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

EAST SIANG DISTRICT, ARUNACHAL PRADESH

उत्तर पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

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Central Ground Water Board

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MINISTRY OF JAL SHAKTI

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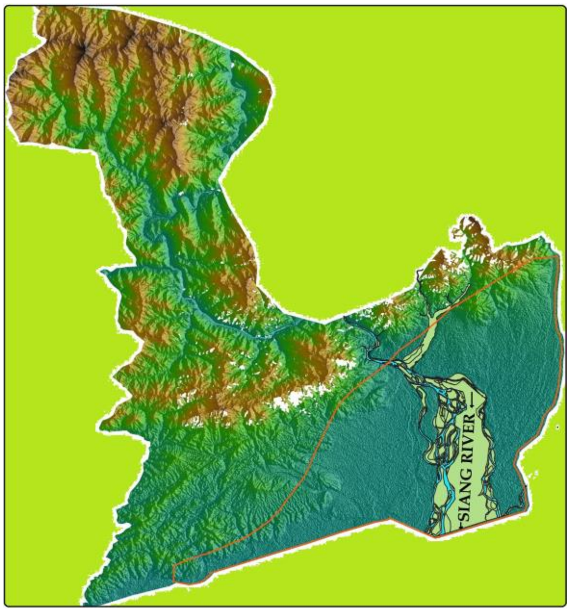

REPORT ON AQUIFER MAPPING AND MANAGEMENT IN
EAST SIANG DISTRICT, ARUNACHAL PRADESH

ANNUAL ACTION PLAN, 2017-18

NORTH EASTERN REGION

उत्तर पूर्वी क्षेत्र

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March 2019

REPORT ON AQUIFER MAPPING AND MANAGEMENT IN

EAST SIANG DISTRICT, ARUNACHAL PRADESH

ANNUAL ACTION PLAN, 2017-18

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1.0
INTRODUCTION

1.0 Introduction

1.1 Objectives: As part of national aquifer mapping programme, 1101sq.km of the unconsolidated alluvial aquifer of East Siang district of Arunachal Pradesh was taken for study. (Fig. 1)

The objective of the study can be defined as follows:

a) to define the aquifer geometry, type of aquifers, ground water regime behaviours, hydraulic characteristics and geochemistry of aquifer systems in 1:50,000 scale and
b) Existing scenario of groundwater regime in shallow/deep aquifer
c) to work out a management plan for sustainable development of ground water.

1.2 Scope of the study

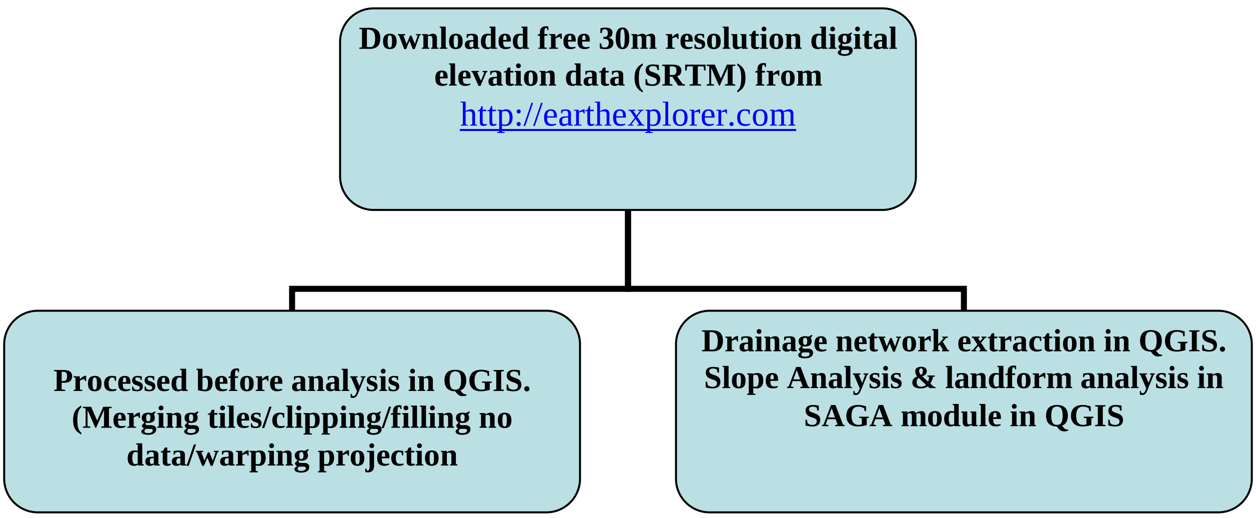
Present study aims to discuss ground water scenario under different geological and geomorphological set up of the area. Scope exists to discuss surface and ground water interaction to formulate a sustainable management plan for the study area.

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 the base map on GIS Platform. On the basis of available data, data gaps were identified.

Digital Elevation Data: Digital Elevation Data is a very useful for terrain analysis and also to identify drainage. In this study an attempt has been made to classify the landform of the study area from digital elevation data. 30m resolution shuttle radar topographic mission (SRTM) and 228m Global Terrain Data (GTD) elevation data downloaded from http://earthexplorer.com . The elevation data is processed in QGIS software. The terrain analysis was performed in SAGA module of QGIS. The work flow is shown in the flow chart.



Data Generation: Efforts were made to fill the data gaps by multiple activities such as exploratory drilling, geophysical techniques, hydro-geochemical analysis, water level monitoring, yield tests and soil infiltration studies.

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

Aquifer Management Plan Formulation: Based on **a**quifer map and analysis of present requirement and future demand, a sustainable development plan of the aquifer is formulated

1.4 Area Details: The area chosen for aquifer mapping is bounded by 93^{0}00'E to 94^{0}15'E longitude and 27^{0}00'N to 27^{0}30'N latitude and the area is included in Survey of India toposheet numbers 82P/4, 82P/8, 82P/12, 83M/1, 83M/5 and 83 M/9 (all in parts) (Fig. 1.1).

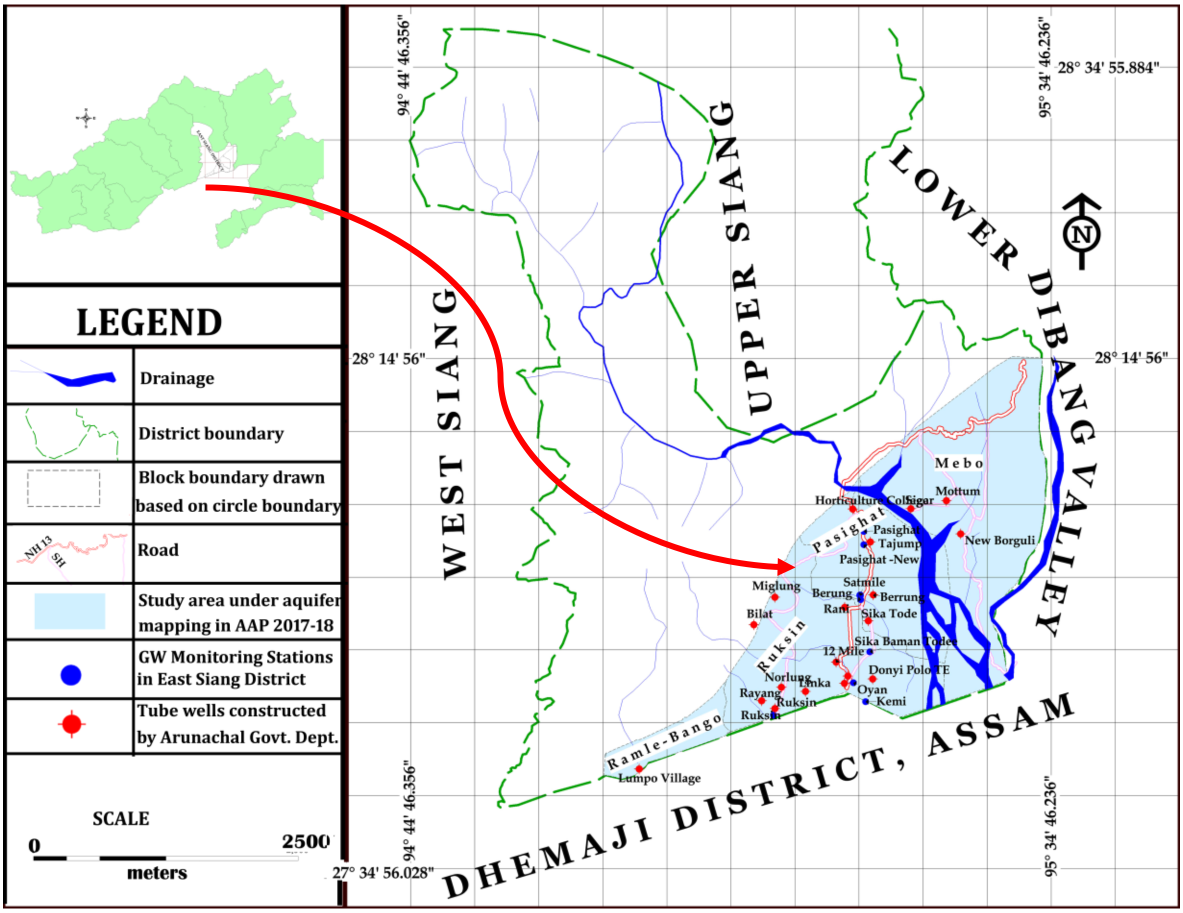


Fig. 1.1: Base map of the study area

Table 1.1: Administrative area (Source: East Siang Statistical Handbook 2011)

Block	Population	Female	Male	No. of villages	Toposheet
Ruksin	20128	10015	10113	30	83M/1, 83M/5
Pasighat	5785	5913	11698	26	82P/8, 83M/5,9
Mebo	7381	7093	14474	19	82P/8, 83M/9
Total	33294	23021	36285	75	

The district head quarter Pasighat is well connected with rest of the country by road.

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, State Groundwater Departments. All data were plotted in base map on GIS Platform (MapInfo-6.5 using Projection category longitude/latitude (Indian for Pakistan, India, Bangladesh, Nepal projection).

The available data, data gap and data generation work is tabulated in Table: 1.2 and shown in Fig. 1.2 to 1.3.

Table 1.2: Data availability, data gap and data generation in East Siang district of Arunachal Pradesh

SN	Theme	Type	Data available	Data gap	Data generation	Total	Remarks
1	Borehole Lithology Data		20	11	Nil	11	19 TWs belong to State Govt (WRD) and 1 belongs to Educational Institute. Maximum depth of TW is only 80m.
2	Geophysical data		Nil	31	Nil	31	
3	Groundwater level data	Dug well (Aquifer-1)	4				GW abstraction structures are not available in hilly area.
		Spring (Aquifer-1)	Nil		4	4	
4	Groundwater quality data	Dugwell-Aquifer-I	6	18	Nil	24	GW abstraction structures are not available in hilly area.
		Spring (Aquifer-I)	2				
5	Specific Yield		Nil	12	Nil	12	
6	Soil Infiltration Test		Nil		3		

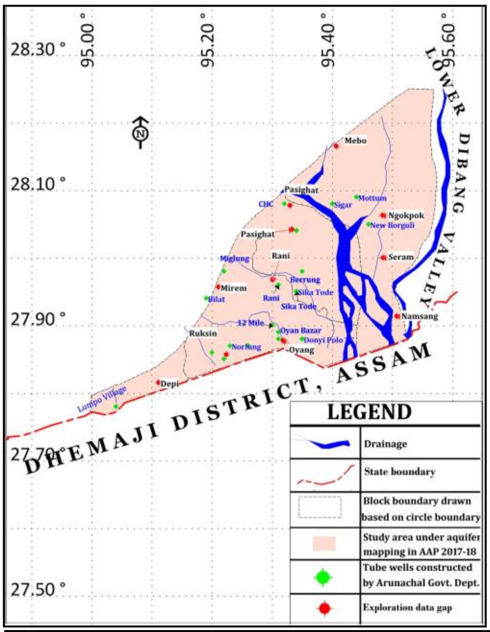


Fig. 1.2: EW data availability and data gap. Only lithologs of TW constructed by Water Resources Dept., Govt. of Arunachal Pradesh are available.

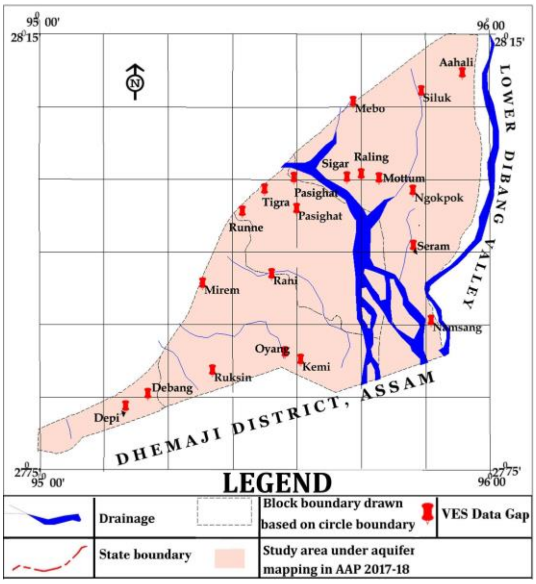


Fig. 1.3: VES data gap in the study area.

1.6 Rainfall-spatial, temporal and secular distribution: The rainfall distribution of the area is influenced by altitudinal difference. The average rainfall of the area is 3580mm.

Isohytes were constructed on the basis of rainfall data of four raingauge stations viz., Namsai of Lohit district, one rain gauge station in the campus of Central Horticulture College at Pasighat and another rain gauge station of Rural Works Dept., Govt., of Arunachal Pradesh near Pasighat, East Siang district, Roing of Lower Dibang Valley district (Fig.1.4). It is observed that rainfall increases towards northeastern direction of the study area and decreases towards Assam Plains. The entire northern part of the study area coincides with the Himalayan Foothill. Dhar and Nandargi (2004) opined that Himalayan foothill receives highest precipitation due to the fact that most of the moisture is precipitated after encountering the foothills and the next few higher ranges of the Himalayas. Thereafter, the moisture-holding capacity of the air decreases rapidly as the southerly winds encounter the higher ranges of the Himalayas to the north.

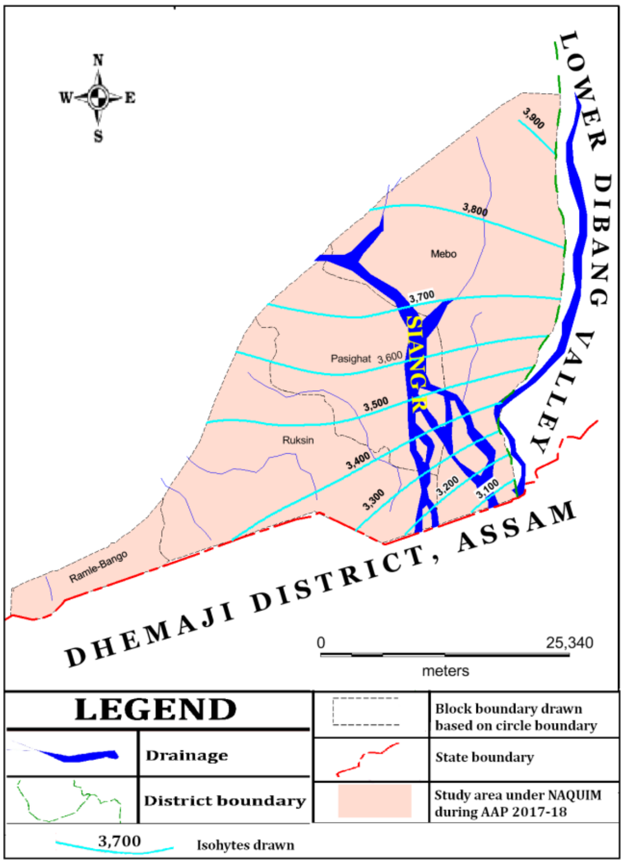
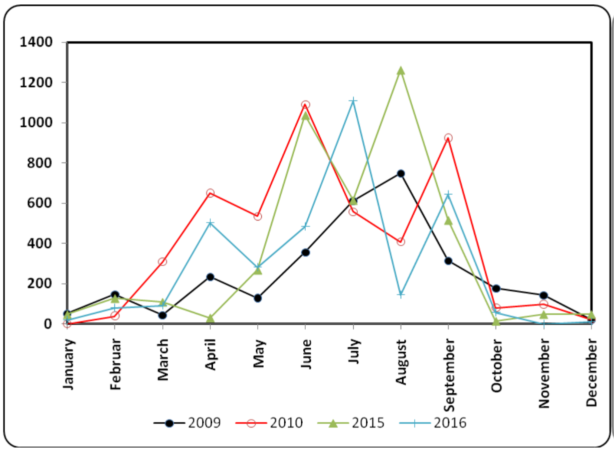


Fig. 1.4: Isohytal map of the area



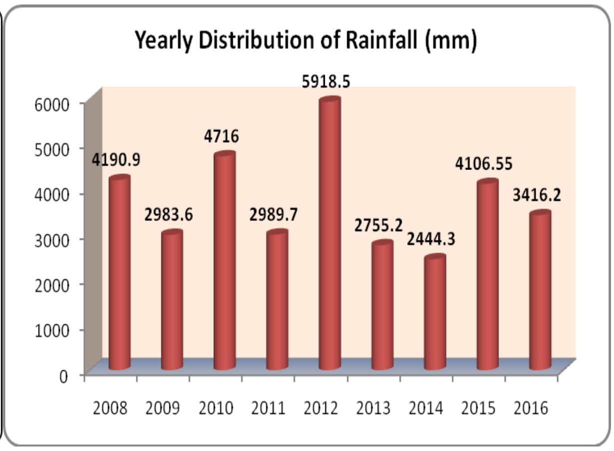


Fig. 1.5a: Monthly rainfall distribution Fig. 1.5b: Yearly rainfall distribution

From the climatic graph (Fig. 1.5c), it can be said that the post-monsoon season continues from October to December while March to May constitutes pre-monsoon season. Monsoon season starts from June and continues up to September. The monsoon rainfall distribution is in general bi-model in nature where the first peak rainfall is generally observed in July and second is generally observed in September (Fig. 1.5a). Pre-monsoon average maximum temperature ranges from 27.3 to 30.2^{0}C and minimum temperature ranges from 15.5 to 21.3 ^{0}C. Post monsoon average maximum temperature ranges from 23.3 to 29.8^{0}C and minimum temperature ranges from 13.4 to 20.6 ^{0}C. Monsoon maximum temperature remains above 30^{0}C and minimum temperature above 20^{0}C.

