Draft Report

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Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

AQUIFER MAPPING REPORT

Parts of Papum Pare District, Arunachal Pradesh

उत्तरी पूर्वी क्षेत्र, गुवाहाटी

North Eastern Region, Guwahati

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Govt. of India
Central Ground Water Board
Ministry of Water Resources, River Development & Ganga Rejuvenation

AQUIFER MAPPING REPORT OF PART OF PAPUM PARE DISTRICT, ARUNACHAL PRADESH
(AAP 2012-13 & 2013-14)

State Unit Office
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ANNUAL ACTION PLAN 2012-13 & 2013-14

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CHAPTER 1.0

INTRODUCTION

1.0 Introduction

1.1 Objectives: As part of national aquifer mapping programme, part of the Tertiary aquifer and the unconsolidated alluvial aquifer of Papum Pare district of Arunachal Pradesh was taken for study. During AAP 2012-13 750 sq.km and during AAP 2013-14 40 sq.km of the district was surveyed. (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 on 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

The part of Papum Pare district has rugged topography and major part of the district is covered by hills with varying heights. The Tertiary Siwalik forms Hills and the unconsolidated alluvium is found in river valleys, intermontane valleys, terrace, etc. The Siwalik has vast vertical and horizontal extension compared to the unconsolidated alluvium. The Siwalik area is less inhabited than the alluvial area. The valley or terrace of the district which has limited areal extent is heavily populated. Therefore, hydrogeological information can be gathered for a very narrow stretch of the area. Similarly scope of exploration and use of geophysical technique to gather subsurface information is again restricted only in the valley portion. Poor communication due to hostile terrain condition again restricts the scope of the study.

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 (MapInfo-6.5 using Projection category longitude/latitude (Indian for Pakistan, India, Bangladesh, Nepal projection). 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, 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 aquifer 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 83E/4, 83E/8, 83E/12, 83E/15, 83E/16 and 83 I/3 (Fig. 1.1).

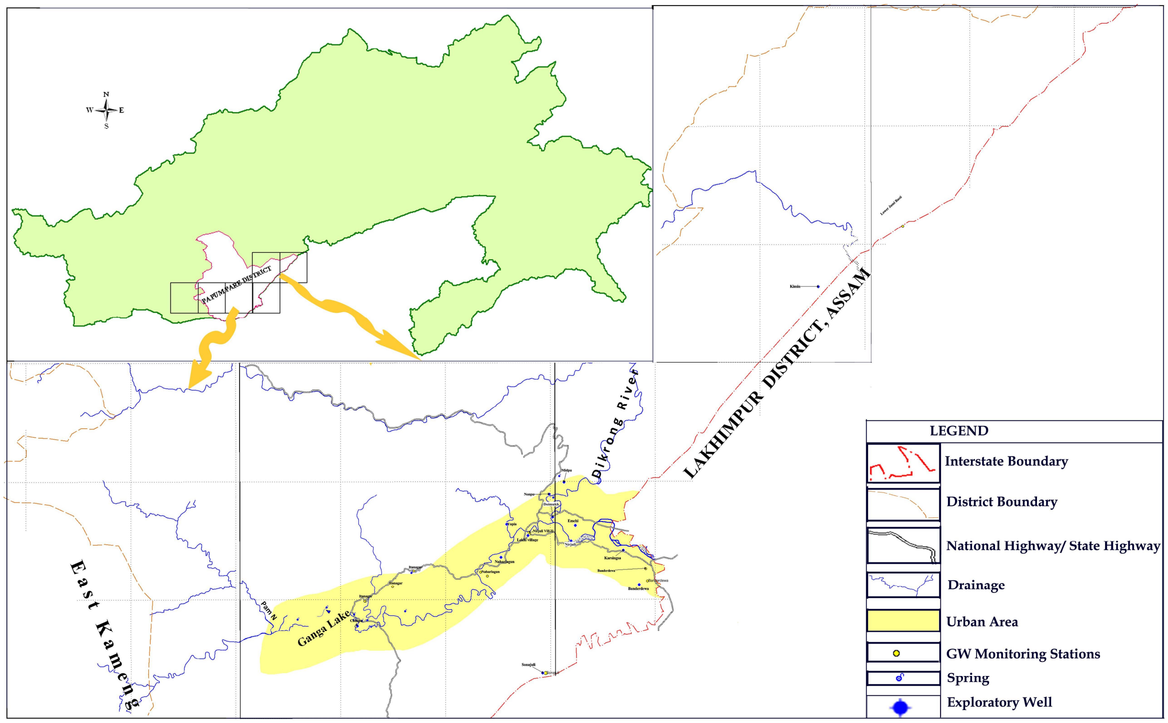


Fig. 1.1: Index map of the study area

Table 1.1: Administrative area

S. N.	Toposheet number	District	CD Block	**Circle****	**No. of Gram Panchayats*****	**No. of villages******
1	83E/8	Papum Pare	Balijan			
2	83E/12		Doimukh-Kimin	Doimukh	**53**	**25**
				Naharlagun	33	35
3	83E/16			**Itanagar**		22
				Banderdewa		52
4	83E/15			**Gumto**		6
				Kimin	29	26
5	83I/3			**Kimin**		

*** Source: D.C s' Office, (Panchayat Branch) Yupia ****Papum Pare District Statistical Handbook 2011

As per 2011 Census total population of the study area is 13239.

Major part of the area has poor communication facility due to hostile terrain condition. Itanagar, capital of Arunachal Pradesh, is located in Papum Pare district and approachable by NH 52 A from Banderdewa from Gohpur, Sonitpur District, Assam and from Harmutti, North Lakhimpur District of Assam. There is helicopter service from Naharlagun with other districts of the State and Guwahati of Assam. The area is also connected by rail service since 2013. The railway station is established at Yupia which is nearly 20km northeast of Itanagar and 7km north of Naharlagun.

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 Papum Pare district of Arunachal Pradesh

SN	Theme	Type	Data available	Data gap	Data generation	Total	Remarks
1	Borehole Lithology Data		**9 (Maximum depth of well is 103mbgl only.)**	**10**	**4**	**19**	**Wells are clustered only in valley portions. 300m penetration is not achieved.**
2	Geophysical data		**15**	**31**	**11**	**26**	**Difficult to obtain spread of 600 or even 500m in hilly terrain with variable slope**
3	Groundwater level data	**Dug well (Aquifer-1)**	**10**	**20**	**1**	**30**	GW abstraction structures are not available in hilly area.
		Spring (Aquifer-1)	**2**		**2**		
		Piezometer Aquifer-II	**Nil**	**11**	**Nil**	**11**	
4	Groundwater quality data	Dugwell-Aquifer-I	6	18	Nil	24	GW abstraction structures are not available in hilly area.
		Spring (Aquifer-I)	2				
		Piezometer Aquifer-II	Nil	12	Nil	12	
5	Specific Yield		Nil	12	2	12	
6	Soil Infiltration Test		Nil	20	7	20	

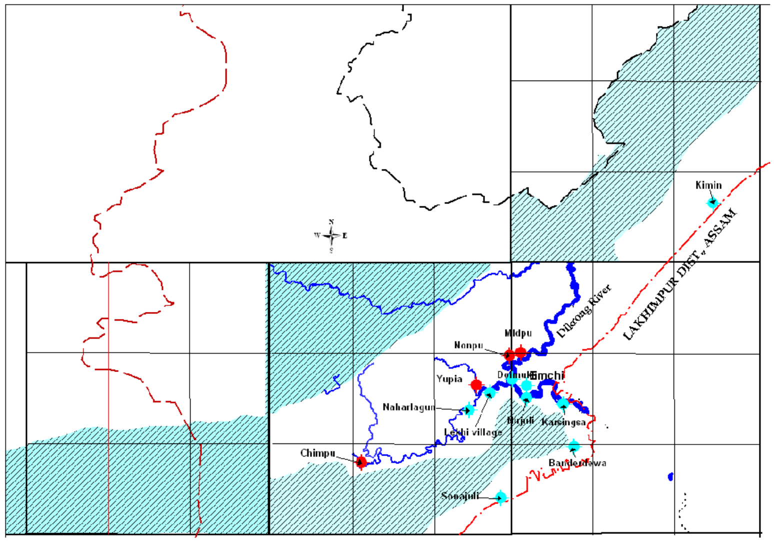


Fig. 1.2: EW data availability and data generation

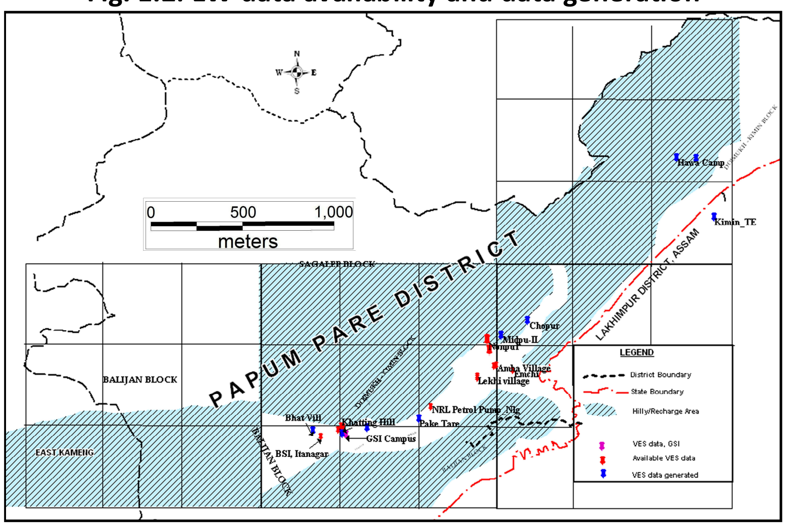


Fig. 1.3: VES data availability and data generation

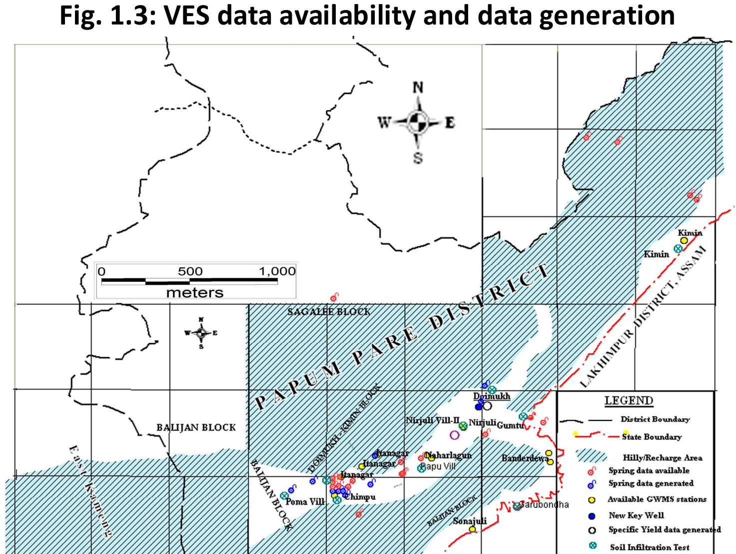


Fig. 1.4: Hydrogeological data availability and data generation

1.6 Rainfall-spatial, temporal and secular distribution: **The rainfall distribution of the area is influenced by altitudinal difference. There are two rain gauge stations in the area, viz., at Itanagar and at Doimukh. For 2003-12, the average annual rainfall of Itanagar is 3368.91mm whereas at Doimukh during the same period it is 3202.91mm. A difference of 166.0mm rainfall is observed between these two stations which are hardly 20kms apart. The average annual rainfall at Itanagar and at Doimukh during 1993-2002 is 3942.44mm and 3251.67mm respectively. A difference of 690.77mm rainfall is observed between these two stations. In this current decade there is a drastic reduction of rainfall in Itanagar is observed. The difference of rainfall of these two places is gradually reduced.**

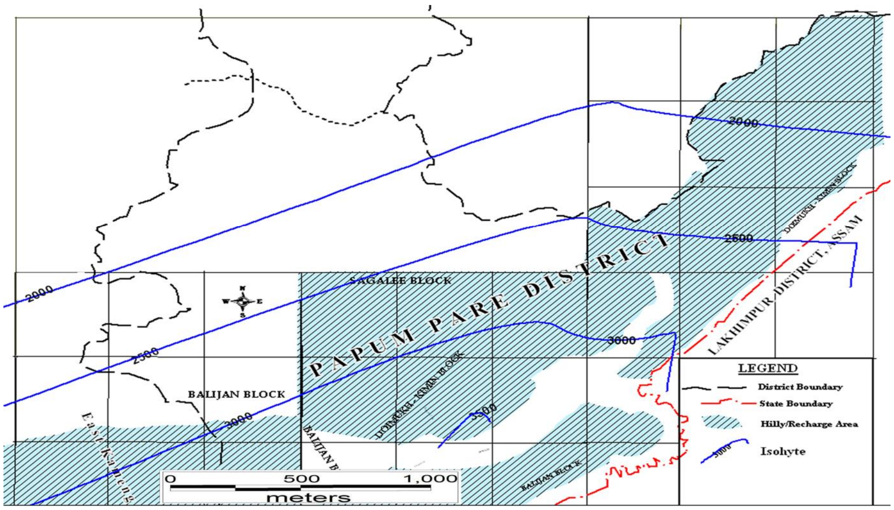


Fig. 1.5: Spatial distribution of rain

Isohytes were constructed on the basis of rainfall data of five raingauge stations viz., Seijosa of East Kameng district, Doimukh and Itanagar of Papum Pare district, Ziro of Lower Subansiri district and Harmati and North Lakhimpur of Lakhimpur district of Assam (Fig.1.5). It is observed that foothills of the Himalayas receive highest rainfall whereas towards the higher ranges of the Himalayas, rainfall decreases sharply. According to Dhar and Nandargi (2004) this may perhaps 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.

