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जलभृत मानचित्रण और प्रबंधन योजना
लाहुल घाटी, जिला लाहुल और स्पीति
हिमाचल प्रदेश

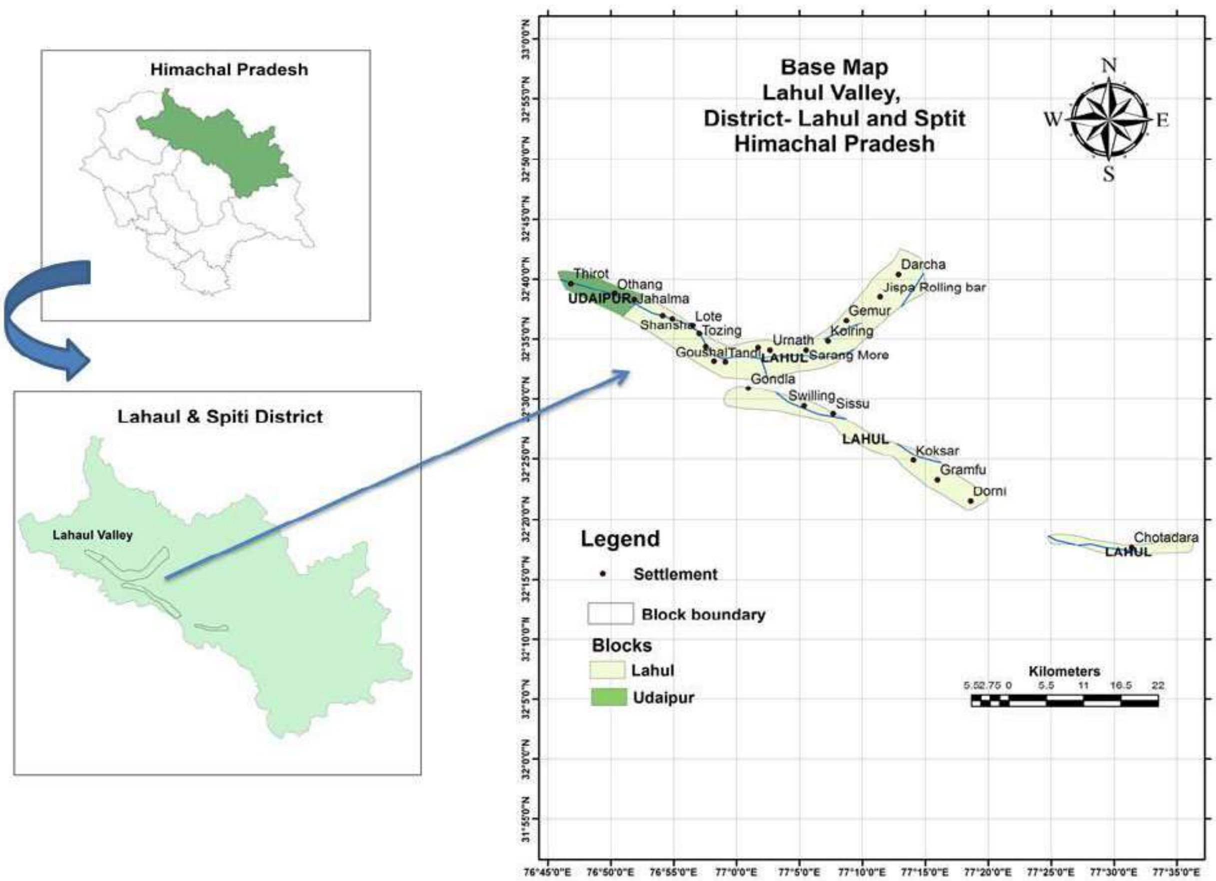
AQUIFER MAPPING AND MANAGEMENT PLAN OF LAHUL VALLEY, DISTRICT LAHUL & SPITI HIMACHAL PRADESH

उत्तरी हिमालयन क्षेत्र, धर्मशाला

Northern Himalayan Region, Dharamshala

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RD & GR
CENTRAL GROUND WATER BOARD,

AQUIFER MAPPING AND MANAGEMENT PLAN OF LAHUL VALLEY, DISTRICT LAHUL & SPITI, HIMACHAL PRADESH



Lahul Valley at a Glance

Northern Himalayan Region, Dharamshala

2021

AQUIFER MAPPING AND MANAGEMENT PLAN OF LAHUL VALLEY, DISTRICT LAHUL & SPITI, HIMACHAL PRADESH

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AQUIFER MAPPING AND MANAGEMENT PLAN of LAHUL VALLEY ,DISTRICTS (LAHUL & SPITI), HIMACHAL PRADESH

1. INTRODUCTION

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. There has been a paradigm shift from “groundwater development” to “groundwater management”. An accurate and comprehensive micro-level picture of groundwater in India through aquifer mapping in different hydrogeological settings will enable robust groundwater management plans at the appropriate scale to be devised and implemented for this common-pool resource. This will help achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural India, and many parts of urban India as well. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus the crux of NAQUIM is not merely mapping, but reaching the goal – that of ground water management through community participation.

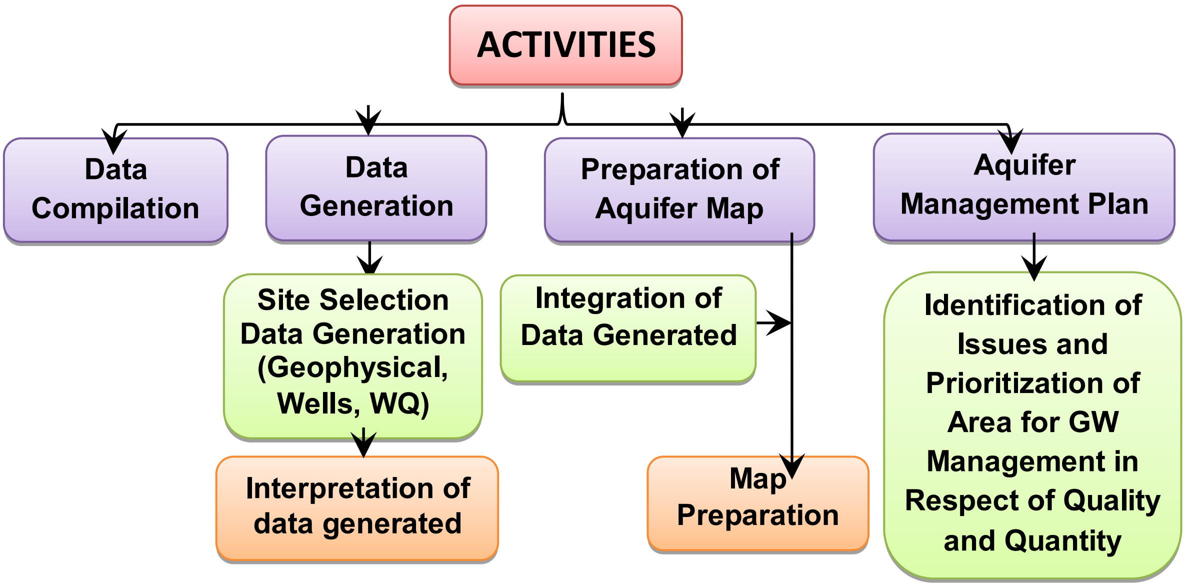
1.1 Objectives

The primary objective of the Aquifer Mapping Exercise can be summed up as “Know your Aquifer, Manage your Aquifer”. Demystification of Science and thereby involvement of stake holders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership amongst the stakeholders. This is an activity where the Government and the Community work in tandem. Greater the harmony between the two, greater will be the chances of successful implementation and achievement of the goals of the Project. As per the Report of the Working Group on Sustainable Ground Water Management, “It is imperative to design an aquifer mapping programme with a clear-cut groundwater management purpose” This will ensure that aquifer mapping does not remain an academic exercise and that it will seamlessly flow into a participatory groundwater management programme. The aquifer mapping approach can help integrate ground water availability with ground water accessibility and quality aspects.

With these aims, Aquifer Mapping Study is carried out Lahul Valley, Lahaul and Spiti Districts of Himachal Pradesh under the Annual Action Programme 2014-15. These surveys are carried out to integrate the information on the scenario of groundwater occurrence, availability and utilization in terms of quality and quantity along with exploratory drilling, monitoring of water levels with quality, spring monitoring (discharge and quality), pumping tests, infiltration tests, geophysical surveys etc. Development of aquifer mapping at the appropriate scale and formulation of sustainable management plan will help in achieving drinking water security, improving the sustainability of water resources development through springs. It will also result in better management of vulnerable areas. During this study, 24 key observation points, Springs (24 Nos.) were established. Subsequently, all the available data on ground water from the earlier studies are compiled and integrated with these studies to bring out the ground water scenario, lateral and vertical characteristics of the aquifers and better management plan of ground water in a scientific manner.

1.2 Methodology

Various activities of NAQUIM are as follows:



1.3 Location, Extent and Accessibility

The study area Lahaul valley falls between north latitude 32°30' to 32°45' and eastern longitudes 77°00' to 77°15' and falls in the survey of India toposheet No.52D/14, 52D/15 and 52H/1, 52H/2, 52H/7. 52H/11.The valley is bounded on the north by the State of Jammu and Kashmir, on the East by Spiti valley and on South by Kullu district and Bara Bhangal areas of Kangra district and on the west by Chamba district. The valley is accessible through Rohtang pass during May to October only and remains cut off for the rest of year due to heavy snow fall at Rohtang pass.The Lahaul valley is also accessible from Leh & Doda districts of Jammu & Kashmir during summer months. The Aquifer mapping area of lahaul Valley 375 Sq Km. Administrative map and other important places and features are given in Base map. (Fig 1)

1.4 Administrative Divisions and Demographic Particulars

The Lahaul and Spiti district is divided into three Sub division.

i. Lahaul Tehsil

ii. Spiti Tehsil

iii. Udaipur sub Tehsil.

The study was limited to the Lahaul & Udaipur sub Tehsil only.. The administrative divisions of the study area are given in fig-1

Table 1: Demographical details of the area

Sr. No	District	Tehsul	Area Sq. Km	NAQUIM Area Sq. Km	Total Population	Male	Female	SC	ST	
1.	Lahul & Spiti	Lahul	6250	339	10218	5415	4803	1109	7499	
		Udaipur		36	8889	4482	4407	590	7664	
			Total	**375**	**19107**	**9897**	**9210**	**1699**	**15163**	

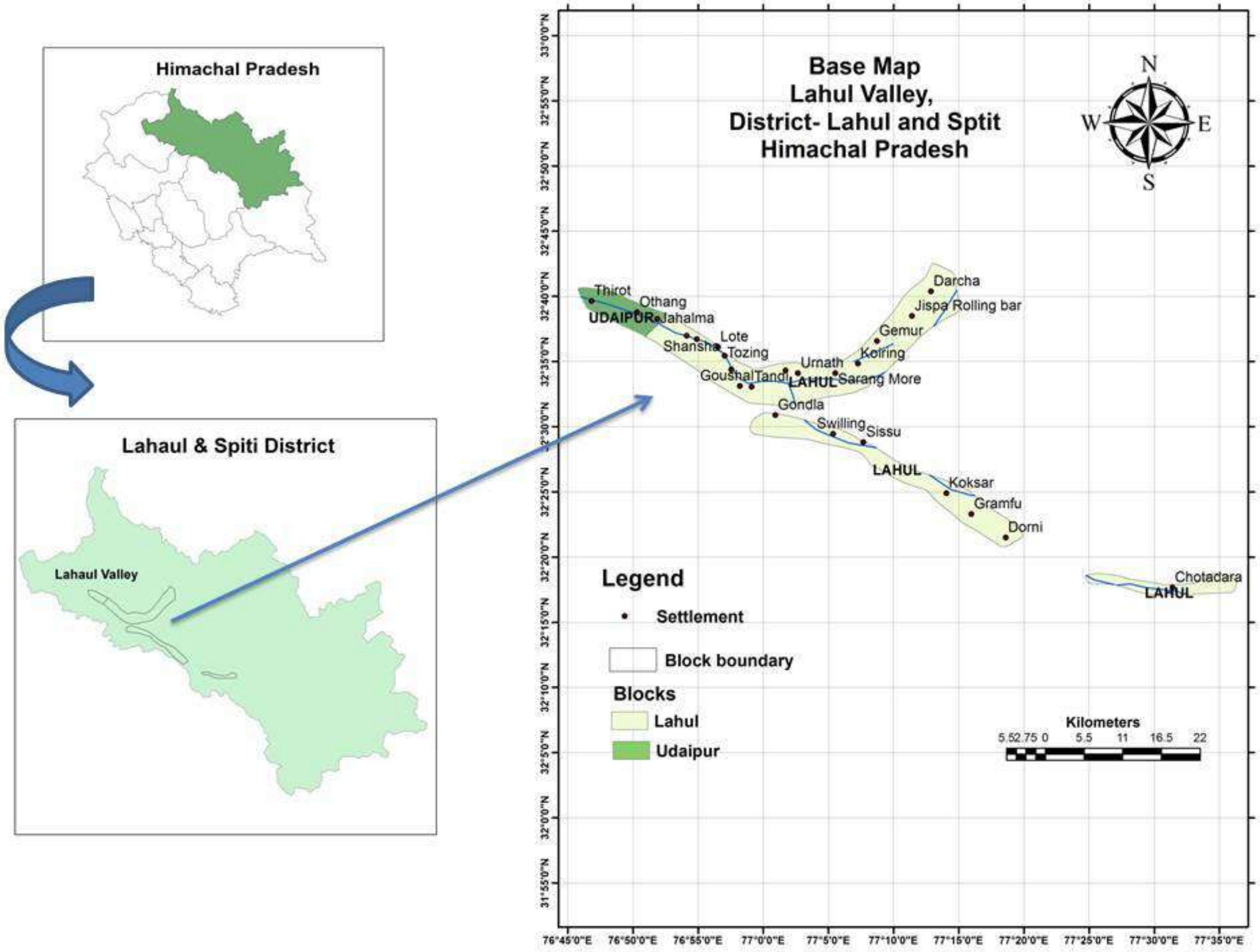


Fig. 1: Administrative division of the study area.

1.5 Land Use: Being hilly and mountainous region, most of the geographical area is under snow-clad mountain ranges, passes, river gorges and inhospitable terrains. Consequently, there is limited area available for cultivation. This can be clearly judged from the scenario of land use pattern in this Valley presented in Table 2.1

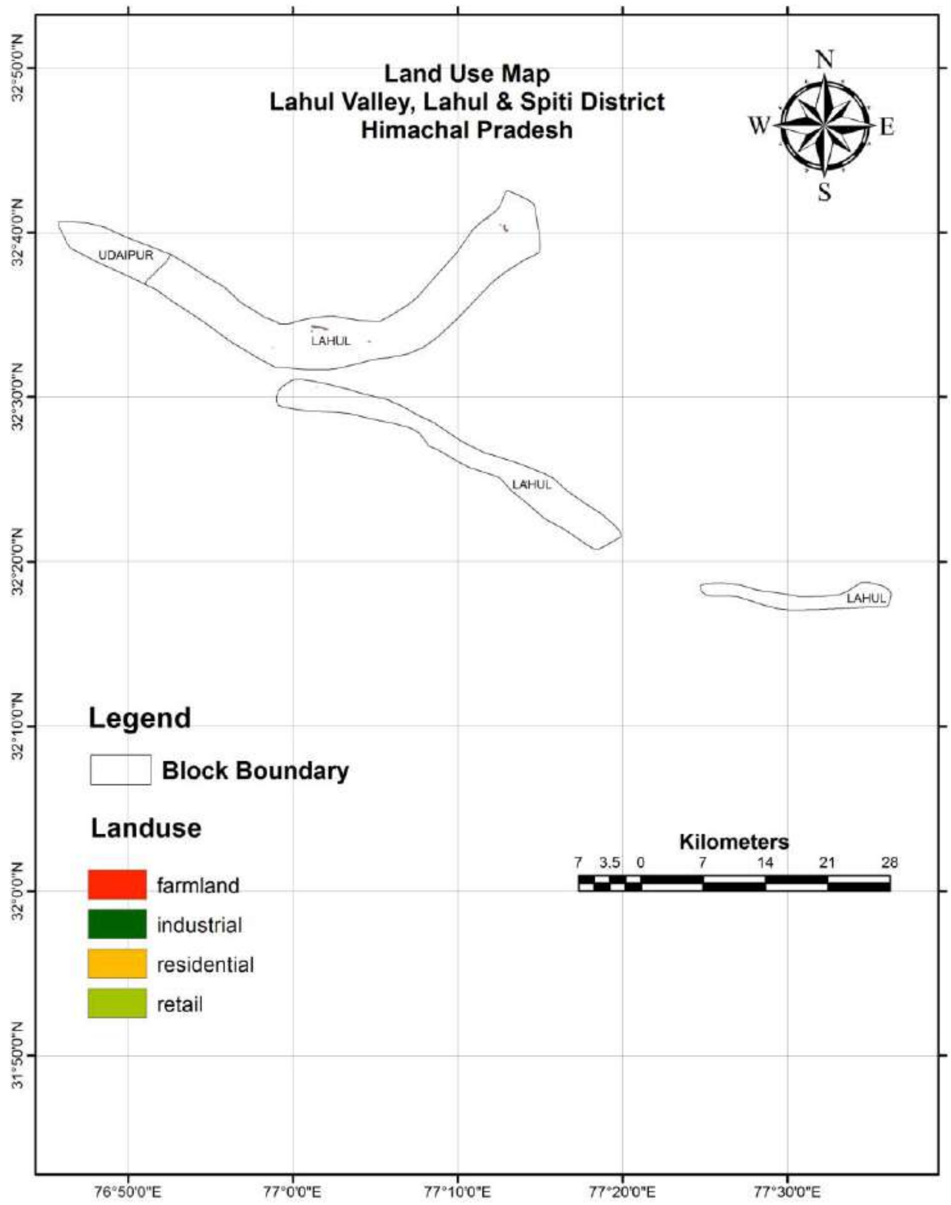
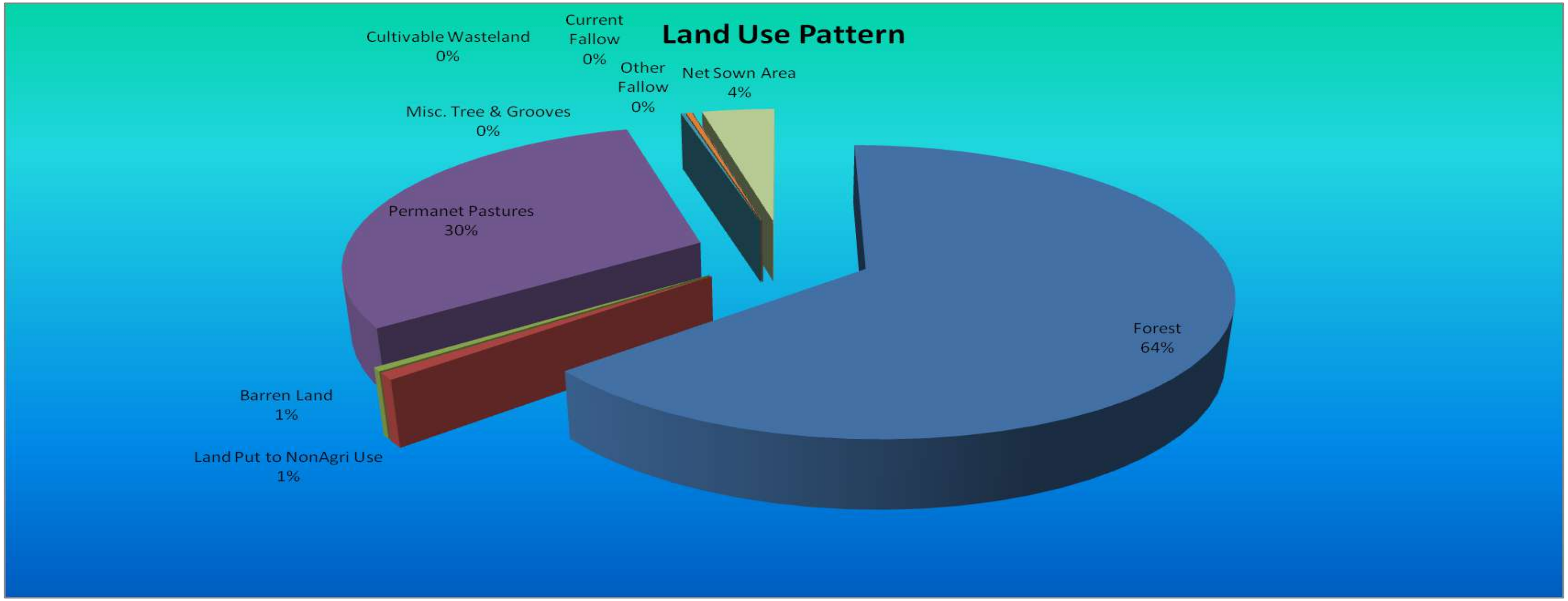