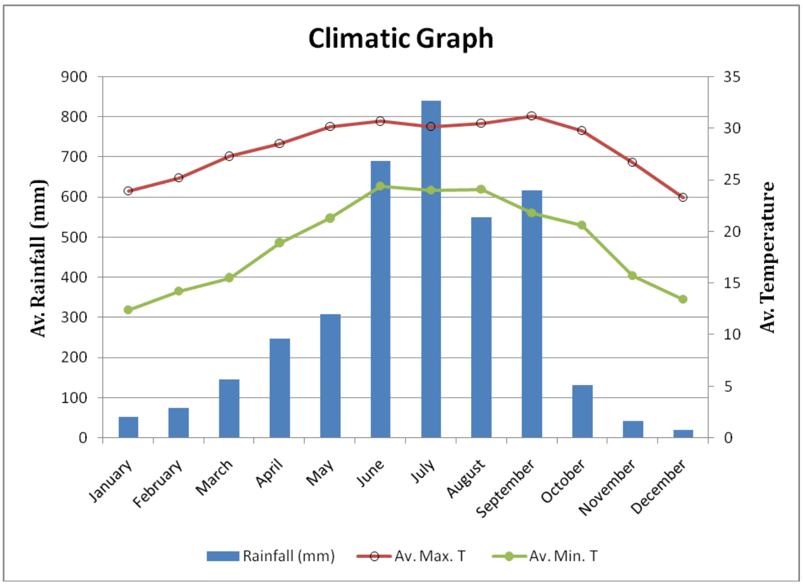


Fig. 1.5c: Climatic graph prepared based on climatic data received from Central Horticulture College, Pasighat

1.7 Physiographic set up: Phisiographically the area can broadly be divided into three parts, i.e., the hilly tract, the piedmont and the flood plain. The hilly tracts are characterized by low to high relief hills and corrugated landform. The higher hill ranges to the north and northwest of the study area rising to about 1260mamsl. The slope of the area drops from northern and western corners towards south. The topography of these hills is rugged with deep V-shaped valleys. Piedmont areas are found on the right bank of the Siang River. This zone is characterized river terraces, alluvial fans, channel bars and point bars. Flood plain is found on both the banks of the Siang River and it merges with the Assam Plain (Fig. 1.6).

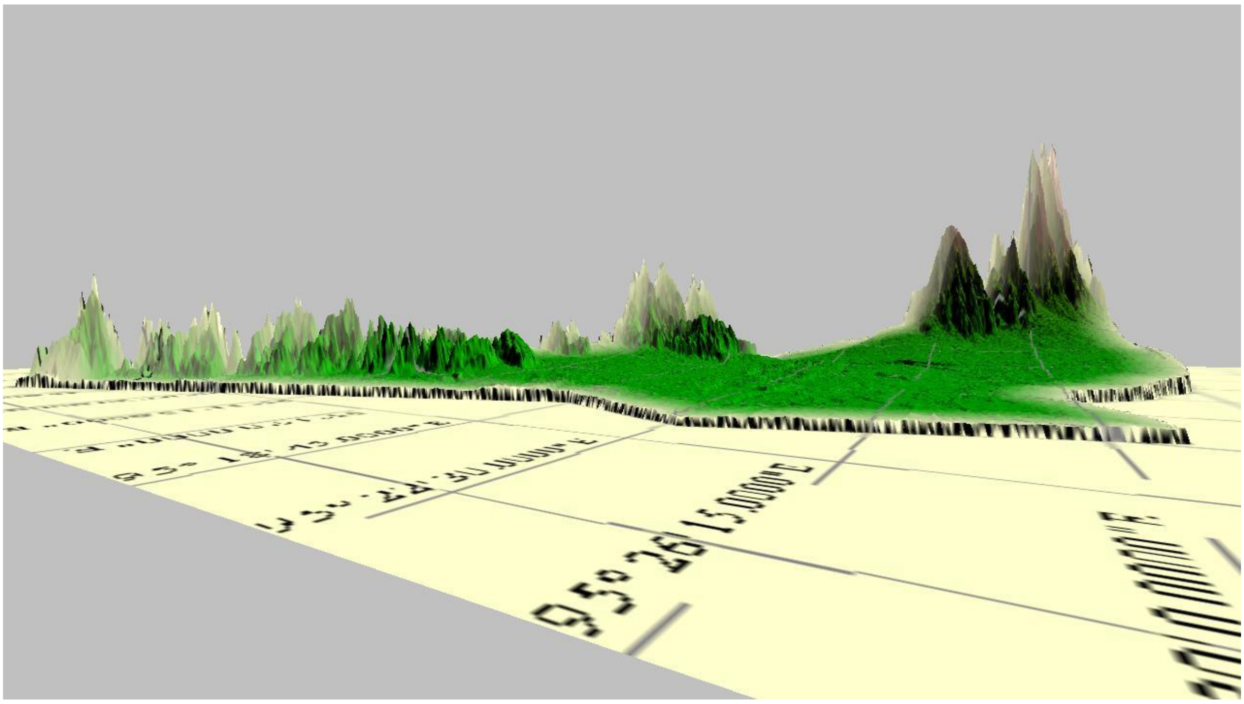


Fig. 1.6: Three dimensional view of the study area

1.8 Geomorphology: Three major Quaternary geomorphic units are identified ((GSI 19810. These units are: the Roing surface, the Pasighat surface and the Sadiya surface. The Roing Surface is occurring between the foothills and downwards to near 140m topographic contour is predominantly a composite alluvial fan surface, comprising rudaceous sediments ranging in size from boulders to pebbles, in a highly oxidized sandy silt matrix. It shows a break-in-slope relationship with the Siwalik Hills, occurring to its north and northwest. It is characterized by a distinct southerly and southeasterly sloping gently undulating surface, covered with natural forests.

The Pasighat surface comprises a stepped sequence of five fluvial terraces, viz, the Tigra terrace, the Balek terrace, the Pasighat terrace, the Oyang terrace and the Koboghat terrace from the oldest to the youngest. These are unpaired terraces, developed on the right bank of the Siang River. The terraces rise to a composite height of about 80m above the river level at Pasighat and are usually bounded by scarps ranging in height, in general, from 7m to 40m approximately. Lithologically, the older/higher terraces are composed of coarser detritus comprising comprising mainly bounded mainly boulder, cobbles and pebbles of quartzites and volcanic. Reduction in size fraction of the sediments from north to south, in general, has been noticed. The higher terraces contain boulders, cobbles, pebbles in minor sandy matrix and show no definite stratification while younger terraces show rudimentary stratification, cross-bedding, etc. in finer sediments which are more in proportion compared to the higher terraces.

The Sadiya surface is the combined flood plain of the Siang-Dibang-Lohit river system, comprising by and large, unoxidised fine sediments like sand and silt/clay with occasional pebbly horizons.

Geomorphic Analysis: Geomorphology can also be defined as landforms description and classification. GIS based analysis of Digital Elevation Data helps to classify landform. In this study downloaded and processed DEM is classified into 10 classes based on Terrain Power Index (TPI) (Fig.). Area under different landforms are shown in Table:1.3.

Using TPI at different scales, plus slope, users can classify the landscape into both slope position (i.e. ridge top, valley bottom, mid-slope, etc.) and landform category (i.e. steep narrow canyons, gentle valleys, plains, open slopes, mesas, etc.). The algorithms are clever and fairly simple. The TPI is the basis of the classification system and is simply the difference between a cell elevation value and the average elevation of the neighborhood around that cell. Positive values mean the cell is higher than its surroundings while negative values mean it is lower.

The degree to which it is higher or lower, plus the slope of the cell, can be used to classify the cell into slope position. If it is significantly higher than the surrounding neighborhood, then it is likely to be at or near the top of a hill or ridge. Significantly low values suggest the cell is at or near the bottom of a valley. TPI values near zero could mean either a flat area or a mid-slope area, so the cell slope can be used to distinguish the two.

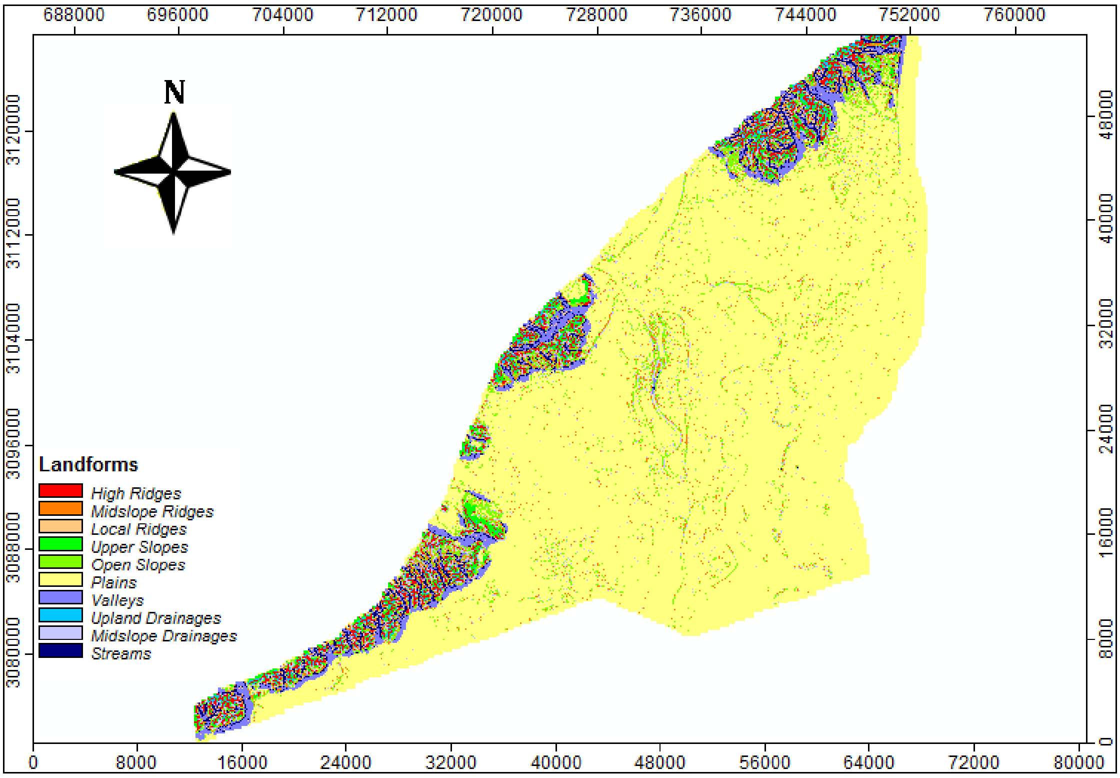


Fig. 1.7: Landform classification in the study area.

Table 1.3: Area under different landform

Class	Name	Area (in sq.metre)	%area
1	Stream	27229217.12	2.26
2	Midslope Drainages	29629917.73	2.46
3	Upland Drainages	10135001.94	0.84
4	Valleys	39416751.76	3.28
5	Plains	949323729.8	78.92
6	Open Slopes	56783698.48	4.72
7	Upper Slopes	21308704.79	1.77
8	Local Ridges	4750833.968	0.39
9	Midslope Ridges	33643796.3	2.8
10	High Ridges	30652039.22	2.55

From the figure and table it becomes clear that majority of the area is classified as plains.

Slope and aspect: In this study attempt has been made to classify the study area based on slope.

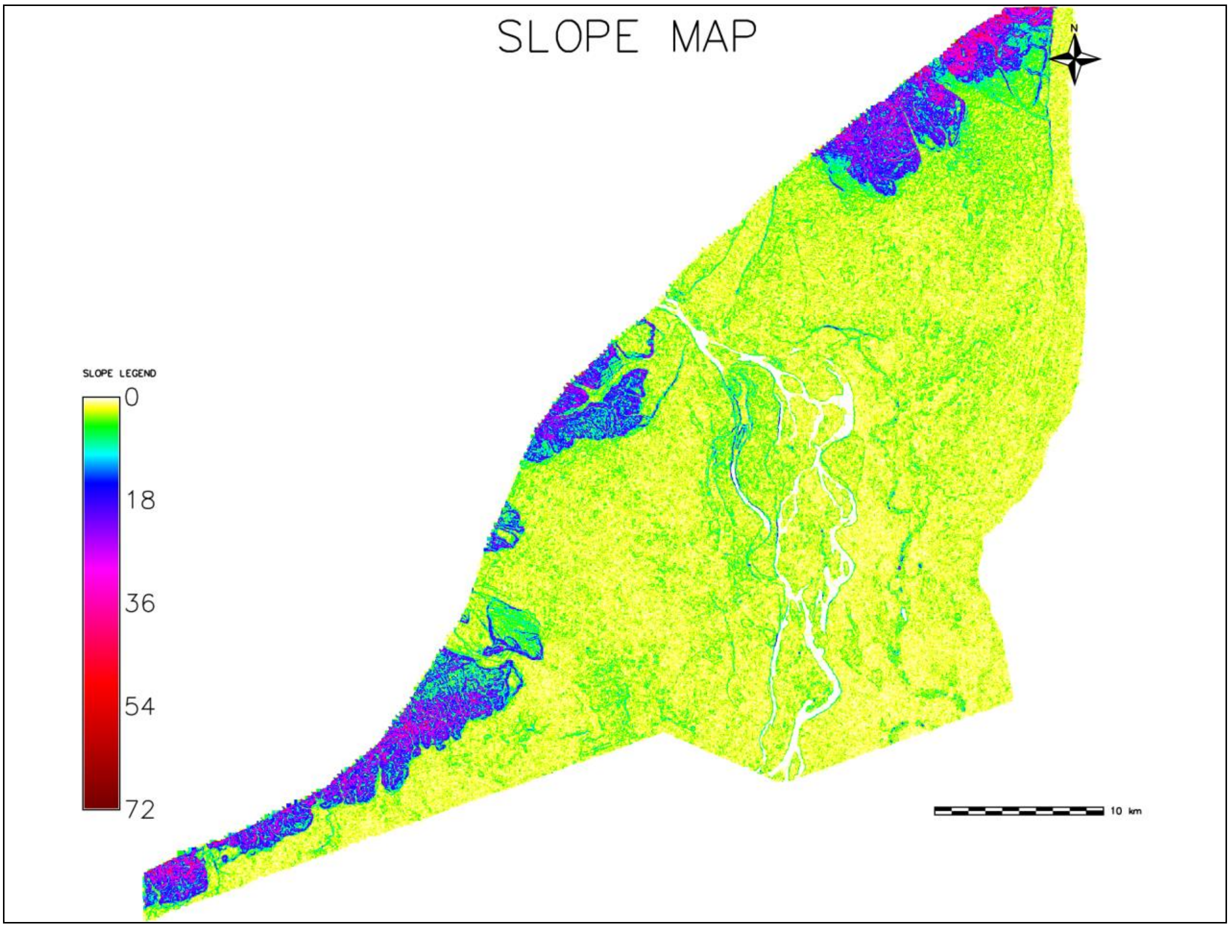


Fig. 1.8: Slope map of the study area

Table 1.4: Slope based classification of the study area

Degree		Slope %		Terminology	Area (Ha)
From	To	From	To		
0	0	0	0	Level	4723.15
0.3	1.13	0.5	2	Nearly Level	29711.41
1.13	3	2	5	Very Gentle Slope	51610.42
3	5	5	9	Gentle slope	19150.98
5	8.5	9	15	Moderate Slope	5542.58
8.5	11.33	15	20	Strong Slope	2201.25
11.33	16.5	20	30	Strong Slope	7267.58
16.5	24	30	24	Very Strong Slope	4483.59
24	35	45	70	Extreme Slope	1699.38
35	45	70	100	Steep Slop	519.78
>45		>100		Very Steep Slope	93.36
				Total area	127003.48

1.9 Land use Pattern: Block wise land use data is available in 2010-11 agriculture census. The land utilization pattern of the study area is given in Table: 1.5

Table: 1.5 Land utilization pattern, as per 2010-2011 agricultural census (Area in Hect)

Block	Area	Net sown area (ha)	Area under current fallow (ha)	Net cultivated area (ha) (2+3)	Other uncultivated land excluding fallow land	Fallow land other than current fallows	Culturable waste land (ha)	Total uncultivated land (5+6+7)	Land not available for cultivation (ha)
	1	2	3	4	5	6	7	8	9
Pasighat	4378	2195	706	2901	290	643	366	1299	179
Ruksin	5525	4355	57	4412	318	296	272	887	226
Mebo	5089	3614	1038	4652	117	130	83	330	107

Note: Total May not Tally Due to Rounding off (Agriculture Census 2010-11)

1.10 Soil: The soil developed in each physiographic unit has their distinct morphological and other related properties. It indicates a good soil-landform relationship in this region. Taxonomically the soils of the district are divided into 28 classes (Fig. 1.9 & Table 1.6).