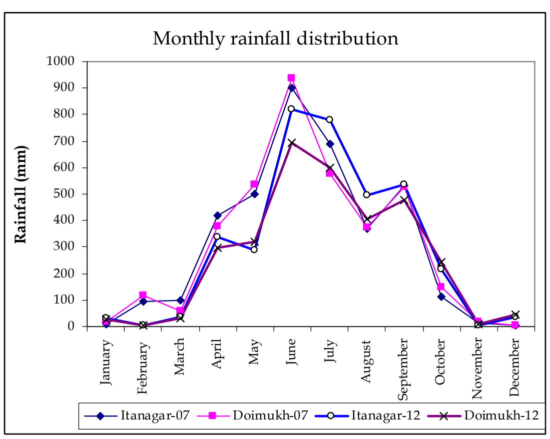


Fig. 1.6a: Monthly rainfall distribution

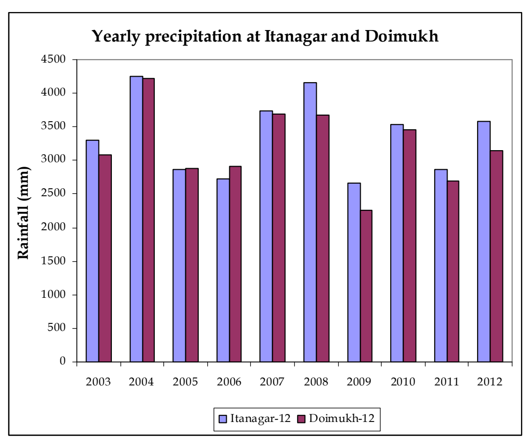


Fig. 1.6b: Yearly rainfall distribution

In the area the pre-monsoon season continues from January to March, April witnesses the onset of monsoon and it continues up to September and November-December constitute the post monsoon season. The monsoon rainfall distribution is in general bi-model in nature where the first peak rainfall is observed either in May or June and second is generally observed in August/September (Fig. 1.6a)

1.7 Physiographic set up: **Phisiographically the area can broadly be divided into three parts, i.e., the hilly tract, the piedmont and the intermontane valley. The hilly tracts are characterized by low to high relief hills and corrugated landform and comprise of Siwalik sediments of lesser Himalayas. The Himalayan Frontal Fault (HFF) marks the southern limit of the sub-Himalaya where the Siwalik Hills terminate abruptly with steep slope and come in contact with Brahmaputra plain towards south. The slope of the area drops from northern and eastern corners towards south. Piedmont areas are found along the Pachin and Dikrong rivers and are characterized by fans, terraces, etc. Intermontane valleys are formed mainly by the Dikrong and Pachin rivers along with other rivers. This zone is characterized river terraces, alluvial fans, channel ars and point bars.**

1.8 Geomorphology: **The main geomorphic elements of the area are-structural hills, piedmont zone and alluvial plains. High relief structural hills occupy the northern part of the study area. Geologically these are formed by Siwalik, Gondwana and Bomdila Group of rocks. The northern extension of Siwalik is restricted to Main Boundary Fault. The lower Siwalik (Dafla Formation) forms low relief structural hills with height restricted to 1200m amsl and show deep valleys and gullies with gently sloping land developed due to stream or river erosion. This unit is associated with folds and faults. The middle and upper Siwalik forms dissected and highly dissected structural hills and are found in the central and southeastern part of the district. The hills of this unit exhibit badland topography characterized by sharp crest and steep slopes. The hill ranges vary between 300 to 700m and locally to 1000m. The Neogene Siwalik rocks exhibit a close parallelism between the structure and topography, i.e., structural high and lows correspond to topographic high and lows. Hence, the Siwaliks belt is considered to be an illustration of 1st order topography (Kunte et.al, 1976).**

Two NE-SW trending linear ridges present in Itanagar, the state capital (the central part of toposheet no. 83E/12). The one extending from Raj Bhawan to Doordarshan Colony through Ita Fort shows cuesta slopes of $\sim 15^0$-20^0 towards NW direction with nearly vertical fault scarp facing towards Pachin River. The other extending from Mowb II to Chief Minister's Bunglow has a cuesta slope of $\sim 15^0$-20^0 towards SE direction with nearly vertical fault scarp facing towards Senkhi Stream.

Most of the dissected hills are characterized by nearly flat tops, which are caused due to erosion of the immature Siwalik and Quaternary sediments. The flat top topography is observed near Chimpu, Niti Vihar, Dony Polo Vidya Mandir, Youth Hostel, Yupia and Rono Hills.

Dissected hills are characterized by high occurrence of river terraces indicating that the area has remained tectonically active in comparison to the low-relief structural hills where there is less development of the river terraces. In the study area terraces are mostly found all along the Pachin River and along some of its tributaries.

The broad valley between Naharlagun and Nirjuli represents intermontane valley filled with Quaternary sediments. Piedmont area occurs as nearly flat to gently sloping surface sloping southwards, covering a large area towards the foothills. Area around Harmuti, Banderdewa, Holangi represnts this unit and mostly occupied by Quaternary sediments. Alluvial plain occurs along the wide flood plain areas of Pachin and Dikrong rivers. It represents various sub-features, viz., palaeochannel, swampy/marshy land, river terraces, flood plains, point bar, channel bar, and river channel.

1.9 Land use Pattern: **Village wise land use data is not available in 2011 census data. Therefore, district wise land use data are presented here. A large part of the study area is covered by thick forest which has sub-tropical, deciduous and humid type of vegetation. The low land and valleys are occupied by inhabitations. The land utilization pattern of the district is given in Table: 1.3**

Table: 1.3 Land utilization pattern, as per 2010-2011 agricultural census (Area in Hect)

Block	Total Holdings Area		Net Area Sown	Area Under Current Fallows	Net Cultivated Area	Other Uncultivated Land Excluding Fallow Land	Fallow Land Other than Current Fallows	Culturable Waste Land	Total Uncultivated Land	Land Not Available for Cultivation
(1)	(2)	(3)	(4)	(5)	-6	(7)	(8)	(9)	(10)	(11)
Doimukh	1790	5915	4095	100	4195	485	487	177	1149	570
Kimin	703	1583	1139	36	1175	84	153	132	369	40
Balijan	2140	6354	5030	145	5175	433	196	201	830	349

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 various classes (Fig. 1.8).

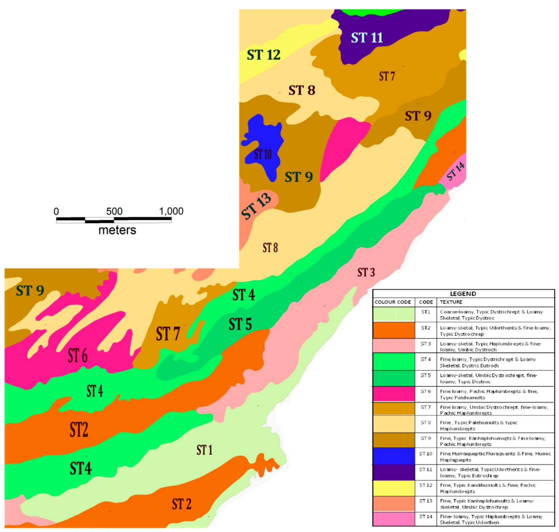


Fig.1.8: Soil Map of the study area

1.11 Hydrology and drainage: The study area is a part of Brahmaputra river basin. The main rivers of the area are Dikrang, Pachin, Panyar, Pare, Kimin and Kud. However, no hydrological data is available in the area.

The drainage density is high in the district and the 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 (Fig. 1.9).

1.12 Agriculture: Agricultural land is very limited in the area. Compared to district total area of 83743 sq.km the total agriculture land is only 154.89 sq.km. The traditional agricultural practice is Jhumming or shifting cultivation. But now, practice of settled cultivation in foothill plains is increasing in the area. The summer paddy area is very limited and confined to the intermontane valleys and in the

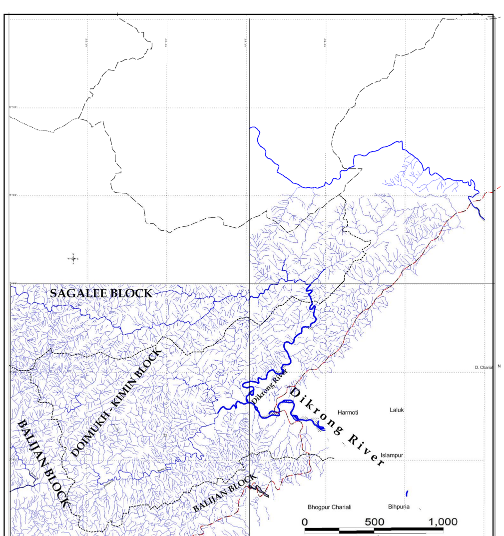


Fig. 1.9: Drainage Map of the study

foothill area. Paddy is the principal crops followed by maize, millet. Vegetables, mustard and fruits like banana are also cultivated in these villages. Details of the area and production of food crops in Papum Pare district is given in Table: 1.5.

Table 1.4: Area & production of Food crops in Papum Pare District

Rice		Mize		Millet		Wheat		Pulses		Total	
Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.
9300	11615	2500	3497	695	861	160	280	410	423	13065	16676

Source: The District Agriculture Officer, Papum Pare district, 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. In Doimukh CD block 22.7%, in Kimin CD block 0.63% and in Balijan CD block 37.39% of total agricultural land is irrigated by other sources.

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, exploration and geophysical data. Geological Survey of India carried out one VES survey in the GSI Campus of Itanagar and the data is also incorporated in the present study. Population data is collected from Census of India website. Agricultural data is collected from the website of Ministry of Agriculture, Govt. of India.

CGWB had carried out spring study during AAP 2008-09. The spring discharge data is compiled in the present study. CGWB has started drilling activities since 1987 at Sonajuli Seed Farm, Govt, of A.P. From 1987 to 2011 CGWB had constructed 7 exploratory wells in this 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 coordinate data. Details of the wells are given in Table 2.5. Rainfall data was collected from Rural Works Department, Govt. of Arunachal Pradesh, Itanagar. CGWB has 10 groundwater monitoring station in the area and these monitoring stations were regularly monitored (Table 2.1 and 2.2).

2.2 Data Generation

2.2.1 Hydrogeological data: Major part of the area is covered with hill and communication is very poor. As such habitation is clustered in plain area and ground water abstraction structures are also clustered in the plain area. Due to this reason entire study area could not be covered by establishing new water level monitoring stations. Spring data of earlier study was utilized as well as new spring monitoring stations was 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/D	Type (DW/Pz/Spring)	Aquifer group	Measuring point (magl)	Source/Agency

					W (mbgl)				
PPDK_01	Banderdewa-I	27.11	93.83	127.711	13.4	DW	Unconsolidated (I-Aquifer)	0.6	CGWB
PPDK_02	Banderdewa-II	27.10	93.83	102.10	5.11	DW		1	CGWB
PPDK_03	Nirjuli Vill-IIA	27.13	93.73	118.57	4.18	DW		0.8	CGWB
PPDK_04	Nirjuli Vill-IIB	27.13	93.73	117.65	2.5	DW		1	CGWB
PPDK_05	Naharlagun-I	27.10	93.69	144.17	9	DW		0.6	CGWB
PPDK_06	Naharlagun-II	27.10	93.70	146.91	4.45	DW		0.9	CGWB
PPDK_07	Itanagar-I	27.10	93.64	347.78	5.8	DW		0.8	CGWB
PPDK_08	Itanagar-II	27.09	93.62	326.44	9.63	DW		1.5	CGWB
PPDK_09	Itanagar-III	27.08	93.60	243.00	3.79	DW		0.9	CGWB
PPDK_10	Chimpu	27.07	93.60	197.51	4.24	DW		0.4	CGWB
PPBL_01	Sonajuli	27.03	93.74	122.00	9.14	DW		0.6	CGWB
PPDK_11	Doimukh	27.15	93.75	209.00	2.82	DW		0.7	CGWB
PPDK_12	Kimin	27.31	93.97		4.05	DW		1	CGWB
PPDK_13	On Sagalee road	27.17	93.76	214.00		Spring	Siwalik (II-Aquifer)		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
PPDK_14	Doimukh	27.16	93.75	119.00		Spring	Unconsolidated (I-Aquifer)		CGWB
PPDK_15	D-Colony, Naharlagun	27.11	93.69			Spring			CGWB
PPDK_16	Barapani, Naharlagun	27.10	93.69			Spring			CGWB
PPDK_	Car	27.10	93.64	407.00		Spring			CGW

17	Washing centre								B
PPDK_ 18	Jully Basti	27.08	93.63	189		Spring			CGW B
PPDK_ 19	Chimpu-I	27.06	93.61	192		Spring	Siwalik (II-Aquifer)		CGW B
PPDK_ 20	Chimpu-II	27.07	93.60	179		Spring			CGW B
PPDK_ 21	Chimpu-III	27.07	93.60	217		Spring			CGW B
PPDK_ 22	Chimpu-IV	27.07	93.59	266		Spring	Unconsolidated (I-Aquifer)		CGW B
PPDK_ 23	Chimpu-V	27.07	93.59	259		Spring	Siwalik (II-Aquifer)		CGW B
PPDK_ 24	Ganga Lake	27.08	93.57	423		Spring			CGW B
PPDK_ 25	Ganga Lake	27.08	93.57	426		Spring			CGW B
PPBL_0 2	Poma Village	27.07	93.55	377		Spring			CGW B

Table 2.2 Water level and spring discharge of monitoring stations

Unique ID	Date	Depth of	Unique ID	Date	Depth of
1	2	3	4	5	6
PPDK_01	1/3/2012	12.03	PPDK_04	25/08/2013	-0.5
	20/8/12	10.53		7/11/2013	-0.48
	2/11/2012	10.33		3/1/2014	-0.11
	5/3/2013	11.64		12/3/2014	-0.07
	25/08/201	11.24		22/08/2014	-0.7
	7/11/2013	11.5		4/11/2014	-0.28
	2/1/2014	11.72		7/1/2015	-0.06
	12/3/2014	11.69		9/3/2015	0.17
	22/08/201	10.09		22/08/2015	-0.55
	4/11/2014	10.87		3/11/2015	-0.16
	10/1/2015	11.66	PPDK_05	1/3/2012	7.69
	5/3/2015	11.51		20/8/12	5.23
	23/08/201	10.72		5/11/2012	6.1
	3/11/2015	11.46		10/3/2013	7.66
PPDK_02	1/3/2012	7.77		25/08/2013	5.5
	20/8/12	5.43		7/11/2013	6
	2/11/2012	5.82		3/1/2014	6.31
	5/3/2013	7.56		12/3/2014	7.99
	25/08/201	5.09		22/08/2014	4.38
	7/11/2013	Well filled up		4/11/2014	5.78
PPDK_03	1/3/2012	1.34		7/1/2015	6.68
	20/8/12	0.68		9/3/2015	7.77
	2/11/2012	0. 3		16/11/2015	5.91
	5/3/2013	0.89	PPDK_06	1/3/2012	1.89
	25/08/201	0.92		20/8/12	0.47
	7/11/2013	0.95		5/11/2012	1.17
	3/1/2014	1.16		10/3/2013	1.76
	12/3/2014	1.15		25/08/2013	0.72
	22/08/201	0.72		7/11/2013	
	4/11/2014	1		3/1/2014	1.56