Fig-2: Forest cover map of the study area

Table 2: Category wise Land use/Land Cover in the study area									
Sr. No.	**District**	**Tehsil/ Sub Tehsil**	**Cultivable Wasteland**	**Other Fallow**	**Current Fallow**	**Net Sown Area**	**Area sown more than once**	**Gross Sown**	**Net Sown/ Total Sown**
1	Lahul	Lahul	6.2	0	0.4	74.4	0	74.4	100.0
2		Udaipur(S.T)	0.47	0	0.05	8.59	0.37	8.96	95.9
		Total	**6.67**	**0**	**0.45**	**82.99**	**0.37**	**83.36**	99.6

Source: District Statistical Abstracts of respective districts for the Year-2019-20. (Figures in Hectares)



1.6 Cropping patterns: Maize and wheat are the major crops in the valley. These are under cultivation with Maize cropped area is 0.12 hectares and with wheat is 0.21 hects. Another important crops grain is Potato mainly for seeds with an area of 31.62 hects. In Khariff season in addition to Maize, , Fruits, Vegetables are also cultivated over small area. During Rabi season Wheat is principal crop along with potato, fruits, onions and fodders etc.

Table 3: Block-wise breakup of area cropped under each crop type in study area

			Rabi		Khariff		others	
Sr. No	**District**	**Tehsil/ Sub Tehsil**	**Wheat**	**Vegetables**	**Maize**	**Other Pulses/Pea**	**Fruits**	**Fodder**
1.	Lahul	Lahul	0.15	28.85	0	19.8	75.15	0
2.		Udaipur(S.T)	0.06	2.77	0.12	3.58	15.03	0
		Total	**0.21**	**31.62**	**0.12**	**23.38**	**90.18**	**0**

Source: District Statistical Abstracts of respective districts for the Year: 2019-20. (Figures in Hectares)

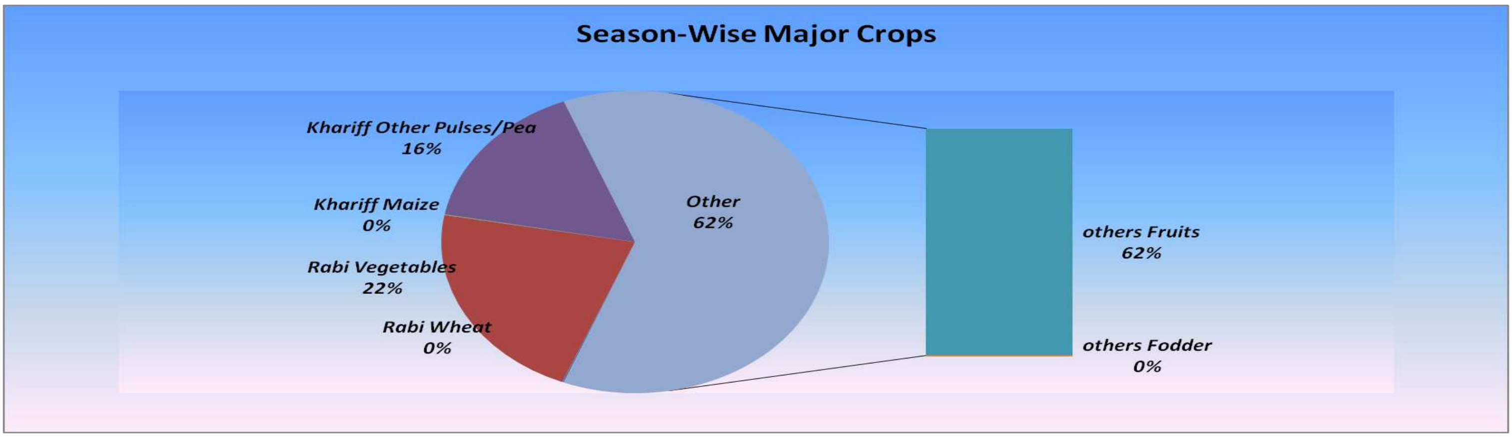


Fig 3 : Season wise major crop in the study area

1.7 Irrigation: The study area , Irrigation is practiced only with Kuhl (Irrigation Channels)/from snow melt or springs. Perennial springs exist throughout the valley and the supply of drinking water is in general satisfactory. the main streams which are fed by glaciers and snow do not dry up through flow of water varies considerably at different seasons, being very little during winter and much more during spring with the thawing of the snow. Numerous irrigation channels (kulhs) are taken out from streams near habitation for irrigationing agricultural crops, grasslands, willow and poplar trees. In lahaul valley, Cultivation is done only by irrigation from kulhs. The source wise breakup of irrigation in area is given below:

table 4: Irrigation pattern in study area

Sr. No	District	Tehsil/ Sub Tehsil	Kuhl/ Canal	Ponds	Wells/TW	other
1.	Lahul	Lahul	74.4	0	0	0
2.		Udaipur(S.T)	8.45	0	0	0.14
		Total	**82.85**	**0**	**0**	**0.14**

Source: District Statistical Abstracts of respective districts for the Year: 2019-20. (Figures in Hectares)

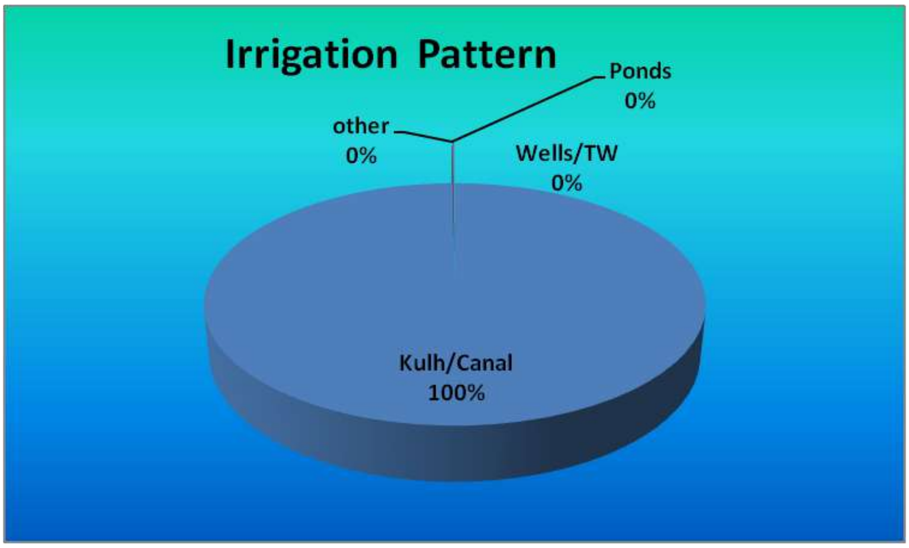


Fig4: Source Wise Irrigation Pattern

1.8 Climate:

1.8.1 Rainfall:

Lahaul valley is enclosed between mountains which form a barrier against the monsoon. It therefore experiences an almost rainless summer though there are occasional showers during monsoon period and heavy snow fall during winter. The annual rainfall varies from 125 mm to 381 mm.

1.8.2 Snowfall

Though there can be occasional snowfall during September or October, regular snowfall usually starts from the middle of December and continues till the beginning of April. Very heavy snowfall is experienced on the higher altitude areas (ridges) and comparatively less snowfall in the valley areas. In the Lahaul valley the intensity of the snow fall increases towards the upstream of the valley. It varies from 2.44 m to 5.40 m. Total annual precipitation varies from 457 to 625mm in year. Snow stays almost throughout the year in the areas above 5000m mean sea level altitude.

1.8.3 Temperature

There is a considerable variation in temperature. The maximum temperature at Keylong, district headquarter ranges from 7° C in February to 23°c in August while minimum temperatures range from -10.5°c in February to 10.1°c in July. The mean temperatures at Keylong for each month are given below:

Month	Temp. in °c	Month	Temp. in °c
January	4.5	September	13.1
February	4.8	October	7.9
March	4.7	November	3.9
April	4.7	December	1.4
May	9.8		
June	14.2		
July	16.5		
Aug	16.5		

Lower areas in the valley are warmer, winters are comparatively short and spring sets in early. Strong wind blows down the valley during summer afternoon whipping up dust.

1.9 Physiography

The geomorphologial set up of the area is highly complex. The terrain has an immature topography and is traversed by deep valleys and high hill ranges. The district can be divided into two major geomorphological unit viz. Structural hills and valley fills.

i) Structural hills: The mountain ranges are almost uniformly 5500 m or higher above main sea level and the sole access to Lahaul from Himachal Pradesh lies over the 4000 m high Rohtang pass. Lahaul valley has a Central main of high mountains and vast glaciers. The main Himalayas are to the north and the mid Himalayas are to the south with connecting ranges on the east and west. The mountains rise to a mean elevtion of 5500 m amsl. with the highest peak reaching to over 6400 m. The lower point in the valley is 2743 mm amsl at the exist of river Chenab in Chamba district. The area is underlain by the rocks belonging to Pre-Cambrian, Paleozoic & Mesozoic. Pre-Cambrian rocks occupy the central & western parts while others are exposed in the eastern part. The rocks are generally trending in NNE-SSW, NW-SE & NE-SW directions with steep slopes. Escarpments, Cuesta & hog backs are the common features.

ii) Valley Fills: Valley fill includes both fluviatile deposits and moraine. These deposits occur as narrow and elongated strips along the main streams. The glacial deposits are under the continues influence of running water and has been termed as glaciofluviatile deposits.

a. Fluviatile terrain : It is demarcated in the lower reaches of Chenab river and have thick vegetation. The width of these deposits is generally less than 3 km and is not uniformly distributed.

b. Glacio-fluviatile terrain: These are confined to upper reaches of drainage system of the water sheds. The areas are either along the snow line or near to it mostly these are demarcated along the river/stream courses. These valleys are broad and gently sloping and are generally devoid of any vegetation cover.

iii) Glaciers: Glaciers are the masses of ice which under the influence of gravity flow out from snow fields from where they originate. The important glaciers of the area are Bara-Lacha, Gang's Tong, Mulkia gang and Bara shingri. These are aligned in EW, WWN-EES direction with their off shoot glacier in N-S direction feeding the tributaries of various rivers in either direction.

iv) Snow line: Snow line is the level upto which the snow melts with summer. Snow cover is more in the northern part. Nunataks are common in all over the snow covered areas.

1.10 Drainage :

The drainage network of Lahaul valley forms a part of Indus river basin. The drainage is coarse and dendritic. The wide river valleys in glaciated areas become deep and narrow downstream. The rivers of the area are in their younger stage.The river Chandra-Bhaga is the major river with one of its major tributary originating from Bara Lacha glacier(4891m a msl) flowing towards south and takes an westerly turn in the south of Batal. The river up to Ghosal is known as Chandra. The river valley is broad and wide upto Batal and become narrow downstream. Bhaga also originate from Baralcha glacier and meets Chandra at Tandi 6 km. South of Keylong and then this river is known as Chandra bhaga river. The main tributaries to the Bhaga river are:-

a). Milang river originating from Tempo la (4930m amsl) and flowing in north westerly direction.

b). Jhankar nadi originating from Oji Biha1(5915 a msl) and flowing in south easterly direction.

c). Seling lungpa river originating from Kelas buk(6110m amsl).

Other tributiaries to Chandra-bhaga river (Chenab) are Thirat and Shangha nadies flowing from north to south and joining the Chandra bhaga at Thirat and Shansha respectively.

Lakes: There are two lakes in the valley known as Chandra Tai & Sarchu lakes. These are of the glacial origin and are of smaller Dimensions.

1.11 Soil Formation and Soil Erosion

I) Soil Formation:

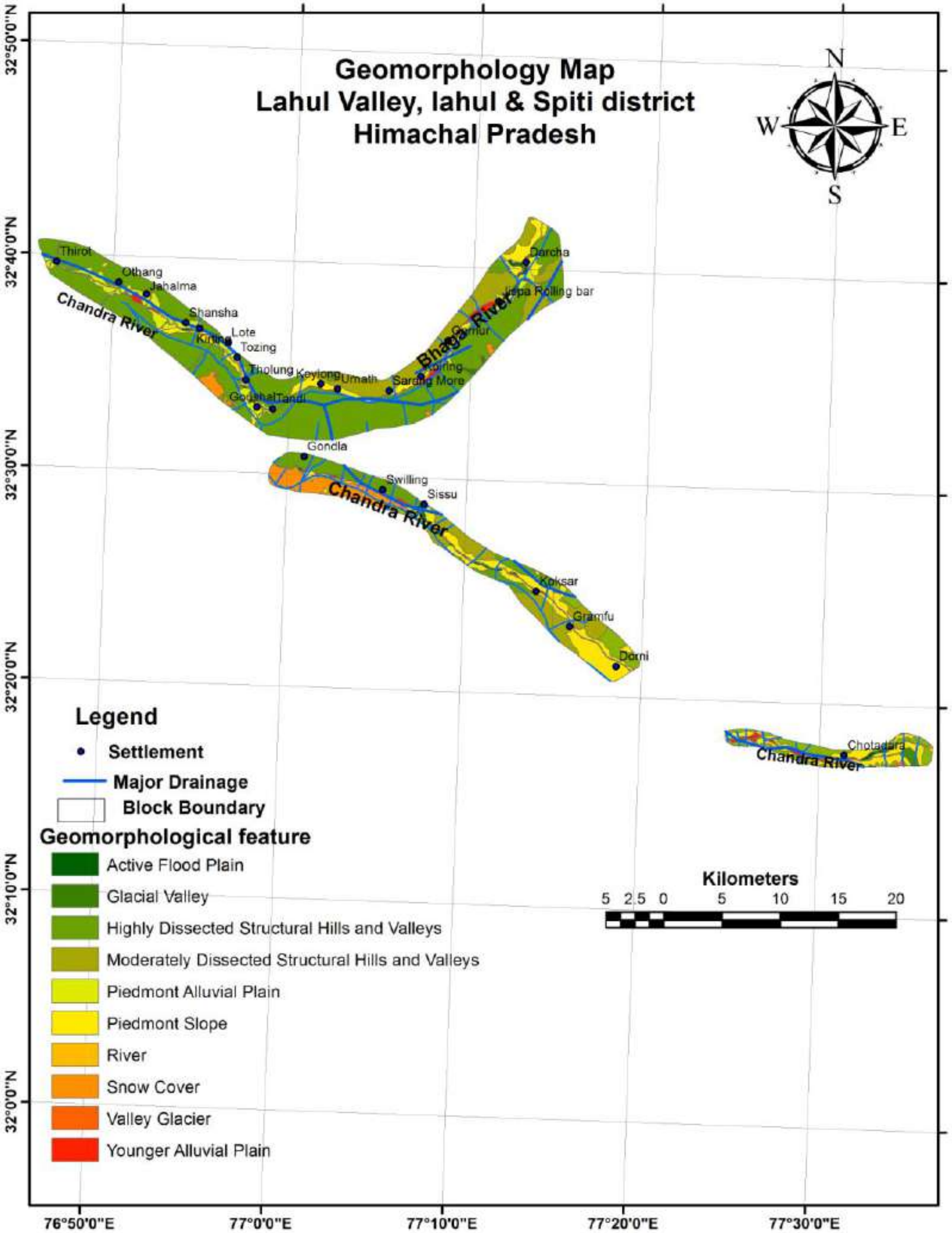
It appears that after the last ice age, some 20000 years ago, when the glaciers started receding and moving up the mountain tops, this typical U shaped glacial valley increasingly became subject to water actions which deposited most of round stones in the gently sloping valley of the rivers Chandra, Bhaga and Chenab. This alluvial deposit went on raising and spreading till the recession of Glaciers on the tributaries made it possible for them to bring down large detrital masses to spread fan shaped partially cover up alluvial flats in the river valley. Subsidiary valley thus began to be formed in the side of Nallahs also. Elshewhere slopes of detritals mass began to be formed at the foot of cliffs. Another agency that helped water from productive soil was vegetation particularly lichous,mosses, grasses, weeds advanced upwards and by retarding the flow of water from melting snows, made it possible for smaller particles deposit in hill slopes which would otherwise have been washed down. Thus fertile production soil was stabilized on steep slopes and exteneded right upto the snow line which now lies at an elevations about 4877 m, with the gradual change in the climate and soil, there was succession in vegetation which brought in herbs and shrubs and trees to the valley in stages.