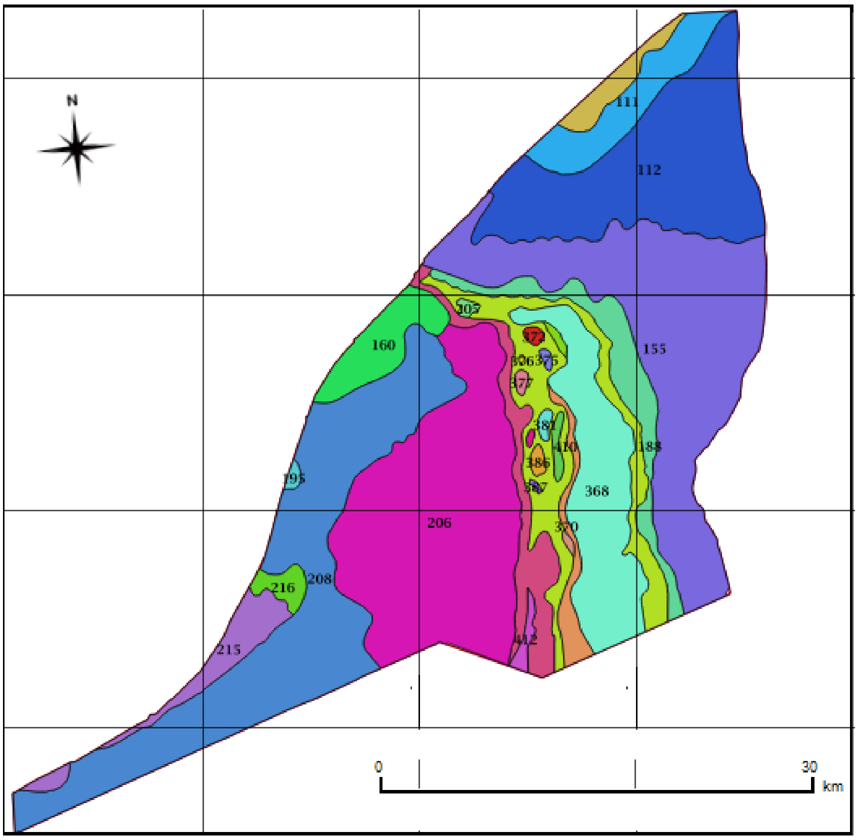


Fig. 1.9: Soil Map of the study area

Table 1.6: Description of soil map of the study area

SN	Symbol	ID	Soil Texture	Description
1		84	Fine-loamy Pachic Haplumbrepts & Fine, Typic Palehumults	Very deep, well drained, fine-loamy, soils on moderately sloping side slope of hills having loamy surface with moderate erosion hazard and slight stoniness: associated with; Very deep, well drained, fine soils with moderate erosion hazard
2		111	Loamy-skeletal, Typic Udorthents & Coarse-loamy, Entic Haplumbre	Moderately shallow, well drained, loamy-skeletal soils on very gently sloping upper piedmonts having loamy surface with severe erosion and slight flooding hazard: associated with: moderately deep, well drained, coarse-loamy soils with moderate erosion hazard
3		112	-	-
4		155	Coarse-Sitty Aerie Fluvaquents & Coarse-loamy Fluventic Dystroch	Deep, imperfectly drained, coarse-silty soils on very gently sloping active flood plain having loamy surface with severe erosion and severe flooding hazards: associated with: very deep, moderately well drained, coarse-loamy soils with moderate erosion
5		159	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
6		160	Loamy-skeletal, Typic Udorthents & Coarse-loamy, Entic Haplumbre	Moderately shallow, well drained, loamy-skeletal soils on very gently sloping upper piedmonts having loamy surface with severe erosion and slight flooding hazard: associated with: Moderately deep, well drained, coarse-loamy soils with moderate erosion hazard
7		188	Coarse-loamy, Typic Udifluvents & Coated Aquic Udipsamments	Deep, well drained, coarse-loamy soils on very gently sloping active flood plain having sandy surface with very severe erosion and very severe flooding hazards: associated with: Moderately deep, somewhat excessively drained, sandy soils with moderate erosion
8		195	Loamy-skeletal, Typic Haplumbrepts & Fine-loamy, Umbric Dystroch	Deep, somewhat excessively drained, loamy-skeletal soils on moderately sloping side-slopes of hills having loamy surface with severe erosion hazard and slight stoniness: associated with: Very deep, well drained, fine loamy soils with moderate erosion hazard
9		205	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
10		206	Coarse-Sitty Aerie Fluvaquents & Coarse-loamy Fluventic Dystroch	Deep, imperfectly drained, coarse-silty soils on very gently sloping active flood plain having loamy surface with severe erosion and severe flooding hazards: associated with: very deep, moderately well drained, coarse-loamy soils with moderate erosion
11		208	Coarse-loamy, Umbric Dystrochrepte & Coarse-loamy, Dystric Eutro	Very deep, well drained, coarse-loamy soils on very gently sloping upper piedmonts having loamy surface with moderate erosion hazard and slight stoniness: associated with: Deep, well drained, coarse-loamy soils with severe erosion and slight flooding hazard
12		215	Fine-loamy, Typic Haplumbrepts, & Loamy-skefetal, Typic Udorthen	Deep, somewhat excessively drained, fine-loamy soils on steeply sloping side-slopes of hills having loamy surface with severe erosion hazard and slight stoniness associated with: Deep, well drained loamy-skeletal soils on

				moderately sloping side slopes"
13		216	Loamy-skeletal, Typic Haplumbrepts & Fine-loamy, Umbric Dystroch	Deep, somewhat excessively drained, loamy-skeletal soils on moderately sloping side-slopes of hills having loamy surface with severe erosion hazard and slight stoniness: associated with: Very deep, well drained, fine loamy soils with moderate erosion hazard
14		368	Coarse-loamy, Typic Udifluvents & Coated Aquic Udipsamments	Deep, well drained, coarse-loamy soils on very gently sloping active flood plain having sandy surface with very severe erosion and very severe flooding hazards: associated with: moderately deep, somewhat excessively drained, sandy soils with moderate erosion
15		369	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
16		370	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
17		371	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
18		372	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
19		375	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
20		376	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
21		377	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
22		381	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
23		383	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
24		384	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
25		386	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards
26		387	Coated, Typic Udipsamments	Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards

1.11 Hydrology and drainage: The study area is a part of the Siang or Brahmaputra river basin. Some of the tributaries of river Siang are Siku, Ramro Korong, Sibu, etc. The Siang River data is not available in the area.

The drainage density in the flood plain is medium in the study area and density in the whole district varies according to geology and geomorphology. Drainage pattern is generally sub-dendritic to sub-parallel. Each geomorphic unit has its own drainage pattern. The drainage pattern in the high relief structural hills is parallel and trellis. Streams of low relief structural hills are sub-parallel to dendrtitic pattern whereas in the dissected hills the drainage pattern is closely spaced sub-dendritic. In the Piedmont plain the drainage channels are nearly straight and sub- parallel, whereas in the flood plains they are meandering.

1.12 Agriculture: As per agriculture census 2010-11, net sown area is nearly 10000 ha.. Paddy is the principal crops followed by maize, millet. Vegetables, mustard and fruits like orange are also cultivated in these villages. Details of the area and production of food crops in East Siang district is given in Table: 1.5.

Table 1.7: Area under major crops in East Siang District

Area in hectare					
Paddy	Maize	Millet	Wheat	Pulses	Total
11743	3091	2001	123	1120	18078

Source: Office of the Deputy Director Agriculture, East Siang district, Pasighat, A.P.

As per Agriculture Census of 2010-11, the areas do not have any canal, well or any conventional sources of irrigation rather there is other sources of irrigation.

CHAPTER 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. Population data is collected from Census of India website. Agricultural data is collected from Office of the Deputy Director Agriculture, East Siang district, Pasighat, Govt. of Arunachal Pradesh and also from the website of Ministry of Agriculture, Govt. of India.

CGWB has not initiated exploration in the area. Water Resource Department, Govt. of Arunachal Pradesh had constructed number of tube wells in the area. However, all the wells are not incorporated in the present study due to lack of location details (coordinate). Details of the wells are given in Table 2.5. Rainfall data was collected from Rural Works Department, Govt. of Arunachal Pradesh, Itanagar. Central Horticulture College, Pasighat. Horticulture College, Pasighat has also supplied rainfall and other climatic data. CGWB had 8 groundwater monitoring station in the area till 2014. However, three GWMS had to abandon and other monitoring stations were regularly monitored (Table 2.1 and 2.2).

2.2 Data Generation

2.2.1 Hydrogeological data: Groundwater abstraction structures are not found in the entire study area. The ground water abstraction structures are mainly found in the lower level terraces and in the flood plain area. Due to this reason entire study area could not be covered by establishing new water level monitoring stations. Spring monitoring stations are also established.

Water level data: The location details of water level monitoring stations are given in Table 2.1.

Table 2.1: Water level monitoring stations and spring locations

Unique ID	Name of village/ site	Latitude	Longitude	RL (mamsl)	Total depth of Pz/DW (mbgl)	Type (DW/Pz/Spring)	Aquifer group	Measuring point (magl)	Source /Agency
ESRB_01	Depi	95.110	27.808	118	7	DW	Unconsolidated (I-Aquifer)	0.6	CGWB
ESRU_02	Debang	95.140	27.833	116	6.53	DW		1	CGWB
ESRU_03	Jone Jo	95.172	27.853	159	7.63	DW		0.8	CGWB
ESRU_04	Ruksin	95.218	27.841	135		DW		1	CGWB
ESRU_05	Niglok	95.232	27.900	179	5.09	DW		0.6	CGWB
ESRU_06	Mirem	95.209	27.958	202	9.5	DW		0.9	CGWB
ESRU_07	Pogdum	95.245	27.970	168	18.69	DW		0.8	CGWB
ESRU_08	Rani	95.314	27.958	131	7.16	DW			CGWB
ESRU_09	Sille	95.302	27.910	132	6	DW		0.6	CGWB
ESRU_10	Oyan	95.322	27.878	136	11.95	DW		0.7	CGWB
ESRU_11	Sika Baman Todee	95.344	27.913	128	6.63	DW		0.91	CGWB
ESRU_12	Kemi	95.338	27.856	122	5.13	DW		GL	CGWB
ESP_13	Pasighat	95.336	28.051	153		DW			CGWB
ESP_14	Pasighat1	95.315	28.085	175	4.46	DW		0.74	CGWB

Unique ID	Name of village/site	Latitude	Longitude	RL (mamsl)	Total depth of Pz/DW (mbgl)	Type (DW/Pz /Spring)	Aquifer group	Measuring point (magl)	Source /Agency
ESP_15	Pasighat _New	95.336	28.036	138		DW			CGWB
ESP_16	Yagrung	95.252	27.970	165	16.15	DW		1.5	CGWB
ESP_17	Tode WRC	95.265	27.961	161	8.82	DW		0.9	CGWB
ESP_18	Satmile	95.331	27.978	**146**		DW			CGWB
ESP_19	Tajump (5^{th} Mile)	95.340	27.997	144	8.38	DW			CGWB
ESP_20	Mangang	95.259	27.912	146	6.31	DW	Unconsolidated (I-Aquifer)	0.4	CGWB
ESM_21	Serum	95.472	28.000	127	5.22	DW		0.58	CGWB
ESM_22	New Borguli	95.463	28.036	133	6.85	DW		0.73	CGWB
ESM_23	Borguli	95.464	28.042	140	3.08	DW		0.52	CGWB
ESM_24	Ngopok1	95.474	28.087	155	10.26	DW		1.5	CGWB
ESM_25	Ngopok2	95.474	28.074	156	5.24	DW		0.96	CGWB
ESM_26	Sigar	95.398	28.078	158		DW			CGWB
ESM_27	Tenga Bari	95.499	27.905	115	3.65	DW		0.33	CGWB
SPRING									
Unique ID	Name of village/site	Latitude	Longitude	RL (mamsl)	Discharge (lps)				CGWB
ESR_01S	Mirem				**26.8**		Unconsolidated (I-Aquifer)		CGWB
ESM_02S	Mottum				**6.25**				CGWB
ESM_03S	Raling				**5.83**				

Table 2.2 Water level data of monitoring stations

Unique ID		Date	Depth		Unique		Date	Dept
1		**2**	**3**		**4**		**5**	**6**
ESRB_01	Depi	16/05/2017	5.21		ESP_14	Pasighat1	16/05/201	6.94
		10/11/2017	3.57				11/11/20	7.09
ESRU_02	Debang	16/05/2017	3.56				23/08/201	1.77
		10/11/2017	2.86				10/01/201	9.43
ESRU_03	Jone Jo	16/05/2017	4.11		ESP_15	Pasighat_New	16/05/2017	9.41
		11/11/2017	4.43				11/11/2017	7.8
ESRU_04	Ruksin	18/05/2017	2.1				23/08/2017	3.39
		23/08/2017	0.65				10/01/2018	10.2
		11/11/2017	2.06		ESP_16	Yagrung	16/05/201	8.21
		10/01/2018	2.15				10/11/2017	3.03
ESRU_05	Niglok	16/05/2017	3.19		ESP_17	Tode WRC	16/05/201	3.14
		11/11/2017	4.75				10/11/2017	-0.04
ESRU_06	Mirem	16/05/2017	5.81		ESP_18	Satmile	16/05/201	1.63
		10/11/2017	7.75				11/11/2017	1.63
ESRU_07	Pogdum	16/05/2017	8.1				23/08/2017	1.30
		10/11/2017	3.75				10/01/2018	2.55
ESRU_08	Rani	16/05/2017	2.57		ESP_19	Tajump (5^{th}	16/05/201	6.24
		11/11/2017	2.06				11/11/2017	6.1
		23/08/2017	1.76		ESM_20	Mangang	16/05/201	1.89
		10/01/2018	2.63		ESP_21	Serum	17/05/2017	2.55
ESRU_09	Sille	16/05/2017	0.51				10/11/2017	3.59
		11/11/2017	1.2		ESM_22	New Borguli	17/05/2017	5.17
		10/01/2018	1.61				10/11/2017	5.03
ESRU_10	Oyan	18/05/2017	8.09		ESM_23	Borguli	17/05/201	0.71

		11/11/2017	7.8					
		23/08/2017	3.38		ESM_24	Ngopok1	17/05/2017	5.68
		10/01/2018	8.75				10/11/2017	2.37
ESRU_11	Sika Baman	18/05/2017	1.22		ESM_25	Ngopok2	17/05/2017	2.26
		11/11/2017	0.96				17/05/2017	2.63
		23/08/2017	0.24		ESM_26	Sigar	17/05/2017	7.20
		10/01/2018	2.15				10/11/2017	5.50
ESRU_12	Kemi	18/05/2017	2.11		ESM_27	Tenga Bari	17/05/2017	2.87
		11/11/2017	2.19				10/11/2017	3.12
		23/08/2017	1.85		ESP_13	Pasighat_Horti	18/05/2017	0.3
		10/01/2018	3.26				10/11/2017	0.73

2.2.2 Soil Infiltration studies: Infiltration test: Salient features of the test sites are provided in Table 2.4 &2.5. A perusal of the table shows that the tests have been conducted only in barren land and the soil types encountered in the sites are silt and sand admixtures. In general, infiltration test was conducted for duration of 210 minutes.

