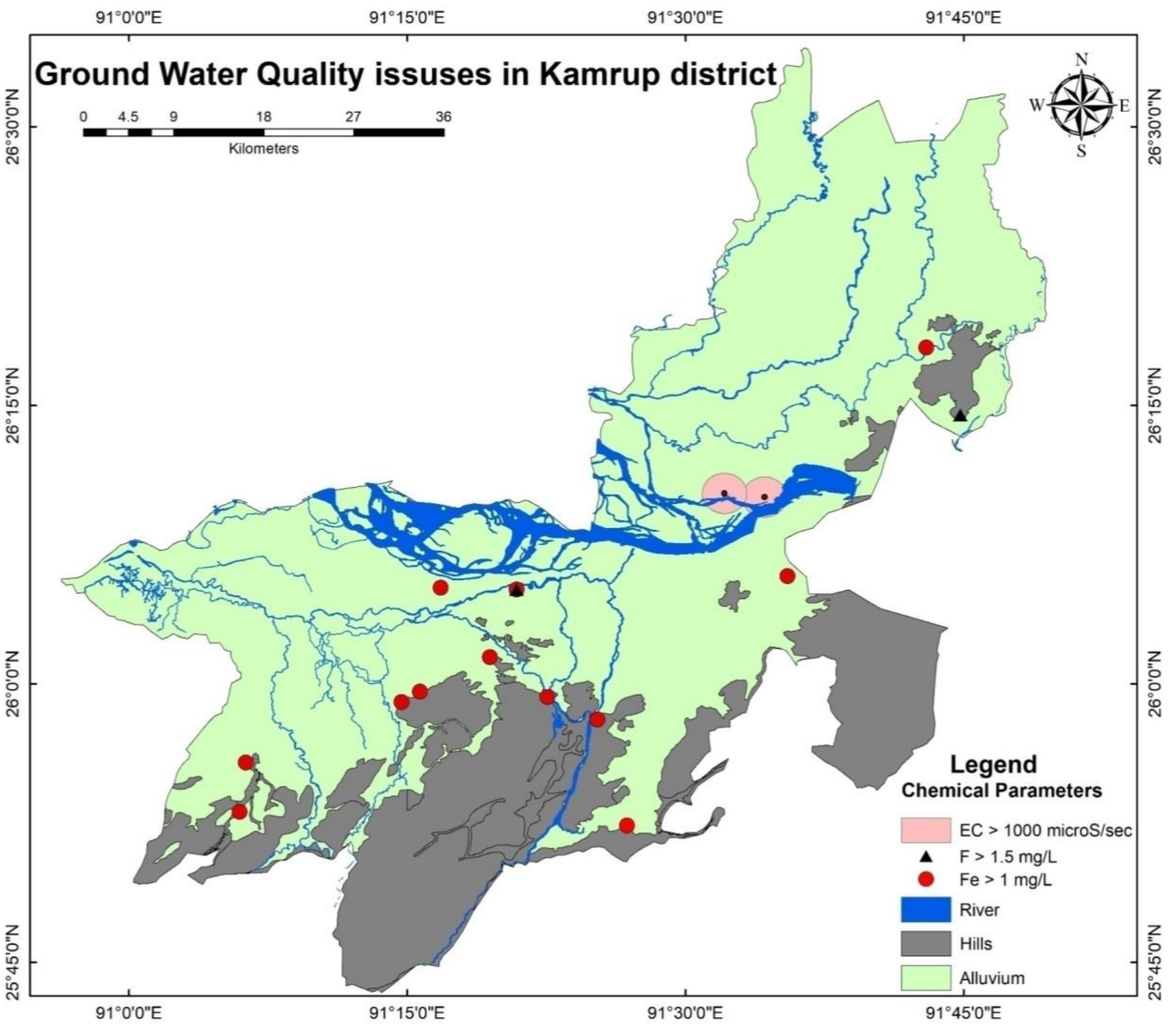

Fig. 5.2 Water Qauality issues of Kamrup distict

High Iron concentration prevails in almost entire district. High concentration of Iron in drinking water can cause diabetes, hemochromatosis, stomach problems, and nausea. It can also harm skin cells as such water does not rinse off the soap residue from the body, it also gives water an unpleasant metallic taste and stains the pipes, bathroom fixtures etc. Locations such as Mirza, Gangrapara, Kulshi, Boko, Rajapara (Chandubi), Bamunigaon, Hatipara, Bullarpar (Bhuban Nagar), Gumi, Chaikata, Hatigarh, Dora Kahara and Agchia have iron more than 1mg/L in pre-monsoon. During post monsoon dug wells at Natun Jarabari, Chaikata, Borjhar Chouk, Damalchos, Agyathuri, Boko, Bamunigaon, Gumi, Dora Kahara, Hatipara, Mirza, Chhaygaon, Maniori Tinali and Rajapara (Chandubi) have high concentration of iron. Concentration range of iron in ground water during pre- and post monsoon in the study area is given in Table 5.1. Groundwater in the area is infested with iron, therefore before consumption aeration/ filtering/ installation of Iron Removal Plant is necessary.