The soil in lahaul valley may be called alpine swards as the upper stratum of earth and vegetable mould is filled with roots of grasses complete decomposition. Depth of the fertile undisturbed horizon of the sward is 20 Cm to 40 Cm. due to melting of snow the soil from the upper slopes has been carried down to the lower slopes. At present soil is very inadequately protected by vegetation but given the necessary protection, grass and the herbs on the upper slopes and trees on the lower slopes of the valley would come in due course of time.

II) Soil Erosion:

At present steep and extensive slopes in the valley are eroding rapidly with thawing snows and by avalanches. During early summers and autumn, wind erosion is very common. Water erosion is also gaining momentum day by day. The valley of Chandra and Bhaga contain only vestiges of the alluvial plains, such as those on which stand and rest of Khoksar and sissu. In pattan valley only Ghosal and tandi villages have stood while the rest have been washed away. Erosion is more severe near habitation, where the impact of grazing is very great.

Fig 5: Geomorphological map of the study



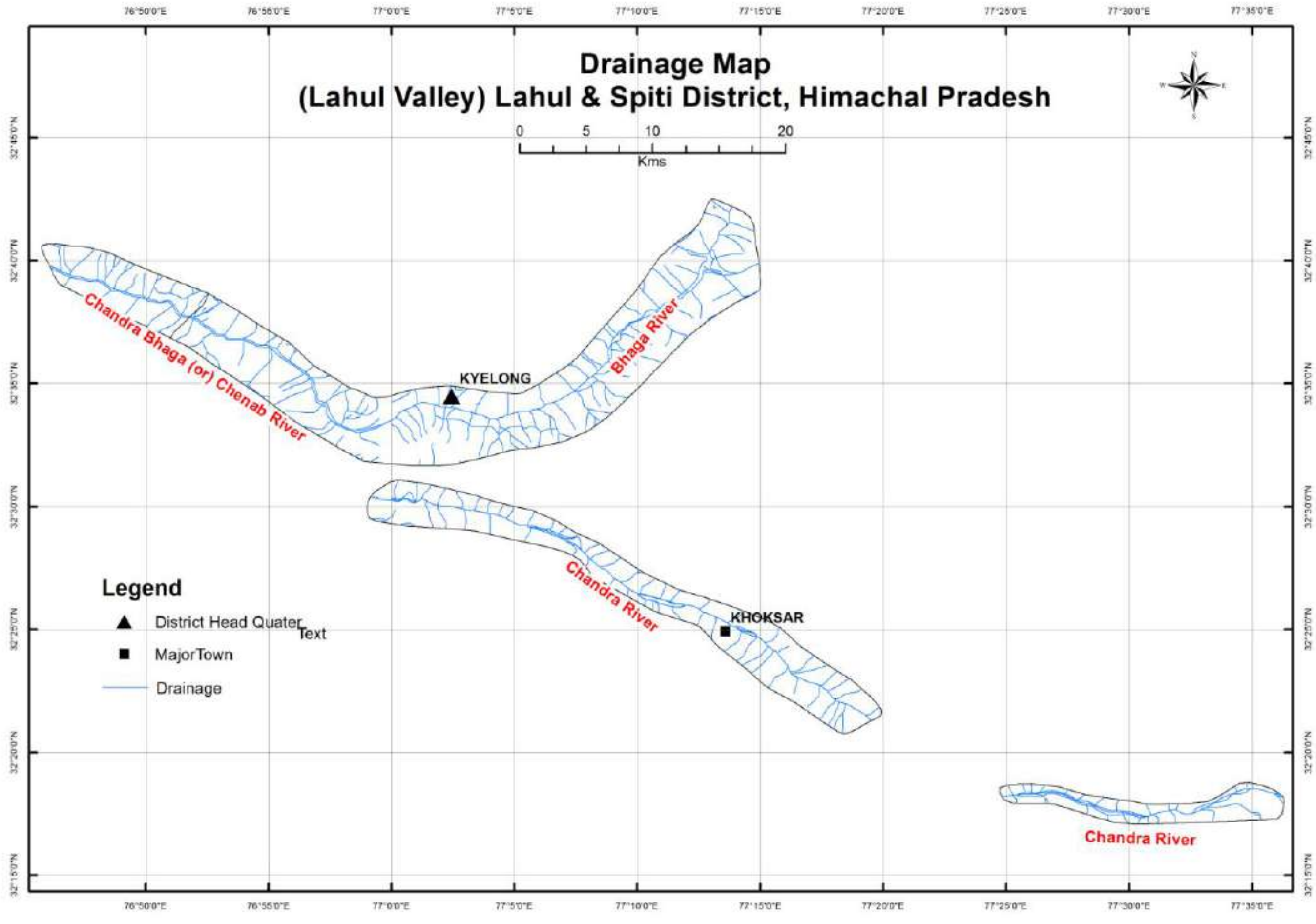


Fig 6: Major Drainage of the study area

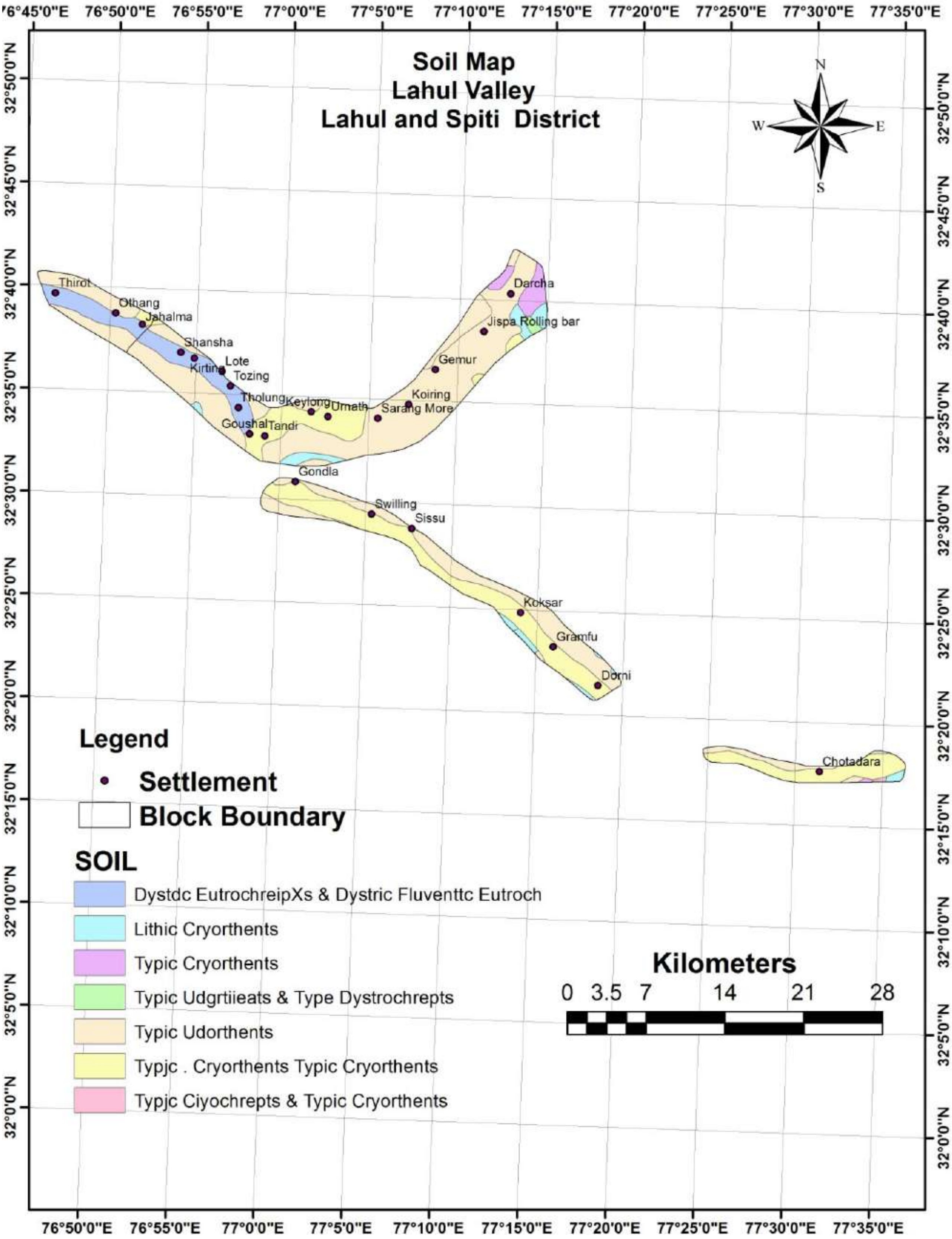


Fig 7: Soil map of the study area

1.12 Data Adequacy & data gap analysis

The Data gap analysis was done on the basis of NAQUIM & EFC guidelines in Aquifer Mapping Study area of 375 sq. kms in Lahaul Valley, Lahaul and spiti Districts of Himachal Pradesh. The study area falls in Survey of India Topo sheets No.52 D/14, D/15, 52H/02, H/03, H/07, and H/11 (Figure -8 -Toposheet Index Map). The Data Gap analysis of all the attributes is given in Table 1.1.

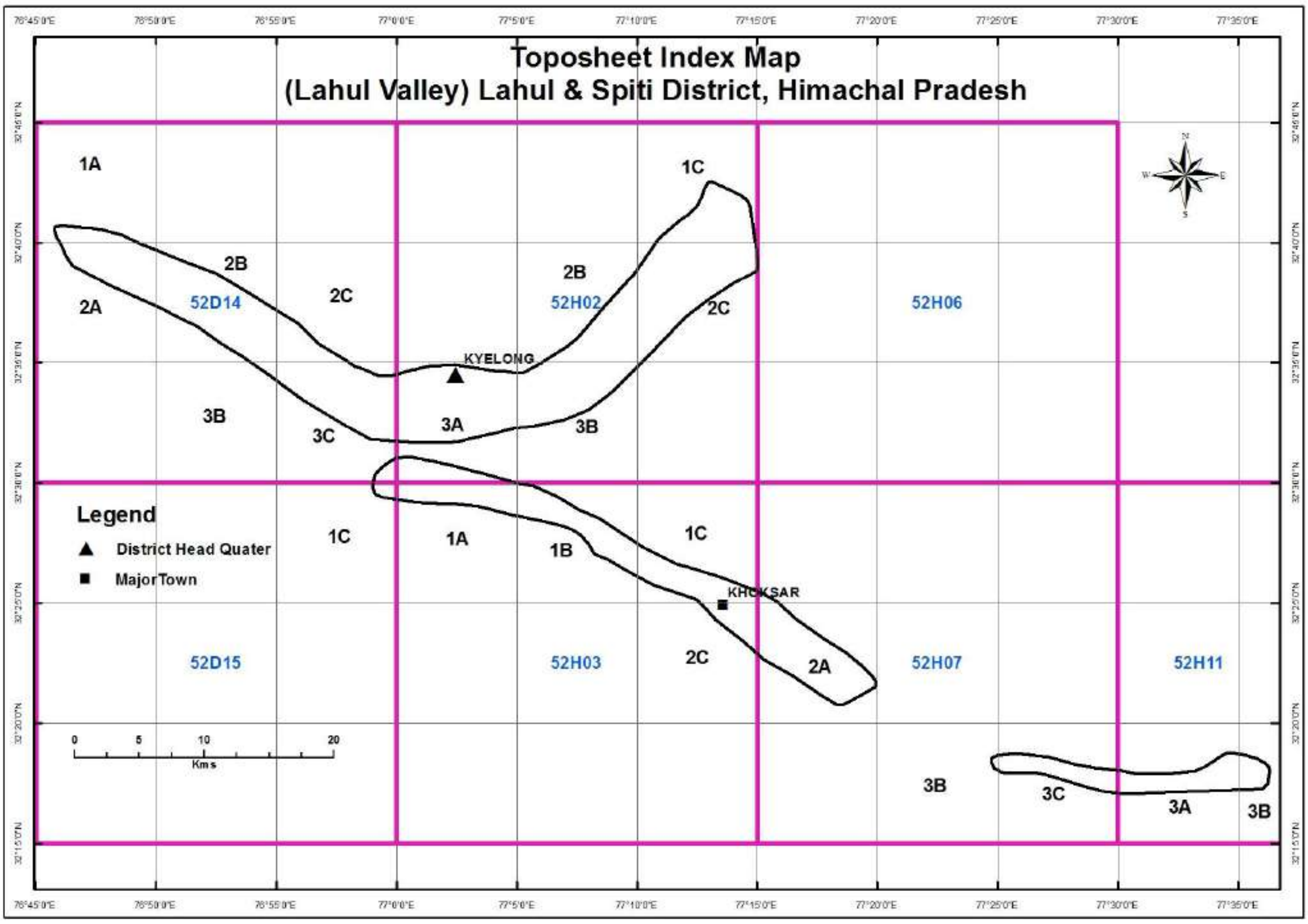


Fig.8: Topo sheet Index Map – Study Area

1.12.1 Exploratory Data

The Data gap Analysis indicates the required Ground Water Exploration sites, sets of exploratory and observation wells to ascertain the aquifer parameters, in the area as per the EFC and the existing number of sites in the area and the Gap is indicated where ever the required number of sites is higher than the existing number of sites. If the number of existing exploratory wells is higher than the required exploration sites, the gap is considered as zero and the existing structures were taken as fulfilling the norms. On the basis of data gap analysis, quadrant-wise existing and recommended sites is presented and shown as square diagram in the figure- and Table No.1.1

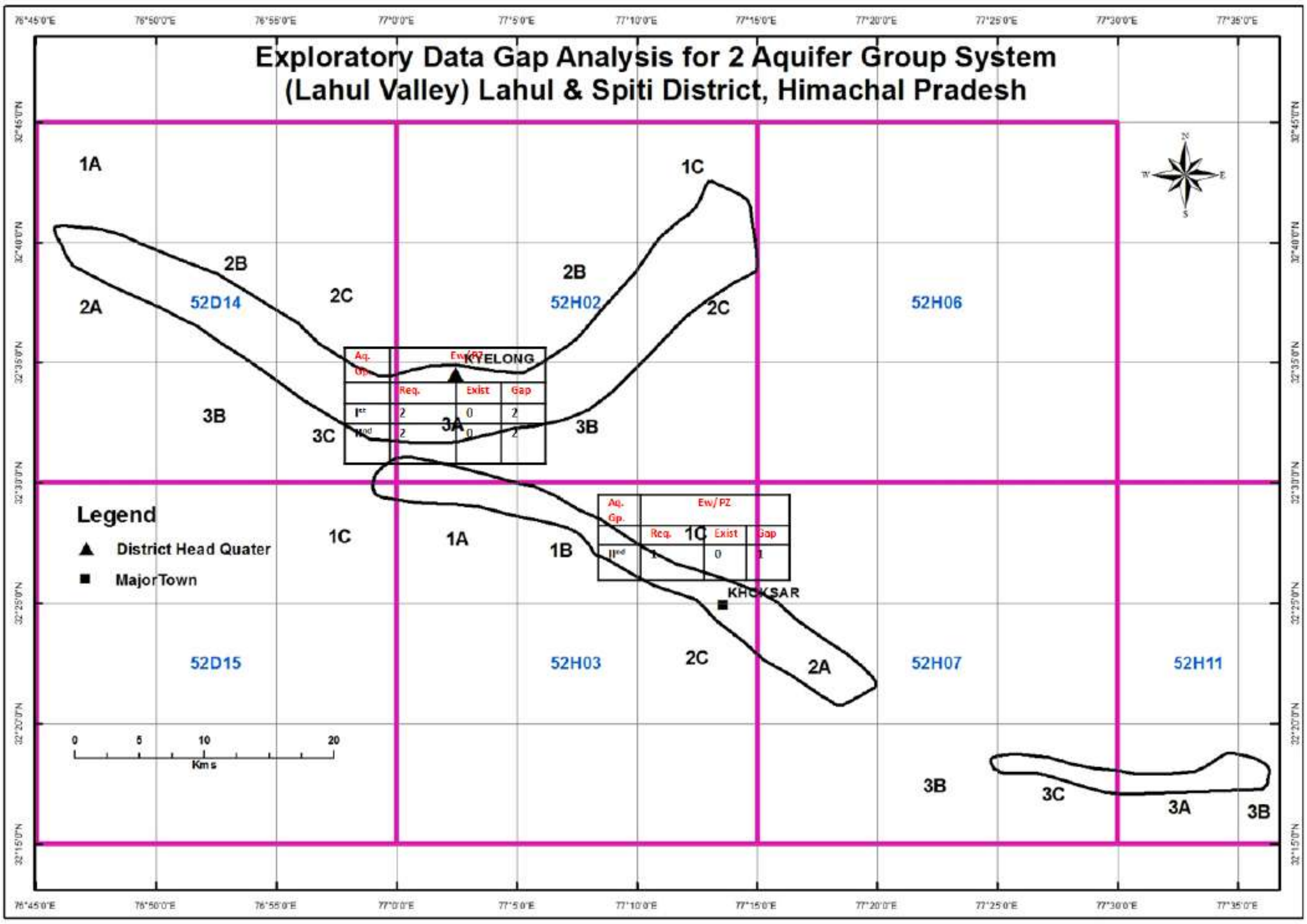


Fig.9: Exploratory Data Required Map in the study area.

1.12.2 Geophysical Data

The Vertical Electrical Soundings (VES) is required for lithological interpretation to a depth of 300 m but due to hilly terrain the adequate spread may not be available, therefore, TEM is also recommended for lithological interpretation to a depth of about 100 m. For the study area, no VES data is available with CGWB and state agencies. On the basis of data gap analysis, the required no. of VES are 13 Nos. The quadrant-wise existing and recommended VES sites is presented and shown as square diagram in the figure -10.