	7/1/2015	1.02		12/3/2014	Well filled

PPDK_03	9/3/2015	1.13	PPDK_07	1/3/2012	3.99
	22/08/2015	0.76		20/8/12	0.94
	3/11/2015	0.97		5/11/2012	2.16
PPDK_04	1/3/2012	0.26		5/3/2013	3.62
	20/8/12	-0.49		25/08/2013	1.51
	2/11/2012	-0.34		7/11/2013	2.1
	5/3/2013	0.07		3/1/2014	4.22
PPDK_07	12/3/2014	4.15	PPBL_01	25/08/2013	NA
	22/08/2014	0.85		7/11/2013	
	4/11/2014	2.21		12/3/2014	
	7/1/2015	3.52		20/08/2014	
	10/3/2015	4.1		4/11/2014	
	22/08/2015	2.09		8/1/2015	3.05
	16/11/2015	2.19		5/3/2015	3.88
PPDK_08	1/3/2012	1.58		23/08/2015	1.71
	20/8/12	NA		3/11/2015	2.08
	5/11/2012	NA	Spring		
	5/3/2013	NA		9/7/2012	
	25/08/2013	NA	PPDK_13	18/08/2012	0.067888663
	7/11/2013	1.39		12/9/2012	0.631313131
	3/1/2014	1.19		8/10/2012	0.137324911
	12/3/2014	2.27		17/11/2012	0.020306218
PPDK_08	4/11/2014	0.37		11/12/2012	0.014326648
	7/1/2015	1.62		9/7/2012	
	10/3/2015	2.39		18/08/2012	0.067888663
	22/08/2015	NA	PPDK_13	12/9/2012	0.631313131
PPDK_09	1/3/2012	5.83		8/10/2012	0.137324911
	20/8/12	3.15		17/11/2012	0.020306218
	5/11/2012	4.2		11/12/2012	0.014326648
	5/3/2013	Well	PPDK_14	9/7/2012	0.215517241
PPDK_10	1/3/2012	4.16		18/08/2012	0.013262599
	20/8/12	1.52		12/9/2012	0.395256917
	5/11/2012	2.96		8/10/2012	0.067558438
	5/3/2013	3.94		17/11/2012	Dry
	25/08/2013	1.67		11/12/2012	Dry
	7/11/2013	NA	PPDK_15	25/05/2012	0.315
	3/1/2014	3.4		22/08/2012	0.41
	12/3/2014	3.1		30/11/2012	0.209
	20/08/2014	0.64		2/1/2013	0.201
	4/11/2014	2.62		11/3/2013	0.195
	7/1/2015	3.35		19/08/2013	0.452
	10/3/2015	3.74		13/11/2013	0.226
	22/08/2015	1.92		10/1/2014	0.2
	16/11/2015	2.69		1/3/2014	0.208
PPDK_11	11/3/2015	2.58		23/08/2014	0.374
	8/8/2015	0.73		1/11/2014	0.225
	18/11/2015	0.91		9/1/2015	0.211
PPDK_12	8/11/2012	2.21		15/3/2015	0.192
	2/1/2013	1.39		30/08/2015	0.417
	5/3/2013	1.23		18/11/2015	0.21
	25/08/2013	NA	PPDK_16	25/05/2012	0.243
	7/11/2013	NA		22/08/2012	0.263
	11/3/2014	1.48		30/11/2012	0.235
	20/08/2014	0.95		2/1/2013	0.185
	3/11/2014	1.44		11/3/2013	0.16

	8/1/2015	1.5		19/08/2013	0.263
	5/3/2015	1.83		13/11/2013	0.283
PPDK_12	23/08/2015	1.03		10/1/2014	0.218
	3/11/2015	1.35		1/3/2014	0.172
PPBL_01	8/11/2012	1.44	PPDK_16	23/08/2014	0.31
	7/1/2013	3.53		1/11/2014	0.286
	5/3/2013	0.31		9/1/2015	.205.164
				15/3/2015	0.159
PPDK_16	30/08/2015	0.25	PPDK_22	10/7/2012	0.065019506
	18/11/2015	0.275		17/08/2012	0.091979397
PPDK_17	10/7/2012	0.151057402		8/9/2012	0.862068966
	17/08/2012	0.4048583		10/10/2012	Dry
	8/9/2012	0.484496124		18/11/2012	Dry
	10/10/2012	0.032004097		10/12/2012	Dry
	18/11/2012	0.024333268	PPDK_23	10/7/2012	0.083001328
	10/12/2012	0.045699662		17/08/2012	0.100623868
PPDK_18	10/10/2012	0.137513751		8/9/2012	0.083166999
	18/11/2012	0.083015109		10/10/2012	0.072275224
	10/12/2012	0.020517029		18/11/2012	Dry
PPDK_19	10/7/2012	0.023696682		10/12/2012	Dry
	17/08/2012	0.040453074	PPDK_24	10/7/2012	0.031271499
	8/9/2012	0.040453074		17/08/2012	-
PPDK_19	10/10/2012	Dry	PPDK_24	8/9/2012	0.074393691
	18/11/2012	Dry		10/10/2012	Negligible
	10/12/2012	Dry		18/11/2012	Dry
PPDK_20	10/7/2012	0.053573342		10/12/2012	Dry
	17/08/2012	0.082508251	PPDK_25	10/7/2012	
	8/9/2012	0.080515298		17/08/2012	0.254194204
	10/10/2012	Dry		8/9/2012	
	18/11/2012	Dry		10/10/2012	0.447227191
	10/12/2012	Dry		18/11/2012	0.072275224
PPDK_21	10/7/2012	0.187969925		10/12/2012	Negligible
	17/08/2012	0.273224044		10/7/2012	0.111607143
	8/9/2012	1.113585746	PPBL_02	17/08/2012	0.007170926
	10/10/2012	0.133120341		8/9/2012	Negligible
	18/11/2012	Dry		10/10/2012	
	10/12/2012	Dry		18/11/2012	
				10/12/2012	

Table 2.3: Spring Discharge Measurement during AAP 2008-09

Station Name	Location	Latitude	Longitude	Discharge measurement (in lps)		
				Pre-monsoon	Monsoon	Post-monsoon
D-colony	**LHS of the Dokum colony-Helipad connecting road. Behind Oju Welfare Mission**	**93.69**	**27.11**	**0.255**	**0.429**	**0.212**
Barapani	**Neraly 500m NW from the D-colony road juncion at NH52A towards the Pachin River**	**93.69**	**27.10**	**0.198**	**0.267**	**0.218**

Sivamandir	2kms from Naharlagun towards Itanagar behind car washing centre	93.68	27.10	0.047		0.062
Zinggang Colony	Near IBP Petrol Pump. LHS of Naharlagun-Itanagar Road	93.69	27.11	Dry	0.057	Dry
Medicinal Plant Garden	LHS of NH 52A towards Itanagar	93.64	27.10	0.210	0.429	0.183
C-Sector, Itanagar	Nearly 300m in the LHS of NH52A towards Itanagar after crossing Military Police Establishment.			0.198	0.600	0.121

Turn City Car washing centre	About 500m towards Itanagar from Pap S6 in the LHS of NH52A.			0.134	0.265	0.032
Vivek Vihar	Just before reaching Chandranagar bridge. RHS of NH52A and in front of Christian Revival Church	93.60	27.08	0.110	0.071	0.058
Chimpu	1km from Chimpu towards Holangi, RHS of NH 52A	93.61	27.06	0.053	0.061	0.012
Near ITBP entrance	At the road junction of Holangi-Itanagar and road towards ITBP campus	93.59	27.08	0.205	0.375	0.108
	RHS of the road towards Itanagar. 500m before reaching signboard of Hornbil Residential School.	93.59	27.08		0.032	Dry
	RHS of the NH52A towards Holangi 200m from Gohpur Tiniali	93.59	27.07		0.059	Dry
Dapoiarllo	Itanagar-Gohpur road			0.033	0.128	0.085
	Near Km Stone 11. LHS of NH52A along Itanagar-Gohpur Road			0.489	0.780	0.032

	From Itanagar towards Juli Basti 2 to 1.5km LHS of the road before reaching Julie Road and Delhi Public School signboard	93.62	27.08	0.005	0.065	0.004
Hoka Basti	After crossing Hoka School 100m towards Julie on the RHS of the road and at the junction of the road towards BSNL tower.	93.61	27.07	Dry	0.054	Dry
Julang Johan	100m before reaching the entrance to Don Bosco School	93.60	27.07	Dry	0.087	Dry
	LHS of the road towards Juli Basti	93.67	27.09	0.006	0.031	Dry
Karsingsa	Itanagar-Banderdewa Road near Durga Mandir	93.76	27.12		0.095	Dry
Rangali Reserve	RHS of Doimukh-Harmati road. 3.5km from Harmati	93.82	27.13		0.354	Dry
	Nearly 1km on the RHS of the road towards Rajiv Gandhi University from Doimukh-Gumto road.			0.170	0.323	0.240
Gumto	Near Police Station	93.80	27.14	1.071	3.000	0.668
	6km from Doimukh Tiniali on way to Sagalee	93.76	27.17	0.120		0.028
	7km from Doimukh on way to Sagalee			0.093		0.066
	8km from Doimukh Tiniali on way to Sagalee	93.75	27.18	0.030		0.011
	8.5km from Doimukh Tiniali on way to Sagalee			0.100		Dry
	9km from Doimukh Tiniali on way to Sagalee	93.76	27.18	0.020		0.037

	10km from Doimukh Tiniali on way to Sagalee			0.040		Dry
	13km from Doimukh Tiniali on way to Sagalee			0.230		0.008
	16km from Doimukh Tiniali on way to Sagalee	93.71	27.20	0.140		0.006
	17km from Doimukh Tiniali on way to Sagalee	93.70	27.21	0.021		0.030
	18km from Doimukh Tiniali on way to Sagalee			0.370		0.230
	19km from Doimukh Tiniali on way to Sagalee			0.210		0.110
	21km from Doimukh Tiniali on way to Sagalee	93.69	27.21	0.170		0.037
	23km from Doimukh Tiniali on way to Sagalee			0.043		0.011
	25km from Doimukh Tiniali on way to Sagalee			1.500		0.923
	27km from Doimukh Tiniali on way to Sagalee			0.038		Dry
	28km from Doimukh Tiniali on way to Sagalee			0.348		0.525
	28.1km from Doimukh Tiniali on way to Sagalee			0.438		0.685
	28.3km from Doimukh Tiniali on way to Sagalee			0.239		0.882
	33km from Doimukh Tiniali on way to Saggalee			0.714		1.587
	34km from Doimukh Tiniali on way to Sagalee			0.041		0.008
	Close to Pap S46			0.305		0.459
	22mile	93.56	27.23	0.196		0.117

	Khel	**93.68**	**27.21**	**0.296**		**0.371**
	17 km from Khel towards Sagalee			**0.090**		**0.095**
	Nimte	**93.68**	**27.22**	**0.056**		**0.080**
	7km from Prayer Hall, Kimin towards Ziro			**0.005**		**0.004**
	8km from Prayer Hall, Kimin towards Ziro	**93.98**	**27.35**	**0.023**		**0.004**
	26km from Prayer Hall, Kimin towards Ziro			**0.142**		**0.082**
	5km from Lichi on way to Kimin	**93.87**	**27.41**	**0.9375**		**2.970**
	11km from Lichi on way to Kimin	**93.9**	**27.41**	**0.061**		**0.033**
	Nyleum village			**0.010**		**Dry**
	50 m from Nyleum			**0.013**		**Dry**
	Water supply			**1.156**		**0.962**

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 2.4: Salient features of the test sites

Site	Location	Land use	Soil type	Latitude	Longitude
Doimukh	**Panchayat Hall Campus**	**Barren Land**	**Sandy soil**	**27° 08' 48.4"N**	**93° 45'12.5"E**
Garubondha	**Garubondha LP School**	**Barren Land**	**Sandy soil**	**27° 03' 42"N**	**92° 46'55.6"E**
Nirjuli	**200m N of VKV School Hostel, Nirjuli**	**Barren Land**	**Sandy soil**	**27° 08' 5.7"N**	**93° 44'18.8"E**
Site	Location	Land use	Soil type	Latitude	Longitude
Chimpu	**Govt. Upper Primary School**	**Barren Land**	**Sandy soil**	**27° 04' 14.6"N**	**93° 36'53.6"E**
Kimin	**Namghar Campus**	**Barren Land**	**Sandy soil**	**27° 18' 26.6"N**	**93° 58'6.5"E**
Khating Hill, Itanagar	**ITBP Campus**	**Barren Land**	**Sandy soil**	**27° 04' 45"N**	**93° 35'14"E**

Summary of the infiltration tests is given in Table .2.5

Table 2.5: Summary of Infiltration Tests

S.N.	**Site**	**Land use**	**Soil type**	**Initial Infiltration rate (cm/hr)**	**Final Infiltration rate (cm/hr)**	**Duration of test (min)**	**Total Quantum of water added in m**	**IF = (6)/ (8)*100)**
1	2	3	4	5	6	7	8	
1	**Chimpu**	**Barren Land**	**Sandy gravel**	**15**	**6.8**	**143**	**22.4**	**30.36**
2	**Kimin**	**Barren Land**	**Sandy gravel**	**9.6**	**5.88**	**120**	**15.3**	**38.43**

3	**Khating Hill**	**Barren Land**	**Clayey gravel**	**57.6**	**0.81**	**52**	**25.6**	**3.16**
4	**Garubandha**	**Barren Land**	**Sandy gravel**	**24**	**14.4**	**100**	**30.1**	**47.84**
5	**Nirjuli**	**Barren Land**	**Sandy gravel**	**8.4**	**2.8**	**120**	**15**	**18.67**
6	**Doimukh**	**Barren Land**	**Sandy gravel**	**22.8**	**3.2**	**80**	**22**	**14.55**

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.