Table 5.1 Range of iron concentration in Ground water

District	**Pre-Monsoon**		**Post-Monsoon**	
	Minimum	**Maximum**	**Minimum**	**Maximum**
Kamrup	0.197	2.311	0.29	2.95

During aquifer mapping pre and post monsoon ground water samples were collected for Arsenic and submitted in NABL accredited Regional Chemical Laboratory of Central Ground water Board, Guwahati. Post Monsoon samples have arsenic concentration within acceptable limit as per BIS standards. Pre-Monsoon result is awaited.

CHAPTER 6.0

Management Strategy

The aquifer system in the study area is a mono aquifer type. From the panel diagram it is clear that central part of district parallel to Brahmaputra river shows that there are four clay layers continuous throughout the district. Five sand formations are encountered in northern part and four sand layers are encountered in the central and south western part of Kamrup district. Thickness of first sand layer varies from 10m in northern and southern extent of the study area to 100m in the central portion of Agchia where Brahmaputra river is traversing across dividing the entire district into two halves. The thickness of the second gravel layer is more or less homogenous throughout the district. The whole district comes under one hydrogeomorphic set up. The characteristic feature of this zone is enumerated in the following table (Table 6.1)

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 dominated	High Fe	Shallow water level/ water logged	High
Hilly area	Granite gneiss and Schist	High Fe	Shallow water level	Moderate

Sustainable Management Plan of Resource: It is observed that there is a huge gap between irrigation water available and irrigation demand. The gap can be minimized by lowering the post-monsoon water level from present nearly 2mbgl to 4mbgl.

6.1 Future demand scenario and stress aspects of the aquifer

Domestic Water Supply Demand: Future demand of water in the area will mainly come from domestic sector. Public Health Engineering Department supplies water using both surface and ground water sources. The dependency on ground water is only 81% as per 2011 census.

As per GEC 2017 the current ground water extraction in domestic sector is 3064.53ham. Water demand in this sector is calculated by projecting the population upto 2025 and allocating 60lpcd water. The ground water demand is found to be 3412.23ham up to 2025.

6.2 Future demand for agriculture

The major crops of Kamrup district are Paddy. Autumn paddy, winter paddy and summer paddy are the three main types of paddy are grown in the district. Winter paddy (Sali) is the most important crop in the district occupying 65.6 % followed by summer paddy (Boro) 27.6% and autumn paddy (Ahu) 6.7% of the total annual paddy area. The common cropping sequence next to paddy, Wheat rape seed & mustard, and vegetables are the main agricultural produce. Among cash crops jute and Sugarcane are the crops grown in the district. Other cereal crops such as maize, wheat, small millets are having negligible area as compared to rice. Cereals, Coarse cereals, pulses, oil seeds, vegetables, Ginger, Turmeric, Chilies, potato, Banana and Assam Lemon are also produced 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 provided Ministry of Agriculture, Govt. of India, in Kamrup the Gross cropped area is 169666 ha and the net cropped area is 100264 ha. During winter season an area of 70465 ha (source: databank.nedfi.com) is used for Winter Paddy production. Out this, 3001 ha (source: databank.nedfi.com) area is irrigated during winter season. The present analysis estimated water requirement in agriculture considered the unirrigated mono cropped area of 67464 ha to increase the cropping intensity to 200% by providing assured irrigation in agricultural field. The whole calculation for projection of cropping intensity to 200% is carried out by use of Cropwat 8.0 software of FAO. The present season wise cropping pattern of Kamrup district is shown in Table 6.2.

Table 6.2: Season wise cropping pattern of Kamrup district

(Source: Agriculture Contingency Plan for District: Kamrup)

SN	**Main Crop**	**Sowing season**					
		Kharif		**Summer**		**Rabi**	
		Rainfed	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**	**Irrigated**
1	Paddy	June to July	June to July		November to December	-	December to January
2	Rape seed Mustard		-		-	October to November	-
3	Pulse			August to September			

As per data provided by Ministry of Agriculture, Govt. of India, in Kamrup district, double cropped area is 69402 ha. Only 70465 ha is under mono cropped area, out of which 3001 ha is irrigated area. There is ample scope for ground water extraction for irrigation purpose which will bring unirrigated mono cropped area of 67464 ha to double crop 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 crop water need can be calculated using the following formula.

$$ET_{crop} = ET_o * K_c$$

Where: ET_{crop} = Crop water need (mm/unit time)

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

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

6.3 Cropping Plan

During Kharif season, paddy is cultivated in 67464 ha land without irrigation. After Kharif crops were grown major portion of this area remains fallow during Rabi season.