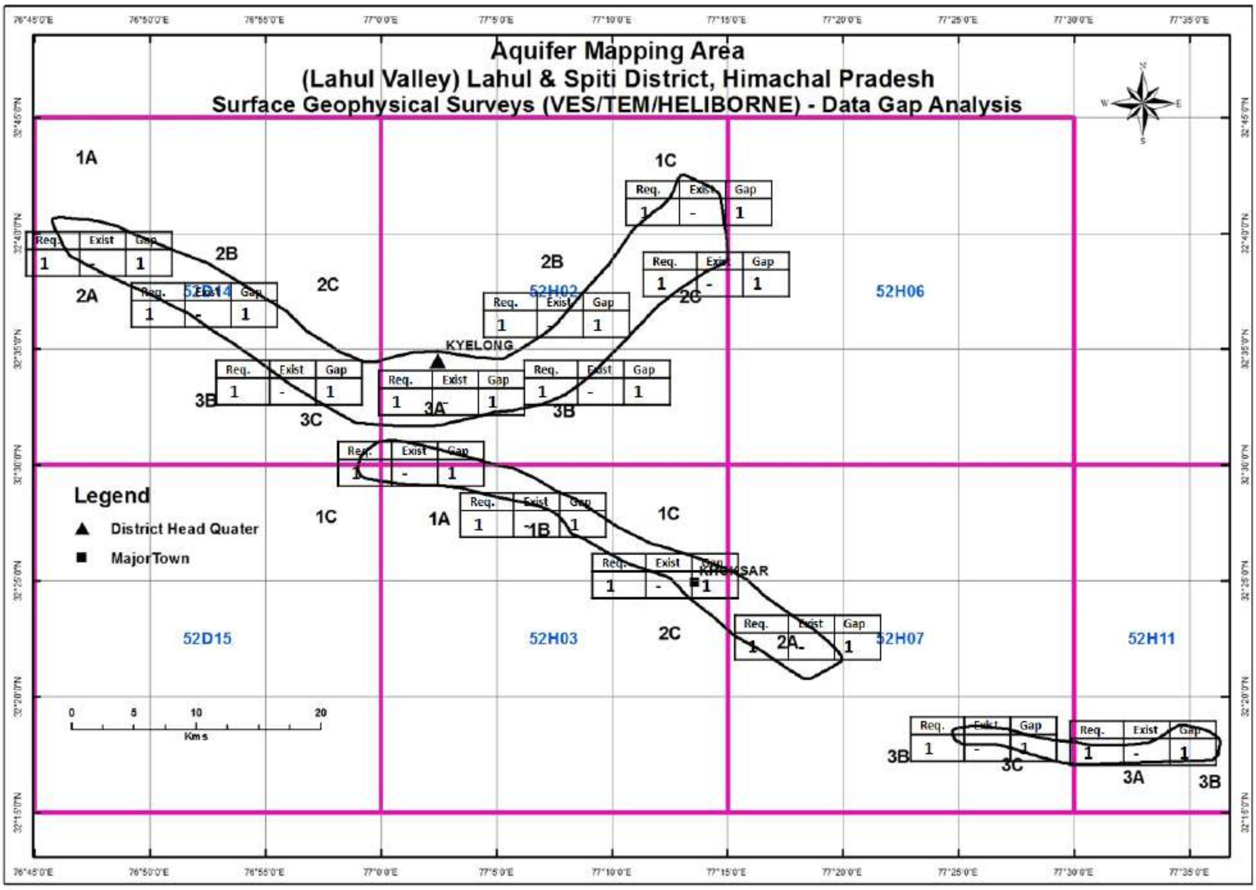


Fig.10: Data Gap Analysis of Surface Geophysical Surveys in the study area

1.12.3 Ground Water Monitoring Stations (GWMS)

The ground water monitoring NHS and Key well observation stations in the area tap the unconfined aquifer. Wells constructed by CGWB and hand pumps by State agencies which tap the deeper and shallow aquifers are utilised for drinking water supply instead of monitoring the piezometric head in the deeper and shallow aquifers. On the basis of data gap analysis, quadrant-wise and aquifer-wise existing and recommended ground water monitoring stations is presented and shown as square diagram in the figure -9

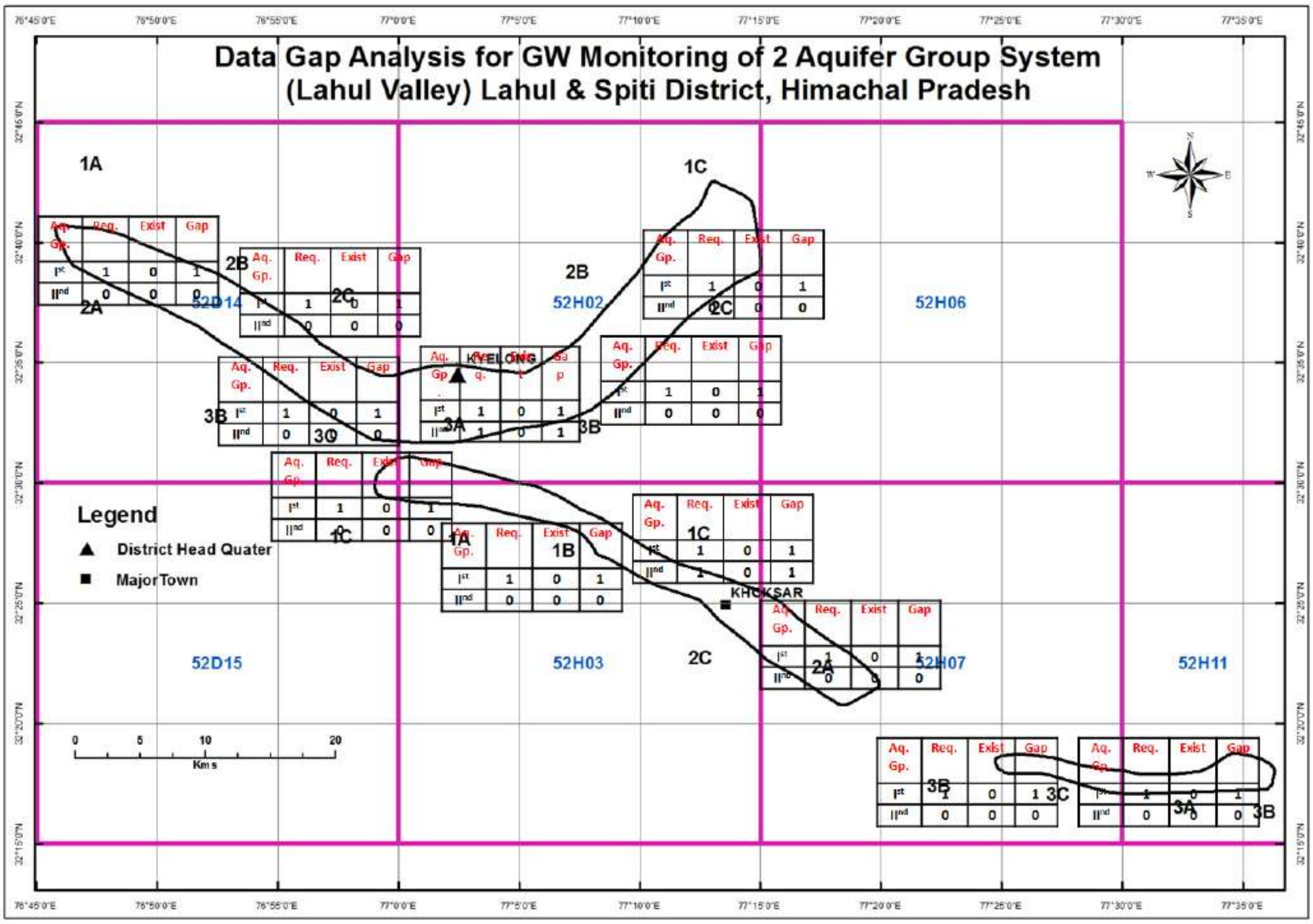


Fig.11: Data Gap Analysis for Ground Water Monitoring

1.12.4 Ground Water Quality Monitoring Stations (GWQMS)

Most of the ground water quality monitoring NHS and Key well observation stations in the area taps the unconfined aquifer. Wells constructed by CGWB and hand pumps by the state agencies tapping the deeper and shallow aquifers are utilised to monitor the quality of ground water in the deeper and shallow aquifers. The quadrant-wise and aquifer-wise existing and recommended ground water quality monitoring stations are shown as square diagram in the fig 12.

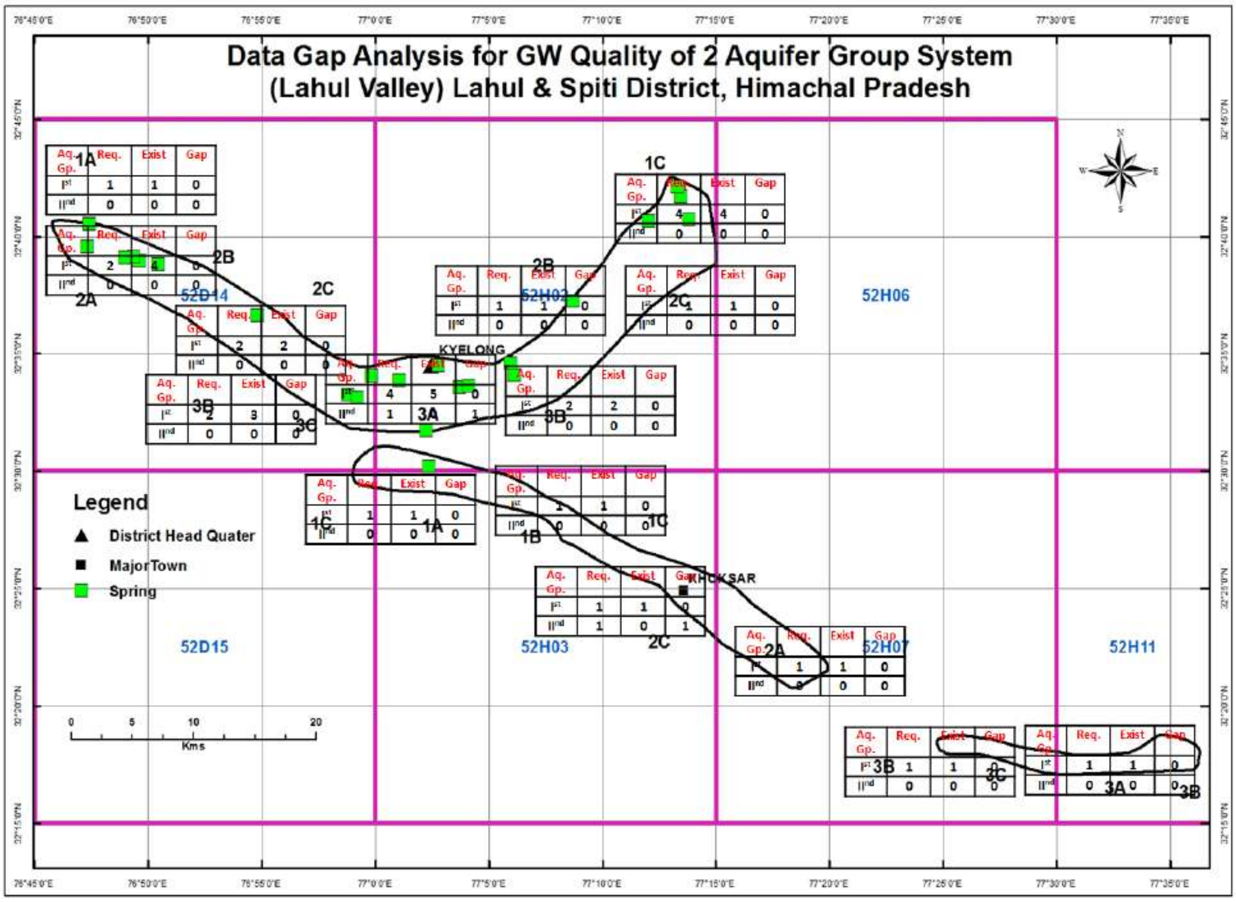


Fig.12: Data Gap Analysis of Ground Water Quality Locations in study area.

1.12.5 Rate of Infiltration

The amount of recharge to ground water depends on the infiltration rates of the soils. No infiltration tests have been conducted in previous surveys by CGWB and even this data is not available with state agencies. To know the infiltration characteristics of the soil in the study area, 39 nos. of infiltration tests are required. On the basis of data gap analysis, quadrant-wise existing and recommended infiltration tests are presented and shown as square diagram in the figure -11

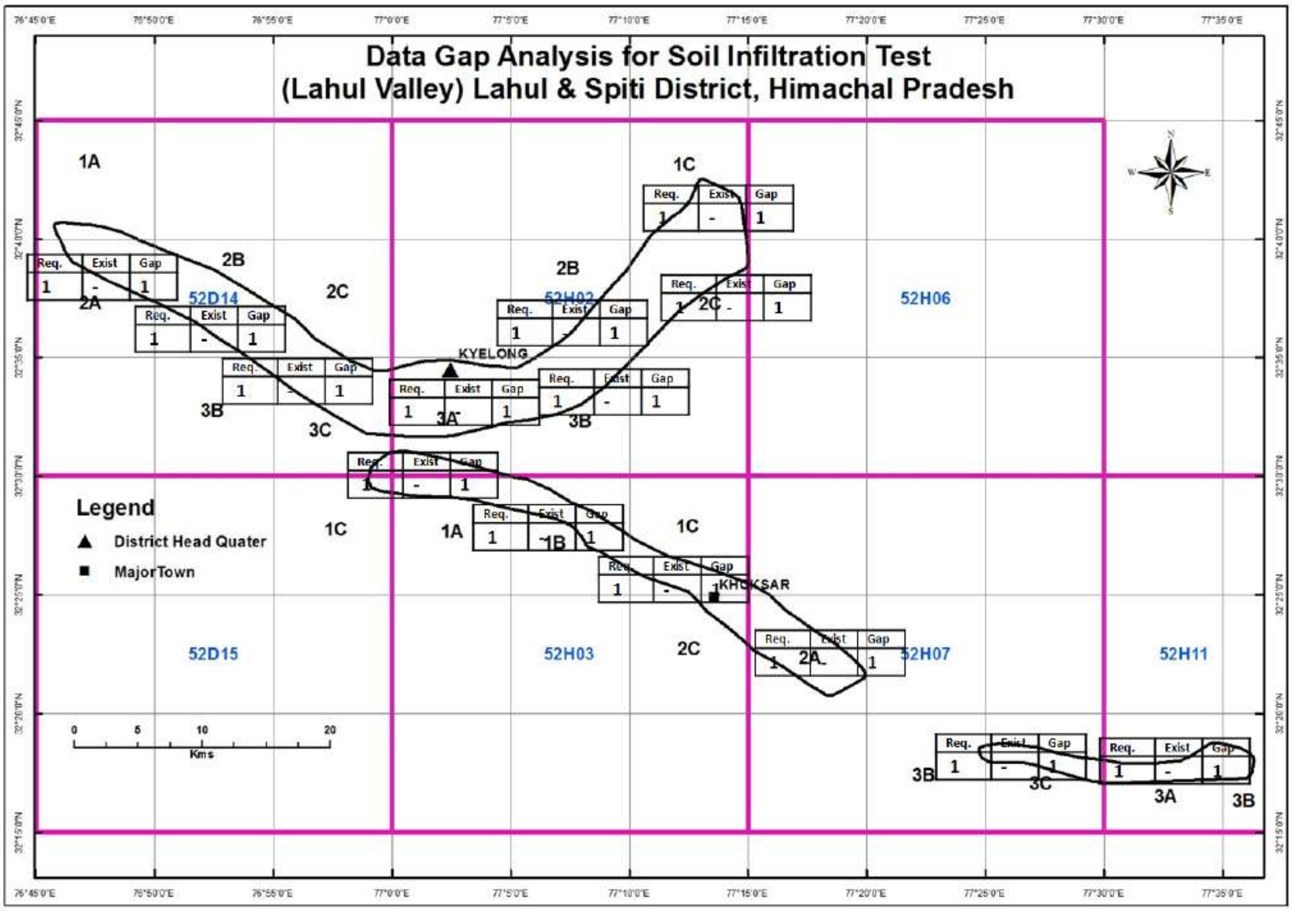


Fig.13: Data Gap Analysis for Soil Infiltration Studies in the study area

1.12.6 Spring discharge

The spring monitoring (discharge and quality) is essential to know the inflow and outflow of the water in the study area and its quality for domestic and other use. In the study area, 24 Nos. springs have been located.

1.13 Previous Work

Central Ground Water Board, NHR, Dharamshala has brought out district reports, ground water management studies reports, ground water exploration reports periodically on all districts of Himachal Pradesh. The systematic surveys and reappraisal hydro geological surveys were carried out by CGWB in area during various field seasons. Central Ground Water Board, NHR, Dharamshala has also carried out ground water exploration studies in the area. Systematic hydrgeological survey in the Lahaul valley were taken up Sh..S.K. Tayag, Sc'D' during 1983-84. Systematic hydrogeological survey (Non-conventional methods) was carried out by Sh.V. M. Sikka Sc'D' and Sh.S.C.Dhiman, Sc'D'.