2.2.4 Geophysical survey

VES survey was carried out in the area for short term water supply investigation as well as VES survey carried out by Geological Survey of India in its Itanagar campus were collected. During Aquifer Mapping total 11 survey was conducted in the area with current electrodes spreading in the range of 200 and 500m. The obtained VES data was plotted on double logarithmic graph sheet. The VES data was interpreted by using IP2WIN software technique. H, HK, K, Q type multilayered VES curves was obtained.

The location of these VES survey is given in Table 2.6.

Table 2.6: Location of VES survey

S N	Name of the site	Latitude	Longitude	RL (mamsl)	Agency	VES/TEM	Depth of interpretation
1	**BSI Complex**	**27.08**	**93.58**		**CGWB**	**VES**	**96**
2	**Nishi village**	**27.08**	**93.58**	**175**	**CGWB**	**VES**	**170**
3	**ITBP Khating Hill**	**27.08**	**93.59**	**287.27**	**CGWB**	**VES**	**150**
4	**ITBP Khating Hill1**	**27.08**	**93.59**	**319**	**CGWB**	**VES**	**200**
5	**ITBP Khating Hill2**	**27.08**	**93.59**	**287**	**CGWB**	**VES**	**150**
6	**ITBP Khating Hill3**	**27.08**	**93.59**	**280**	**CGWB**	**VES**	**200**
7	**GSI Complex**	**27.09**	**93.67**	**270**	**GSI, Shillong**	**VES**	**60**
8	**NEEPCO, Doimukh**	**27.15**	**93.78**	**166**	**CGWB**	**VES**	**210**
9	**RG Univ, Doimukh**	**27.18**	**93.82**	**256**	**CGWB**	**VES**	**200**
10	**Amba village, Doimukh**	**27.14**	**93.75**	**127**	**CGWB**	**VES**	**150**
11	**Amba village, Doimukh**	**27.14**	**93.75**	**127**	**CGWB**	**VES**	**150**
12	**Emchi village**	**27.13**	**93.77**	**118**	**CGWB**	**VES**	**150**
13	**Papu Nala, Naharlagun**	**27.10**	**93.69**	**153.93**	**CGWB**	**VES**	**200**
14	**Papu Village.**	**27.09**	**93.69**	**126.96**	**CGWB**	**VES**	**170**
15	**Lekhi Village**	**27.13**	**93.73**	**137**	**CGWB**	**VES**	**200**
16	**Lekhi Village**	**27.13**	**93.73**	**137**	**CGWB**	**VES**	**150**
17	**Nonpu Village**	**27.16**	**93.75**	**137**	**CGWB**	**VES**	**>156**
18	**Nonpu Village1**	**27.16**	**93.75**	**132**	**CGWB**	**VES**	**>30**

19	**Bhat village**	**27.07**	**93.56**	**307**	**CGWB**	**VES**	**119m**
20	**Chimpu**	**27.07**	**93.60**	**192**	**CGWB**	**VES**	**>67**
21	**Hawa Camp**	**27.35**	**93.94**	**197**	**CGWB**	**VES**	**>23**
22	**Sher**	**27.35**	**93.96**	**213**	**CGWB**	**VES**	**>40**
23	**Dijoo TE, Kimin**	**27.29**	**93.98**	**130**	**CGWB**	**VES**	**>181**
24	**Chopur**	**27.19**	**93.79**	**144**	**CGWB**	**VES**	**>132**
25	**Midpu-II**	**27.16**	**93.75**		**CGWB**	**VES**	**>11**
26	**Jollang Llang**	**27.08**	**93.62**	**192**	**CGWB**	**VES**	**>125**
27	**Pake Tare**	**27.09**	**93.67**	**158**	**CGWB**	**VES**	**>56**

2.2.5 Exploratory Drilling

As part of data generation four exploratory wells were constructed from 2012-2014. Following is a delaied list of wells constructed by CGWB.

Table 2.7: Details of exploratory wells in the study area

Village/ Location	Taluka/ Block	District	Toposhe et No.	Lat	Long	Type of well	Depth (m)	Dia (mm)	Source/ Agency
Yupia	Doimukh-Kimin Block	Papum Parea	83E/12	27.14	93.72	TW	72	304.8mmX30m 254.0mmX6.0m 152.4 mmX12m 177.8 mmX6m 152.4mmX7.5m	CGWB
Midpu			83E/16	27.17	93.76	TW	91	254.0mmX33m 152.4mmX23m	CGWB
Nonpu			83E/12	27.16	93.75	TW	42.5	254.0mmX6.0m 152.4 mmX12m	CGWB
Chimpu			83E/12	27.07	93.6	TW	100	304.8mmX36m 152.4 mmX59.0m	CGWB
Nirjuli (NERIST)			83E/16	27.13	93.77	TW	47.3	203.2	CGWB
Lekhi			83E/12	27.13	93.73	TW	103	203.2	CGWB
Kimin-I			83E/15	27.3	93.96	TW	54		CGWB
Doimukh			83E/16	27.14	93.75	TW	55		CGWB
Emchi			83E/16	27.14	93.77	TW	52.5	203.2	CGWB
Naharllagun			83E/12	27.03	93.74	TW	58	101.6	CGWB
Banderdewa			83E/12	27.08	93.74	TW	56		CGWB
Sonajuli			83E/12	27.03	93.74	TW	76	152.4	CGWB
Karsingsa			83E/16	27.12	93.81	TW	62	203.2	CGWB

CHAPTER 3.0

Data Interpretation, Integration and Aquifer Mapping

3.1 Data Interpretation

Geophysics and aquifer Characterization

The interpreted VES results have indicated a four to five layered geoelectric model. The top soil identified by VES survey has resistivity value between 260 to 500Ωm suggesting sandy and pebbly nature. Top soil resistivity increases depending upon presence of boulder in the area. At Doimukh, Hawa Camp area the top soil resistivity value ranges from 1100 to 22000 Ωm indicating extreme bouldery nature of top soil. Thickness of top soil increases towards southern, eastern and western part of the study area. Maximum thickness of top soil is found at Kimin, Assam.

In Doimukh area the thickness of Older Alluvium is found to be more than 200m and have resistivity value ranges from 140 to 1560 Ωm indicating gravelly nature and grain size decreases with the increase of depth.

Siwalik clay layer has low resistivity value within the range of 26 to 84 Ωm and are found in Chimpu Valley, Juli Basti area and north of Kimin. Siwalik clay layer is underlain by sandy/gravelly layer and have resistivity value 144 to 192 Ωm. These interpretations are in conformity with the lithological log of exploratory wells constructed by CGWB.

Based on geophysical and lithological logs of exploratory wells the aquifer system of the area can be classified into two, viz., Aquifer 1 and Aquifer2.

Aquifer 1: **Unconsolidated Quaternary Aquifer**

Unconsolidated Quaternary aquifer consists of older and recent alluvium and flood plain deposits. CGWB constructed seven deep tube wells in Banderdewa, Karsingsa, Nirjuli, Doimukh, Emchi, Nonpu. From the distribution of the grain size of the aquifer it can be inferred that the aquifer is formed by valley fill and/or terrace materials. A thin confining layer of clay of 1 to 2m thick is regionally persistent. Ground water occurs under unconfined to semi-confined condition. The discharge of the tube wells varies from 1.8m^3/day to 37.8m^3/day and the transmissivity value varies from 5.16 to 667m^2/day. Auto flow condition is observed in the wells constructed in the Dikrang valley, i.e., in and around Doimukh. 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 (m^2/day)	Storativity/ S.Yield	Specific Capacity (lpm/m of dd)	Source/ Agency
1	2	3	4	5	6	7	8	9	10	11	12
Nonpu	**Doimukh -Kimin**	**27.16**	**93.75**	**TW**	**42.5**						**CGWB**
Nirjuli (NERIST)		**27.13**	**93.77**	**TW**	**47.3**	**9/6/1996**	**15**	**31.07**		**14.48**	**CGWB**
Doimukh		**27.14**	**93.75**	**TW**	**55**		**8.67**	**39.94**			**CGWB**
Emchi		**27.14**	**93.77**	**TW**	**52.5**	**15/09/1995**	**14.32**	**5.16**		**18.85**	**CGWB**
Banderdewa		**27.08**	**93.74**	**TW**	**56**		**18.73**	**9.92**			**CGWB**
1	2	3	4	5	6	7	8	9	10	11	12
Sonajuli		**27.03**	**93.74**	**TW**	**76**	**13/12/1988**	**20.93**	**32.87**		**12.5**	**CGWB**
Karsingsa		**27.12**	**93.81**	**TW**	**62**	**17/05/1989**	**6.15**	**406.75**		**102.8**	**CGWB**
Itanagar (Akashdeep Market Complex)		**27.09**	**93.61**	**TW**	**52**					**155.4**	**WRD**

Auto flow condition is found in Dikrang-Pachin valley in those tube wells that pierce the thin confining (clay) layer. All tube wells constructed at Doimukh, Lekhi, Nirjuli and Nonpu penetrated the clay layer and groundwater flows automatically. One tube well at Emchi having the same geomorphic setting had struck the confining layer but did not penetrate and groundwater auto flow condition did not encounter.

Aquifer thickness: A perusal of fence diagram and cross-section (Fig. 3.1) shows that the thickness of aquifer-1 increases toward east and western part of the study area, i.e., toward Assam Plains.

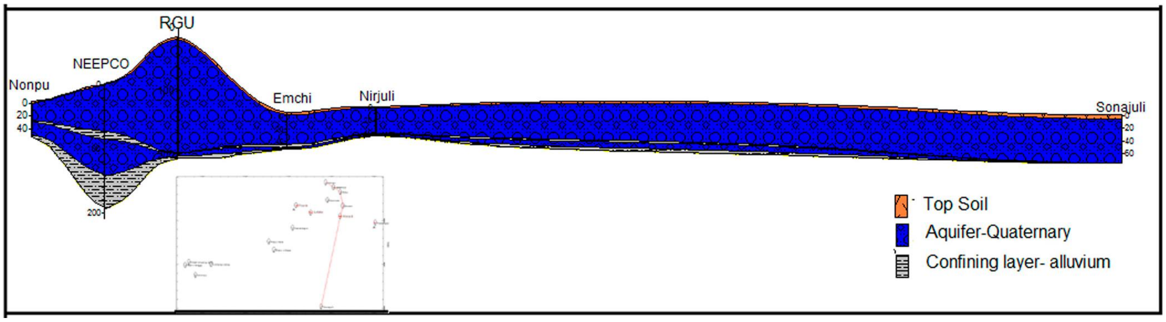


Fig. 3.1: Thickness of aquifer 1 increases towards southeast of the study area

Depth to water level (DTW)

Depth to water level in and around Itanagar area varies from 1.58 to 5.83 m bgl in pre-monsoon period and 2.16 to 4.20 m bgl in post-monsoon period. The depth to water level at Naharlagun varies from 1.89 to 7.69mbgl and 1.17 to 6.10mbgl during pre- and post- monsoon period respectively. At Nirjuli area pre-monsoon depth to water level varies from 0.26 to 1.34mbgl while the post monsoon depth to water level varies from -0.34 to 0.3mbgl. At Banderdewa area the depth to water level for the pre-monsoon period varies from 5.82 to 10.33mbgl while the post monsoon water level varies from 7.77 to 12.03mbgl. Seasonal fluctuation of water level in shallow aquifers as observed in dug wells is within 2 m.

From DTW data it is observed that water logged and deeper water level condition exists in the study area. Deeper water level condition is observed towards southern part of the study area, i.e., in and around Banderdewa and also at Naharlagun township while water logged condition is prevalent in the valley area, i.e., Pachin and Dikrong valley.