Table 2.3: Salient features of the soil infiltration test sites

Site	**Location**	**Land use**	**Soil type**	**Latitude**	**Longitude**
Mirem	Open Ground	Barren Land	Sandy soil	**27.957781**	**95.20884**
New Borguli	Open Ground	Barren Land	Sandy soil	28° 0'33.4"N	95° 27'39.8"E
Satmile	Open Ground	Barren Land	Sandy soil	27° 58'37.9"N	95° 19'50.9"E

Summary of the infiltration tests is given in Table .2.4

Table 2.4: Summary of Infiltration Tests

S.N.	Site	Land use	Soil type	Duration of test (min)	Total Quantum of water added in m	Total Quantum of water infiltrated in m	Specific Yield (Sy)	Total quantum of water recharged in m (5X6)	IF = Recharged water/ added water
1	**2**	**3**	**4**		**8**	**5**	**6**		**7**
1	Mirem	Barren Land	Sandy gravel	219	0.209	15	0.16	0.016	7.579
2	New Borguli	Barren Land	Sandy gravel	154	0.465	9.6	0.16	0.063	13.454
3	Satmile	Barren Land	Clayey gravel	174	0.22	57.6	0.16	0.006	2.909

2.2.3 Water Quality:

To understand the chemical quality of groundwater in the study area and its suitability for domestic, drinking and agricultural uutilization, water quality data of spring and existing quality data of CGWB were collected. Water samples were collected from monitoring wells for detailed, iron, heavy metals and arsenic. However, heavy metal and arsenic analysis data are yet to be received. Available chemical analysis report of ground water as well as river (Siang River) is provided in Table 2.5.

2.2.4 Geophysical survey

VES survey could not be conducted as the geophysicist of NER was transferred.

Table 2.5: Post monsoon water quality data of ground water and surface water of East Siang District, Arunachal Pradesh

SN	Location	Type of sample (EW or DW)	pH	EC (µs/cm) 25C	TDS	CO_3^{-2}	HCO_3^{-1}	TA (as CaCO3)	Cl^-	SO_4^{-2}	NO_3^{-1}	F^-	Ca^{+2}	Mg^{+2}	TH (as CaCO3)	Na	K	Fe
1	Kiyit	DW	7.21	79.68	44.84	0	50	50	17.73	0	0.7	0.2	13.61	9.29	72.31	5.32	35.13	0
2	New Borguli	DW	7.04	148	83.5	0	65	65	17.73	0	0.5	0.14	32.33	14.45	140.36	25.33	15.13	0
3	Seram	DW	7.21	161.4	90.71	0	80	80	21.27	0	1.9	0.19	34.03	12.39	136.11	8.3	12.61	0
4	Pogdum	DW	6.99	101.4	57.64	0	60	60	21.27	0	0.7	0.18	25.52	10.32	106.34	23.28	5.31	0.02
5	Mirem	DW	6.84	90.66	52.71	0	60	60	14.18	0	1.2	0.16	18.71	9.29	85.07	5.17	5.2	0
6	Debang	DW	7.01	117.1	68.33	0	55	55	21.27	0	1.4	0.15	27.22	8.26	102.08	6.92	9.14	0
7	Pasighat (PP)	DW	6.71	51.8	30.31	0	15	15	24.82	0	1.7	0.09	8.51	8.26	55.29	3.23	5.35	0
8	Satmile	DW	6.76	98.89	57.52	0	35	35	17.73	0	0.9	0.07	17.01	8.26	76.56	4.17	3.62	0
9	Oyan	DW	6.76	53.11	30.87	0	35	35	31.91	0	0	0.08	8.51	6.19	46.79	7.19	10.23	0.09
10	Kemi	DW	7.48	208.3	121.2	0	110	110	127.62	0	0.2	0.18	59.55	4.13	165.88	21.3	5.04	0.01
11	Ruksin	DW	7.47	651.9	378.4	0	130	130	124.08	0	1.3	0.22	74.86	24.78	289.23	98.45	11	0
12	Mirem	Spring	7.56	88.25	52.99	0	45	45	7.09	0	0.96	0.18	8	7.28	50	3.01	1.82	0.22
13	Mottum	Spring	7.01	39.36	22.39	0	20	20	3.55	0	1.08	0.09	4	2.43	20	2.3	1.52	0.03
14	Oiramghat	River (Siang)	7.82	213.1	122.2	0	80	80	10.64	0	0.61	0.54	28	6.07	95	6.21	3.28	3.35
15	Ranaghat, Pasighat	River (Siang)	7.94	185.3	106.1	0	75	75	3.54	0	0.62	0.39	12	14.56	90	5.46	2.9	4.2
16	New Borguli	River (Siang)	7.91	207.6	117.2	0	80	80	10.64	0	0.68	0.47	32	2.43	90	7.12	2.91	2.86
17	Rottung	River (Siang)	7.93	250.3	141.8	0	80	80	14.18	0	1.05	0.64	28	8.5	105	9.1	3.87	7.57

2.2.5 Exploratory Drilling

No exploration was carried out by CGWB in the past and present also. Data generated during drilling carried out by Water Resources Departmment, Govt. of Arunachal Pradesh are utilised in the present study.

Table 2.6: Details of tube wells constructed by Water Resources Department, Govt. of Arunachal Pradesh

Village/ Location	Taluka / Block	District	Toposheet No.	Lat	Long	Type of well	Depth (m)	SWL (mbgl)	Dia (mm)	Source / Agency
Donyi Polo TE		East Siang	83M/5	27.88	95.35	TW	51.5	7.52	304.8mmX30.32m 203.2mmX1.030m 203.2mmX16.20m 203.2mmX3.00m	RWD
Rani			83M/5	27.96	95.31	TW	40.7	8.00	203.2mmX22.6m 203.2mmX15.84m 203.2mmX2.0m	RWD
Sika Tode			83M/5	27.95	95.34	TW	60.45	3.66	304.8mmX32.5m 203.2mmX0.97m 203.2mmX24.0m 203.2mmX2.00m	WRD
Tajump			82P/8	28.04	95.34	TW	52	6.00	254.1mmX27.15m 203.2mmX9.20m 203.2mmX14.85m 203.2mmX0.80m	WRD
Berrung			82P/8	27.98	95.35	TW	22	3.66	254.0mmX29.0m 203.2mmX 12.5m	WRD
Miglung			83M/5	27.98	95.22	TW	49.5		254.0mmX30.5m 203.2mmX 1.0m 203.2mmX 9.0m 203.2mmX 9.5m	WRD
Norlung			83M/5	27.87	95.23	TW	27			WRD
Ruksin			83M/5	27.85	95.22	TW	45			WRD
Lumpo Village			83M/5	27.78	95.04	TW	45		203.2	WRD
Sille Camp			82P/8	27.88	95.31	TW	30	5.49	101.6	WRD
Mottum			82P/8	28.09	95.44	TW	39			WRD
Sigar			82P/8	28.08	95.4	TW	36		152.4	WRD
New Borguli			82P/8	28.05	95.46	TW	42		203.2	WRD
Oyan Bazar			82P/8	27.89	95.31	TW	24	3.96		WRD
Linka			82P/8	27.87	95.26	TW	24			WRD
12 Mile			82P/8	27.9	95.3	TW	34			WRD
Rayang			83M/5	27.86	95.2	TW	39	6.10		WRD
Bilat			83M/5	27.94	95.19	TW	32			WRD
CHC			82P/8	28.08	95.32	TW	76.22			Horticulture college
Donyi Polo TE				27.88	95.35	TW	51.5			WRD
Rani				27.96	95.31	TW	40.7			WRD
Sika Tode			83M/5	27.95	95.34	TW	60.45			WRD
Tajump				28.04	95.34	TW	50		254.0mmX24.0m 203.2mmX 6.5m 203.2mmX 0.50m	WRD

CHAPTER 3.0

Data Interpretation, Integration and Aquifer Mapping

3.1 Data Interpretation

The subsurface geology of the study area is interpreted based on available drilling data of Water Resources Department.

From the available data, it is observed that drilling is restricted to 80m. Out 19 numbers of litholog, the depth of 16 wells is restricted to 50m and only one well depth is more than 70m. Perusals of lithologs of the area indicate drilling is costly and problematic due to frequent encounter of boulder. The exposure of Siwalik Group of rocks is found in the north of the study area and on the right bank of the Siang River. However, its extension in the study area could not be ascertained from the litholog. From the available data only one aquifer is demarcated in the area, i.e., the unconsolidated aquifer of Quaternary age.

Aquifer 1: **Unconsolidated Quaternary Aquifer**

Unconsolidated Quaternary aquifer consists of older and recent alluvium. The aquifer is characterized by coarse grained materials ranging in size from gravel to boulder and scanty clay. Grain size distribution indicates high energy condition throughout the area. Details of aquifer parameters are shown in Table 3.1.

Table 3.1: Aquifer parameters

Village/ Location	Taluka/ Block	Lat	Long	Type of well (DW/BW/TW)	Depth (m)	Date of pumping Test*	Draw down (m)	Transmissivity (m²/day)	Storativity / S.Yield	Specific Capacity (lpm/m of dd)	Discharge
1	2	3	4	5	6	7	8	9	10	11	12
Donyi Polo TE, Oyan		27.88	95.35	TW	51.5	01/02/1992	1.15	513		161	11.10
Rani		27.96	95.31	TW	40.7						18.93
Sika Tode		27.95	95.34	TW	60.45						
Tajump		28.04	95.34	TW	50						
Berrung		27.98	95.35	TW	22						
Miglung		27.98	95.22		49.5						
Norlung		27.87	95.23	TW	27						
Ruksin		27.85	95.22	TW	45						
Lumpo Village		27.78	95.04	TW	45						
Sille Camp		27.88	95.31	TW	30						
Mottum		28.09	95.44	TW	39						
Sigar		28.08	95.4	TW	36						
New Borguli		28.05	95.46	TW	42						
Oyan Bazar		27.89	95.31	TW	24						
Linka		27.87	95.26	TW	24						
12 Mile		27.9	95.3	TW	34						
Rayang		27.86	95.2	TW	39						
Bilat		27.94	95.19	TW	32						
CHC		28.08	95.32	TW	76.22						

*CGWB, NER, Guwahati conducted one pumping test for 400min in Donyi Polo TE, Oyan, East Siang District and except it no pumping tests were conducted in that area.

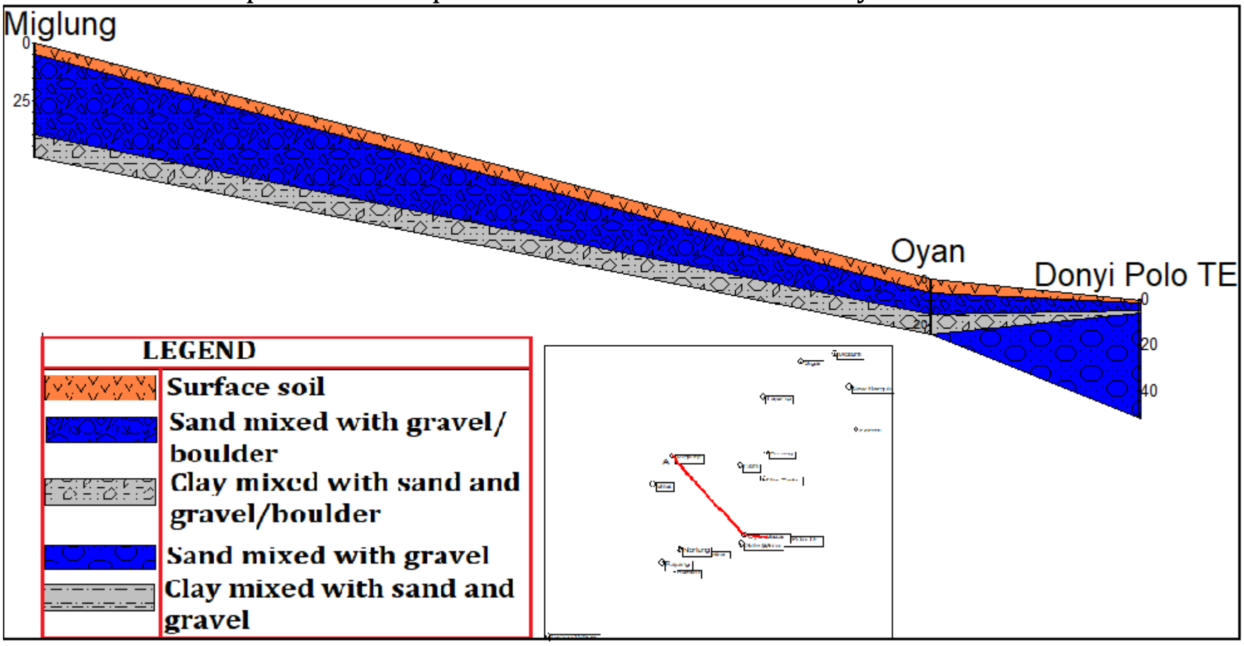
Description of 2D sections: Examinations of the lithologs indicate that subsurface materials are composed of gravels, boulders and minor clay. These coarse grained sub-surface materials can be classified in following way

Top soil: Top soil is composed of sand mixed with gravels and boulders

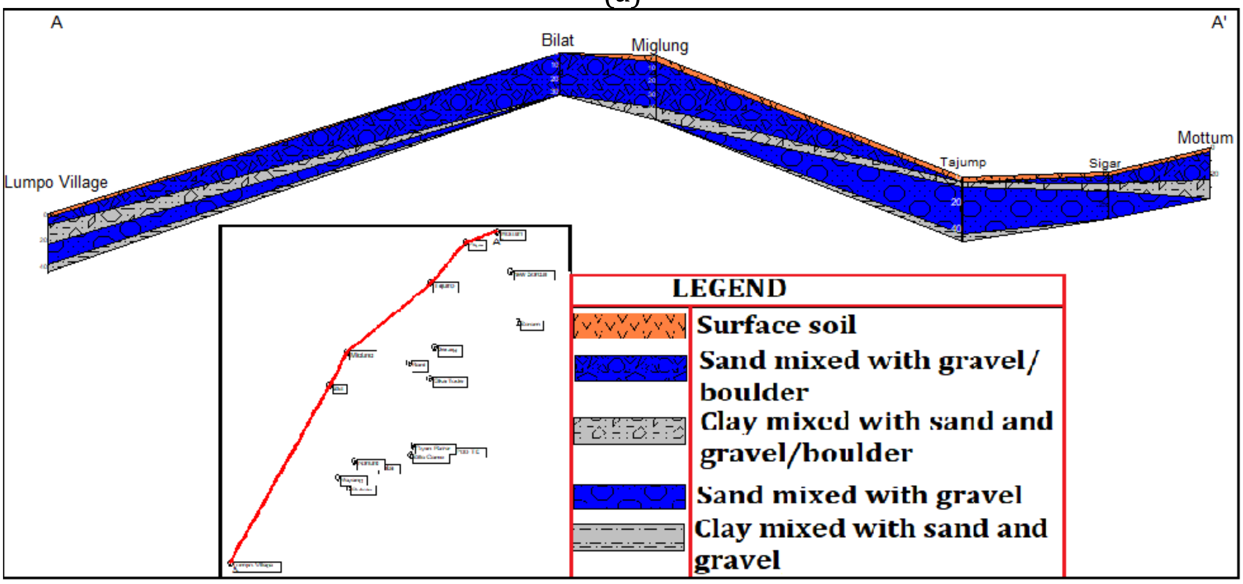
Sand mixed with boulders, pebbles
Clay mixed with boulders, gravels and sand
Sand mixed with gravels
Clay mixed with sand and gravel

Based on the above classification of sub-surface section 2D cross-sections and fence diagram are constructed.