Table:5 AQUIFER MAPPING LAHUL VALLEY, LAHUL & SPITI DISTRICT, H.P.DATA GAP ANALYSIS (AAP 2014-15)										
Toposheet No.- 52 D/14 & 15, 52 H02 & 03, 07, 11										
Quadrant no.	**No. of additional EW's Required**		**No. of additional OW's Required**		**No. of SPW's Required (EW /PZ)**		**No. of additional VES/TEM Required**		**No. of additional water level monitoring Stations(PZ's) Required**	**No. of Soil Infiltration test Required**
	Aq- I	**Aq- II**	**Aq- I**	**Aq- II**	**Aq- I**	**Aq- II**	**Aq- I**	**Aq- II**	**Aq- I**	
52D/14 1A										**1**
52D/14 2A								**1**	**1**	**1**
52D/14 2B								**1**	**1**	**1**
52D/14 2C										
52D/14 3C								**1**	**1**	**1**
52D/15 1C										
52H/02 1C								**1**		**1**
52H/02 2B								**1**		**1**
52H/02 2C								**1**	**1**	**1**
52H/02 3A	**1**	**1**	**1**	**1**				**1**		**1**
52H/02 3B								**1**	**1**	**1**
52H/03 1A								**1**	**1**	**1**
52H/03 1B								**1**	**1**	**1**
52H/03 1C						**1**		**1**	**1**	**1**
52H/03 2C										
52H/07 2A								**1**	**1**	**1**
52H/07 3C								**1**		**1**
52H/11 3A								**1**	**1**	**1**
52H/11 3B										
Total	**1**	**1**	**1**	**1**		**1**		**14**	**10**	**15**

Chapter II

2.0 Geology

The geology of the Lahaul valley is fairly complicated and with remarkable preservation of a wide range of geological formation, it occupies unique place in the geology of India. in Lahaul valley, the predominant formations belongs to Precambrian and these consist of schists, phyllites, slates, quartzites and limestone. These rocks variously appear along the valleys of the rivers Chandra and Bhaga respectively. The area on the right bank of Chandra Bhaga between Tandi and Udaipur and between Keylong and Jispa along the Bhaga river form the dip slope and therefore, it is gentle than the area on the left bank. The area has suffered many phases of folding. Recumbent folds are very common and are best seen along Keylong and Jispa section. Precambrian Batal formation, comprising mainly of quartzite, limestone, slate, and phyllite (Carboniferous and Pyritiferous) are exposed along the right bank of Chandra river from Darcha to Jispa. Jispa granite is intrusive into Batal information around Jispa. On the right bank of Chandra Bhaga River, Batal formation is exposed from Tandi to Uadaipur. The detailed geological succession encountered in the area is given below in table 6:

Era	***Age***	***Group / Formation***	***Lithology***	***GW structure / Yield Potential***
Mesozoic	Cretaceous	Giumal-Chikkim Formation	Sandstone, siltstone, shale, conglomerate.	➢ Springs are the natural sources. ➢ Shallow borewells feasible. ➢ Low to moderate yield potential in borewells (1-5 lps)
	Jurassic	Spiti Formation	Shale, sandstone and siltstone.	
	Triassic-Jurassic	Lilang Group / Kalhel Formation	limestones, shales, dolomites and sandstones.	
	Permo - Traissic-Jurassic	Tandi Group	Limestone	
Palaeozoic	Devonian to Permian	Kuling Group	Quartzites, Sandstones and Black Shales	
	Lower Cambrian to Silurian	Kunamla-Thango-Takche Formation	Shale, schist, sandstone, dolomite	
	Lower Cambrian to Silurian	Rohtang Granitoid	Granitoids	
Proterozoic	Neoproterozoic to Terminal Proterozoic	Batal Formation	Shales, phyllites and Quartzites	
		Manjir Formation	Sandstone, limestone, shale	

	Neoproterozoic	Bhalai Formation (Salkhala Group)	Slates, schists slates, phyllites, quartzites.	
	Mesoproterozoic	Vaikrita Group	slates, phyllites, quartzites, schists	

Source: Geological Survey of India

Lineament: Due to tectonic activity in the area, the lineament development is very prominent in the areas. All these lineament provide necessary weak zones for infiltration as well as movement of groundwater The lineament map of the area has been prepared from National Geological Lineament Map on 1:50000.(Source: Geological Survey of India) Fig:16

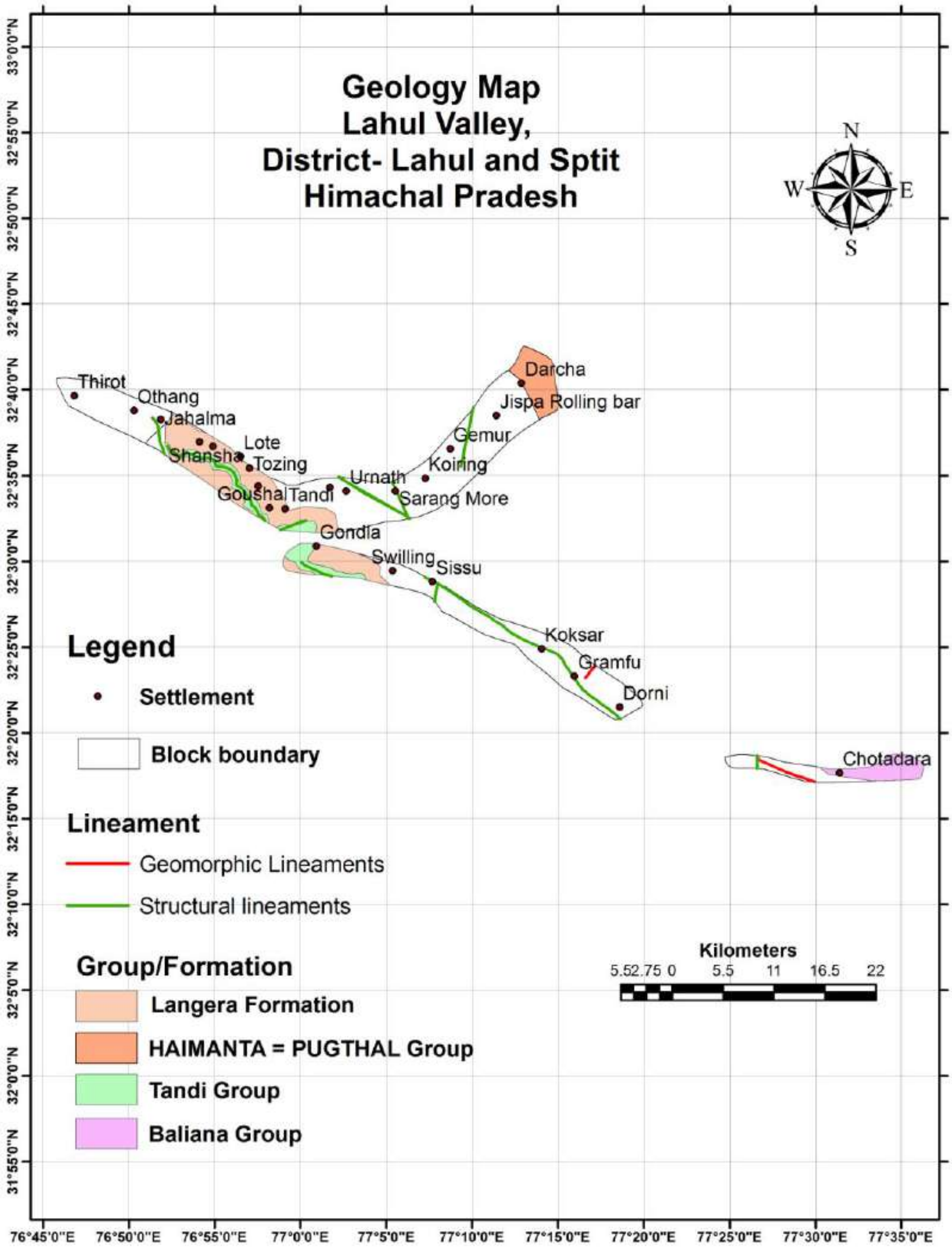


Fig 14: Geological map of the study area

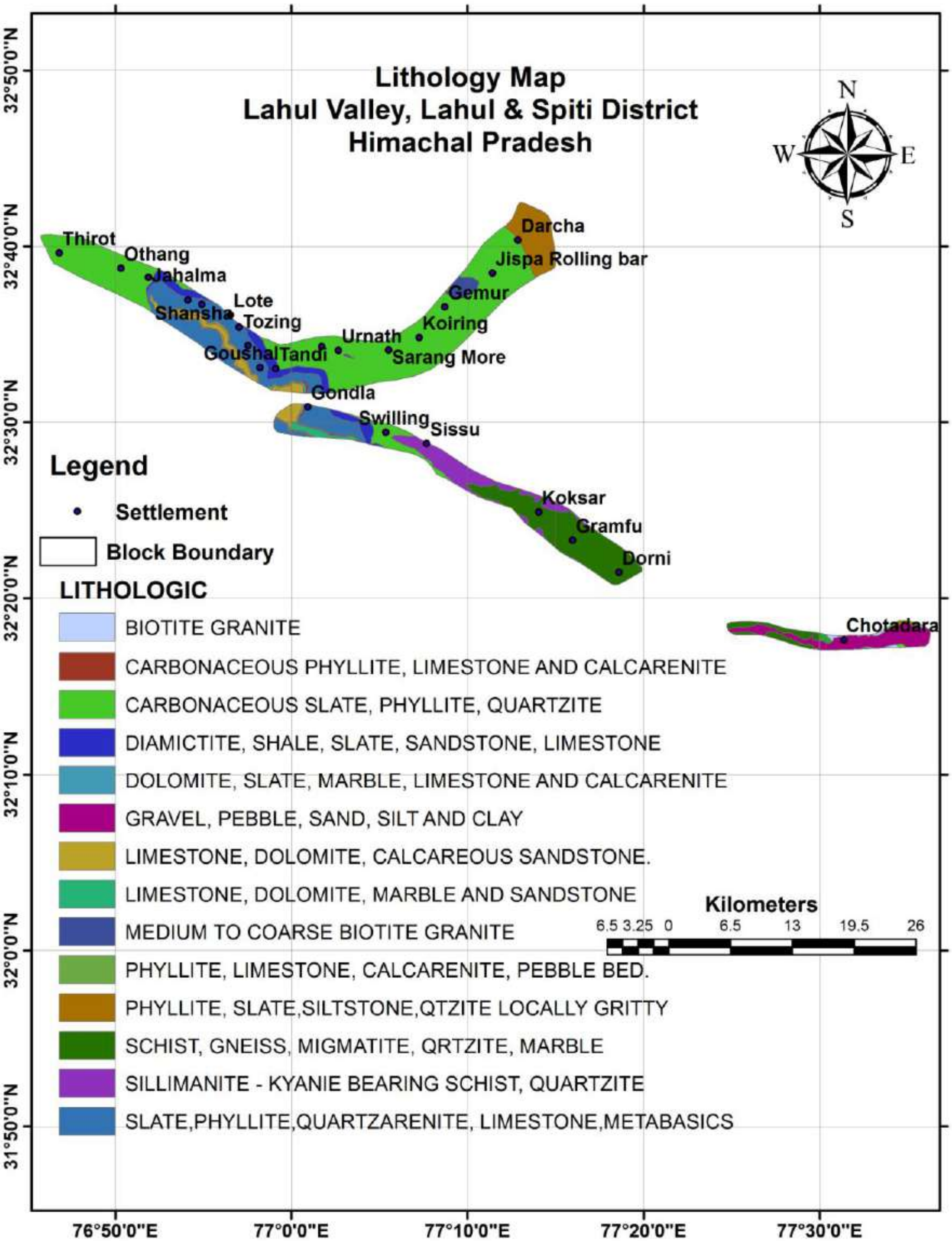


Fig 15: Lithogical map of the study area

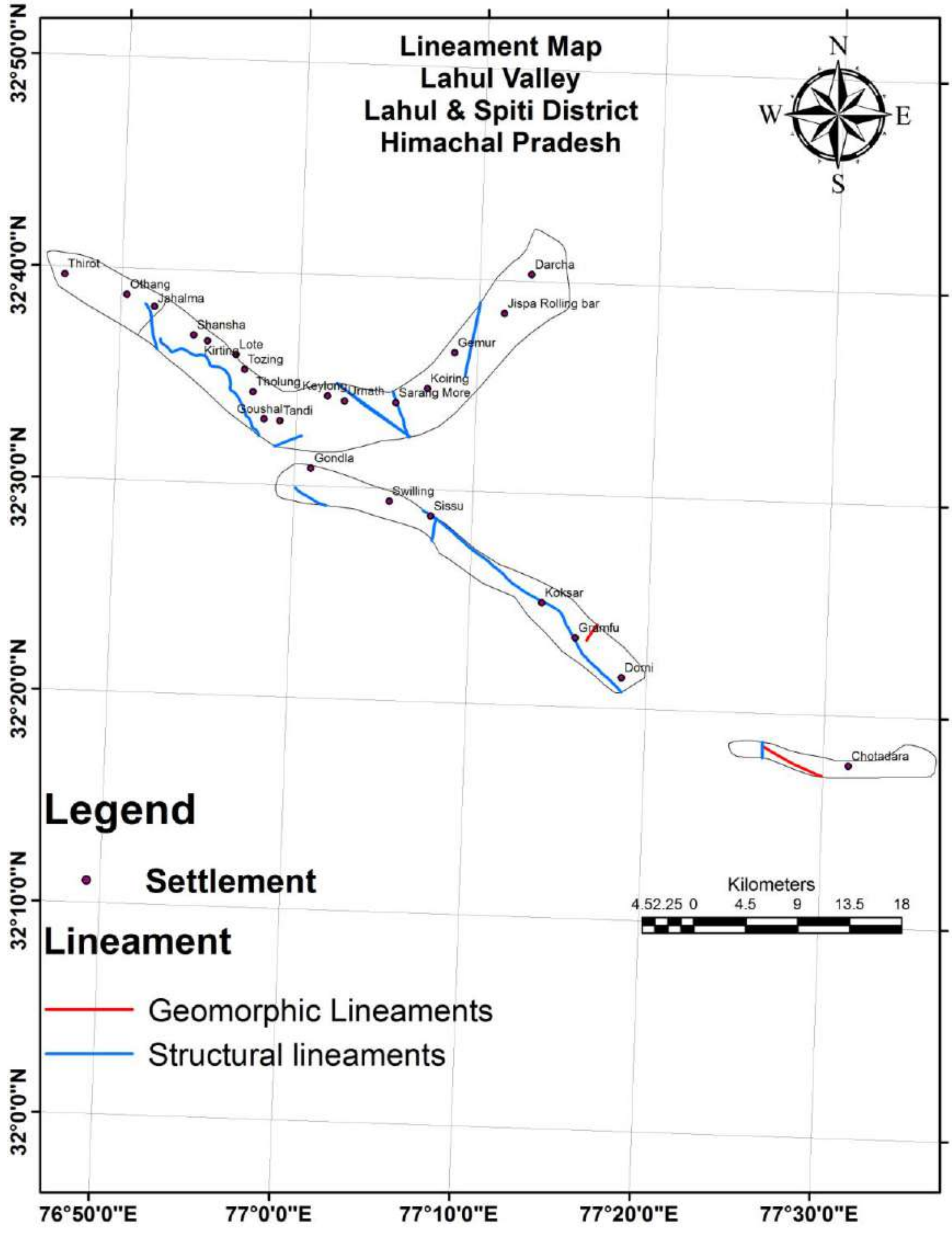


Fig 16: Lineament map of the study area

2.1 Hydrogeology

The hydro geological framework of the area is essentially controlled by geological setting, distribution of rainfall, snowfall and porosity of rocks constituting aquifers. Geologically, the area is underlain by the rocks of Proterozoic era to the quaternary period. Hydrogeologically, all these formations can be divided into units namely fissured and porous formations.

Fissured formations are constituted by hard rock formations ranging in age from Precambrian to Mesozoic and composed mainly of granites, gneisses, slates, phyllites, quarzites, schists and limestones. These rocks are generally massive and devoid of any primary porosity. However due to tectonic activities, secondary porosity has been developed along fractures, joints and faults zones. Weathered zones rarely form any aquifer because of their poor thickness. Sometimes contact zones of rocks unit forms poor to moderate aquifer. These are developed occasionally for localized and domestic water needs in low topographic areas. Ground water occurs generally under unconfined conditions and ooze out in the form of springs. Discharge of the springs varies from mere seepage to more than 20 lps with temperature varies from 10°C to 25°C in normal temperature of springs and 26°C to 60°C in hot water springs. This spring water is utilized for drinking and irrigation purposes.

Porous formations include both fluviatile and fluvio-glacial deposits. There is no development of the alluvial terrains in the valley as most of their river courses flow through narrow valley portions between well defined compact and hard rock valley walls. In broader valleys, like on the right banks of Bhaga and Chandra Bhaga rivers where older glacial terrain exists, large cultivations are being practiced. The width of these deposits varies from less than 500m to about 2.5km with increasing thickness of sediments towards the center of valley. These deposits are isolated and discontinuous and forms potential ground water aquifer.

Ground water generally occurs under unconfined to semi-confined conditions. Recently State Irrigation and Public Health Department has drilled shallow borewells fitted with the handpumps. The depth of these borewells varies from 35.40 to 70.12 m bgl. Depth to water level varies from 7.84 m bgl at Koksar village to 59.38 mbgl at Maragaon village while discharge ranges from 12 to 20 lpm. Water table follows the topography and the formations encountered are valley fill deposits consisting of sand, gravels, pebbles & cobbles. There are two locations, which are worth mentions from the point of view of development of ground water viz. Jispa and Udaipur.

Jispa lies on the right bank of Bhaga river with a gently sloping ground has been formed by the deposition of scree material brought down from hills in the north east due to melting of the snow. This ground is now a cultivated area.This unconsolidated accumulation of sediments may form a site for exploring the possibility for the construction of suitable ground water structure i.e. open dugwell or a tube well depending upon the availability of adequate saturated thickness of the sediments.

Udaipur town and the Chandra Bhaga river exists a gently sloping alluvial plains merging with the river. large amount of debris consisting of huge boulders and finer clastics is brought down by Miyar Nala and deposited in this valley called Patten valley at Udaipur. This alluvial flat plains is located within few meters height from the river level. it would be worthwhile to ascertain the thickness of these unconsolidated sediments lying at the top and that of weathered consolidated rocks below as well as their hydrological characteristics. and is suitable for development of ground water resources.

Springs are widely distributed all over the area in all types of formation at varying altitudes. These are the major sources of water supplies both for irrigation as well as for domestic purposes. Springs are of both fracture and seepage types. The fracture types of springs exist in the low topographic areas either along structurally weak zones or at the contact of geological formations where as seepage type of springs are formed on the slope of hills covered with loose material such as talus and scree. These springs are both perennial and seasonal with varying discharges and temperatures. Springs get recharged from rainfall and snowfall. Discharge of these springs generally increases during the summers. Irrigation and domestic water supply needs are met from these springs. The discharge generally varies from seepages to more than 20 lps with temperature varying from less than 10^{0} C to 25^{0}C in normal temperature springs and 26°C to 60°C in hot water springs.

The Hydrogeological map of the area is shown in Fig. 17 on next page.

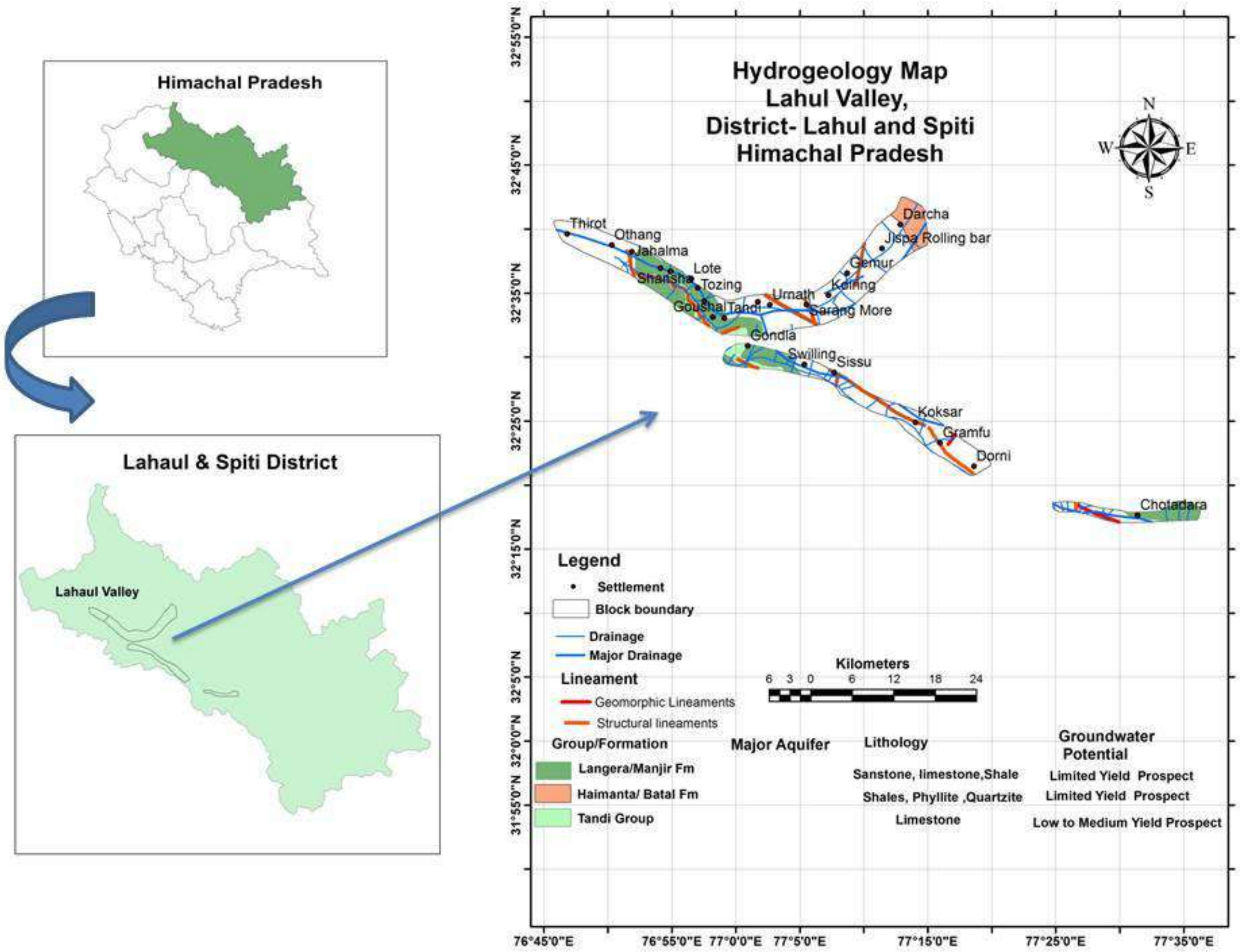


Fig 17: Aquifer Map of the study area in Lahaul Valley.