Water level trend: Historical water level data of three Ground Water Monitoring Stations (GWMS) is available. Of this three GWMS one GWMS at Doimukh is defunct since 2005. Comparison of historical water level data of two GWMS with the water level data of March 2013 and November 2012 indicate rise of water level except WL of Kimin GWMS. Post monsoon water level of Kimin GWMS 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-2013**	**Difference**	**Rise/Fall**
Sonajuli	**9**	**3.49**	**0.31**	**3.18**	**Rise**
Doimukh	**5**	**1.36**	**Defunct**		
Kimin	**8**	**1.57**	**1.23**	**0.34**	**Rise**

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

	No. of observation	**Mean WL-November**	**WL of Nov-2012**	**Difference**	**Rise/Fall**
Sonajuli	**9**	**2.43**	**2.21**	**0.22**	**Rise**
Doimukh	**5**	**1.40**	**Defunct**		
Kimin	**9**	**1.86**	**2.21**	**-0.35**	**Fall**

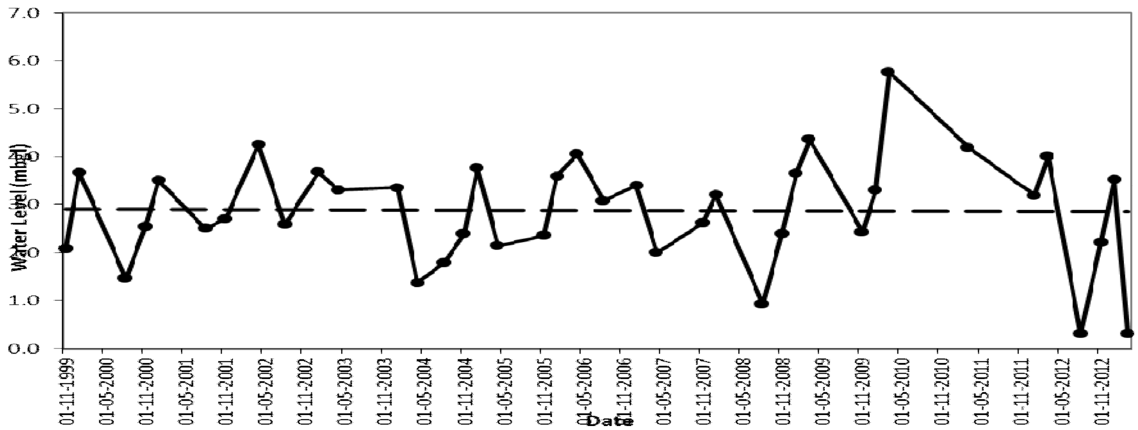


Fig. 3.2: Water level trend of Sonajuli GWMS

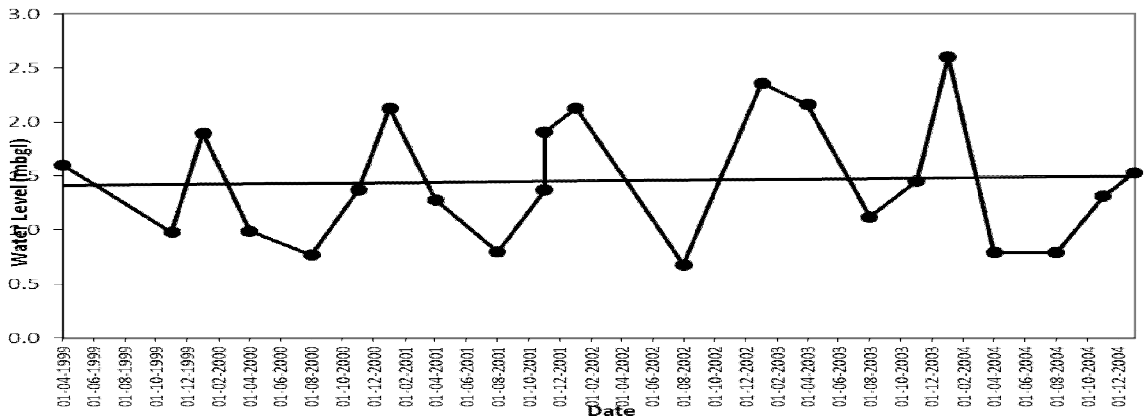


Fig. 3.2: Water level trend of Doimukh GWMS

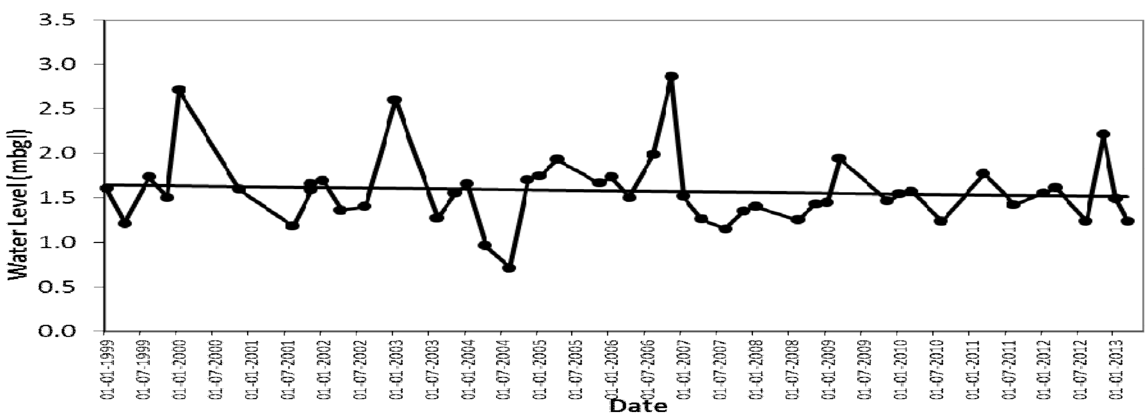


Fig. 3.4: Water level trend of Kimin GWMS

3.2 Ground Water Movement

Water table contour could not be prepared as the major portion of the area has more than 20% slopes. Generally the flow of groundwater in this area is from piedmont to flood plain or valley. This phenomenon can be understood considering the ground water condition

of monitoring stations. For example, there are two monitoring stations at Nirjuli which are 20m apart. Geomorphological setting of these monitoring stations is such that one monitoring station is located in piedmont and the other is in flood plain of Pachin River. It is observed that the water level of well in the piedmont is always at higher level compared to well in the flood plain (Fig.3.5). Similarly, in other parts of the study area also the ground water level conditions clearly indicate that dissected and highly dissected hills and the Quaternary piedmont deposit form the recharge area and the movement of groundwater is from NW to SE direction. Thus intermontane valleys as well as the alluvial plains of Pachin and Dikrang rivers form the discharge zone.

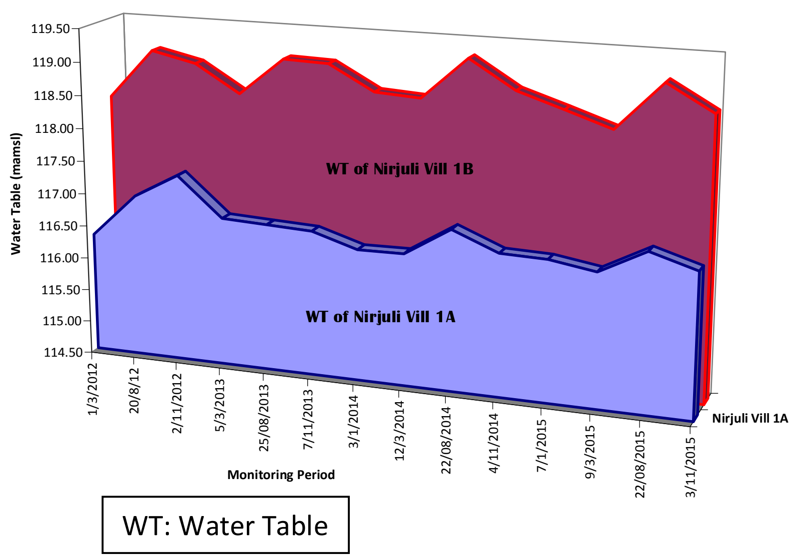


Fig. 3.5: Water table elevation at Nirjuli

Spring Discharge: **During AAP 2008-09 the author carried out spring study in Papum Pare district. All total 60 spring monitoring stations were established in the pre-monsoon period and 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. From 2008 to 2009 spring discharge of two springs at Naharlagun, (D-Colony and Barpani) were measured in a daily basis. Spring hydrograph of these two springs also corroborate the observation that the springs of this area are rain fed (Fig.3.6 and 3.7).**

From the analyse of spring hydrograph it is observed that as the rainfall decreased from September to March, spring discharge also decreases, until the onset of monsoon rainfall which reverses the phenomena. In case of D-colony spring no lag was observed between monthly rainfall and spring discharge. In case of Barapani spring, a lag exists between discharge and rainfall from August to September.

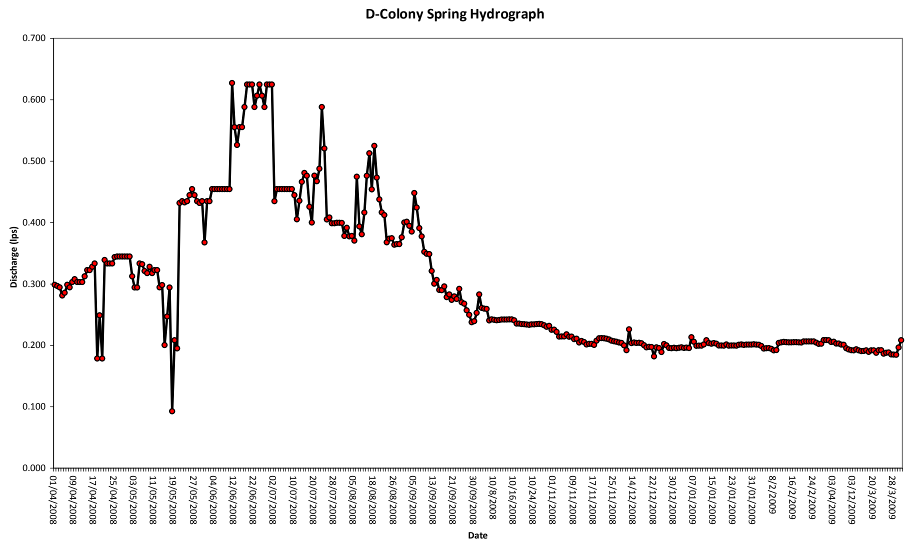


Fig. 3.6: D-Colony, Naharlagun, Spring hydrograph

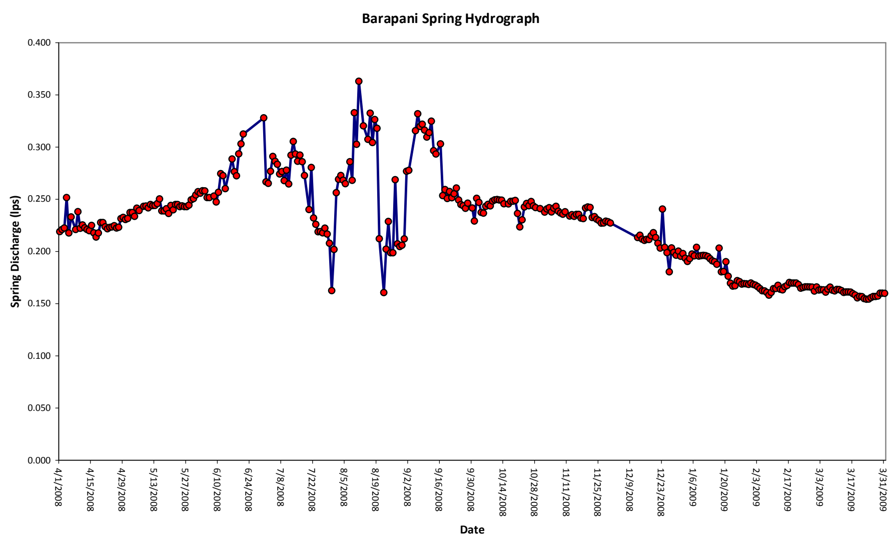


Fig. 3.7: Barapani, Naharlagun, Spring hydrograph

Water quality: **All total 11 numbers of ground water samples from dug wells and springs representing phreatic aquifer were collected and were analyzed for major ions. The Electrical conductivity of the phreatic aquifer ranges between 64.9 to as high as 462.6 microsimens/cm. Total dissolved solids in the groundwater ranges from 41.7 to 216.8mg/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 barring iron. Iron content in groundwater ranges from 0.04 to 12.33mg/l. The highest concentration of iron is found in the valley areas. The EC infers that the Phreatic aquifer (aquifer – I) is fresh and is suitable for drinking, domestic and Irrigation purpose.

Tube well constructed in unconfined aquifer has also low EC, TDS and total hardness. The EC value of the tube well ranges from 132 to 270 microsimens/cm. TDS value ranges

from 84 to 180 mg/l. The water of the tube wells is soft. However, iron content ranges from 0.45 to 7.4.

Aquifer 2: Tertiary Siwalik Aquifer: **The deep tube wells constructed at Chimpu, Naharlagun, Lekhi, Kimin had struck the Kimin Formation of Siwalik Group. Although Siwalik Group has three formations, exploration activities are mainly confined to the Kimin Formation. The oldest formation of Siwalik Group is the Dafla Formation and the overlying Subanisiri Formation form high hills with slope more than 20% and thus acts as run-off zone. Therefore Kimin Formation is considered as Siwalik aquifer. Ground water in this aquifer occurs under semi-confined conditions. Siwalik aquifer is abruptly terminate toward southeast of the study area (Fig. 3.8). Two zones have been identified in this aquifer. The first zone is composed of whitish grey colour fine to medium size sand/sandstone alternating with thin grey colour sticky clay bed and gravel beds. The maximum thickness of this first zone is 50m as inferred from VES survey so far carried out in this area. However, from 3D block diagram it is observed that these two zones sometimes merge together (Fig. 3.40).**

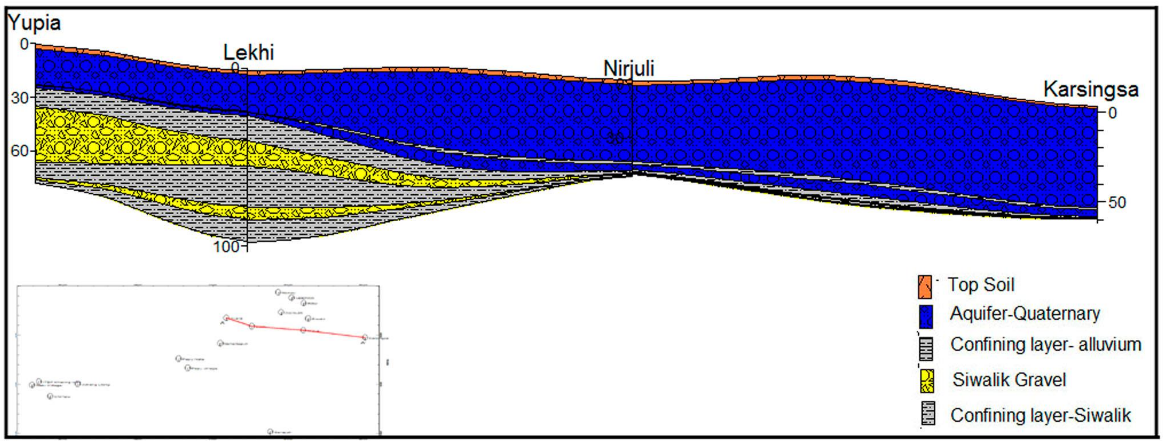


Fig.3.8: Siwalik aquifer thins out towards south east

The discharge of the tube wells tapping the sand or gravel horizon of the Siwalik (Kimin Formation) varies from 1.8 to 6.84m$^{3/}$hr. Transmissivity value of the first zone of the aquifer is 43.95m^2/day and the storativity value of this zone is 0.347X10^{-3}. The second zone is found in three deep tube wells constructed at Lekhi, Chimpu and Midpu. The zone is separated from the first zone by a dominantly silty/clayey horizon of nearly 30m thick. These two zones may not be regionally extensive. The overall transimissivity value of the Siwalik (Kimin Formation) is 5.53m^2/day to 43.95m^2/day.