A northwest-southeast section of the area connecting Miglung and Donyi Polo Tea Estate shows that the upper bouldery layer thickness is decreasing towards southern part of the study area, i.e, towards Assam Plain. Moreover, the upper confining layer also thinning out toward southeast. The lower gravelly layer is absent in north of the study area down to a depth of 40m is present in the south of the study area.



(a)



(b)

Fig. 3.1 (a & b): 2D disposition of Quaternary aquifer

Another section constructed connecting wells of both the banks of the Siang River. This northeast and southwest section indicates the presence of two clayey layers in the area. The second clayey layer is absent in the northern part. The gravelly layer thickness increases towards southern part while the bouldery layer thickness increases towards northern part in the vicinity of hills.

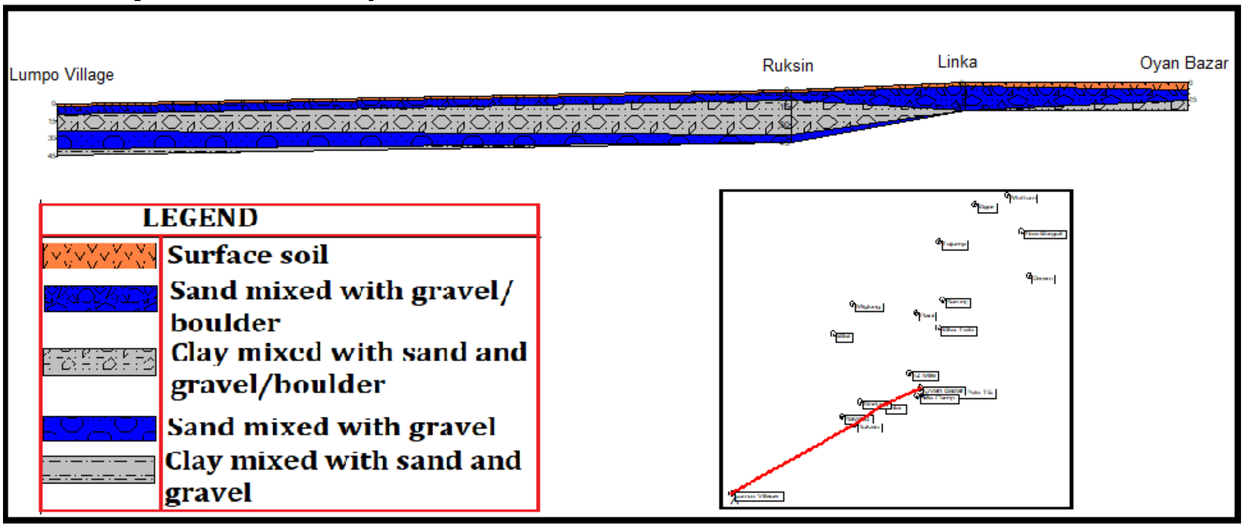


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Fig. 3.1 (C): 2D disposition of Quaternary aquifer

The southeast –southwest section drawn along the Assam-Arunachal border also confirms the fact that first clayey layer thickness is decreasing towards southeast and southwest directions.

The fence diagram of the area depicts the subsurface geometry of the area

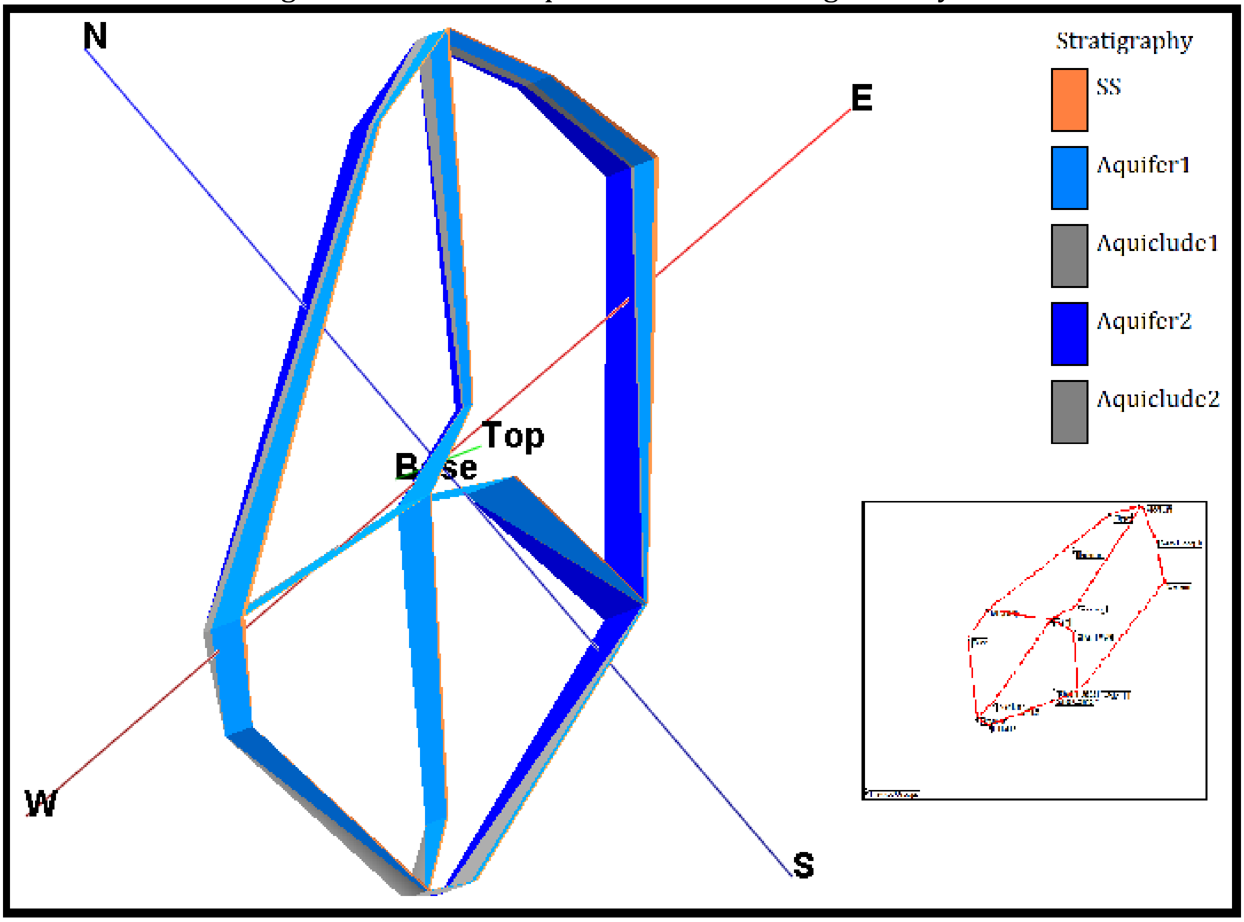

Fig. 3.2: 3D disposition of Quaternary aquifer

Ground water occurs mostly under unconfined condition. The discharge of the tube wells varies from 1.8m^3/day to 37.8m^3/day. Other hydraulic parameters were not determined except one well, viz., Donyi Polo T.E. The transmissivity value determined in that well is 513m²/day.

Aquifer thickness:, A perusal of fence diagram and cross-section (Fig. 3.1) indicate that

(i) bouldery materials are dominant in the subsurface formation bordering foothills and decreases towards south, i.e., towards Assam Plain

(ii) gravelly materials are abundant in the subsurface formation along Assam border. This indicates that grain size of the aquifer materials are decreasing from north to south.

(iii) The first clay layer pinches out towards south of the area (Fig. fence) and second clay layer is found only in southern wells.

Depth to water level (DTW)

In the study area deepest pre-monsoon water level is observed during the month of March. Depth to water level of two Ground Water Monitoring Stations at Pasighat varies from 10.45 to 10.86mbgl and at Ruksin area March 2016 depth to water varies within 3.0mbgl in the month of March. Whereas the water level of the same monitoring stations in Pasighat township varies from 6.94 to 9..41 during May 2016 and in the Ruksin area the water level of the same monitoring stations varies from 2.1 to 2.13mbgl. From Fig 3.3 is is observed that deeper water level condition is found in the north-east and north west part of the study area and shallow water level condition is found towards the southern part.

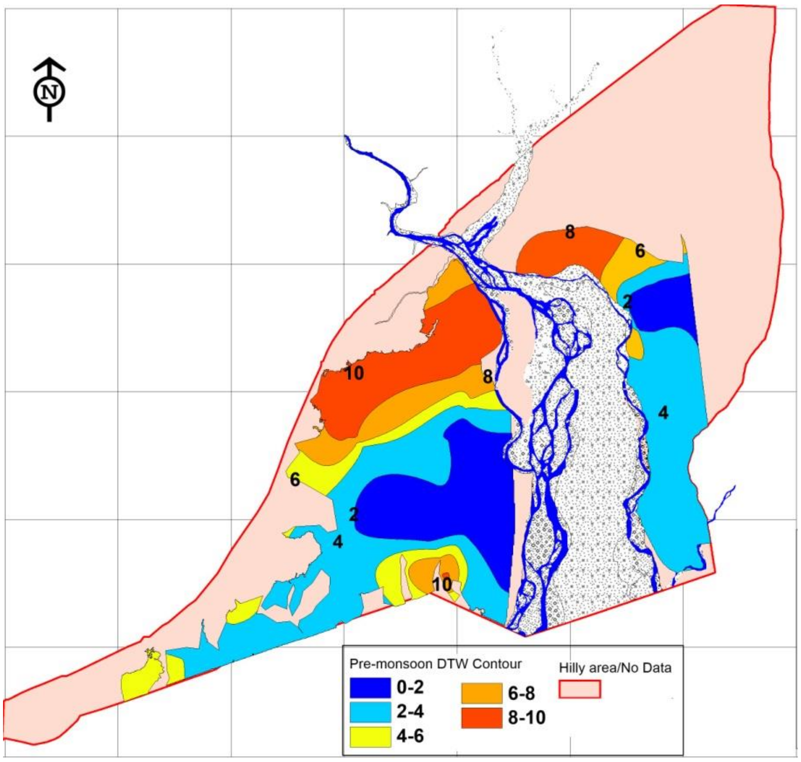

Fig. 3.3: Pre-monsoon depth to water level map

DTW around Pasighat town varies within 7.0mbgl and around Ruksin area it varies within 3mbgl. Deeper water level conditions are found in the northeast and northwest direction.

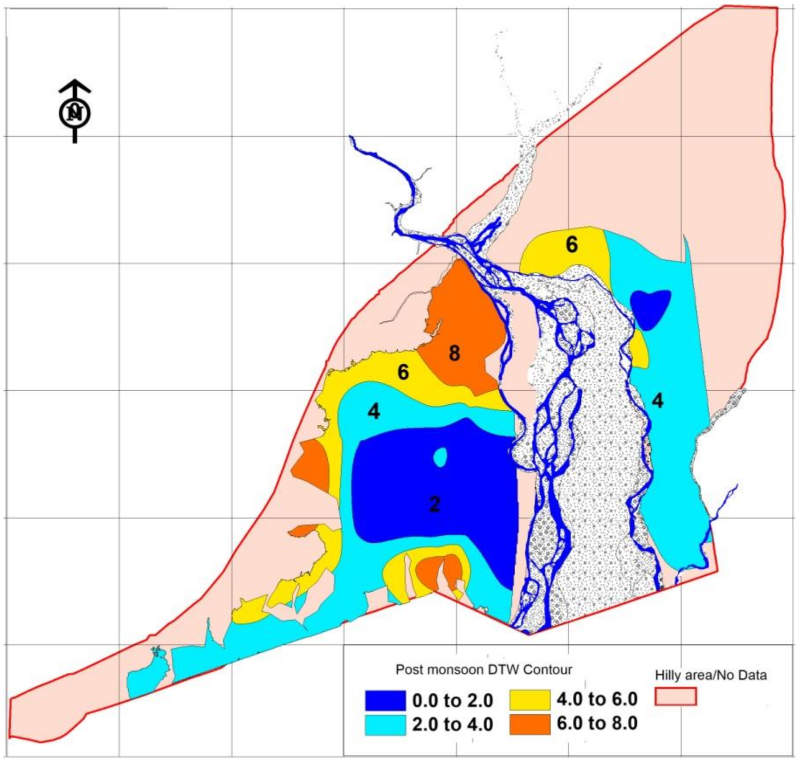

Fig. 3.4: Post-monsoon depth to water level map

Water level fluctuation: Difference between pre- and post monsoon water level is maximum towards northern part of the study area while most of the areas in the south water level fluctuate within 0 to 2m (Fig. 3.5)

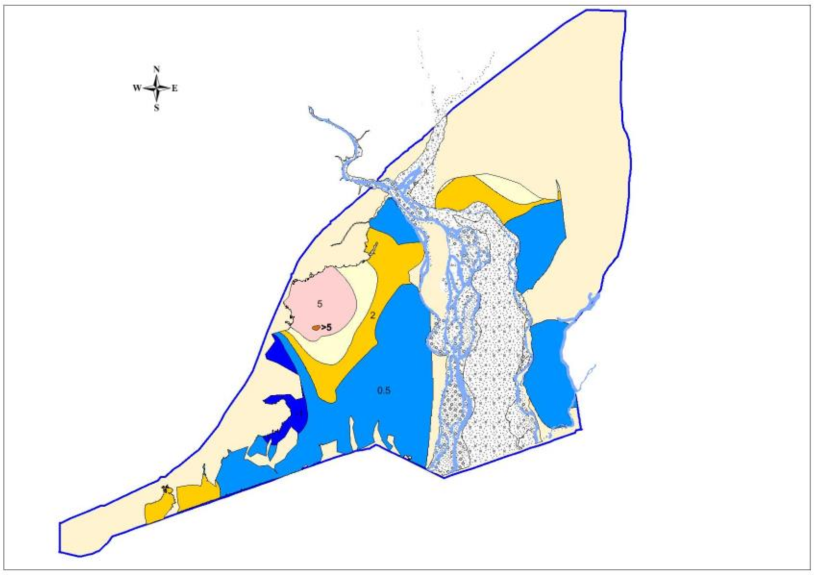

Fig. 3.5: Water level fluctuation map

Water level trend: Historical water level data of three Ground Water Monitoring Stations (GWMS) is available. Comparison of historical water level data of three GWMS with the water level data of March 2017 and November 2017 indicate rise of water level except WL of two GWMS at Pasighat. Pre monsoon water level of two GWMS at Pasighat indicate fall of water level. Pre- and post- monsoon depth to water level trend is given in Table: 3.2 and 3.3 respectively. Water level trend is graphically illustrated in Fig. 3.2 to 3.4.