III DATA COLLECTION AND GENERATION

3.1 Hydrogeological Data

Water Level Behavior: To know spring discharge and its behavior with respect to time and space, 24 dug wells have been inventoried for Ground Water Management Studies all over the area. The Springs are mainly located in Lahaul valley, Lahaul and Spiti districts. The Spring Discharge were taken during the month of May, November of 2016, 2017 & 2018 and on the basis of these data, Pre-monsoon and Post monsoon map have been prepared for the study area. The hydrogeological data of the inventoried springs are given in Table 10

In Study area, Spring discharge varies from 0 to 25.64 lpm during pre-monsoon to 0 to 54.54 lpm during post monsoon season.

Table 7: Spring discharge data (July & Oct 2015 and July & Oct 2016) of Lahaul Valley, lahaul and Spiti Districts Himachal Pradesh

S.No	Location	Latitude	Longitude	Water Level, 2015 (mbgl)		2015 Fluctuation (m)	Water Level, 2016 (mbgl)		2016 Fluctuation (m)
				July 2015	Oct, 2015		July 2016	Oct, 2016	
1	Tholung	32.5729	76.959	NA	5	5	12	15	3
2	Kirting	32.6118	76.9151	8.95	20	11.05	60	30	30
3	Othang	32.646	76.8386	16	15	1	15	16	1
4	Thirot	32.6605	76.7802	20	20	0	20	30	10
5	Sarang More	32.5684	77.0921	20.47	26.66	6.19	15	15	0
6	Gemur	32.6093	77.1452	Meagre	24	24	60	30	30
7	Darcha	32.6728	77.2145	20	10	10	7.5	5.45	2.05
8	Jispa Rolling bar	32.6414	77.1903	2.4	54.54	52.14	60	60	0
9	Keylong	32.5718	77.02853	25.64	20	5.64	25	20	5
10	Tandi	32.5509	76.985	8.57	30	21.43	15	20	5
11	Gondla	32.5146	77.0154	10	19.35	9.35	20	12	8
12	Sissu	32.4801	77.1281	16	18	2	15	20	5

13	Koksar	32.4149	77.2341	46	60	14	15	20	5
14	Tozing	32.5904	76.9505	20	60	40	12	10	2
15	Lote	32.6019	76.942	12	20	8	30	20	10
16	Shansha	32.616	76.902	10	20	10	10	6	4
17	Jahalma	32.6375	76.8645	15.22	12	3.22	7.5	20	12.5
18	Goushal	32.552	76.9702	Meagre	20	20	30	30	0
19	Koiring	32.5804	77.121	Meagre	60	60	20	Meagre	20
20	Urnath	32.5682	77.0443	Meagre	6.86	6.86	10	4.28	5.72
21	Swilling	32.4905	77.0893	20	10	10	Meagre	Meagre	NA
22	Gramfu	32.3882	77.2661	25.21	20	-5.21	30	7.5	22.5
23	Dorni	32.358	77.3102	Meagre	8.57	8.57	7.5	8.57	1.07
24	Chotadara	32.2941	77.5233	8	12	4	7	10	3

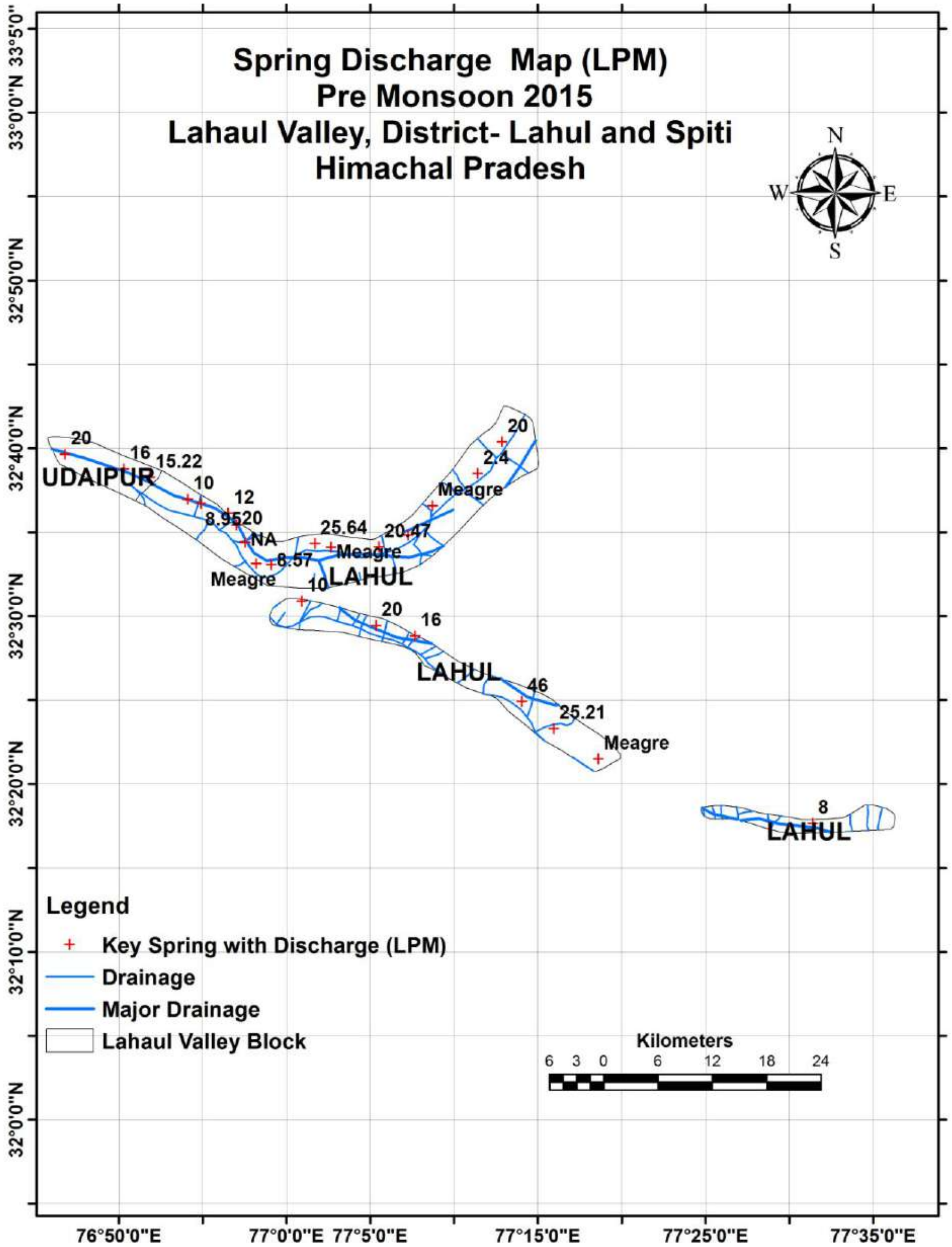


Fig 18: Spring Discharge Map – Pre Monsoon 2015 in study area

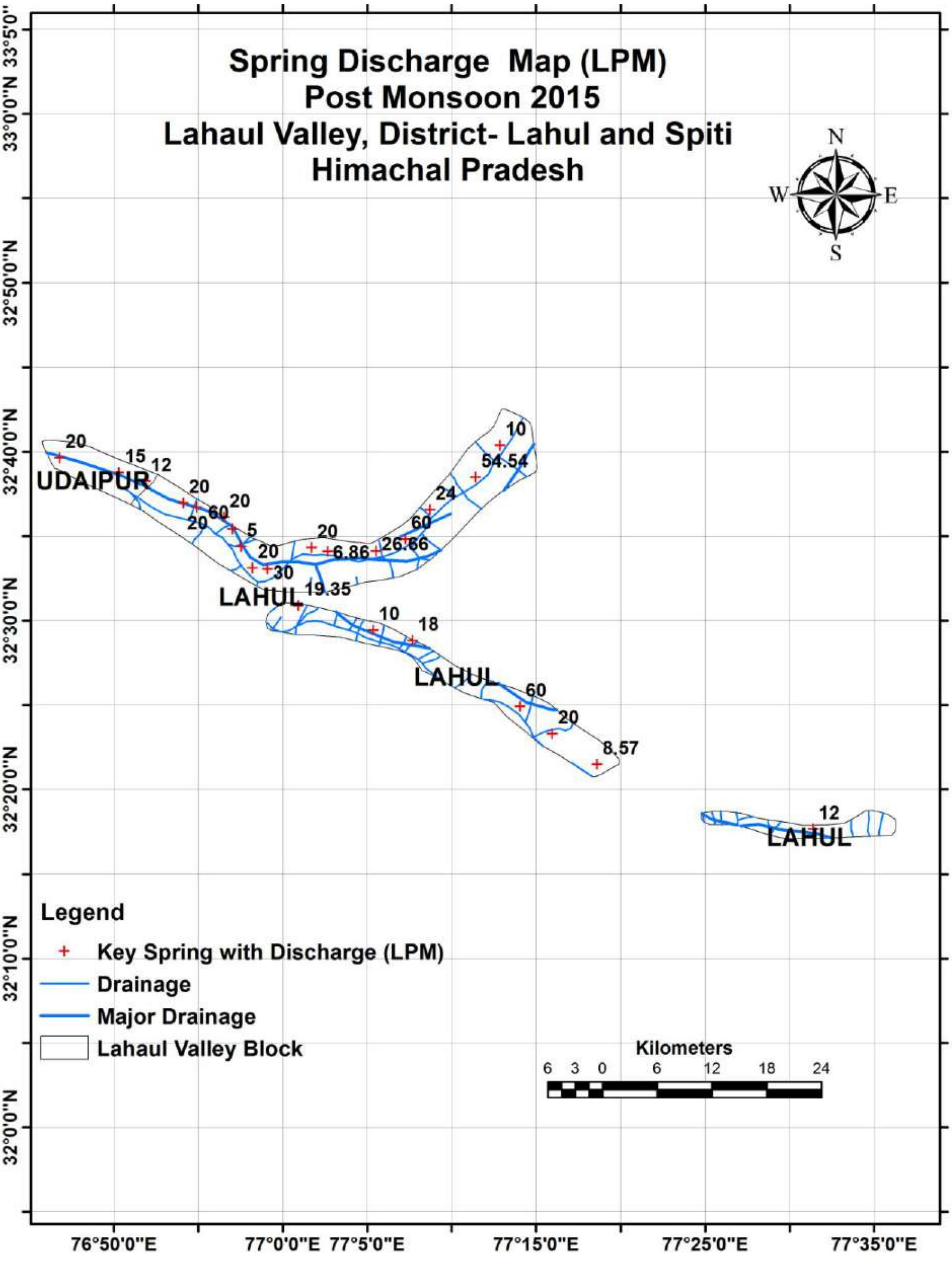


Fig 19: Spring Discharge Map – Post Monsoon 2015 in study area

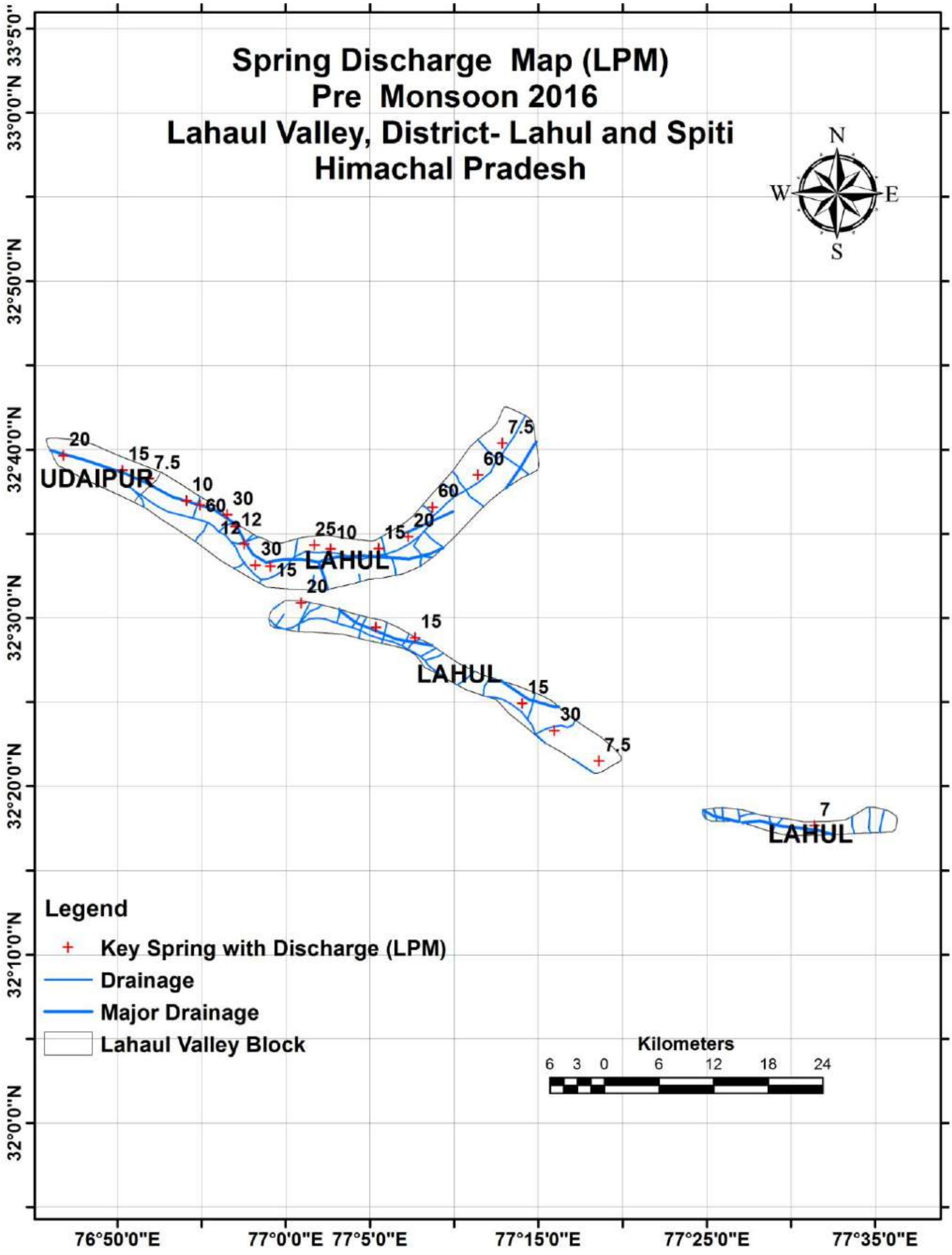
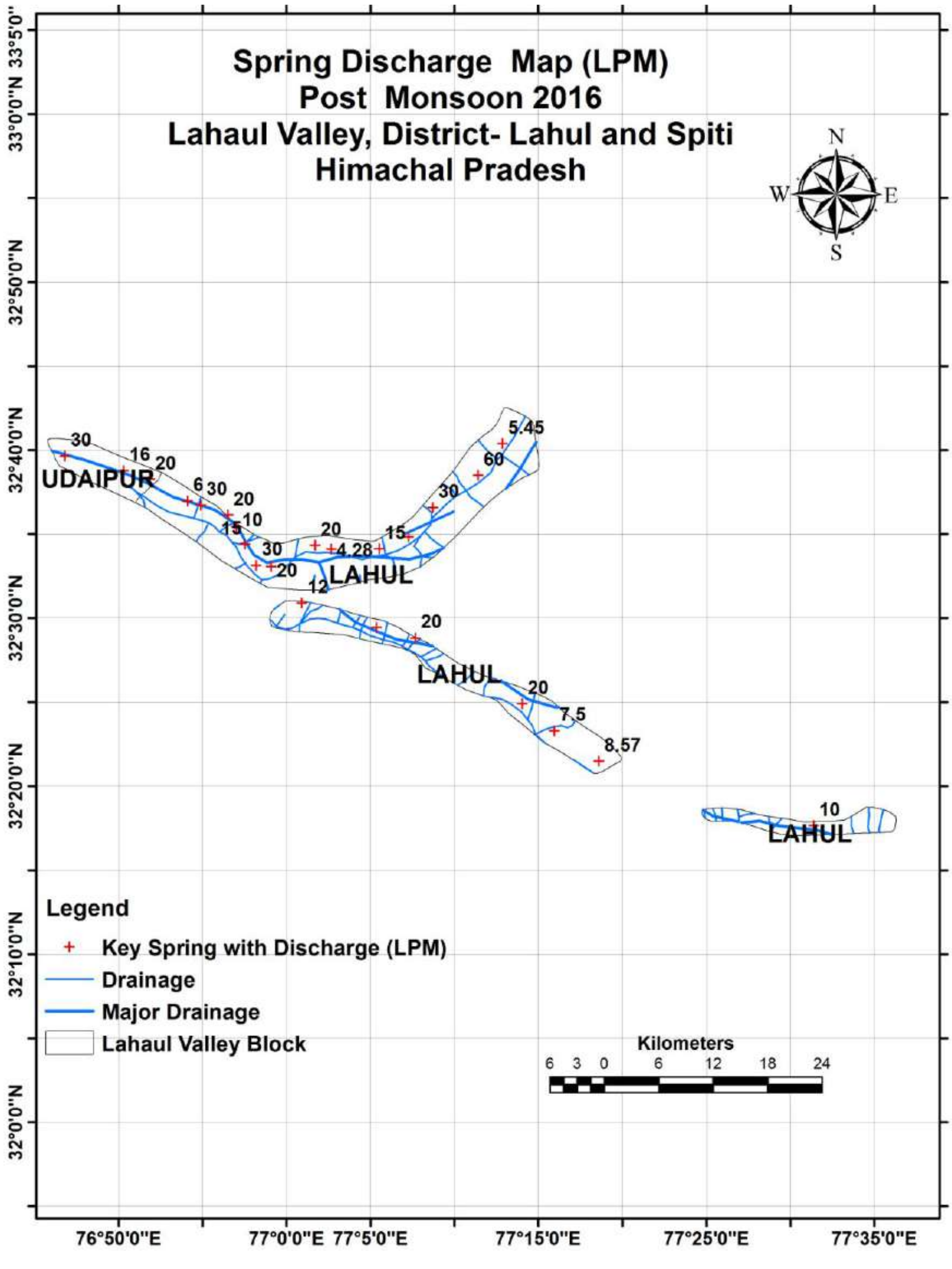


Fig 20: Spring Discharge Map – Pre Monsoon 2016 in study area



Spring Discharge Map (LPM)
Post Monsoon 2016
Lahaul Valley, District- Lahul and Spiti
Himachal Pradesh
N
W
E
S
UDAIPUR
LAHUL
LAHUL
LAHUL
30
16
20
6
30
20
10
15
30
20
20
4.28
15
30
60
5.45
12
20
20
7.5
8.57
10
Legend
Key Spring with Discharge (LPM)
Drainage
Major Drainage
Lahaul Valley Block
Kilometers
6 3 0 6 12 18 24
33°5'0"
33°0'0"N
32°50'0"N
32°40'0"N
32°30'0"N
32°20'0"N
32°10'0"N
32°0'0"N
76°50'0"E
77°0'0"E
77°5'0"E
77°15'0"E
77°25'0"E
77°35'0"E

Fig 21: Spring Discharge Map – Post Monsoon 2016 in study area

3.2. Exploratory Drilling – Ground water exploration has not been carried out by CGWB in the district because of hard approachability for the heavy machinery.