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 134,928 ha and thereby increase cropping intensity up to 200%. This can be achieved by growing pulse, potato, mustard, 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				
Summer Rice- Autumn Rice- Winter Rice- Winter Rice	Present Cultivated area (ha)	Area to be cultivated (%)	Area to be cultivated (ha)	Irrigation water requirement (ha m)
Winter Vegetables-Summer Vegetables-Pulses--Potato-Oilseed				
Cultivated Area	67464			
	1	2 (= % of 1)	3	4
Rice (main crop)	67464		67464	
Winter Rice	67464	100	67464	11665.20
Winter Vegetables		30	20239	3230.17
Pulse		20	13493	2285.00
Potato		20	13493	3157.99
Oilseed		10	6746	1914.63
Wheat		10	6746	1977.37
Summer Vegetables		10	6746	371.05
Total			**134928**	**24601.42**
Net cultivated area	67464		67463	24601.42
Gross cultivated area (Paddy/+Wheat+Pulses)	**134928**			
Total irrigation requirement (70% irrigation efficiency)				**35145**

Table 6.4 : Crop-wise and month-wise precipitation deficit (IWR) from CROPWAT 8.0

Precipitation deficit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Winter Rice	0	0	0	49.1	98	0	0	0	0	0	0	0
Winter Rice	0	0	0	0	198	0	0	0	3.2	0	0	0
Winter Rice	0	0	0	0	49.7	98	0	0	0	0	0	0
Winter Rice	0	0	0	0	48.5	98	0	0	0	11.4	0	0
Winter Rice	0	0	0	0	0	48.9	98	0	0	47.6	13.3	0
Winter Vegetables	0	0	0	0	0	0	0	0	0	21.8	70.3	51.3
Winter Vegetables	59.2	4.9	0	0	0	0	0	0	0	0	49	54.6
Pulses	39.7	0	0	0	0	0	0	0	0	2.8	55.8	65.1
Pulses	66.6	33.6	0	0	0	0	0	0	0	0	24	51.1
Potato	66.4	58.6	13.4	0	0	0	0	0	0	3	33.4	53.9
Potato	66.3	65.5	40.6	0	0	0	0	0	0	0	25.6	41.4
Mustard	54	53.4	68	0.2	0	0	0	0	0	2.8	52.8	52.6
Wheat	50	55.1	80.4	7.4	0	0.9	0	0	0	8.7	47.8	42.8
Summer Vegetables	0	2.1	45.9	0	0	7	0	0	0	0	0	0

Table 6.5 : Actual monthly water requirement for different crops in Flood prone areas of Kamrup district, Assam

Crop	Net sown area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Cropwise Total IWR (Ham)	Total	Gross irr. Requirement with 70% irr. Efficiency
Winter Rice	6746.4	0.0	0.0	0.0	331.2	661.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	992.4		
Winter Rice	13492.8	0.0	0.0	0.0	0.0	2671.6	0.0	0.0	0.0	43.2	0.0	0.0	0.0	2714.8		
Winter Rice	16866.0	0.0	0.0	0.0	0.0	838.2	1652.9	0.0	0.0	0.0	0.0	0.0	0.0	2491.1	11665.20	16664.57
Winter Rice	16866.0	0.0	0.0	0.0	0.0	818.0	1652.9	0.0	0.0	0.0	192.3	0.0	0.0	2663.1		
Winter Rice	13492.8	0.0	0.0	0.0	0.0	0.0	659.8	1322.3	0.0	0.0	642.3	179.5	0.0	2803.8		
Winter Vegetables	6746.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	147.1	474.3	346.1	967.4	3230.18	
Winter Vegetables	13492.8	798.8	66.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	661.1	736.7	2262.7		
Pulses	6746.4	267.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.9	376.4	439.2	1102.4	2285.01	
Pulses	6746.4	449.3	226.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	161.9	344.7	1182.6		
Potato	6746.4	448.0	395.3	90.4	0.0	0.0	0.0	0.0	0.0	0.0	20.2	225.3	363.6	1542.9	3157.99	18480.32
Potato	6746.4	447.3	441.9	273.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	172.7	279.3	1615.1		
Mustard	6746.4	364.3	360.3	458.8	1.3	0.0	0.0	0.0	0.0	0.0	18.9	356.2	354.9	1914.6		
Wheat	6746.4	337.3	371.7	542.4	49.9	0.0	6.1	0.0	0.0	0.0	58.7	322.5	288.7	1977.4	12936.22	
Summer Vegetables	6746.4	0.0	14.2	309.7	0.0	0.0	47.2	0.0	0.0	0.0	0.0	0.0	0.0	371.1		
Total	**134928**								**Gross irrigation Requirement with 70% irr. Efficiency**							**35144.89**

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

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 35145 ham area, 12,203 numbers of shallow TW can be constructed to cover unirrigated area of 134928 ha area. Currently Kamrup District has a total extraction of 23334.2 ham resulting in a Stage of ground water development of 28.39%. in extracting additional requirement of 35145 ham stage of development in Kamrup District will increase from 28.39% (safe category) to 71.15% (to a little over semi critical category). Hence to keep stage of development within 70%, consumptive use of surface water from rivers in the nearby area and by increasing the efficiency of irrigation can be implemented. Rivers in the study area are perennial rivers with plenty of discharge which will be very viable for surface water irrigation.