Table 3.2: Pre-monsoon water level trend of GWMS in the study area

	No. of observation	Mean WL-March	WL of March-2017	Difference	Rise/Fall
Pasighhat- New	9	10.12	10.45	-0.33	Fall
Pasighat-II	5	10.63	10.82	-0.19	Fall
Ruksin	5	2.52	2.13	0.39	Rise

Table 3.3: Post-monsoon water level trend of GWMS in the study area

	No. of observation	Mean WL-Nov	WL of Nov-2017	Difference	Rise/Fall
Pasighhat- New	6	7.33	6.80	0.53	Rise
Pasighat-II	5	6.50	**6.38**	0.12	Rise
Ruksin	5	1.86	1.11	0.53	Rise

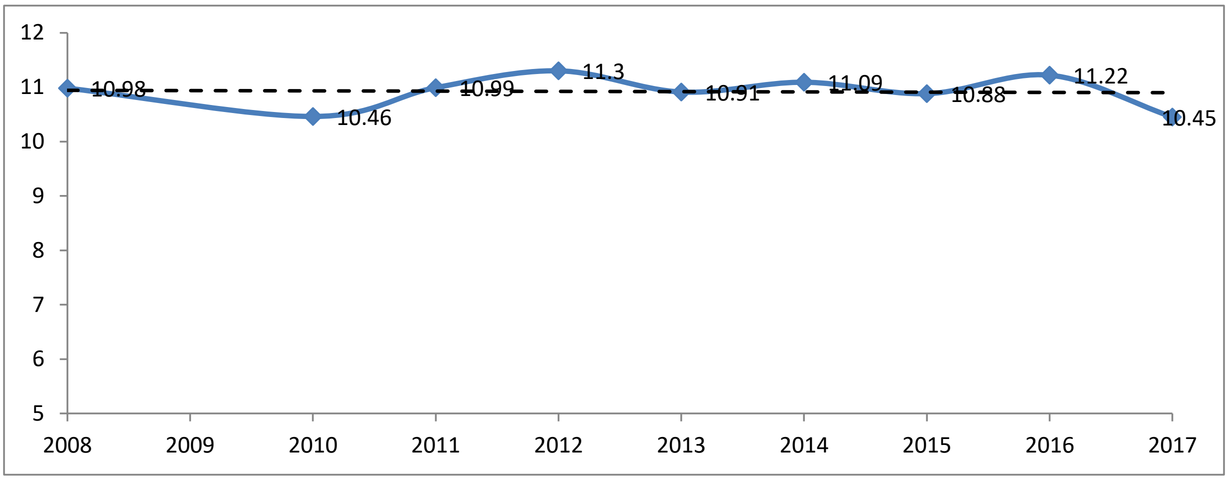

Fig. 3.6: Long term pre-monsoon water level trend of Pasighat New GWMS

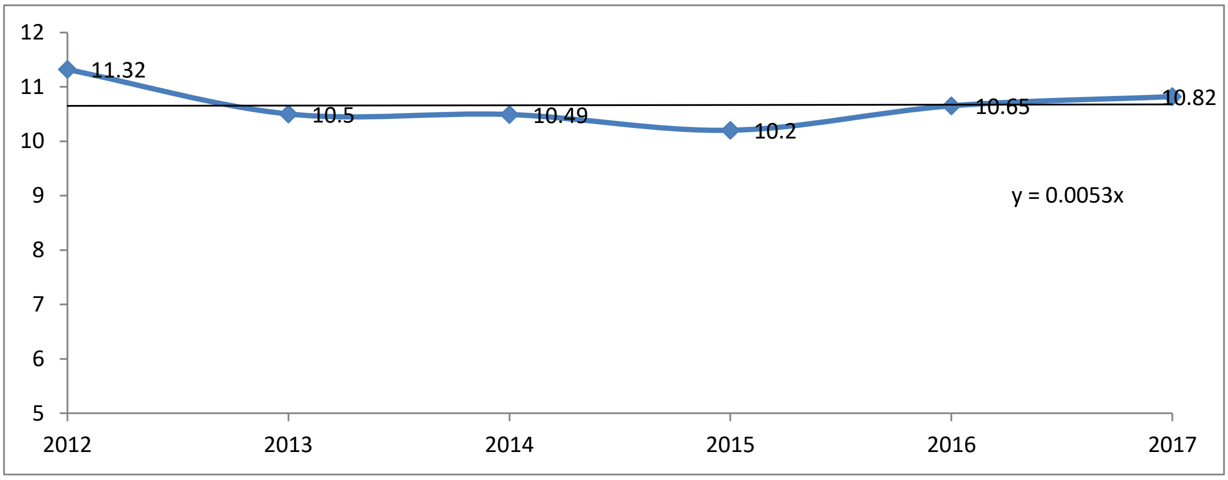

Fig. 3.7: Long term pre-monsoon water level trend of Pasighat-II GWMS

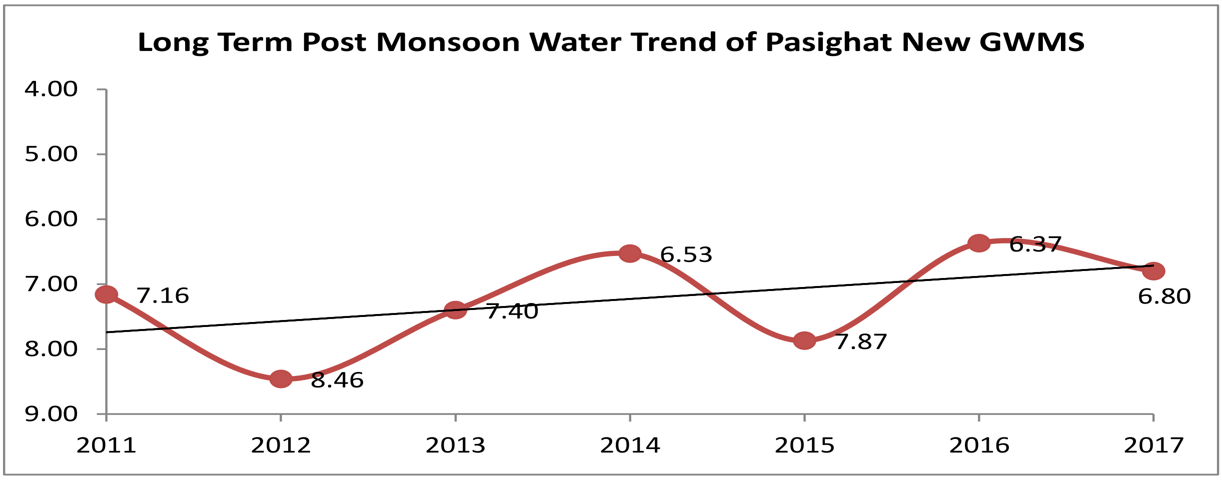

Fig. 3.8: Long term post-monsoon water level trend of Pasighat-New GWMS

3.2 Ground Water Movement

Water table contour map is prepared by adjusting pre-and post-monsoon water level data against mean sea level (Fig. 3.9 and 3.10). A perusal of water table contour maps indicates that river Siang is contributing water to the unconsolidated aquifer in the northern part of the study area. The Siang River receives ground water in the southern part of the study area which is evident from the shape of water table contours.. Ground water flow is almost north south in the left bank. In the right bank the main recharge zone is observed in the northwest part of the study area. A part of the ground water also escapes to the Assam Plain.

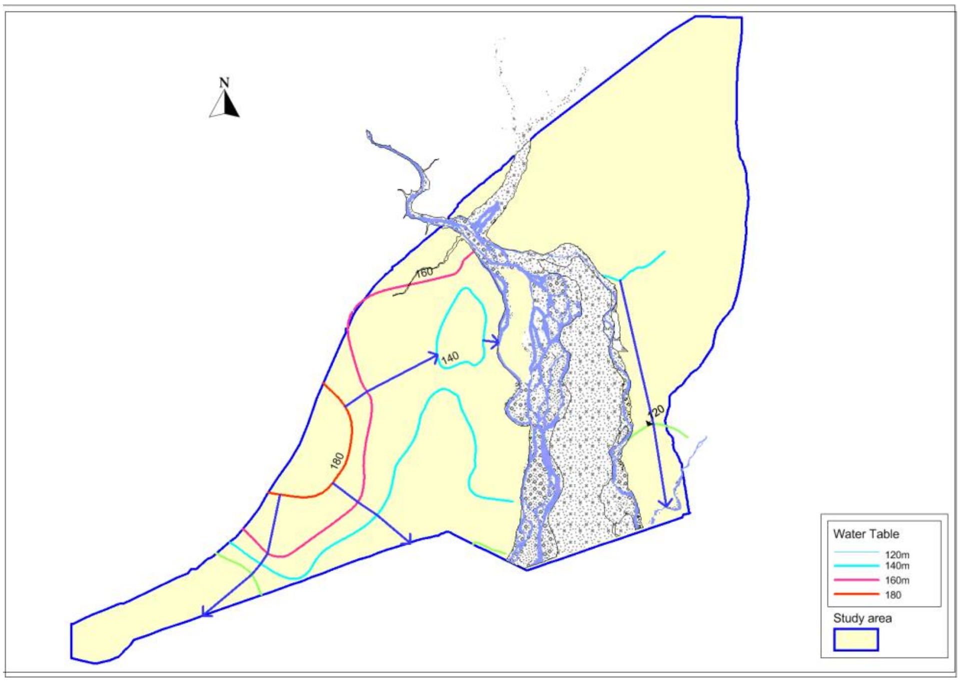

Fig. 3.9: Pre-monsoon water table contour

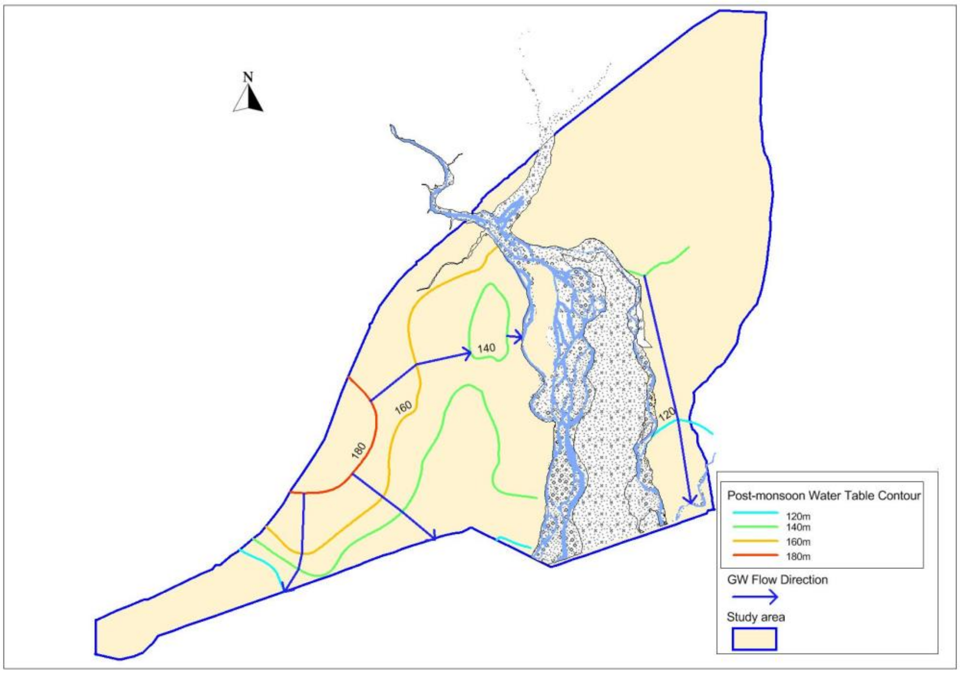

Fig. 3.10: Post-monsoon water table contour

Spring Discharge: Three spring monitoring stations are established in the area. One spring discharge was measured using 90^0 V-notch and other two by volumetric method. Their discharges were measured during monsoon and post-monsoon time by volumetric method. It was observed that all the spring discharge increases during monsoon and decreases from post monsoon to pre monsoon.

Water quality: All total 19 numbers of samples from dug wells, springs representing phreatic aquifer and Siang river were collected and were analyzed for major ions (Table 3.5). pH of dug well samples ranges from 6.71 to 7.48, of spring wells is 7.01 to 7.56 while 7.82 to 7.91. The Electrical conductivity of dug well samples ranges from 51.8 to 651.8 uS/cm and river water samples ranges from 185.3 to 250.3 microsimens/cm. Total dissolved solids in the groundwater ranges from 30.31 to 378.4mg/l., TDS of spring water samples ranges from 22.39 to 52.99 mg/l and river water TDS ranges from 106.1 to 141.8mg/l. Low EC and TDS indicate that the recharged juvenile groundwater has got little residence time. Lowest EC and TDS values are observed in piedmont areas. Highest EC and TDS values are found valley and plain areas. The water is soft. The pH of the samples ranges from 7.5 to 8.29 indicating the ground water of phreatic aquifers is alkaline in nature.

The other chemical constituents are within permissible limit. Iron content in groundwater ranges from 0.04 to 12.33mg/l. The highest concentration of iron is found in 2.86 to 7.57mg/l. The EC infers that the Phreatic aquifer is fresh and is suitable for drinking, domestic and Irrigation purpose.

Aquifer map of the area: The study area has distinct geologic, geomorphologic expression and hydrogeological characteristic (Fig.: 3.41).

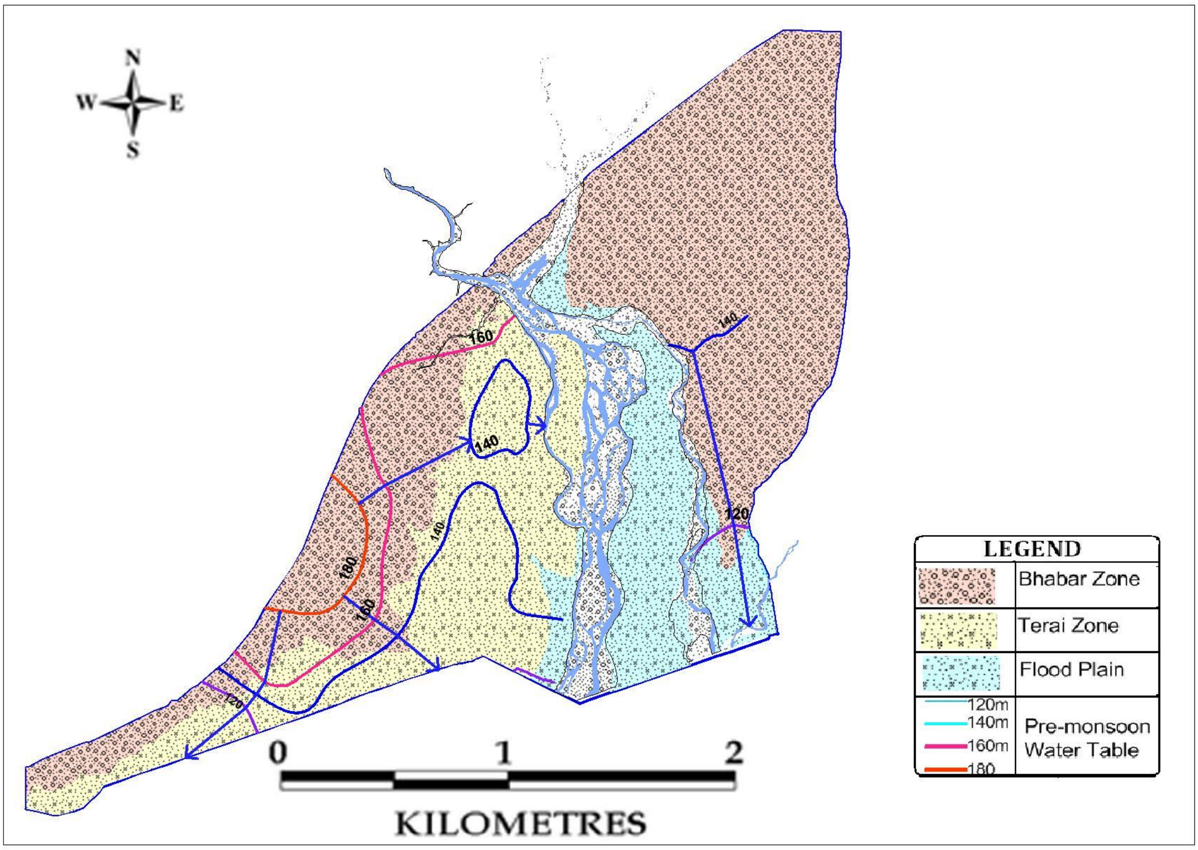

Fig. 3.41: Hydrogeomorphological classification of the study area.

Geology and geomorphology: This area consists of Quaternary fan, terrace and flood plain deposits. Geological Survey of India (GSI) has classified the Quaternary deposits of the area into following three formations:

1. Roing Formation/surface
2. Pasighat Formation/surface and
3. Sadiya Formation/surface

ROING FORMATION: The formation is predominantly a composite alluvial fan surface, comprising rudaceous sediments range in size from boulders to pebbles, in a highly oxidised sandy silt matrix. The formation is deposited in Siwalik foothills and extends downwards to 140m contour.

The formation has a distinct southerly and southeasterly sloping, gently undulating surface. It shows a very coarse drainage with a few discontinuous channels which ephemeral in nature.

It is the oldest Quaternary geologic/geomorphic formation/surface of the area.

Fig 3.42: Dry river channel

Fig. 3.43: Roing Formation exposed left bank of Siku Korong River, Mebo

Pasighat Formation: Pasighat Formation has been named after the township of Pasighat, this surface encompasses primarily the fluvial terraces of the Siang River.