3.3 Ground Water Quality

The water quality standards are laid down to evaluate suitability of water for intended uses and to safeguard water from degradation. These recommended limits form the basis of treatment needed for improvement in quality of water before use. In the formulation of water quality standards, the selection of parameters is considered depending upon its end use. Two types of standards are referred in India decipher the quality of water suitable for drinking purposes, namely Bureau of Indian Standards (BIS) and World Health Organisation (WHO) Standards.

Drinking Water

The BIS has laid down the standard specification for drinking water during 1983, which have been revised and updated from time to time. In order to enable the users to exercise their discretion, the maximum permissible limit has been prescribed especially where no alternative sources are available. It is medically established fact that water with concentration beyond permissible limits cause short term or permanent adverse health effects.

Standards for Chemical Parameters

The water quality standards as laid down in BIS standard (IS-10500, 1991), First Revision, 2003-2009 and WHO (2008) standards are summarized in Table 12 and Table 13 respectively. In addition separate standards for the use of Surface water i.e. lakes and rivers for drinking purposes have been laid down by BIS and have been given in table 14.

Table 12: Drinking water Standards - BIS (IS-10500, 1991)

S. No.	Parameters	Desirable limits (mg/l)	Permissible limits (mg/l)
Essential Characteristics			
1	Colour Hazen unit	5	25
2	Odour	Unobjectionable	-
3	Taste	Agreeable	-
4	Turbidity (NTU)	5	10
5	pH	6.5 - 8.5	No relaxation
6	Total Hardness, $CaCO_3$	300	600
7	Iron (Fe)	0.3	1
8	Chloride (Cl)	250	1000
9	Residual Free Chlorine	0.2	-
10	Fluoride (F)	1	1.5
Desirable Characteristics			
11	Dissolved Solids	500	2000
12	Calcium (Ca)	75	200
13	Magnesium (Mg)	30	100
14	Copper (Cu)	0.05	1.5
15	Manganese (Mn)	0.1	0.3
16	Sulphate (SO_4)	200	400
17	Nitrate (NO_3)	45	100
18	Phenolic Compounds	0.001	0.002
19	Mercury (Hg)	0.001	No relaxation
20	Cadmium (Cd)	0.01	No relaxation
21	Selenium (Se)	0.01	No relaxation
22	Arsenic (As)	0.01	No relaxation
23	Cyanide (CN)	0.05	No relaxation

24	Lead (Pb)	0.05	No relaxation
25	Zinc (Zn)	5	15
26	Anionic Detergents (as MBAS)	0.2	1
27	Hexavelant Chromium	0.05	no relaxation
28	Poly Nuclear Hydrocarbons (as PAH)	-	-
29	Alkalinity	200	600
30	Aluminium (Al)	0.03	0.2
31	Boron (B)	1	5
32	Pesticides	Absent	0.001
33	Mineral Oil	0.01	0.03
34	Radioactive Material		
	Alpha Emmiters, Bq/l	-	.0.1
	Beta Emmiters, pci/l	-	1

NTU = Nephelometric Turbidity Unit

Table 13: Drinking Water Standards, WHO (2008)

S. No.	Parameters	Guideline value (mg/l)	Remarks
1	Aluminium	0.2	
2	Ammonia	-	NAD
3	Antimony	0.005	
4	Arsenic	0.01	For excess skin cancer risk of 6 x 10^{-4}
5	Asbestos	-	NAD
6	Barium	0.3	
7	Beryllium	-	NAD
8	Boron	0.3	
9	Cadmium	0.003	
10	Chloride	250	
11	Chromium	0.05	
12	Color	-	Not Mentioned
13	Copper	2	ATO
14	Cyanide	0.07	
15	Dissolved Oxygen		NAD
16	Fluoride	1.5	Climatic conditions, volume of water consumed, and intake from other sources should be considered when setting national standards.
17	Hardness		NAD
18	Hydrogen Sulfide		NAD
19	Iron		NAD
20	Lead	0.01	It is recognized that not all water will meet the guideline value immediately; meanwhile, all other recommended measures to reduce the total exposure to lead should be implemented.
21	Manganese	0.5 (P)	ATO
22	Mercury (total)	0.001	-
23	Molybdenum	0.07	-
24	Nickel	0.02	-
25	Nitrate (as NO_3) Nitrite (as NO_2)	50	The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1.
26	Turbidity		Not Mentioned
27	pH		NAD
28	Selenium	0.01	-
29	Silver		NAD
30	Sodium	200	
31	Sulfate	500	

32	Inorganic Tin		NAD
33	TDS		NAD
34	Uranium	1.4	
35	Zinc	3	

NAD - No adequate data to permit recommendation

ATO - Appearance, taste or odour of the water

Table 14: Surface Water Quality Standards -BIS

Characteristic	Tolerance Limit				
	Class A	**Class B**	**Class C**	**Class D**	**Class E**
pH value	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
Dissolved Oxygen (mg/l), min.	6	5	4	4	--
BOD (5-days at 20° C, mg/l, min.	2	3	3	--	--
Total Coliform Organism, MPN/100ml, max	50	500	5000	--	--
Colour, Hazen units, max.	10	300	300	--	--
Odour	10	300	300	--	--
Taste	Tasteless	--	--	--	--
Total dissolved solids, mg/l, max.	500	--	1500	--	2100
Total hardness(as $CaCo_3$), mg/l, max.	300	--	--	--	--
Calcium hardness (as $CaCO_3$), mg/l, max.	200	--	--	--	--
Magnesium hardness (as $CaCO_3$), mg/l, max.	100	--	--	--	--
Copper (as Cu), mg/l, max.	1.5	--	1.5	--	--
Iron (as Fe), Mg/l, max.	0.3	--	0.5	--	--
Manganese (as Mn), mg/l, max.	0.5	--	--	--	--
Chlorides (as Cl), mg/l, max.	250	--	600	--	600
Sulphates (as SO_4), mg/l, max.	400	--	400	--	1000
Nitrates (as NO_3), mg/l, max.	20	--	50	--	--
Fluorides (as F), mg/l, max.	1.5	1.5	1.5	--	--
Phenolic compounds (as C_6H_5 OH), mg/l, max.	0.002	0.005	0.005	--	--
Mercury (as Hg), mg/l, max.	0.001	--	--	--	--
Cadmium (as Cd), mg/l, max.	0.01	--	0.01	--	--
Salenium (as Se), mg/l, max.	0.01	--	0.05	--	--
Arsenic (as As), mg/l, max.	0.05	0.2	0.2	--	--
Cyanide (as CN), mg/l, max.	0.05	0.05	0.05	--	--
Lead (as Pb), mg/l, max.	0.1	--	0.1	--	--
Zinc (as Zn), mg/l, max.	15	--	15	--	--
Chromium (as Cr^{6+}), mg/l, max.	0.05	--	0.05	--	--
Anionic detergents (as MBAS) mg/l, max.	0.2	1	1	--	--
Polynucleararomatic hydrocarbons, (as PAH	0.2	--	--	--	--
Mineral oil, mg/l, max.	0.01	--	0.1	0.1	--
Barium (as Ba), mg/l, max.	1	--	--	--	--
Silver (as Ag), mg/l, max.	0.05	--	--	--	--
Pesticides	Absent	--	Absent	--	--
Alpha emitters, uC/ml, max.	10^{-9}	10^{-9}	10^{-9}		
Beta emitters, uC/ml, max.	10^{-8}	10^{-8}	10^{-8}	10^{-8}	10^{-8}
Free ammonia (as N), mg/l, max.	--	--	--	1.2	--
Electrical conductance at 25° C, mhos, max.	--	--	--	1000×10^{-6}	2250×10^{-6}
Free carbon dioxide (as CO), mg/l, max.	--	--	--	61	--
Sodium absorption ratio	--	--	--	--	26
Boron (as B), mg/l, max.	--	--	--	--	--
Percent sodium, max.	--	--	--	--	--

*Explanation for Symbols:

A: Drinking water sources without conventional treatment but after disinfection.

B: Organized outdoor Bathing.

C: Drinking water sources with conventional treatment followed by disinfection.

D: Propogation of wild life and Fisheries.

E: Irrigation, industrial cooling and controlled water disposal.

Standards for Bacteriological Parameters

Faecal contamination is widespread in most of the Rural Areas. The major bacteriological contamination and their limits are given below:

E. Coli is the more precise indicator of faecal pollution. The count of thermo-tolerant, coliform bacteria is an acceptable method however, if necessary, proper confirmatory tests of the sample should be carried out. As per Indian standard for drinking water - specification (First Revision) IS-10500:1991 BIS, ideally, all samples taken from the distribution system including consumers' premises should be free from coliform organisms. In practice, this is not always attainable. The following standard of water collected in the distribution system is therefore recommended when tested in accordance with IS 1622:1981.

a) 95 percent of samples should not contain any coliform organisms in 100 ml;

b) No sample should contain E. coli in 100 ml;

c) No sample should contain more than 10 coliform organism per 100 ml; and

d) Coliform organism should not be detectable in 100 ml of any two consecutive samples.

WHO has also suggested guidelines for bacteriological parameters are as follows (Table 2.10)

Table 15: Bacteriological quality of drinking water (WHO, 2008)

Organisms	Guideline Value
All water intended for drinking	
E. Coli or thermo-tolerant coliform bacteria	Must not be detectable in any 100/ml sample.
Treated water entering the distribution system	
E. Coli or thermo-tolerant coliform bacteria	Must not be detectable in any 100/ml sample.
Total coliform bacteria	Must not be detectable in any 100/ml sample.
Treated water in the distribution system	
E. Coli or thermo-tolerant coliform bacteria	Must not be detectable in any 100/ml sample.
Total coliform bacteria	Must not be detectable in any 100/ml sample. In the case of large supplies, where sufficient samples are examined must not be present in 95% of sample taken throughout any 12 month period.

The detrimental effect of various pesticides/ organic compounds cannot be ignored.

The ground water sampling was carried out in the study areas through Ground Water Observation Wells in every year pre-monsoon period by CGWB. The water samples for both pre monsoon and post monsoon were collected during the year 2015-16 & 2016-17. To assess the impact of ground water quality, 24 numbers of water samples were collected from the study area of in 2015-16 and 2016-2017, as per the list below:

Sr.No	Type of Source	Total Nos.
1.	Spring	32 Nos.

S. N o.	District	Location	Lat	Long	Source	Depth Zone	Temp. (Celsius) Sample/ Atm	Analysis
1	Lahaul&Spiti	Tholung	32 34 22.1	76 57 32.7	Spring	Shallow	9	Basic
2	Lahaul&Spiti	Tozing	32 35 25.6	76 57 02.0	Spring	Shallow	9	Basic
3	Lahaul&Spiti	Lote-1	32 36 07.0	76 56 31.4	Spring	Shallow	10	Basic+Heavy Metal
4	Lahaul&Spiti	Lote-2	32 36 07.0	76 56 31.4	Spring	Shallow	10	Basic
5	Lahaul&Spiti	Kirting	32 36 42.8	76 54 54.7	Spring	Shallow	9	Basic
6	Lahaul&Spiti	Shansh	32 36 57.8	76 64 07.4	Spring	Shallow	16	Basic
7	Lahaul&Spiti	Phura			Spring	Shallow	10	Basic
8	Lahaul&Spiti	Jahalma	32 38 12.9	76 51 49.2	Spring	Shallow	12	Basic
9	Lahaul&Spiti	Junda	32 38 30.6	76 50 52.7	Spring	Shallow	18	Basic
10	Lahaul&Spiti	Thirot	32 39 38	76 46 59	Spring	Shallow	10	Basic
11	Lahaul&Spiti	Goushal	32 33 07.4	76 58 12.8	Spring	Shallow	10	Basic
12	Lahaul&Spiti	Sarang More	32 34 06.3	77 05 31.7	Spring	Shallow	9	Basic
13	Lahaul&Spiti	Koiring	32 34 49.5	77 07 15.9	Spring	Shallow	12	Basic
14	Lahaul&Spiti	Gemur	32 36 54.7	77 08 58.4	Spring	Shallow	6	Basic
15	Lahaul&Spiti	Rolingbor (Jispa)	32 37 35.4	77 09 63.3	Spring	Shallow	16	Basic
16	Lahaul&Spiti	Jispa	32 38 29.2	77 11 25.1	Spring	Shallow	12	Basic
17	Lahaul&Spiti	Darcha	32 40 22.3	77 12 52.4	Spring	Shallow	9	Basic
18	Lahaul&Spiti	Urnath	32 34 05.8	77 02 39.5	Spring	Shallow	10	Basic
19	Lahaul&Spiti	Keylong	32 34 18.8	77 01 42.9	Spring	Shallow	12	Basic
20	Lahaul&Spiti	Tandi	32 33 3.5	76 59 06	Spring	Shallow	10	Basic
21	Lahaul&Spiti	Near army Camp (Gondla)	32 30 35.5	76 59 32.1	Spring	Shallow	12	Basic
22	Lahaul&Spiti	Dangal	32 34 19.6	77 01 42.9	Spring	Shallow	10	Basic
23	Lahaul&Spiti	Gondla	32 30 28.6	77 01 59.8	Spring	Shallow	8	Basic

24	Lahaul&Spiti	Swirling	32 29 25.9	77 05 21.5	Spring	Shallow	10	Basic
25	Lahaul&Spiti	Sissu	32 28 48.5	77 07 41.7	Spring	Shallow	9	Basic
26	Lahaul&Spiti	Gudbiyal	32 26 00.8	77 11 55.8	Spring	Shallow	10	Basic
27	Lahaul&Spiti	Koksar	32 24 53.8	77 14 02.9	Spring	Shallow	5	Basic+Heavy Metal
28	Lahaul&Spiti	Gramfu	32 23 17.8	77 15 58	Spring	Shallow	8	Basic
29	Lahaul&Spiti	Dorni	32 21 28.8	77 18 36.8	Spring	Shallow	12	Basic
30	Lahaul&Spiti	Chatru	32 18 48.5	77 23 00.4	Spring	Shallow	11	Basic
31	Lahaul&Spiti	ChotaDara	32 17 39.1	77 31 24.1	Spring	Shallow	6	Basic+Heavy Metal
32	Lahaul&Spiti	Chatru	32 19 11.2	77 22 19.0	Spring	Shallow	8	Basic

All the collected samples are to be analyzed at chemical laboratory of CGWB, North Western Himalayan Region, Jammu, (J&K), by adopting Standard methods of analysis (APHA)

pH

The pH is a numerical scale which express the degree of acidity or alkalinity of solution and represented by the equation pH= $\log 1/aH^{+}= -\log aH^{+}$ or in other words pH may be defined as negative logarithmic of Hydrogen ion concentration.

Electrical conductivity

Electrical Conductivity can be defined as the ability of a solution to conduct an electric current and measured in micromhos /cm and reported at 25°C. Electrical Conductivity is a function of concentration of ions, charge and ionic mobility Electrical Conductivity is approximately indicative of ionic strength.

Chloride

Chloride is one of the most common constituent in groundwater and very stable as compared to other ions like SO_4, HCO_3, NO_3 etc.

Nitrate

Nitrate is one of the important pollution related parameter. Nitrate is the end product of the aerobic oxidation of nitrogen compounds. Mainly it is contributed by nitrogenous fertilizers, decomposition of organic matter in the soil, fixation of nitrogen by bacteria etc. Human and animal excreta may also add nitrate to water by bacterial decomposition. For drinking water maximum permissible limit of nitrate is 45 mg/l as per BIS 1991-Rev-2007.

High concentration of nitrate causes infant methaemoglobinaemia (Blue baby disease).Very high concentration of Nitrate causes gastric cancer and affects central nervous and cardiovascular system.

Fluoride

Fluoride is an important water quality parameter for accessing the water quality for drinking purpose. Fluoride is more abundant than chloride in the igneous and as well as sedimentary rocks. Fluoride differs from other halogen members due to high electronegative character.

Calcium

The calcium is a major constituent of various rocks. The precipitates (limestone) contain about 27.2% of calcium ions. It is one of the most common constituent present in natural water. Calcium minerals associated with sodium, aluminium, silica, sulphate, carbonate and Fluoride. Maximum permissible limit for calcium is 200 mg/l (Fig-2.25).

Magnesium

Magnesium is the 8th most abundant element in the solar system. It is available in various rocks .The maximum concentration of Magnesium, 4.53 % is found in the evaporates of sedimentary rocks. The concentration of Magnesium in natural water is mainly controlled by dissolved CO_2.