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 35145 Ham	12203 STW to be constructed to provide 35145 ham water to cover 134928 ha.
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 300 m. A tube well tapping 15 to 30m granular zone can expected to yield 20 to 50m3 /hr. Tube wells can be constructed by using 8” dia. Housing pipe down to 30 m.

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 8 m in the flood plain area.

Demand side management: Demand side management implies sustainable management of water. In irrigation as well as in drinking water supply sufficient quantity of water is lost

The general slope of the area is towards Brahmaputra River. The slope is greater in hilly area of southern and eastern part of the district than in the flood plain. Therefore water logging condition is observed in the flood plain, alluvial plain area. Therefore water use efficiency should be high in all sectors particularly in the irrigation sector. Loss in irrigation water will increase water logged area.

Irrigation efficiency can be increased by

(i) reducing convenience loss

(ii) improving water application efficiency

Following demand side interventions will increase water use efficiency

1) Use of water efficient irrigation method: Drip and sprinkler irrigation methods are very useful in saving water. Both of them save conveyance losses and improve water application efficiency by applying water near the root-zone of the plant. Drip systems convey water in small quantities through drippers/micro-tubes while sprinklers are pressurized systems where a fountain or spray of water is released by the sprinkler connected by pipes, resulting in foliar irrigation. Drip irrigation can increase crop yield per hectare and also saves water up to 70% than conventional irrigation.

2) Water loss through supply canals can be minimized by proper lining in the canals.

3) Adopting water saving rice irrigation: In this method instead of submerging the paddy field for longer duration, the rice field have to provide water through irrigation only after a certain number of days when the ponded water disappears. This technology is known as alternate wetting and drying (AWD) irrigation. With the optimal management, this technology reduces the amount of water required by about 25% without reduction in yields.

International Rice Research Institute (IRRI) has developed a simple tool to help farmers make decisions on when to irrigate. They found that when field water level recedes to 15 cm below the soil surface, soil water tension in the root zone is always <10 kPa, ensuring good yield. Thus a practical way to implement safe AWD is to monitor the depth of ponded water using a field water tube/ pipe This tube can be made of plastic pipe or bamboo 30 cm long and 15 cm or more in diameter and having perforations on all sides (Fig. 6.2). After transplanting, farmers would keep the field submerged for about 2 weeks to suppress weed growth. The tube is then inserted into the soil by leaving 10 cm above the soil surface. Soil inside the tube is then taken out.

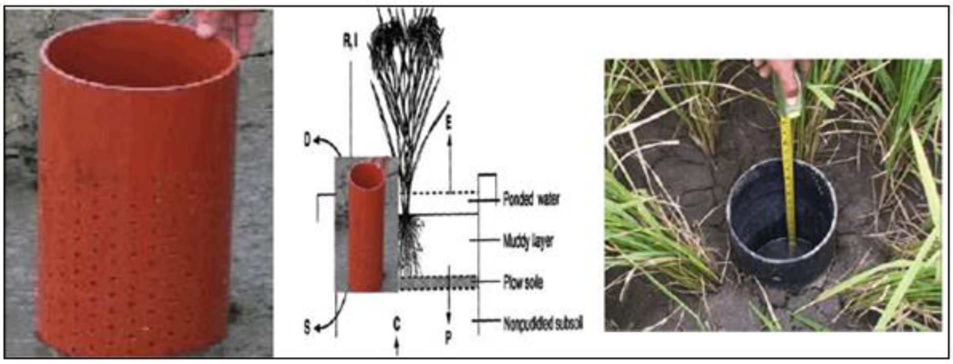

Fig. 6.2: A simple perforated pipe (water tube) installed in the rice field allows farmer to monitor water level beneath the soil surface (Kulkarni, 2011)

4) Reduce losses of water during leveling: As per Food Agriculture Organization, 200mm of water per hectre is required to level the rice field by traditional method. However, use of laser land leveler help in fine leveling of rice field by eliminating unnecessary depression and elevated contour. It saves 40 to 50% water. A uniformly leveled field allows

uniform spreading of irrigated water. It is reported that in Punjab 100% use of laser land leveler in the existing cropping pattern (rice-wheat) can prevent 19cm groundwater draft in entire state (Aggarwal, et. al., 2010)

Approximate Water saving through use of Laser Land Leveler in the rice cultivated area of the district

District	Present Paddy cultivated area	40% reduction of water for land leveling by the use laser land leveler	Approximate saving of water (ham)
Kamrup	100264		8021.12

Stress aspect future demand: Numerical modelling and aquifer simulation study could not be done due to paucity of various data, it was not possible to test a model under different stress conditions.

However, stress aspects of aquifer are analyized for different situations.

Stress on aquifer due to drinking water supply: The population of the study area has been projected based on 2011 census data up to 2025. Based on this projected population drinking water demand of the area is calculated.

There will surplus of supply in domestic and industrial demand considering groundwater 81% dependency on groundwater.

Irrigation:

The additional withdrawal of water may not adversely affect the ground water regime of the area as major portion of the area is under shallow water table condition.