Dug wells are few in this formation. From the exploration carried out so far in the Kimin Formation it can be deduced that ground water potentiality of the Kimin Formation is not very good. The reason for low ground water potentiality of this formation is attributed by poor sorting of the formation material which ultimately affects the hydraulic conductivity of the formation. Moreover, the thickness of sandstone or gravel beds is not persistent along the strike length. Details of aquifer parameters are given in Table 3.4.

Springs emanating from sandstone or fractured sandstones of the Siwalik (Kimin Formation) are not perennial. 12 springs were inventoried in the Siwalik rocks. Perusal of discharge data of springs indicate that the springs are rain fed and during the lean periods only three springs have negligible discharge.

Table 3.4: Aquifer parameters for Siwalik

Village/ Location	Taluka / Block	Lat	Long	Type of well (DW/BW/TW)	Depth (m)	Draw down (m)	Transmissivity (m^2/day)	Storativity / S.Yield	Specific Capacity (lpm/m of dd)
Yupia	Doimukh-Kimin Block	27.14	93.72	TW	72				
Midpu		27.17	93.76	TW	91				
Chimpu		27.07	93.6	TW	100	16.36	5.88		7.08
Lekhi		27.13	93.73	TW	103	9.11	35	$6.65X10^{-5}$	331
Naharllagun		27.03	93.74	TW	58	10.327	43.95	$0.347x10^{-3}$	4.28

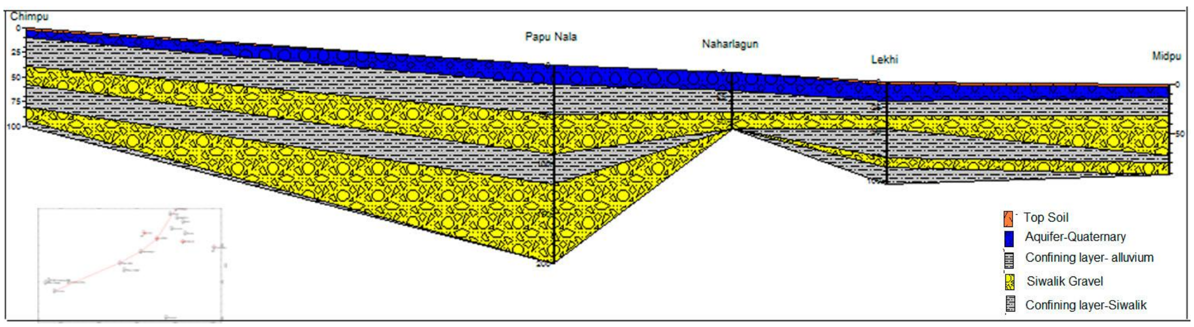


Fig. 3.9: 2D disposition of aquifers

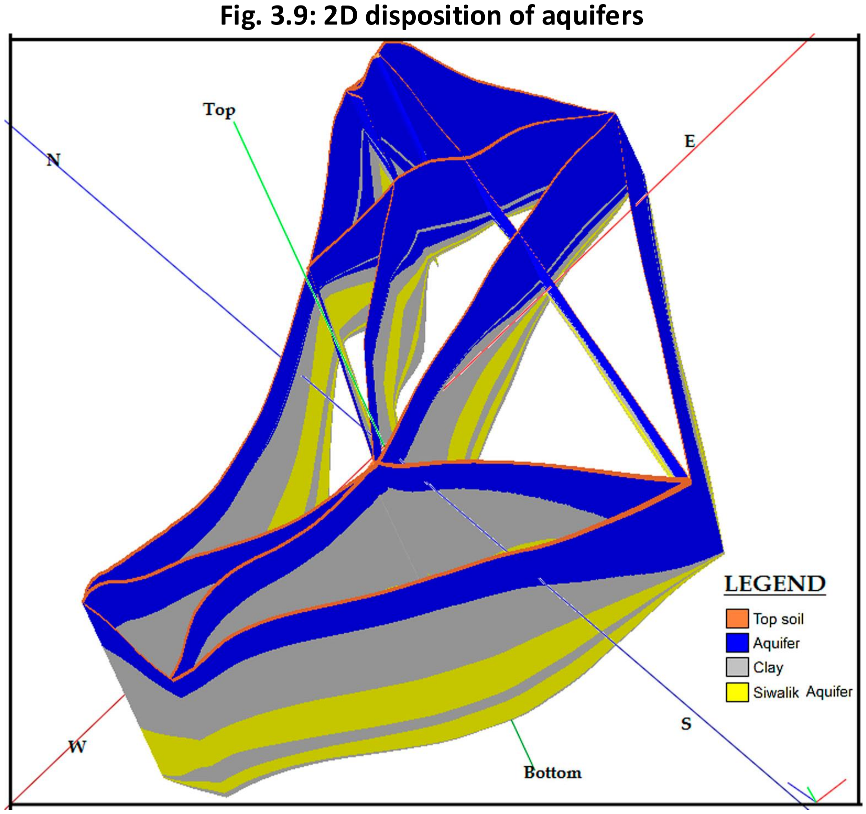


Fig. 3.40: 3D disposition of two aquifers in the study area

Aquifer map of the area: The aquifer systems of the study area consist of two aquifers, viz., the Tertiary Siwalik and the Quaternary alluvium. The Siwalik is extended from main boundary fault to HFF (Himalayan Frontal Thrusts) in the east and the Quaternary alluvium is extended from HFF to the Assam Plains.

The conceptualization of the aquifer systems of the area is based on the geologic and hydrogeologic setting within which the aquifer functions (Fig.: 3.41).

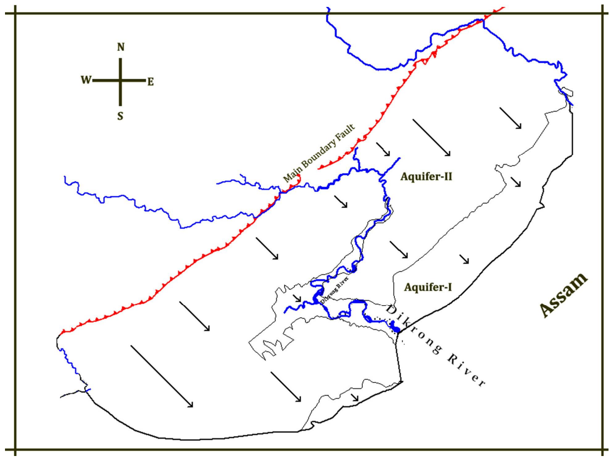


Fig. 3.41: Demarcation of study area based on habitation and agricultural activities

As this area is hilly with undulatory topography, slope analysis is very important to demarcate the recharge and discharge area. Based on slope analysis using srtm 90m resolution data file, run-off zone, recharge and discharge areas are demarcated for an area extending from the Panyor or Ranga River in the northeast to the Pare River in the southwest. The entire area is not demarcated as this portion has the highest population density and also almost all agricultural works are concentrated in this area. (Fig.3.42).

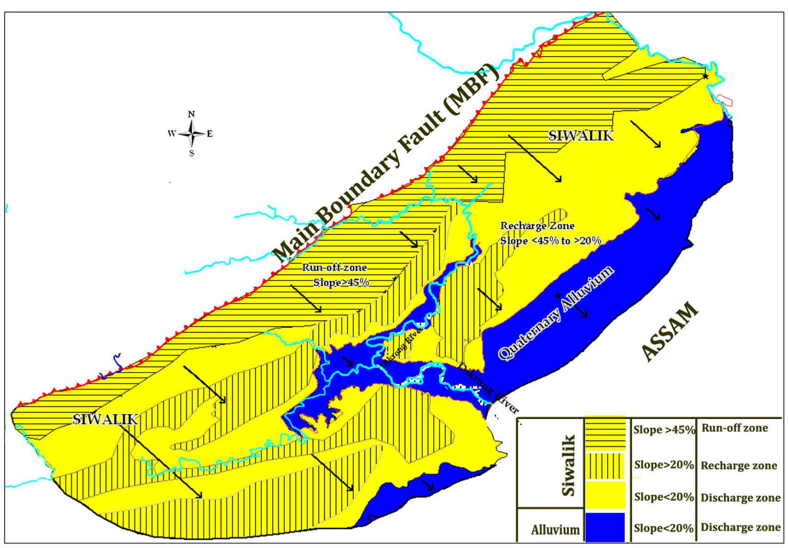
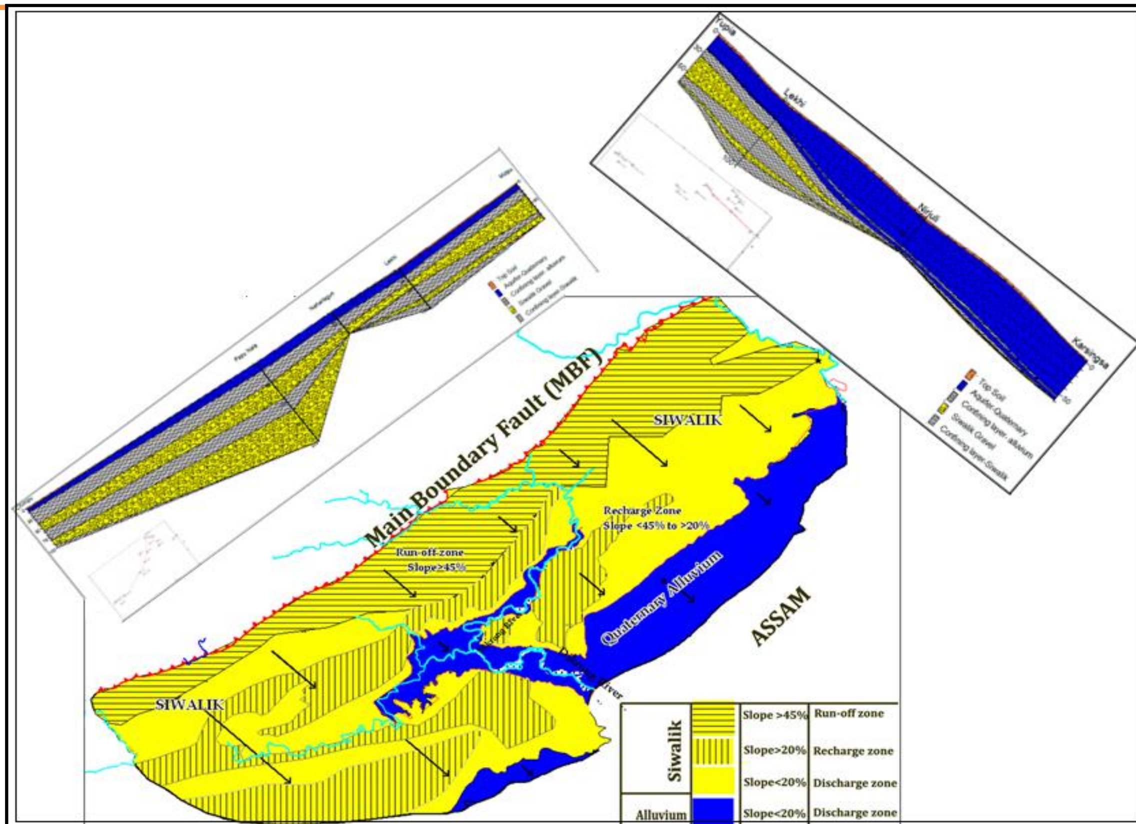
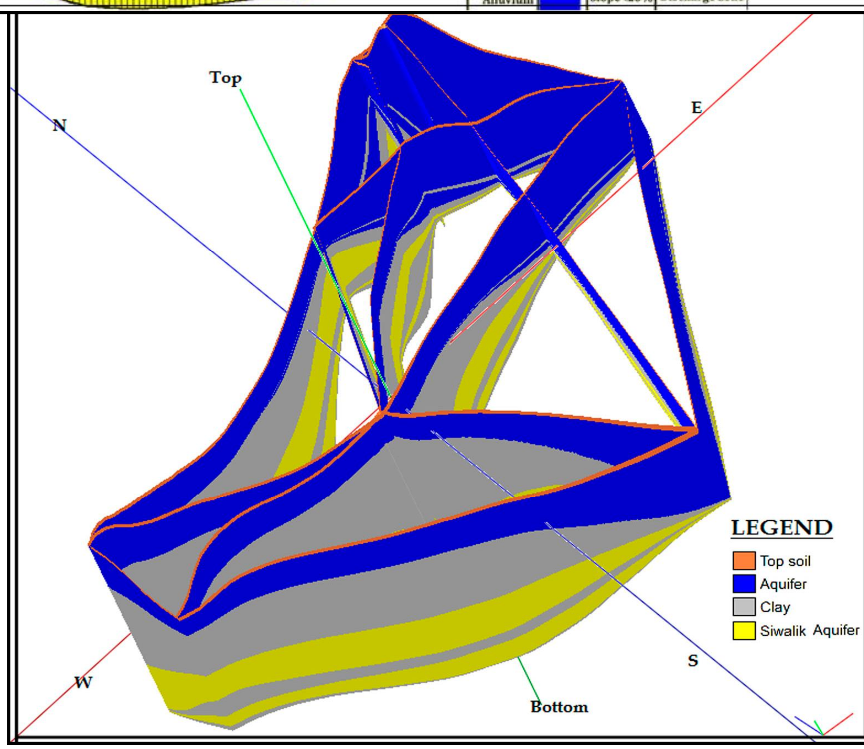


Fig. 3.42: Classification of the study area based on slope

From Fig. 3.42, it can be inferred that Siwalik rock which is the main stratigraphic unit acts as run-off zone, recharge zone and also discharge zone due to variation of slope. The Quaternary alluvium is recharged mainly by infiltration of rainfall on the outcrop.