The Pasighat formation comprises five members,

- the Tigra Member,
- the Balek Member,
- the Pasighat Member,
- the Oyang Member and
- the Koboghat Member

Geomorphologically these members of Pasighat Formation deposited in terrace and they formed stepped sequence of terraces. These are unpaired terraces, developed on the right bank i.e. the west bank of the Siang River. The terraces rise to a composite height of about 80 m above the river level at Pasighat. The Tigra terrace is the oldest and the Koboghat is the youngest terraces.

Lithologically, the older/higher terraces are composed of coarser detritus comprising mainly boulders, cobbles and pebbles in oxidised sandy silt matrix. In general reduction in size fraction of the sediments from north to south has been noticed.

Sadiya Formation/surface: Sadiya is the youngest Quaternary geologic/geomorhic surface in the area. The formation is composed of un-oxidised fine sediments like sand and silt/clay with occasional pebbly horizons. The Sadiya Surface can be defined as the combined flood plain of the Lohit-Dihang/Siang-Brahmaputra river system.

Hydrogeology: The Roing Formation has the similarity with bhabar formation of north India considering the hydrogeological properties of the formation. The hydrogeologic characteristics of Roing, Pasighat and Sadiya formations are discussed below:

Bhabar Zone: The deepest pre and post monsoon water levels are noticed in bhabar zone and maximum water level fluctuation is also noticed in this zone. The average pre- and post-monsoon depth to water level is 4.51mbgl and 3.07mbgl respectively. The average water level fluctuation is 1.43m. The water table contour map indicates that Bhabar zone also recharged by the Siang River (Fig. 3.41).

Moreover, in this zone streams disappear and flow subsurface due to highly porous formation materials of this zone. The losing stream reappears in terrace zone. Presence of depression spring is another characteristic of this zone. The spring line at Mirem, Motoum and Ralings are also found in Bhabar zone.

Table 3.4: Depth of dug well, water level & fluctuation of water level in Bhabar Zone

Village	Longitude	Latitude	Elevation	MP (m)	Depth (m)	May	November	Fluctuation
Tode WRC	95.26508	27.96106	161	0.9	8.82	3.14	-0.04	3.18
Yagrung	95.25219	27.97003	165	1.21	16.15	8.21	3.03	5.18
Pogdum	95.24522	27.97042	168	1.14	18.69	6.96	2.61	4.35
Mirem	95.20897	27.95761	202	0.4	9.5	5.41	7.35	-1.94
New Borguli	95.46286	28.03628	133	0.73	6.85	5.17	5.03	0.14
Ngopok1	95.47389	28.08736	155	1.5	10.26	5.68	2.37	3.31
Ngopok2	95.47389	28.07383	156	0.96	5.24	2.26	2.63	-0.37
Borguli	95.464	28.04169	140	0.52	3.08	0.71	-0.52	1.23
Niglok	95.2323	27.90217	178.3	0.16	5.09	3.03	5.17	-2.14
			Average		9.30	4.51	3.07	1.44

Litholog of tube wells constructed by Water Resources Department, Govt. of Arunachal Pradesh indicates that bouldery zone is encountered down to a depth of 30 to 40mbgl, i.e., drilled depth. There are instances of failure of drilling in Bhabar zone especially in the higher altitudes of this zone (northern part of bhabar zone).

Pasighat Formation or terrace zone: The average pre and post-monsoon depth to water level and water level fluctuation of this zone is 3.93mbgl, 3.23m bgl and 0.71m respectively.

Table 3.5: Depth of dug well, water level & fluctuation of water level in Pasighat Formation or terrace zone

Village	Longitude	Latitude	Elevation	MP (m)	Depth (m)	May	November	Fluctuation
Mangnag	95.2593	27.9122	146	0.53	6.31	1.89	-0.53	2.42
Debang	95.1396	27.8326	116	0.47	6.53	3.09	2.39	0.7
Depi	95.1103	27.8084	118	0.5	7	4.71	3.07	1.64
Sille	95.3019	27.9095	132	0	6	0.51	1.2	-0.69
Rani	95.3137	27.9577	131	0.1	7.16	2.47	1.96	0.51
Satmile	95.3311	27.9778			2.45	2	2	0
Tajump	95.3398	27.9966	144	1	8.38	6.24	6.1	0.14
Pasighat -New	95.3359	28.036	138		10.87	9.41	7.8	1.61
Pasighat	95.3359	28.0511	153		9.48	6.94	7.09	-0.15
Pasighat	95.3152	28.0849	175	0.74	4.46	0.3	0.73	-0.43
Sika Bamen Todee	95.3437	27.9134			3.1	2.13	1.87	0.26
Kemi	95.3383	27.8564	122	0	5.13	2.11	2.19	-0.08
Oyan	95.3224	27.8779	136	1.06	11.95	7.03	6.74	0.29
Ruksin	95.2183	27.8409			2.78	2.1	2.06	0.04
Sigar	95.364	28.0217		0.14	8.82	7.06	5.36	1.7
Jone Jo	95.1721	27.8526		0.77	7.63	3.34	1.83	1.51
Donyo Polo TE	95.3291	27.9217	126	1.03	7.8	5.56	2.97	2.59
Average					**7.22**	**3.93**	**3.23**	**0.71**

It is observed that disappeared streams in the bhabar zone reappear in the terrace zone. The terrace zone consists of stepped sequence of five terraces, viz., Tigra, Balek, Pasighat, Oyan and Koboghat. It is observed that springs emanating in this zone are at the base of each terrace.

Litholog of tube wells constructed by Water Resources Department, Govt. of Arunachal Pradesh indicates that bouldery zone is pinching out toward south of the area. Gravelly zone is dominant in the lower level terraces.

Flood plain zone: There is one key well in the flood plain. The pre and post monsoon water level 2.87 and 3.12mbgl. Water level fluctuation in -0.25.

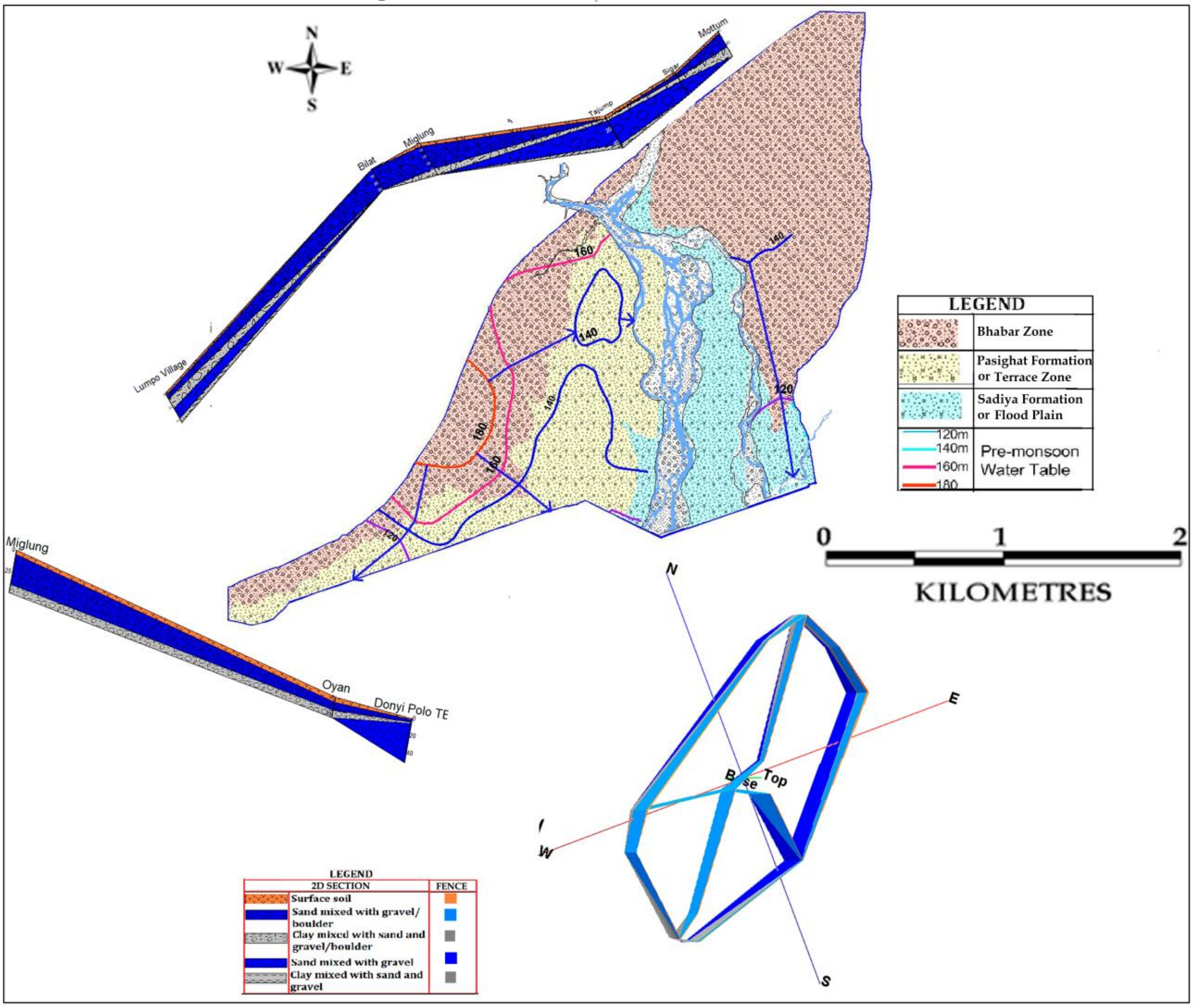

Fig. 3.44: Aquifer Map of East Siang District, Arunachal Pradesh

CHAPTER 4.0
Groundwater resources

The study area covers three blocks of East Siang district, viz., Mebo. Pasighat, Ruksin and this part covers the entire ground water rechargeable area of the district. The rechargeable area with slope ≤20% is identified by downloading 30m resolution DEM of Shuttle Radar Topography Mission (SRTM) from **http://earthexplorer.com**.

Major part of the district is hilly with slope more than 20%. Compared to district total area of 3603 sq.km, rechargeable area is found to be only 110.01 sq.km. Like other part of country, no land survey was conducted in this state. Village, circle or block wise geographical areas are not available. Even in 2011 census data only district wise geographical areas are provided. Therefore, it was not possible to carry out block wise resource calculation. Here district wise resource calculation is presented.

The computation of ground water resources available in the district has been done using GEC 2015 methodology.

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. Rain fall infiltration value of 22% is taken for valley-fill deposits are considered for calculation. In WLF method, specific yield has been taken as 0.16 for valley fill deposit following the norms recommended by GEC'2015. The rainfall of East Siang district is 3285.91mm.
2) Water level data has been considered for 2017-18. Water level fluctuation based on data of May (Pre monsoon) and November (post monsoon) has been considered. The average pre- and post-monsoon water level of East Siang district is 4.10mbgl and 3.52mbgl. The average water level fluctuation is 0.58m
3) The population figures were collected from Census, 2011and projected to 2017. The per capita domestic requirement for the is considered as 60 lpcd.
4) Recharge from water conservation structure has been taken calculated based on 2006-07 minor irrigation census data as latest data (MIS 2013-14) is not available
5) Ground water extraction for irrigation and industrial use is considered as nil as no data is available.

Recharge: The aquifers of the study area are recharged by rainfall. The area experiences south-east monsoon. Monsoon rainfall contributes approximately 87 percent of total rainfall (June, July, August, September) while share of post and pre monsoon rainfall are approximately 7 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 June to September has maximum number of rainy days.

The monsoon recharge of the 110100hectre of recharge worthy area is 51408ham while non-monsoon recharge is 11382ham. Total ground water recharge is 62789ham.

Extraction: The agriculture in the area generally rain fed and whatever irrigation potential created and utilized is by surface source only. Moreover, industrial activity in the district is almost nil and as such ground water extraction for irrigation and industry is considered as nil. So ground water is extracted only for domestic use. Dependency on ground water is worked out by downloading total public water supply scheme from national drinking water supply web site and total number of ground water based scheme by total number of schemes. Ground water extraction is estimated by consumptive use is 145.61ham

Allocation of resources up to 2025: The net ground water resource is allocated for domestic use 233.41ham. Net available resource for future use is 56277ham.

Stage of groundwater development: Groundwater is mainly utilized for domestic purposes. The stage of groundwater development in the district is mere 0.41%.

Table 4.1: shows the net groundwater availability, existing draft and stage of development for 2017.

District	Recharge worthy area Ha	Total annual GW recharge Ham	Environmental flow Ham	Annual extractable GW resource Ham (3-4)	Existing gross GW draft for all uses Ham	Stage of GW development [(6/5)*100%]
1	2	3	4	5	6	7
East Siang	110100	62789	6279	56510	145.61	0.41

Extraction from unconfined aquifer/deeper aquifer: Groundwater in this area is utilized mainly for drinking or domestic purposes. Dug wells are the main groundwater abstraction structures. In the bhabar zone dug wells depth ranges from 3.08 to 19mbgl. In the right bank of the Siang River, the dug well depth in the bhabar zone is more than the southern bank. In Pasighat township which is situated over the terrace deposit, dug well depth ranges from 9.0 to nearly 15.0mbgl. In depth of dug wells in the terrace deposit of Ruksin block the depth of tube wells 2.5 to 8.0mbgl. Shallow depth dug wells are found in the flood plain areas of Mebo block.

Shallow tube wells are also found in the area and its depth is limited to 5ombgl. Few tube wells of 50 to 100m are also constructed by some institutions.

Very few tube wells have so far constructed in the area. The construction of tube wells is again a costly affair due to bouldery nature of the formation particularly in the bhabar zone.

5.0 Groundwater Related Issues

5.1 Identification of issues: Two main groundwater issues can be pointed out in the area.

1) Low stage of groundwater extraction**:** The rechargeable area of East Siang district due to its unique geological and geomorphological condition has vast ground water resource. As per present groundwater resource estimation extractable ground water availability is 513mm per hectare. However, this resource is little used and is evident from stage of ground water extraction which is less than 0.5%. Ground water extraction for irrigation and industrial use is almost nil. The vast agricultural lands remain fallow during non-monsoon period. Many dug wells in agriculture field are dried during pre-monsoon season.

The construction of tube wells becomes a costly affair due to frequent encounter of boulder in bhabar and in higher terraces. Many tube wells are drilled without success due to improper site selection. As such ground water extraction is low in the area.

2) Wastage of spring water: There are number of spring lines in this part of the district. Mirem, Motum and Raling spring lines are monitored in the present study. At the base of higher terrace springs oozing out through entire scarp faces. In an area called Banskata at Pasighat town huge quantity of spring water daily flowing away through drain without proper use while Pasighat town is frequently faced water crisis in lean season.

Quality issue: The water quality of the area is generally good for all uses. However, iron content in ground water, above permissible limit is found in few localities bordering Assam.

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 0.28 as per 2011 census.

Current demand of ground water in domestic sector is 109.8ham. Water demand in this sector is calculated by projecting the population to 2025 and allocating 60lpcd water. The ground water demand is found to be 176.16ham up to 2025. The demand of water in 2025 is also calculated by allocating 135lpcd water and demand rises to 393ham.

Future demand for agriculture: Future demand of water for agriculture is estimated in the present analysis by projecting the cropping intensity to 200%. As per data provided by Dept. of Agriculture, Pasighat, the cultivated area is 18078ha while irrigated area is only 2568ha. The present analysis estimated water requirement in agriculture 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 main crop of the district is paddy and about 65% of the net sown area is occupied by paddy cultivation. Vegetables, Pulses, Oilseeds, Tuber crops are also sown in the district. Generally Sali rice, Zinger, Turmeric, etc. are practised as monoculture in major parts of the district. The common cropping sequence is Sali rice followed by Rabi Vegetables and in some parts Rape & Mustard. The present season wise cropping pattern of East Siang is shown in Table 5.1.