Following recommendations are suggested

1) Water distribution mechanism should minimize water loss by using lining distribution canals. Locally available materials are to be preferred as these materials are cheap and eco-friendly.

2) Conservation of rain water in the up dip of cultivated field. During rabi season the conserved water can be drained to paddy field through gravity.

6.4 Water Quality Management:

Except three water quality parameters of iron, fluoride and electrical conductivity, overall quality of ground water in Kamrup district is potable for drinking and other domestic and irrigation use.

Iron:

Presence of iron and manganese promotes the growth of bacteria in water. These bacteria harness energy for growth from the chemical reaction that occurs when iron and manganese mix with dissolved oxygen. Presence of iron in ground water is mainly geo-genic and it originates from the underlying rock formation. As water infiltrates into the aquifer, it dissolves some iron and accumulates in aquifer.

Since iron occurs naturally in nature, it cannot be removed in situ. There are several methods by which iron can be removed. Iron filters/iron removal plants are to be installed in order to remove iron from ground water.

1. **Iron removal by ion exchange**: Resins such as polystyrene-type gel resin in water softeners can remove iron from water by the process of ion exchange if the water is not exposed to oxygen.
2. **Iron removal by filtration**: Iron (and Manganese) can be easily removed from water by the process of gravity and pressure filtration after oxidation with air (aeration), chlorine or potassium permanganate.

Fluoride:

Fluoride is a natural contaminant of geo-genic origin. Weathering of fluoride containing minerals such as micas (abundant in gneissic and schistose rocks), apatite and fluorspar etc. contributes to fluoride concentration in water. Excess of fluoride in human body can cause teeth fluorosis and bone fluorosis which damages and pains the bones.

Removal of fluoride can be done by conventional filters equipped with reverse osmosis, ion exchange process using resins, activated alumina and activated limestone (Fluoride Nilogon).

1. **Fluoride removal by reverse osmosis:** In this process untreated water is pressured to be passed through a semi permeable membrane to get purified water.
2. **Fluoride removal by ion exchange resins:** High concentration of Fluoride can be removed by use of lime precipitation as calcium fluoride is very common. For low concentration, ion exchange using a strong base anion resin can remove fluoride.
3. **Fluoride Nilogon:** The Fluoride Nilogon method is a patented fluoride removal technique developed by the Department of Chemical Sceince, Tezpur University, where water pre-treated with phosphoric acid is passed through crushed limestone. In return fluoride is removed from the water by the process of adsorption.
4. **Alternate source of water:** Going for an alternate source for drinking water like tapping deeper aquifers free from fluoride or supplying water from a fluoride free area is also advisable.

Electrical Conductivity:

High electrical conductivity in water increases the salinity. High conductivity can be reduced by ion exchange process also called deionization plant. In this process untreated water is passed through an electric chamber with porous electrodes to get deionized water.

Annexure I

Table: 1 a. Concentration range of chemical constituents in groundwater (Pre Monsoon)