Main Boundary Fault (MBF)
SIWALIK
Recharge Zone
Slope <45% to >20%
Run-off zone
Slope≥45%
Quaternary Alluvium
ASSAM
SIWALIK
Siwalik
Slope >45%
Run-off zone
Slope>20%
Recharge zone
Slope<20%
Discharge zone
Alluvium
Slope<20%
Discharge zone
Lekhi
Nirjuli
Karsingsa
Top Soil
Aquifer Quaternary
Confining layer: alluvium
Siwalik Gravel
Confining layer: Siwalik


Top
N
E
W
S
Bottom
LEGEND
Top soil
Aquifer
Clay
Siwalik Aquifer

CHAPTER 4.0
Groundwater resources

The study area covers three blocks of Papum Pare district, viz., Doimukh-Kimin, Balijan (part) and Sagalee (part). Major part of the study area has slopes more than 20%. Rechargeable areas are confined within river and intermontane valleys only (Fig.4.1). 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.

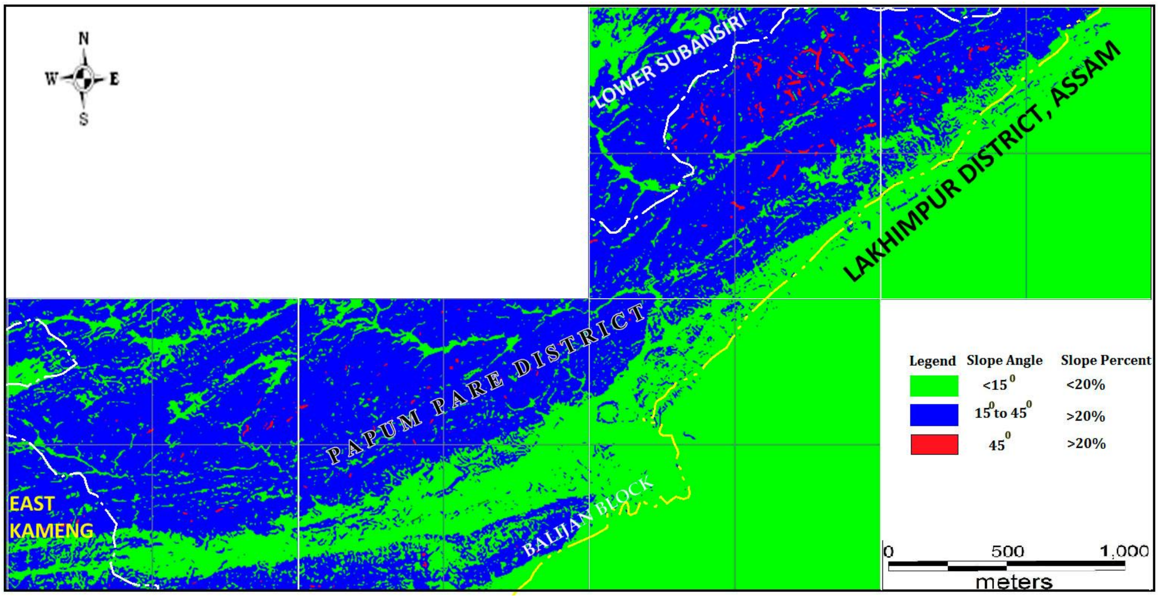


Fig. 4.1: Slope map showing recharge worthy area of the study area with less than 20% slope

The computation of ground water resources available in the district has been done using GEC 1997 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. Soil infiltration tests were conducted in the study area as part of value addition to the present study. Analysis of soil infiltration data shows that value of infiltration factor varies between 3.16 and 47.84 percent. Average infiltration factor value of 0.255 is taken for calculation. In WLF method, specific yield has been taken as 0.10 for coarse grained sandy alluvium and 0.08 for silty alluvium following the norms recommended by GEC'97. The rainfall of Papum Pare district is 3285.91mm.**
2) **Water level data has been considered for 2012. 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 Papum Pare district is 3.97mbgl and 2.89mbgl.
3) **The population figures were collected from Census, 2011and projected to 2013. The per capita domestic requirement for the rural population has been considered as 60 lpcd and for urban population, it is 135 lpcd.**
4) **Recharge from water conservation structure has been taken as nil.**

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 (April, May, 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 April to September has maximum number of rainy days. The maximum recharge to the unconsolidated aquifer takes place in Doimukh, Banderdewa and Sonajuli area. Moreover, the small intermontane valleys are also the areas where recharge to the unconsolidated aquifer takes place.

The monsoon recharge of the 17819hectre of recharge worthy area is 12434ham while non-monsoon recharge is 2902ham. Total ground water recharge is 15336ham.

Draft: The draft of unconsolidated aquifer and also the Siwalik aquifer is created by natural discharge like seepages, spring and free flowing wells (artesian condition) and draft created by human interference, viz., withdrawals for irrigation and industry and public-supply wells.

In Doimukh area there are numbers of free flowing wells. Moreover, seepages and springs are numerous in the study area. Perrenial springs in the study area are generally contact type. During monsoon season numerous non-perrenial springs are also ooze out. A major seepage surface was found along Banderdewa-Naharlagun portion of national highway no. NH-52A. In the district natural discharge is considered to be 10% of the total groundwater recharge, i.e., 1534ham.

Irrigation draft is created by five shallow tube wells as per Water Reources Department data. Total draft created by these wells is 15ham. There is only one industry in the area and one shallow tube well is installed. Draft created by this tube well is 4ham. Draft for domestic uses is 55ham.

Total groundwater draft for all uses is only 141.40ham.

Allocation of resources up to 2025: The net ground water resource is allocated for domestic and industrial and irrigation sector. 110ham of resource is allocated for domestic and industrial purposes while 13635ham resource is allocated for irrigation.

Stage of groundwater development: The area has very little groundwater irrigation facilities. Existing irrigation is through surface water only. Similarly industrial development in the area is practically nil. Public Health Engineering & Water Supply Department has supplied water mainly through surface water sources. Groundwater is mainly utilized for domestic purposes. The stage of groundwater development in the district is 1.02%.

Table 4.1: shows the net groundwater availability, existing draft and stage of development for 2013.

District	Recharge worthy area Ha	Total annual GW recharge Ham	Provision for natural discharge Ham	Net GW availability 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
Papum Pare	17819	15336	1534	13802	141.4	1.024

Static resource: **The static groundwater resource of the district has been calculated for the base year 2009. Here also the administrative district has been considered as the assessment unit due to paucity of block-wise data. Hilly areas having slope more than 20% are excluded from the total geographical area to get the area suitable for recharge. The average thickness of saturated unconfined aquifer below ground level as obtained from dug wells / bore wells in the district has been considered.**

The Pre-monsoon (i.e., March) Water Level from Monitoring Wells of CGWB in Arunachal Pradesh has been considered as the maximum depth below ground level up to which the zone of water level fluctuation occurs. Since the State of Arunachal Pradesh receives pre-monsoon showers, which commences from the first week of April, the deepest water levels are recorded during the month of March. Specific yield value of 0.10 is considered for the district.

Finally the Static Ground Water Resource is computed from the data as obtained:

$$Y = A^* (Z_1 - Z_2)^* Sy$$

Where, Y = Static ground water resources, A = Area of ground water assessment unit

Z_1 = Thickness of saturated unconfined aquifer below ground level

Z_2 = Pre-monsoon water level

Sy = Specific yield of the unconfined aquifer

The salient information of the calculation is given in Table 4.2.

Table 4.2: Salient information of static resource of the district

Name of the assessment unit	Type of rock formation	Total Geographical Area Ha	Assessment Area Ha	Bottom of the unconfined aquifer (m)	Average Pre-monsoon Water Level (m)	Thickness of the saturated zone of the un-confined aquifer below WLF zone (m) [(5)-(6)]	Volume of Saturated zone of the unconfined aquifer below WLF zone (ham)
1	2	3	4	5	6	7	8
Papum Pare District	Alluvium	287500	17819	42.05	3.89	38.16	67997.30

Static/In-storage Ground Water Resources (ham): Volume of saturated zone X specific yield
= 67993X0.1=67997.3ham

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 plain area of Doimukh numbers of dug wells have been constructed whose depth ranges from 1.5 to 8.0mbgl. In Naharlagun area dug well depth ranges from 3.5 to 18.0mbgl. Dug well depth in Itanagar-Holangi area ranges from 2.0 to 16.0mbgl. In the Karsingha area dug well depth rages from 5.0 to 9.0mbgl. In Banderdewa area dug well depth ranges from 4.0 to 15.0mbgl. Shallow depth dug wells are found in the flood plain area whereas deeper depth wells are found in the older terrace areas.

As per 2011 census 138 numbers of village populations are habituated in using water from untreated source predominantly from open well. Only seven villages use water from tube wells and 28 villages use spring water. Surface water is also used by the villagers.

Tube wells depth in Doimukh area is around 50mbgl. In Itanagar area depth of the tube wells in the unconfined aquifer ranges from 38 to 70mbgl. In Naharlagun area tube wells encounter the Siwalik Formation at shallow depth.

Groundwater resource in Siwalik Aquifer: The groundwater storage of the Siwalik aquifer is calculated with the following parameters:

Rechargeable area: 17819ha.   Storage coefficient of Siwalik first gravel zone is 0.347×10^{-3}

Change in piezometric surface: 0.40m

Groundwater storage= Area X change in piezometric surface X S

$=17819\text{ha} \times 0.4\text{m} \times 0.347 \times 10^{-3} = 2.473\text{ham}$

5.0 Groundwater Related Issues

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

1) **Potentiality of aquifer:** The groundwater potentiality of the two aquifers is different. The unconsolidated older alluvial aquifer (Aquifer-I) is more prolific than the Siwalik aquifer (Aquifer-II). From the aquifer property table it is observed that yield of the Aquifer-1 varies from 1.8 to 37.8m^3/hr while discharge of Aquifer-II varies from 1.8 to 6.84m^3/hr.

Table 5.1: Comparison of two aquifer of the study area

	Aquifer-I	Aquifer-II
Lithology	Unconsolidated older alluvium	Siwalik
Occurrence	Older and recent alluvium and flood plain deposits	River valley and structural hills.
Depositional environment	Valley fill and/or terrace materials	
GW occurrence	Unconfined to semi-confined condition	Semi-confined conditions
Aquifer Properties	Yield: 1.8 to 37.8m^3/hr Transmissivity: 5.16 to 667m^2/day. Auto flow condition in Dikrang Valley	Yield: 1.8 to 6.84$m^{3/}$hr. Transmissivity: 43.95m^2/day
Spring	Perennial springs emanate from this aquifer	Springs are not perennial

The thickness of first aquifer is less in central part of the study area, i.e., in and around Naharlagun, southwest part of Itanagar and Yupia-Midpu area. That means in the river valley of Dikrang and Pachin the thickness of older alluvium is less. VES survey and drilling data indicate that Siwalik aquifer is encountered within 20m which stretches from Midpu through Naharlagun-Jully Basti- Chimpu area. 3D block diagram depicts the area where Siwalik is encountered within 20m depth.

2) Groundwater quality: Groundwater qualities of the aquifers are good except presence of high iron content in the flood plain of Dikrang River. Even the Siwalik aquifer has high iron content.

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. After establishment of capital at Itanagar, there was a spurt of population in the area. The area of Capital Region, Itanagar, as per the cadastral survey 2002, is 152 sq. kms (Fig. 1.1).**

Public Health Engineering Department supplies water using surface water sources. The main surface water sources are Senki River at Itanagar, Kankar River at Naharlagun and Nirjuli Nala & Kamarjuli Nala jointly at Nirjuli.

The Capital Complex is stretching almost in a linear fashion from Banderdewa in the east to Chimpu in the west. The main localities that fall in the Capital are: Chimpu, Ganga, Itanagar, Juli, Pappu Nalla, Naharlagun, Tarajuli, Yupia, Doimukh, Nirjuli, Karsingsa and Banderdewa. There are certain problems in the Capital Complex, viz., 1) limited plain area, 2) poor infrastructure, 3) unplanned settlement and development, 4) encroachment of settlement over ecologically sensitive areas.

All these activities have an impact on water cycle in the region. The impact which are evident now are: 1) increase in surface run-off and decrease in infiltration resulting frequent flash floods, 2) some of the streams are dying in the Doimukh area due to setting up of institutes in the upstream and 3) partial and in some places total excavation of main water bearing zone in the region.

The projected population of Itanagar and Naharlagun Town for 2025 will be 117707 and 53268 respectively while the district population will be 286456. The two towns will bear nearly 60% district total population. The high and ever increasing population in the town area is not completely covered by PHED water supply scheme. Itanagar Capital Complex development plan prepared during 2008 had predicted that the gap between demand and supply would be increasing in 2025. However, the growth rate has been dropped in the last decade and as such the population

in both the town in 2011 was below 1,00,000. Based on 2011 census data the population is projected to 2013, 2025 and 2030 for Doimukh-Kimin and part of Balijan Block and water requirement for the area is calculated (Table 5.2).

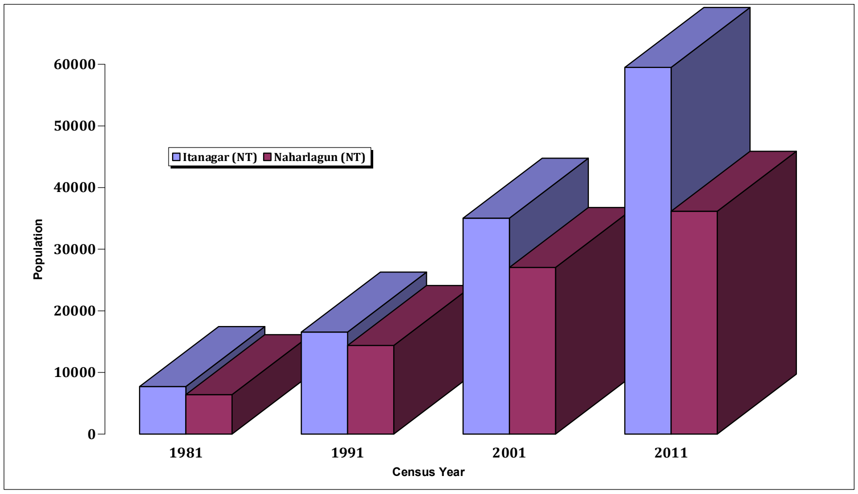


Fig.5.1: Population growth in Itanagar and Naharlagun town, Papum Pare District, Arunachal Pradesh

The groundwater resource of this area is yet to be developed to its full potentiality. Ground water rechargeable area is limited to the valley portion of the area. Stage of groundwater development is merely one percent.