Table 5.1: Season wise cropping pattern of East Siang district

(Source: KVK East Siang, CHF, CAU, Pasighat, Arunachal Pradesh-791102)

SN	Main Crop	**Sowing season**					
		Kharif		Summer		Rabi	
		Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
1	Paddy	4th week of june to 2nd week of kuly	-		-	-	-
2	Maize		-	4th week of March to 2nd week of April	-	-	-
3	Oilseed		-		-	1st week of September to 3rd week of September	-
4	Potato		-		-	1st week of September to 4th week of September	-
5	Ginger		-	4th week of March to 1st week of May	-	-	-

Table 5.2: Area under different crops (Dept. of Agriculture, Pasighat, East Siang District)

Crop	**Area (Ha)**	**% of Total Area**
Paddy	11743	64.96
Maize	3091	17.10
Millet	2001	11.07
Wheat	123	0.68
Pulses	1120	6.20
Total	18078	100

Present land under irrigation is 2568 ha. Present minor irrigation schemes are using surface water sources only. Present irrigation from ground water sources is almost nil. Hence, there is ample scope for ground water extraction for irrigation purpose which will bring prosperity to the society and help the district in achieving self-reliance on food grain. 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.

$$ETcrop = ETo * Kc$$

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

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

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

CALCULATION OF REFERENCE EVAPOTRANSPIRATION (ETo): The FAO Penman-Monteith method is the recommended method for determining reference crop evapotranspiration (ETo).In this method ETo of reference crop is calculated by considering maximum and minimum temperature data of received from Central Horticulture College, Pasighat as no FAO's climatic station exists to estimate by Climewat 2.0 software (Table 6.3).

Table 5.3: Month wise evapo-transpiration determined by Cropwat 8.0 from climatic data

Climatic Station	Pasighat		Longitude	95.32E	Latitude	28.08N	El:151m
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	12	23.7	74	173	6.8	12.9	2.39
February	14.4	24.6	77	173	6.3	14.3	2.72
March	15	26.3	75	173	7.3	18	3.5
April	18.6	27.9	79	173	6.6	18.9	3.87
May	20.7	29.5	80	173	6.7	20	4.24
June	24.6	31	84	173	5	17.6	4.01
July	23.8	28.8	87	173	3.5	15.3	3.36
August	24	30.9	83	173	5.2	17.1	3.9
September	20.9	30.3	79	173	6.8	17.9	3.99
October	20.3	30	78	173	6.5	15.2	3.44
November	15.3	27	74	173	7.2	13.7	2.9
December	12.9	23.2	76	173	6.1	11.5	2.2
Average	18.5	27.8	79	173	6.2	16	3.38

Irrigation requirement: Etc - Effective Rainfall

Effective rainfall is defined as the portion of the rainfall which is available to the root zone. Run-off and deep percolation of rainfall are not effective for crop. Effective rain fall is calculated by empirical method provided by USDA soil conservation service where

Effective rainfall= (rainfall*(125-0.2*3*rainfall))/125 for P<=250/3mm

P_{eff}=125/3+0.1P for P>250/3mm .

The effective rainfall for different months for Pasighat station as calculated by Climwat 2.0 is shown in Table 6.4:

Table 5.4: Effective rainfall estimated by Crowat 8.0

Month	Rain	Eff rain
	mm	mm
January	52.3	47.9
February	75.1	66.1
March	144.4	111
April	247.7	149.5
May	308.2	155.8
June	692.9	194.3
July	841.8	209.2
August	555	180.5
September	615.6	186.6
October	129.4	102.6
November	41.4	38.7
December	20.6	19.9
Total	3724.4	1462.1

Cropping Plan: During kharif season, paddy is cultivated in 11743 ha and maize is cultivated in 3091 ha land. 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 29668 ha and thereby increase cropping intensity up to 200%. This can be achieved by growing potato, mustard and rabi vegetables in rice and maize fallow with the support of irrigation. Present cropping pattern, proposed cropping pattern, intended increase in cropping intensity were shown in tabular form (Table 6.5)

Table 5.5: Cropping pattern, proposed cropping pattern, intended cropping intensity

Cropping pattern (s)				
Rice-Maize based cropping pattern				
Rice-Potato Rice-Mustard Rice-Vegetables Rice-Millet Maize-Millet	Present Cultivated area (ha)	Area to be cultivated (%)	Area to be cultivated (ha)	Irrigation requirement (ha m)
	1	2 (= % of 1)	3	4
Rice (main crop)	11743		11867	1762.52
Potato	2349	20	2967	390.16
Millet	1761	15	2225	0
Wheat	587	5	742	132.92
Pulses	2349	20	2967	139.45
Oilseed (mustard)	2349	20	2967	91.49
Vegetables	2349	20	2967	254.1
Maize	3091		3091	5.04
Net cultivated area (Paddy+Maize)	14834		14835	
Gross cultivated area (Paddy+Millet+Wheat+Pulses+potato/+Oilseed/+Veg+Maize)	26578		29670	
Cropping intensity	114% (Present)		200% (Intended)	
Total irrigation requirement				2774.68
Considering Irrigation scheme efficiency 70%				
Gross irrigation requirement				3965 HAM

Table 5.6: Crop-wise and month-wise precipitation deficit (IWR) from CROPWAT 8

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
Rice	0	0	0	0	48.5	94.2	0	0	0	0	0	0
Rice	0	0	0	0	0	147.2	0	0	0	9.4	0	0
Rice	0	0	0	0	0	147.2	0	0	0	15.2	3.1	0
Rice	0	0	0	0	0	49.5	59.9	0	0	17.4	6.9	0
MAIZE Grain)	0	0	1	0	0	0	2.4	0	0	0	0	0
MAIZE (Grain)	0	0	0	0	0	0	0	0	0	0	0	0
MILLET	0	0	0	0	0	0	0	0	0	0	0	0
MILLET	0	0	0	0	0	0	0	0	0	0	0	0
Pulses	0	0	0	0	0	0	0	1.5	0	18.4	27	0
Small Vegetables	0	0	0	0	0	0	0	0	0	11.2	38.7	0
Small Vegetables	17.5	0	0	0	0	0	0	0	0	2.7	26.1	50.1
Small Vegetables	26.8	18	0	0	0	0	0	0	0	0	11.3	35.8
Potato	9.1	0	0	0	0	0	0	0	0	11	57.3	54.2
Winter Wheat	8.5	4.5	0	0	0	0	0	0	0	0	1.9	29.9
Mustard	20.7	9	0	0	0	0	0	0	0	0	27.5	45.6

Table 5.7: Actual monthly water requirement for different crops in East Siang district, Arunachal Pradesh

Crop	Net sown area	Area (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total IWR (ham)
1. Rice		5	0	0	0	0	71.93	139.7	0	0	0	0	0	0	211.63
2. Rice		10	0	0	0	0	0	436.74	0	0	0	27.59	0	0	464.33
3. Rice		10	0	0	0	0	0	436.74	0	0	0	45.1	9.2	0	491.04
4. Rice		15	0	0	0	0	0	220.28	266.56	0	0	76.99	30.71	0	594.54
5. MAIZE		5	0	0	1.48	0	0	0	3.56	0	0	0	0	0	5.04
6. MAIZE	29669Ha	5	0	0	0	0	0	0	0	0	0	0	0	0	0
7. MILLET		4	0	0	0	0	0	0	0	0	0	0	0	0	0
8. MILLET		5	0	0	0	0	0	0	0	0	0	0	0	0	0
9. Pulses		8	0	0	0	0	0	0	0	4.45	0	54.59	80.41	0	139.45
10. Small Vegetables		5	0	0	0	0	0	0	0	0	0	6.64	22.95	0	29.59
11. Small Vegetables		5	25.95	0	0	0	0	0	0	0	0	4	38.71	74.15	142.81
12. Small Vegetables		3	23.85	16.02	0	0	0	0	0	0	0	0	10.06	31.77	81.7
13. Potato		10	27	0	0	0	0	0	0	0	0	32.64	170.01	160.51	390.16
14. Winter Wheat		8	25.22	13.35	0	0	0	0	0	0	0	0	5.64	88.71	132.92
15. Mustard		2	18.42	8.01	0	0	0	0	0	0	0	0	24.56	40.5	91.49
	Total	100	120.44	37.38	1.48	0	71.93	1233.46	270.12	4.45	0	247.55	392.25	395.64	2774.71
Gross irr. Requirement with 70% irr. Efficiency			172.07	53.4	2.11	0	102.76	1762.09	385.89	6.36	0	353.64	560.36	565.2	3963.87

The irrigation requirement for different crops is estimated after projecting the cropping intensity to 200% and assuming that the entire irrigation water will be supplied by ground water. The irrigation requirement of the entire district is found to be 2774.71ham and if the irrigation scheme efficiency is 70% then the gross irrigation water requirement will be 3963.87ham.

Stress Aspects of aquifer: The stress aspects of aquifer is worked out after finding water requirement in various sector and comparing the requirement with allocation of dynamic groundwater in various sector up to 2025.

Therefore the water requirement for the area can be summed up as follows:

Table 5.8: Water requirement for all sectors

District	Drinking water requirement up to 2025 Ham	Water requirement to increase the cropping intensity to 200% Ham	Water allocated for domestic purposes up to 2025 Ham	Water allocated for future use up to 2025 Ham
East Siang	176.16	3963.87	176.16	56117

Supply and demand gap: It is observed that drinking water allocation is sufficient to meet the future demand and it will not give additional stress in the aquifer. Irrigation water demand can suitably be met from future allocation of resources.

Table 5.9: Supply and demand gap in drinking water sector

District	Drinking water demand up to 2025 Ham	Water allocated for drinking and domestic purposes up to 2025 Ham	Gap between supply and demand (+ve for surplus supply and –ve for deficit supply) Ham
East Siang	176.16	393.06	No shortage

Table 5.10: Supply and demand gap in irrigation

District	Total irrigation demand Ham	Water allocated for irrigation up to 2025 Ham	Gap between supply and demand (+ve for surplus supply and –ve for deficit supply) Ham
East Siang	3963.87	**56510.27**	(+) **52546**
Total irrigation demand: 13649ham			

CHAPTER 6.0
Management Strategies

The objective of management is to utilize the available ground water resources to fulfill human needs and also to boost economy of an area without hampering the interest of future generation. That objective can be achieved by finding out demand of various sectors and adjusting the demand with available resource.

The demands of various sectors in the study area under East Siang district is worked out and it is observed that the available dynamic ground water resources of this area is sufficient to meet the demand of domestic as well as agricultural and industrial sectors. Various issues pertaining to the management of ground water resources will be discussed in the following paragraphs.

The irrigation requirement for different crops is estimated considering the entire net sown area of East Siang district. The gross irrigation requirement of the area is found to be 8582ham and the net groundwater availability for future is found to be 56510.27ham. Therefore above mentioned cropping plan can be safely implemented for the area.

Numbers tube well required for irrigation: A tube well of 50m depth tapping 20m saturated thickness of aquifer can yield 15m^3/hr. If the well is allowed to run for 8hrs for 120days, it will create a draft of 1.8ham. To meet irrigation demand of 3965ham, 2203 numbers of TW can be constructed.

Drilling: In this area percussion rig is useful as bouldery formation is encountered in the area. Combination rig is more useful. Private party use odex drilling technology. Although the drilling rate is fast, non-use of slotted pipe reduces the life of the well and also the yield.

Well Construction: Tube wells can be designed within a depth of 50m. Tube wells can be constructed by using 8$^{//}$ dia. Housing pipe down to 30 m. A tube well tapping 12m granular zone can expected to yield 10 to 20m^3/hr.

Perennial spring source may be nurtured properly to increase yield by constructing spring box and to take spring shed development programme wherever possible.

SPRING AN ALTERNATIVE SOURCE

Drilling in bhabar area is costly and chances of well failure are more. Even in terrace or terai area drilling is difficult. There are instances of drying up of dug well in bhabar and terrace area (Pasighat, Yagrung, etc). Spring water can be used as an alternative source. There are number of spring/spring line in the area. During this survey three spring lines were monitored (Table 6.7)

Table 6.1 : Spring discharge of East Siang District

Name of spring line	Mirem	Mottum	Raling
Block	Ruksin	Mebo	Mebo
Coordinate	27^{0}57’17.46” 95^{0}12’7.34” & 27^{0}57’26.69” 95^{0}13’23.13”	28° 4'40.21" 95°26'28.05"	28° 5'58.16" 95°25'49.64"
Discharge measurement time	Dec-17	Dec-17	Dec-17
Discharge lps	26.8	6.25	5.83
Discharge in ham/year	85	20	18

Aquifer wise availability of unsaturated zone: Aquifer wise availability of unsaturated zone is found out from the area enclosed by 5.0mbgl post monsoon water level contour (Manual of Artificial Recharge: CGWB, 2007). The area is found to be 7537.2ha.

Table 6.1: Estimation of Sub-surface Storage Capacity

District	Geographical area (ha)	Area identified for artificial recharge (ha)	Depth to Water level (Post monsoon) below cut-off level (m)	Volume of unsaturated zone ham	Average Specific yield (%)	Total subsurface storage potential as volume of water (ham)
East Siang	110000	7537.2	37686	0.16	6029.76	37686

The area identified for recharge is piedmont zone. The unconfined aquifer may be recharged by construction of recharge pits or percolation tanks.

Demand side management: Demand side management implies sustainable management of water. In irrigation and in drinking water supply also sufficient quantity of water loss occurs. In the study area there is no groundwater irrigation and the surface water irrigation is provided through unlined canals. Although cost of preparation of unlined canals is less, there is considerable water loss through unlined canals.

Irrigation efficiency can be increased by

(i) reducing convenience loss

(ii) improving water application efficiency

Traditional Techniques: Water loss through supply canals can be minimized by proper lining in the canals. The wet rice cultivation of Apatani tribe in Zero Valley of Lower Subansiri is an example of efficient water management. The Apatanis utilized bamboo pipe or wooden lining in the distribution channel to effectively utilize the water resource for cultivation. Therefore, wooden or locally available materials can be utilized for lining canals.

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 hectre and also saves water up to 70% than conventional irrigation.

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 (Figure 1). 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.

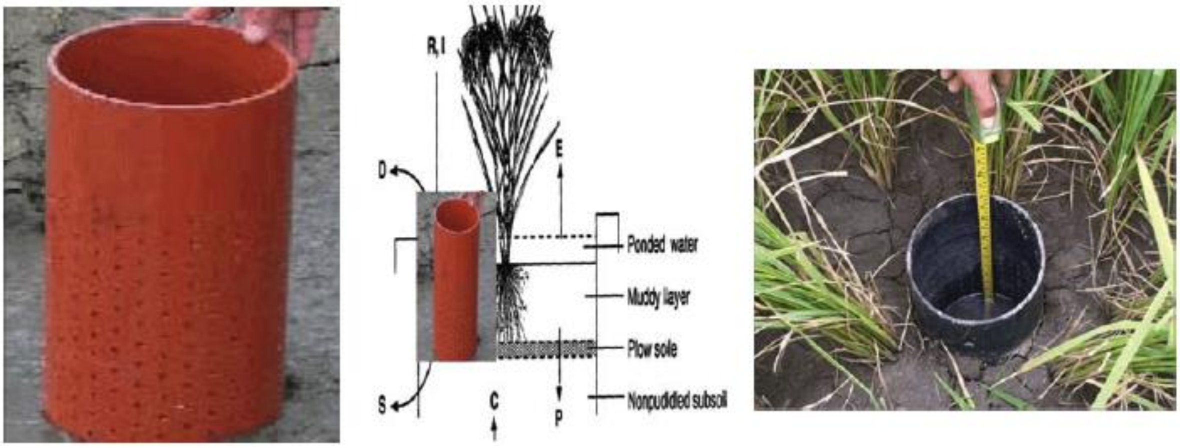

Fig. 6.2: A simple perforated pipe (water tube) installed in the rice field allows farmer to monitor water level beneath the soil surface (Kulkarni, 2011)

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	Paddy cultivated area (as per Dept. of Agriculture) (ha)	40% reduction of water for land leveling by the use laser land leveler	Approximate saving of water ham
East Siang	11743		939.44

Use of laser land leveler is also help in preventing water logging condition as it reduces water use during preparation of field for cultivation.

Stress aspect future demand: As mentioned earlier 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 is 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 be deficient supply gap of 198.9 ham from groundwater (Table 5.6). Since major drinking water supply projects are based on surface water, it is expected that the supply side gap will not adversely affect the aquifer.

Irrigation:

The total water requirement to bring the present unirrigated area under irrigation is well within quantity of the allotted dynamic groundwater resource for irrigation.

Even though the supply is more than demand, for sustainability following strategy is suggested.

1) Conserve and improve traditional irrigation techniques. Traditionally perennial streams are used as source water for irrigation. Wherever irrigation from perennial stream exists they need to be preserved and modified so that cropping intensity can be increased.
2) Ground water abstraction structure for irrigation is feasible only in lower southern part of bhabar and comparatively younger terraces. Tube wells of 50m depth tapping granular zone 12m will expect to yield 10 to 15m^3/hr. These structures can be utilized where there is no perennial stream source for irrigation.
3) 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.
4) Conservation of rain water in the up dip of cultivated field. During rabi season the conserved water can be drained to cultivated land through gravity.