Location	Lat	Long	Tem p°C	pH	EC	Turbidity	TDS	CO_3^{-2}	HCO_3^{-1}	TA (as CaCO3)	Cl-	SO_4^{-2}	NO_3^{-1}	F-	Ca^{+2}	Mg^{+2}	TH (as $CaCO_3$)	Na	K	Fe
					(µs/cm)	(NTU)	mg/L													
Agchia	25.99	91.26		8.13	325.00	BDL	171.60	BDL	225.88	225.88	28.36	14.87	0.17	0.81	52.04	9.68	170.00	19.29	4.69	2.31
Bamundi	26.17	91.49		7.61	122.50	BDL	64.28	BDL	61.05	61.05	24.82	14.04	1.00	0.36	6.00	7.28	45.00	20.89	1.94	0.61
Bamunigaon	26.02	91.32		7.56	169.10	BDL	90.03	BDL	103.78	103.78	28.36	13.29	0.49	0.89	18.01	4.85	65.00	23.71	8.18	1.44
Bhurkibari	26.01	91.30		7.76	119.40	BDL	64.43	BDL	91.57	91.57	24.82	7.66	0.51	0.78	18.01	4.85	65.00	18.96	2.29	0.83
Boko	25.98	91.25		7.87	208.50	BDL	109.60	BDL	54.94	54.94	24.82	35.06	0.19	1.00	26.02	7.27	95.00	13.51	2.76	1.27
Borjhar Chouk	26.00	91.35		7.27	47.61	BDL	25.40	BDL	18.31	18.31	17.73	10.22	0.74	0.48	6.00	7.28	45.00	3.89	1.72	0.72
Bullarpar (Bhuban Nagar)	26.10	91.59		7.84	707.50	BDL	375.00	BDL	250.30	250.30	127.62	16.52	0.96	1.10	30.02	21.83	165.00	73.58	47.76	1.48
Chaikata	25.93	91.11		6.71	126.90	0.20	66.16	BDL	54.94	54.94	31.91	3.73	2.80	0.39	4.00	6.07	35.00	19.33	8.10	2.09
Chandubi	25.88	91.42		8.66	99.87	BDL	51.34	6.00	109.89	115.89	21.27	5.37	1.05	0.39	10.01	6.06	50.00	26.94	12.29	0.67
Chhaygaon	26.04	91.36		7.96	266.70	BDL	140.50	BDL	109.89	109.89	24.82	55.36	3.89	1.00	22.02	6.06	80.00	32.11	19.80	0.99
Damalchos	26.00	91.10		7.25	201.00	BDL	105.20	BDL	73.26	73.26	209.16	23.32	1.37	0.40	16.01	8.49	75.00	95.87	48.75	0.83
Dhopguri	25.94	91.12		7.83	120.70	BDL	62.79	BDL	91.57	91.57	21.27	3.47	1.27	0.51	18.01	4.85	65.00	14.50	4.39	0.56
Dimakhuli	25.92	91.23		6.62	34.41	BDL	18.08	BDL	48.84	48.84	21.27	2.22	0.75	0.33	4.00	2.43	20.00	22.22	1.43	0.20
Dirgheswari	26.24	91.75		7.96	365.50	0.10	194.30	BDL	219.78	219.78	24.81	21.14	0.65	1.70	42.03	8.47	140.00	39.40	3.91	0.38
Dora Kahara	26.30	91.72		7.77	536.00	BDL	282.10	BDL	219.78	219.78	53.18	84.79	1.74	1.00	46.04	21.82	205.00	40.08	17.71	2.29
Gangrapara	25.88	91.10		7.58	132.70	BDL	69.62	BDL	85.47	85.47	17.73	7.74	1.04	0.53	20.02	6.06	75.00	7.87	5.45	1.18
Gumi	26.08	91.35		7.94	311.90	BDL	165.40	BDL	189.25	189.25	31.91	11.63	2.21	1.60	34.03	18.19	160.00	13.75	4.44	1.73
Hajo New	26.25	91.54		7.58	152.30	BDL	80.03	BDL	85.47	85.47	31.91	13.18	0.81	0.78	10.01	6.06	50.00	28.38	7.29	0.50
Hatigarh	25.99	91.38		7.15	82.82	BDL	44.26	BDL	189.25	189.25	17.73	7.26	0.39	0.46	8.01	4.85	40.00	47.97	19.17	2.22
Hatipara	26.09	91.28		8.19	554.60	0.20	295.80	BDL	256.40	256.40	77.99	62.17	0.74	0.95	48.04	32.74	255.00	42.36	2.02	1.44
Howli	26.08	91.16		7.93	524.50	BDL	278.10	BDL	250.30	250.30	63.81	44.49	0.68	0.97	44.04	21.82	200.00	45.51	19.65	0.50
Kulshi	25.97	91.42		8.85	78.30	BDL	41.71	18.00	103.78	121.78	24.82	9.69	1.17	0.98	10.01	3.64	40.00	40.96	14.15	1.18
Kulshi_forest	25.97	91.42		7.74	102.10	BDL	54.34	BDL	61.05	61.05	24.82	5.97	0.89	0.44	16.01	3.63	55.00	12.49	3.00	0.72
Malini than	25.95	91.38		7.20	59.02	BDL	31.46	BDL	54.94	54.94	24.82	5.50	0.92	0.40	6.00	4.85	35.00	18.08	5.00	0.67
Maniori Tinali	26.07	91.53		7.61	106.00	BDL	57.11	BDL	61.05	61.05	21.27	3.90	1.16	0.61	8.01	4.85	40.00	17.56	2.60	0.83

Location	Lat	Long	Tem p°C	pH	EC	Turbidity	TDS	CO_3^{-2}	HCO_3^{-1}	TA (as CaCO3)	Cl-	SO_4^{-2}	NO_3^{-1}	F-	Ca^{+2}	Mg^{+2}	TH (as $CaCO_3$)	Na	K	Fe
					(µs/cm)	(NTU)	mg/L													
Mirza	26.09	91.55		7.73	208.50	BDL	110.00	BDL	122.10	122.10	31.91	8.46	1.33	0.77	22.02	6.06	80.00	26.82	2.31	1.08
Rajapara (Chandubi)	25.87	91.45		7.93	177.40	BDL	94.77	BDL	109.89	109.89	17.73	10.32	2.17	0.71	24.02	4.84	80.00	18.35	3.89	1.35
Ramdia	26.22	91.50		7.96	508.80	0.10	268.00	BDL	146.52	146.52	63.81	101.34	8.71	0.78	44.04	23.04	205.00	32.30	14.48	0.20
Rangia	26.44	91.62		8.16	829.20	BDL	441.20	BDL	360.19	360.19	67.35	76.88	0.85	1.10	46.04	27.89	230.00	56.58	76.42	0.38
Rani	26.04	91.58		8.17	281.70	BDL	152.60	BDL	177.04	177.04	28.36	14.64	1.15	0.75	36.03	12.12	140.00	18.16	8.77	0.61
Rani II	26.04	91.59		7.35	71.23	0.10	38.21	BDL	73.26	73.26	21.27	8.28	1.04	0.49	6.00	6.07	40.00	15.81	12.39	0.78
Ranikhamar	25.86	91.38		7.49	124.40	BDL	66.97	BDL	85.47	85.47	24.82	16.15	0.87	0.53	18.01	2.42	55.00	26.62	7.69	0.61
Simina (Sulikata)	26.11	91.45		8.12	595.70	BDL	317.10	BDL	268.61	268.61	56.72	91.27	0.97	1.10	56.04	38.81	300.00	26.61	3.29	0.67
Sualkuchi	26.17	91.57		8.07	1207.00	BDL	636.10	BDL	488.39	488.39	106.35	53.17	9.09	1.20	110.09	4.80	295.00	85.97	58.85	0.44
Sualkuchi 1	26.17	91.53		8.07	1655.00	BDL	870.90	BDL	427.34	427.34	170.16	212.63	10.76	1.20	70.06	50.94	385.00	64.36	181.46	0.20