Water demand in domestic sector is calculated by projecting the population to 2025 and allocating 60 lpcd water. During calculation water dependency is considered as 60%.

Table 5.2: Projected population and water demand for domestic purpose of the area

Block	Name of Circle	Circle Population 2011	% Decadal population growth	Projected Population			Projected Water Demand considering per person water need of 60litre per day (ham)		
				2013	2025	2030	2013	2025	2030
Balijan	Banderdawa	8523	38.5	9179	12461	14101	12.06	16.37	18.53
	Sangdupota (Besar Nello)	4053	54.8	4497	6718	7829	5.91	8.83	10.29

Block	Name of Circle	Circle Population 2011	% Decadal population growth	Projected Population			Projected Water Demand considering per person water need of 60litre per day (ham)		
				2013	2025	2030	2013	2025	2030
Doimukh-Kimin	Itanagar (rural)	5811	40	6276	8600	9762	8.25	11.30	12.82
	Itanagar(urban)	59490	69.9	67807	109390	130182	89.10	143.74	171.06
	Naharlagun (rural)	12948	58.1	14453	21975	25737	18.99	28.88	33.82

	Naharlagun (urban)	**36158**	**33.8**	**38602**	**50824**	**56934**	**50.72**	**66.78**	**74.81**
	Doimukh	**9479**	**9.9**	**9667**	**10605**	**11074**	**12.72**	**13.94**	**14.55**
	Gumto	**1638**	**29.3**	**1734**	**2214**	**2454**	**2.28**	**2.91**	**3.22**
	Kimin	**6756**	**23.6**	**7075**	**8669**	**9467**	**9.30**	**11.39**	**12.44**
	Kakoi	**1627**	**102.6**	**1961**	**3630**	**4465**	**2.58**	**4.77**	**5.87**
	Total	146483		146483	235086	272005	211.88	308.90	357.41

As per 2011 census data the installed storage capacity of water for Itanagar and Naharlagun town are 1675000 litre and 6500000litres respectively.

Name of Town	Source of supply (Codes)	System of storage with capacity in kilo litres (along with Codes) @
Itanagar (NT)	**TT,**	**RIG(1675000)**
Naharlagun (NT)	**TU,**	**SR(6500000)**
Abbreviation		
TT: **Tap water from treated source**	TU:**Tap water from un-treated source**	
RIG:**River Infiltration Gallery**		

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 the area, particularly in river valley. The groundwater of Pachin and Dikrang River Valley is heavely infested with iron. The Siwalik Aquifer has also high iron content.

Future demand for agriculture: Compared to the district total land area, cultivable land is very limited in the district. As per 2010-11 agriculture census, the study area has 13852ha of cultivable land of which net sown area is 10264Ha. Since there is little scope to increase net sown area, a paradigm shift of cropping pattern has to be made to increase agriculture production of the area. Cropping pattern change is always associated with increase in irrigation.

In this area, large or medium surface irrigation scheme is difficult to adopt due to its topography and continuous stretch of cultivable land is not available. Therefore, groundwater based irrigation scheme coupled with small scale surface water irrigation has to be adopted.

Table: 5.3 Blockwise water requirements for winter paddy cultivation through irrigation (Area in Hect)

Block	Irrigated Area	Unirrigated Area	Total Area	∆ in m	Water requirement
	Based on Agricultural Census 2010-11				
Doimukh	**1286**	**747**	**2032**	**1.2**	**896.4**
Kimin	**10**	**416**	**426**		**499.2**
Balijan	**2276**	**1107**	**3383**		**1328.4**
Total water requirement					**2724 Ham**

Table 5.4.: Blockwise water requirement for rabi crops other than paddy through irrigation based on agriculture census 2010-11

Block	Total Area Based on Agricultural Census 2010-11	∆ in m	Water requirement (Ham)
Doimukh	**2163**	**0.3**	**648.9**
Kimin	**749**		**224.7**
Balijan	**1792**		**537.6**
Total water requirement			**1411.2 Ham**

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 5.5: Water requirement for all sectors

Block	Drinking water requirement up to 2025 Ham	Water requirement to bring un irrigated area under irrigation for paddy cultivation Ham	Water requirement to bring 40% of net sown area under irrigation for non-paddy cultivation Ham	Water allocated for drinking and domestic purposes up to 2025 Ham	Water allocated for irrigation up to 2025 Ham
Doimukh	**267.54**	**896.4**	**648.9**	**110**	**13635**
Kimin	**16.16**	**499.2**	**224.7**		
Balijan	**25.20**	**1328.4**	**537.6**		

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. However, if entire net sown area is bring under irrigation then allocated water for irrigation will not be sufficient to meet the future demand.

Table 5.6: Supply and demand gap in drinking water sector

Block Name	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
Doimukh	**267.54**	**110**	**(-) 198.9**
Kimin	**16.16**		
Balijan	**25.20**		
Total	**308.9**		

Table 5.7: Supply and demand gap in irrigation

Block Name	Total irrigation demand Ham	Water allocated for irrigation up to 2025 Ham	60% of the allocated water for irrigation available for use	Gap between supply and demand (+ve for surplus supply and –ve for deficit supply) Ham
Doimukh	**1545.3**	**13635**	**8181**	
Kimin	**723.9**			
Balijan	**1866**			
Total irrigation demand: 4135.2ham				**(+) 4045.8**

The scope of groundwater development in Dikrang and Pachin Valley, Banderdewa to Balijan and Kimin areas are briefly discussed below,

Dikrang and Pachin Valley: The average thickness of unconfined aquifer in the valley area is almost 30m. Thickness increases towards eastern part. The valley area is surrounded by recharge area of Rono Hills. The aquifer is extending below river bed. The Dikrang River gets additional water from Ranganadi Hydroelectric Project. After power production maximum 160 cumec water of the Ranganadi River is released to the Dikrang during monsoon season and during lean period maximum 26 cumec water is released by NEEPCO. In this scenario decrease of natural discharge of water from the aquifer to Dikrang and Pachin rivers is unlikely to greatly alter the ecosystem.

However, affect of the proposed Pare hydroelectric project at Midpu over river DIkrang is not considered here.

Banderdewa to Balijan: The average thickness of the unconsolidated aquifer is nearly 45m. The alluvial plain area of this part is recharged by rainfall as well as up dip infiltrated water. The area is sufficiently recharged and it is unlikely that lowering of water level up to 5m will not stress the aquifer. Provision exists in this area to artificially recharge the aquifer.

Kimin

In this area the thickness of unconsolidated aquifer is only within 10m and slope of the area is such that aquifer is discharging to Assam plains. The aquifer is unlikely to take additional stress.

CHAPTER 6.0

Management Strategies

There are two aquifers in the study area, viz., the Tertiary Siwalik and Quaternary unconsolidated aquifers. The spatial distribution of the Siwalik aquifer is more than the Quaternary aquifer. The unconsolidated aquifer is more prolific than the Siwalik aquifer.

The average rain fall in the study area is 3286mm or 3.286m. Of the total annual rain fall monsoon rainfall contribute 71% and non monsoon rainfall contribute 29%. The monsoon recharge to groundwater in the unconsolidated aquifer is 12434ham while non-monsoon recharge is 2902ham. Recharge from other sources which include canal recharge during non-monsoon is 26.74ham. Total ground water recharge is 15336ham.

The discharge from Siwalik aquifer occurs as (a) withdrawals for domestic purpose and (b) seepages and springs. There are numbers of unsuccessful drilling in Siwalik.

The unconsolidated aquifer discharge occurs as (a) withdrawal for domestic purpose (b) free flowing well and (c) springs. Numbers of wells drilled in this aquifer. Numbers of dug wells are operating in this aquifer. Some of the dug wells are energised. Dug well yield tests were performed during pre-monsoon (February-2016) to determine the yield of this aquifer. Yield tests data was analyzed using

Romani Method. It is found that yield of this aquifer is around 1966m^3/day. Higher yield of dug well is found at Nirjuli, Dikrang Valley whereas low yield was found in piedmont areas. Dikrang valley dug wells can be pumped 10times in a day.

Present scenario of stress in aquifer: Currently there is no groundwater irrigation in the area as per Agriculture Census report 2010-11 and also 2011 Census data. Groundwater is entirely used for domestic purpose. As per PHED data there are 22 deep tube wells for water supply and the draft created by these well is 55ham considering unit draft as 2.5ham. Dug well census is not available.

There is no decline of ground water level in GWMS.

Sustainable groundwater development plan: Groundwater has to play an important role in future for economic progress of the area and also for domestic water needs. Here recharge worthy areas is very limited and a narrow stretch of land is available for recharge.

In this context management plan should be such that the water level of the valley area may be allowed to lower by 1m while in the piedmont zone it may be allowed to remain in the present stage. Allowing 1m drop of water level in the valley areas will make room for increased recharge both in piedmont as well as in the valley portion.

Construction of groundwater abstraction structures: 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 15m^3/hr and 35m^3/hr. If the well is allowed to run 10hrs a day for 150days of a year then a tube well having discharge of 15m^3/hr will create a draft of 0.0225MCM while a tube well with 35m^3/hr discharge will create a draft of 0.0525MCM.

Therefore with available resource of 8181ham and with 0.0225MCM draft 3636 numbers of tube wells and with 0.0525MCM draft 1558 numbers of tube wells can be constructed in the area.

However, based on total net sown area and total unirrigated status of the land is worked out. Therefore, the required numbers of tube wells are worked out and shown in Table 6.1.

Table 6.1: Numbers tube well required for irrigation

Block Name	Total irrigation demand Ham	No. of TW required with Q=35m^3/hr for 10 hrs pumping hrs for 150days Probable unit draft to be created =0.0525MCM	No. of TW required with Q=15m^3/hr for 10 hrs pumping hrs for 150days Probable unit draft to be created =0.0225MCM
Doimukh	**1761.6**	**336**	**783**
Kimin	**798.8**	**152**	**355**
Balijan	**2045.2**	**390**	**909**
Total	**4605.6**	**878**	**2047**

The pump test data of CGWB has indicated that the drawdown of the tube wells is generally high particularly in the area where bouldery formation is dominant. Therefore it is advisable to keep the discharge of tube wells within 15m^3/hr.

The pump test data of CGWB has indicated that the drawdown of the tube wells is generally high particularly in the area where bouldery formation is dominant. Therefore it is advisable to keep the discharge of tube wells within 15m^3/hr.

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: CGWB drilling experience in the area indicates that drawdown is very high in the bouldery formation. As such 30m housing provision should be kept in the well construction.

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

Aquifer wise availability of unsaturated zone: **Aquifer wise availability of unsaturated zone is found out from the area enclosed by 3.0mbgl post monsoon water level contour (Manual of Artificial Recharge: CGWB, 2007). The area is found to be 72.41sq.km. However, the groundwater monitoring stations are not uniformly spread out in the area due to lack of dug wells. The area can be further extended after establishing representative monitoring stations.**

The marked area belongs to 1st aquifer, i.e., phreatic unconsolidated aquifer. There is no dug well in the 2nd aquifer, i.e., Tertiary Siwalik. Hence unsaturated zone could not be found out.

Volume of sub-surface storage space available for recharge= Area (3m WL contour)X Specific yield

$=72.41 X 0.1 = 7.241 m^3$

Considering recharge efficiency of individual recharge structure 70%, surface water required to recharge the unsaturated storage space is

= (Sub-surface volumeX100)/recharge efficiency

= $(7.241 X 100)/0.7\ m^3$ or $1034.4 m^3$

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

However, the permeability of the subsurface formation is high and also the slope of the area is such that the recharge water will immediately move down and create water logging condition in the valley area. Therefore it is not recommended to recharge in this area.

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.

Fig. 6.1 : Water loss from supply line

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.

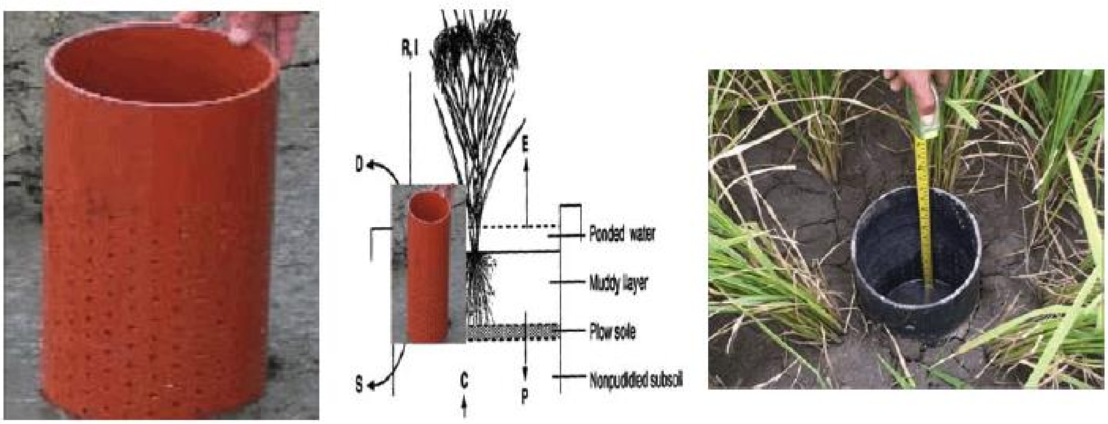


Fig. 6.2: A simple perforated pipe (water tube) installed in the rice field allows farmer to monitor water level beneath the soil surface (Kulkarni, 2011)

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

Block	**Paddy cultivated area (as per Agriculture Census 2010-11) (ha)**	**40% reduction of water for land leveling by the use laser land leveler**	**Approximate saving of water ham**
Doimukh	**1286**		**102.88**
Kimin	**416**		**33.28**

Balijan	**2276**		**182.08**
Total water saving			318.24

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

Water loss in domestic supply**: As per city development report by JNURAM, nearly 25% of the water is loss from supply pipe line (City Development Plan for Capital Region, Itanagar under JNURAM).**

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 unconsolidated aquifer. From Doimukh to Balijan area via Sonajuli tube wells of 50m depth tapping granular zone 20m will expect to yield 10 to 35m^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.**

Conservation of rain water in the up dip of cultivated field. During rabi season the