Table: 1 b. Concentration range of chemical constituents in groundwater (Post Monsoon)

Location	Lat	Long	Temp° C	pH	EC (µs/cm) 25C	Turbidity (NTU)	TDS	CO_3^{-2}	HCO_3^{-1}	TA (as Ca CO3)	Cl-	SO_4^{-2}	NO_3^{-1}	F-	Ca^{+2}	Mg^{+2}	TH (as Ca CO 3)	Na	K	Fe	U	As
												mg/L									µg/L	
Hatigarh	25.99	91.38	27	6.48	68.20	BDL	35.46	BDL	67.15	67.15	7.09	8.95	BDL	0.13	8.01	6.06	45.0	13.46	2.22	0.70	0.10	1.62
Malini than	25.95	91.38	25.6	6.06	34.47	BDL	17.91	BDL	30.52	30.52	7.09	5.26	BDL	0.11	4.00	6.07	35.0	2.93	1.95	0.49	0.07	1.62
Rani	26.04	91.58	27.1	6.35	65.31	BDL	33.83	BDL	42.73	42.73	7.09	9.67	BDL	0.14	8.01	6.06	45.0	5.06	2.27	0.77	BDL	0.94
Rani II	26.04	91.59	27.3	6.60	128.1	BDL	66.29	BDL	42.73	42.73	17.73	17.58	BDL	0.18	12.01	4.85	50.0	10.84	3.41	0.95	BDL	BDL
Bullarpar (Bhuban Nagar)	26.10	91.59	26.1	6.96	85.60	BDL	352.10	BDL	189.25	189.25	106.35	45.16	BDL	0.24	54.04	1.19	140.0	59.46	54.12	0.70	0.05	0.09
Ranikhamar	25.86	91.38	26.3	6.73	97.39	BDL	50.29	BDL	67.15	67.15	7.09	13.49	BDL	0.20	10.01	4.85	45.0	10.26	8.53	0.54	0.13	0.26
Sualkuchi 1	26.17	91.53	25.90	7.29	1702	BDL	880.80	BDL	525.02	525.02	145.35	62.92	6.18	0.44	70.06	49.72	380.0	48.02	230.78	0.58	1.00	1.28
Rajapara	25.94	91.12	25.90	6.65	123.0	BDL	63.73	BDL	97.68	97.68	7.09	8.82	BDL	0.22	20.02	3.63	65.00	11.75	3.42	2.95	BDL	4.17
Chhaygaon	26.04	91.36	26.10	7.39	336.0	BDL	175.20	BDL	238.09	238.09	14.18	6.41	BDL	0.40	50.04	15.75	190.0	6.35	1.73	2.29	0.28	1.28
Rangia	26.44	91.62	26.30	8.08	416.0	BDL	215.40	BDL	219.78	219.78	21.27	32.33	BDL	0.44	30.02	19.40	155.0	19.05	36.82	0.54	0.59	1.45
Agchia	25.99	91.26	25.50	7.40	227.60	0.10	117.10	BDL	134.31	134.31	21.27	10.70	BDL	0.28	36.03	6.05	115.0	7.90	5.08	0.30	0.35	0.43
Chandubi	25.88	91.42	25.90	7.30	71.84	0.30	33.64	BDL	54.94	54.94	7.09	6.49	BDL	0.12	16.01	4.85	60.00	1.74	1.40	0.68	0.05	0.60
Bhurkibari	26.01	91.30	27.00	7.29	123.00	0.30	63.13	BDL	85.47	85.47	7.09	5.87	BDL	0.42	14.01	4.85	55.00	10.49	2.51	0.82	BDL	0.43
Sualkuchi	26.17	91.57	26.30	7.49	1368.0	BDL	713.00	BDL	744.80	744.80	102.8	51.94	BDL	0.56	76.06	69.14	475.0	100.0	55.47	0.35	8.01	BDL
Bamundi	26.17	91.49	24.90	6.97	180.40	BDL	92.15	BDL	73.26	73.26	28.36	17.07	BDL	0.18	14.01	4.85	55.00	23.20	1.74	0.96	0.07	BDL
Natun Jarabari	26.07	91.38	25.10	7.00	138.80	BDL	71.15	BDL	61.05	61.05	21.27	23.85	BDL	0.15	6.00	8.49	50.00	25.68	1.53	1.20	BDL	BDL
Chaikata	25.93	91.11	26.20	6.64	60.93	BDL	31.24	BDL	24.42	24.42	14.18	8.82	BDL	0.05	6.00	2.42	25.00	7.57	5.02	1.25	0.05	0.43
Hatipara	26.09	91.28	25.50	7.61	613.90	0.40	314.60	BDL	274.72	274.72	63.81	25.49	BDL	0.31	48.04	35.17	265.0	35.50	1.25	2.05	0.06	0.43
Ramdia	26.22	91.50	25.00	7.86	345.90	BDL	177.20	BDL	122.10	122.10	31.91	27.23	0.42	0.20	34.03	15.76	150.0	15.19	3.26	0.58	0.24	0.94
Dora Kahara	26.30	91.72	26.50	7.58	529.70	BDL	270.80	BDL	268.61	268.61	39.00	23.39	BDL	0.36	30.02	32.75	210.0	36.30	13.85	2.01	0.17	1.11
Mirza	26.09	91.55	25.70	7.23	84.38	0.20	43.25	BDL	67.15	67.15	17.73	11.99	BDL	0.17	16.01	3.63	55.00	13.45	2.62	2.15	BDL	1.62
Boko	25.98	91.25	25.30	6.79	136.70	BDL	69.70	BDL	140.41	140.41	10.64	7.56	BDL	0.18	30.02	7.27	105.0	13.61	1.47	1.53	BDL	1.28
Dirgheswari	26.24	91.75	26.60	7.86	196.70	0.10	100.80	BDL	91.57	91.57	81.54	9.56	BDL	0.26	28.02	10.91	115.0	37.24	1.82	0.44	0.17	2.98

Gangrapara	25.88	91.10	27.10	7.08	488.00	0.40	249.50	BDL	36.63	36.63	10.63	33.08	5.49	0.52	8.01	4.85	40.00	19.29	8.55	0.63	0.19	0.77
Kulshi_forest	25.97	91.42	26.70	7.49	82.38	BDL	42.17	BDL	73.26	73.26	14.18	10.73	BDL	0.15	6.00	2.42	25.00	2.06	4.29	0.68	0.35	2.31
Hajo New	26.25	91.54	26.80	6.88	88.11	BDL	45.05	BDL	48.84	48.84	10.64	6.68	BDL	0.13	10.01	2.42	35.00	8.50	1.99	0.58	BDL	3.93
Agyathuri	26.19	90.64	25.30	7.44	140.00	BDL	71.66	BDL	79.36	79.36	14.18	15.75	BDL	0.37	16.01	4.85	60.00	13.13	1.44	1.44	1.00	1.28
Gumi	26.08	91.35	26.20	7.67	178.00	BDL	90.92	BDL	109.89	109.89	17.73	15.72	BDL	0.29	22.02	9.70	95.00	8.58	2.87	1.96	0.02	2.65
Simina (Sulikata)	26.11	91.45	25.50	8.19	384.50	BDL	196.60	BDL	238.09	238.09	17.73	29.30	BDL	0.35	48.04	20.61	205.0	9.73	7.06	0.92	1.96	1.79
Borjhar Chouk	26.00	91.35	26.00	6.83	44.71	BDL	22.91	BDL	30.52	30.52	7.09	13.09	BDL	BDL	8.01	4.85	40.00	2.21	1.15	1.25	0.33	2.48
Dhopguri	25.94	91.12	26.60	7.21	30.46	BDL	15.64	BDL	24.42	24.42	7.09	4.36	BDL	0.09	4.00	4.85	30.00	2.11	0.63	0.49	BDL	0.94
Maniori Tinali	26.07	91.53	26.90	7.88	136.70	BDL	70.12	BDL	73.26	73.26	17.73	4.34	BDL	0.28	20.02	1.20	55.00	12.13	3.08	2.34	0.05	1.28
Howli	26.08	91.16	26.00	7.93	934.80	BDL	481.70	BDL	329.66	329.66	88.63	48.79	4.37	0.48	50.04	41.24	295.0	83.40	13.78	0.87	3.65	1.62
Bamunigaon	26.02	91.32	25.70	7.85	176.50	0.10	90.24	BDL	85.47	85.47	14.18	26.56	BDL	0.33	20.02	9.70	90.00	10.96	4.95	1.77	0.04	2.48
Damalchos	26.00	91.10	27.20	7.68	295.60	BDL	151.20	BDL	79.36	79.36	14.18	51.58	5.88	0.17	32.03	13.33	135.0	6.12	4.76	1.29	BDL	1.92
Dimakhuli	25.92	91.23	26.70	7.07	30.34	BDL	15.51	BDL	24.42	24.42	7.09	10.17	8.02	0.12	6.00	3.64	30.00	8.39	0.84	0.58	0.36	1.92