The concentration of Magnesium in springs, Ground Water Aquifers (Shallow & Deep) are within the maximum permissible of BIS (100 mg/l) for drinking water.

Sodium

Sodium is the abundant of the alkali element in the earth's crust. Most of the Sodium occurs in the Feldspars, Mica, amphiboles and Pyroxenes.

Potassium

Potassium in sedimentary rock is more abundant than Sodium. The main potassium minerals containing silicates are Orthoclase, micas. Evaporate beds may contain potassium salts.

Total Hardness (TH)

High concentration of carbonates, bicarbonates of calcium and magnesium, in ground water causes hardness. It causes scaling in water supply lines. High concentration of hardness in ground water is social economic problem; hence it is also an important water quality parameter. Hardness of water is the capacity to neutralize soap and is mainly caused by carbonates and bicarbonates of calcium, magnesium.

The results of chemical analysis of water samples collected during study are awaited from Chemical Lab, NWHR, Jammu. The results and spatial distribution thereof will be updated in the report as soon as the results are received.

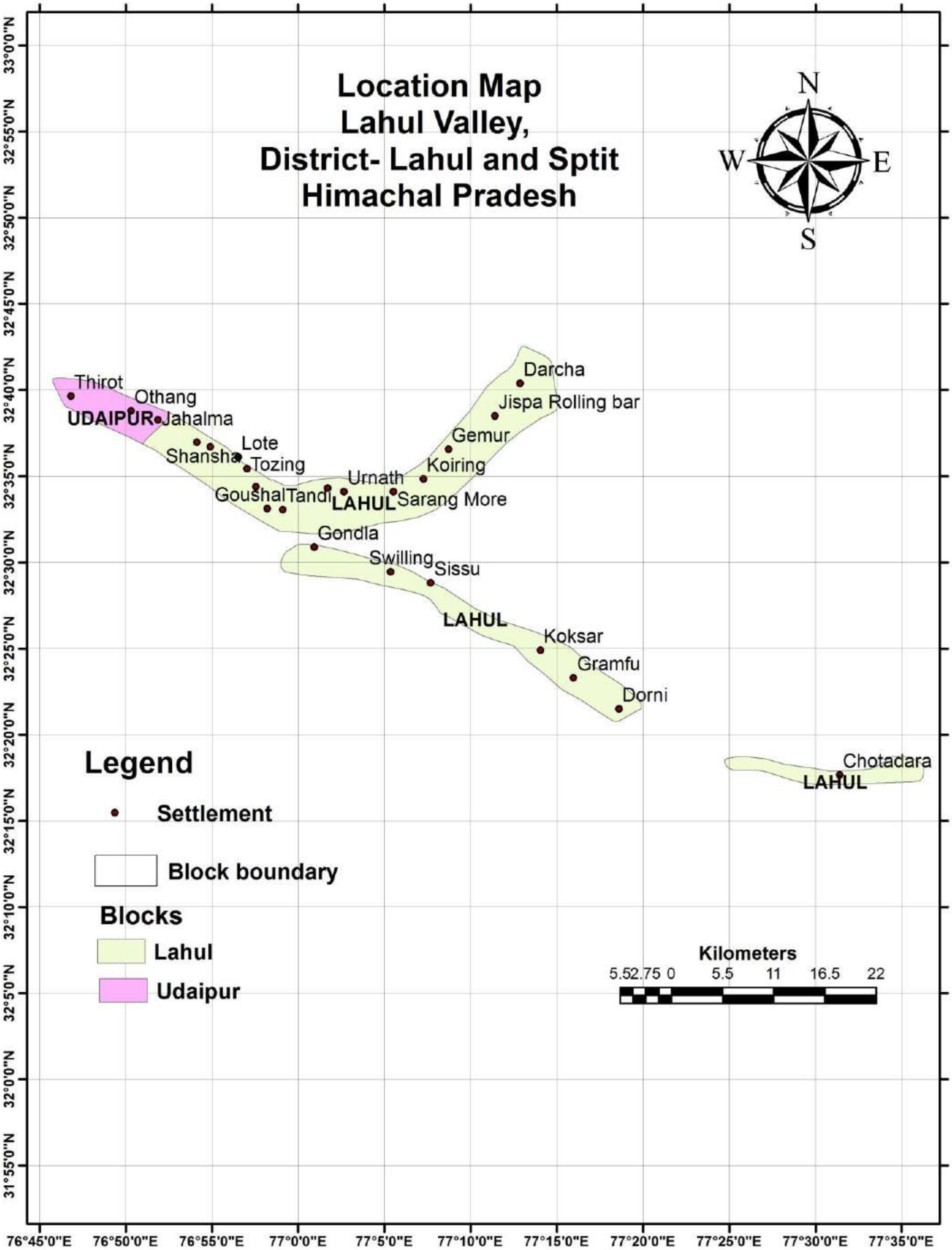


Fig. 22: Locations of Springs in study area.

3.4 Geophysical Data:

The objectives of geophysical surveys were

- ❖ To ascertain sub-surface information and aquifer deposition up to 300m depth in softrock and 200m depth in hard rock,
- ❖ To provide detailed site-specific recommendations based on survey results for drilling or not-drilling the boreholes at the sites proposed and given for the survey, and also,
- ❖ To provide tentative aquifer water quality inferred from VES interpretation.

3.4.1Geophysical Investigations

The surface geophysical methods sense the subsurface remotely. Therefore the depth and dimension of the subsurface target, its position with respect to the sensor at the surface, physical property contrast of the target with the surrounding and scale and orientation of measurement controls the response. The resolution reduces with depth and to obtain a resolvable response from deeper target, it is also necessary that the deeper target has distinct resistivity contrast and an adequate dimension. To reduce the ambiguities, constrain the interpretation and enhance precision, it is necessary to design the data acquisition procedure to a possible extent which could sense the variations in physical properties of the deeper target and the surrounding. The incongruity in data acquisition and the target character brings in non-uniqueness in inversion and thus ambiguity creeps in hydrogeological transformation of geophysical response. Coming out with a positive solution satisfying the conditions is quite a difficult geophysical task and hence the approach becomes a complex geophysical endeavour. For example, to estimate the weathered zone thickness a vertical electrical sounding with conventional current electrode spacings is adequate, but to qualitatively estimate the depth of saturated fractured zone aquifers, a close spacing observation is essential, and even that too may not suffice to yield the desired results. Thus, the success in geophysical investigations for weathered and fractured zone aquifer mapping in hard rocks depends on a number of factors. They are

- Local terrain and hydrogeological conditions vis-a-vis point of demand,
- Approachability to the area/site for survey, cultural noise, scale and quantum of measurements,
- Geophysical method and technique used and their inherent limitations, and
- Standardization of geophysical parameters and defining the geophysical signatures for hydrogeological transformation

The geophysical exploration method of electrical resistivity, having direct bearing on the presence of groundwater, has been used widely in hard rock, to identify the weathered zone and saprolite, their thicknesses and aquifer characteristics, depth to compact formation, saturated fractured zones, their lateral extension and orientation and other structures like basic dyke and quartz reef controlling the groundwater conditions and delineation of granular zones and clays. In Deccan Trap basaltic terrain having a good number of stacked basalt flows it is used to delineate the weathered zone, vesicular and fractured basalts and the massive basalts. However, as already mentioned, it is extremely difficult to delineate the deeper relatively less resistive saturated fractured zones, which are hardly a metre thick and surrounded by highly resistive compact rock and the productive vesicular and fractured basalts underlying the massive basalts. In soft rock the method is used to delineate the granular aquifers and the clays. The method is also used to qualitatively assess the aquifer water quality in terms of salinity. In the present investigation, Vertical Electrical Sounding (VES) technique of resistivity method was used to delineate the aquifers. It is explained below.

3.4.2 Vertical Electrical Sounding (VES)

The Vertical Electrical Soundings (VES) were carried out using Schlumberger configuration (Figure 21). The only modification made in sounding data collection was to increase the current electrode spacings at a smaller increment of 5 m up to AB/2:100 m, increment of 10 m up to AB/2 : 200 m and there after it was 20 m and the potential electrode spacing was increased at the minimum to avoid static shifts. In general where there is no space constraint, the VES were spread in strike direction of the formation or structure. The curves were interpreted for the layered-earth model as well as for fracture depth determination using empirical methods of 'current increase', 'curve –break' and 'factor-method' wherever required.

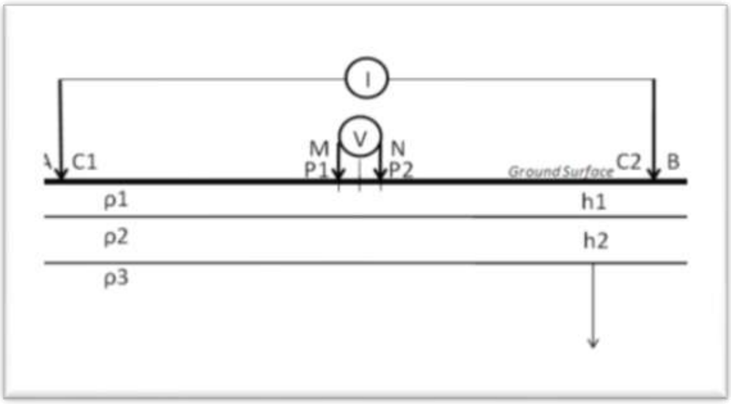


Figure 25: The Schlumberger configuration of collinear electrodes used for conducting vertical electrical sounding (VES). AB separation is increased in a sequence of close increments up to 600 to 1000 m. MN collinear with AB is kept fixed at the centre of the configuration at a maximum spacing of AB/5. MN is changed when the potential values measured are too low for the instrument.

3.4.3 Field Procedure

The maximum current electrode spacing (AB) used was 600 to 700 m for the Schlumberger configuration of electrodes. The VES were carried out using indigenous instruments CRM AUTO-C 500 Resistivity Meter, Pune. In Schlumberger VES, the potential electrodes symmetrically placed at the centre of configuration with a spacing equal to 1/5th the current electrode spacing are kept fixed and the measurements are made by successively increasing the current electrode spacing to increase the depth of investigation. The potential electrode spacing is increased when the potential value drops substantially compared to the measurement accuracy of the instrument. The apparent resistivity values for each current electrode spacing is calculated by multiplying the resistance 'R' (δV/I) by Geometric Factor for that current and potential electrode spacings of Schlumberger configuration. The apparent resistivity values thus obtained with increasing values of current electrode separation are plotted as graphs and interpreted to estimate the thickness and resistivity of the sub-surface layers.

3.5 VES Data Processing and Interpretation

Vertical Electrical Sounding (VES)

The VES field curves comprise apparent resistivity (ρa) values plotted against half current electrode separations (AB/2) on 62.5 mm double-log transparent graph paper. The distorted curves, if any, were smoothened manually. The quantitative interpretation of VES field curves to determine the thickness and resistivities of the sub-surface layers is done at two stages. First it is manually interpreted and then the curves are interpreted on computer by IX1D software using the layer model generated through manual interpretation as initial guess. The curves can also be interpreted directly using Occam's inversion and few-layer inversion schemes. For the present study computer based direct inversion was adopted. The techniques of inversion of VES using the computer software are described below.

Computer Based Inversion

This method is based on computer based technique, which provides more flexibility to compare different scenarios. In this method, sounding data are analyzed with computer based automatic iterative curve fitting technique. It is a forward and inverse modeling program for interpreting resistivity sounding data in terms of layered earth (1D) model. The field VES data as apparent resistivity (pa) versus spacing (AB/2) and an initial guess model of layer parameters obtained from manual interpretation are entered. The curve generated from guess model is compared with the field curve. In case the field curve and the computer generated curve based on guess model are not matching with RMS difference value more than 5%, the layer parameters of the guess model are automatically modified to get the best fit within the defined RMS value. It is an iterative process and continues till a satisfactory fit is obtained. The method is also used for forward modeling to generate synthetic VES curves from borehole electrical resistivity log data. It is used to assess the types of field VES curve expected from the area and also the limitations of VES in resolving the layers under prevailing subsurface conditions in the area. Generally the resistivity log presents a large number of layers. Therefore, selected sequence of layers observed in the log is combined through computation of transverse resistance and longitudinal conductance and a mean resistivity for the combined layer is obtained. Since computation of true resistivity from log is a tedious process, for small diameter borehole and fresh water formations, the 64” Normal apparent resistivities against the layers are taken as the true resistivities for computation of combined-layer mean resistivities. In this way the log is reduced to ‘few-layer’ model. The resistivity of surface layer which is not obtained from log is taken from nearby field VES. The synthetic VES curve is generated from the ‘few-layer’ model so obtained from the log. The synthetic curve is compared with
the smoothened VES field curve and if matches satisfactorily with RMS difference within limit (less than 5%), the log generated layer model are correlated with the field VES generated layer model and the litho units encountered in the borehole are assigned with the resistivity ranges obtained from VES. The layer resistivities obtained from VES are weighted average and also the general direction of current flow is different from logging, therefore VES generated model need not always match with the layer model obtained from log data. For the present study the computer based interpretation was done using IX1D v3 software from Interpex Ltd. (Golden, Colorado, USA). The static shifts in the VES curve segments for shorter and longer potential electrode spacing were considered while using the software. The inversion was carried out through ridge regression technique. For smooth model eneration Occam’s inversion was used. For direct inversion, i.e., automatic estimation of layered model, Koefoed’s approach was applied. It is worth mentioning that the geoelectrical layer interfaces thus obtained need not always match with the hydrogeological or geological layer interfaces. The major problem encountered in interpretation was of transitional resistivity and equivalence. The transition from weathered zone to saprolite and then the compact formation is characterized by a transitional increase in resistivity with depth without clear cut indication of resistivity interfaces in the VES curve. In such cases, where such transition was expected, a layer with intermediate resistivity was introduced, obviously after studying the nearby VES and *priori* local hydrogeological information. The equivalence occurs in the intermediate relatively thin geoelectrical layers. Equivalence means that the thickness and resistivity of the intermediate geoelectrical layer(s) can be changed over a certain range without noticing any change in the VES curve. This indicates that an intermediate layer can be assigned several combinations of thickness and resistivity within a certain range and hence the interpretation becomes non-unique. The equivalence problem cannot be removed without the support from other geophysical methods. It can be minimized using local hydrogeological information. The provision of equivalence analysis provided by IX1D software after multiple iterations was used to determine the range of intermediate layer parameters wherever found necessary. A point to be noted is that in hard rock areas, while conducting VES, once the compact formation or bed rock is sensed with increasing AB/2, the VES curve starts showing a 45^{o} positive slope with abscissa and for further increase

of current electrode spacing, the same slope continues. From the VES curve segment with 45° slope no further information on layering can be extracted for the layered earth interpretation. In such a situation, providing precise layered-earth information up to 200 m depth by increasing the spread of VES becomes unrealistic, except that the compact resistive formation continues to depths.

Fractured Zone Identification from VES

Besides the layered earth interpretation, the VES were interpreted for fractured zone identifications using curve break and factor methods. The reduction in resistivity gradient between a pair of consecutive AB/2 values with increase in current input was considered as an indication of fracture presence. It was proved at a few VES locations. For this the conventional resistivity meter or a constant voltage source resistivity meter is more effective. In case of constant current source resistivity meter, the increase in current input is not effectively picked up. For factor analysis of the curve, the ratio of the apparent resistivity at a particular AB/2 to the sum of apparent resistivities of the preceding AB/2s is computed and plotted at that AB/2. The flat portion of the factor curve indicates the presence of fractured zones. A commonality in the occurrence of the breaks or kinks in the VES curve and flat factor curve supports the presence of fractured zone. It is mostly effective for AB/2 less than 100 m. However, in the present investigation the analyses were made up to 200 m AB/2. To use these empirical methods two points are essential. They are: the VES measurement has to be with smaller increment in current electrode spacing and with minimum number of shift or no shift of potential electrode positions. Both these were attempted for the present investigation.

4.0 GROUND WATER RESOURCES

Rainfall/ Snowfall is the major source recharge to the groundwater body apart from the influent seepage from the rivers, irrigated fields and inflow from upland areas. The discharge from ground water mainly takes place from wells and tube wells; effluent seepages of ground water in the form of springs and base flow in streams.

The Valley has a hilly terrain having very high slopes. The valley areas are deep, narrow and isolated. The areas therefore not considered for estimation of the ground water resources due to their discontinuous aquifer systems.

4.1 Status of Ground Water Development

The major chunk of demand for domestic and irrigation use is fulfilled by means of either spring or nallah sources. Most of these sources are perennial with low to moderate seasonal fluctuation. At places they are tapped by the irrigation department for implementing water supply schemes.

Ground water exploration has not been carried out by CGWB in the district because of hard approachability for the heavy machinery. However state Irrigation department has drilled number of shallow bore wells fitted with hand pump in various parts of the district for domestic use. The depth of these bore wells ranges between 100 to 200 feet. At places where the discharge is sufficient, depending upon the need, they are energized. These handpumps are installed in hard rock hilly terrain and also along the river valleys.

5.0 GROUND WATER MANAGEMENT STRATEGY

5.1 Ground Water Development

The district being hilly & mountainous, traditional sources of ground water mainly springs has played a major role since past in providing assured irrigation and water supply. These include the nallas, springs. In some of the areas, at present too these are the only sources for the water of the settlements. However modern means for tapping the ground water have been employed in recent years.

During the last 15-20 years, Irrigation and Public Health Department has constructed number of small depth bore wells fitted with handpumps in these areas. High hill ranges occupy more than 95 % of the area of the district. During the very past years, the traditional ground water source has served the settlements. Ground water development on small scale is seen in the valleys areas particularly in the Lahaul and Spiti valley. Handpumps have been installed in these areas and are energized for the water supply. There exists a scope to explore the potentialities of rest of the areas for ground water in low lying valley areas. The hilly area of the district is feasible for only drilling shallow to medium depth bore wells.

5.2 Water Conservation & Artificial Recharge

Ground water extraction through springs and hand pumps are the major sources of water supply, but the availability of water during summer is limited particularly in lean periods and requires immediate attention to augment the ground water resource. Based upon the climatic conditions, topography, hydrogeology of the area, suitable structure for rain water harvesting and artificial recharge to ground water are required. Proper scientific intervention for spring development and revival is required in water scarce areas. In the hilly areas, roof top rainwater harvesting structures like storage tanks are recommended while in low hill ranges, check dam and roof top rainwater / snow harvesting structures can be adopted.

6.0 GROUND WATER RELATED ISSUES

1) High degree of rainfall runoff

    - Due to sloping topography of the areas, type of soil, concentrated period of rainfall, most of the precipitation is lost as surface runoff without significant contribution to infiltration. The entire district is hilly and mountainous and comes under the rain shadow area of Himalaya. In such hard rock terrain, since the aquifers are discontinuous and of different geological/ hydro geological setup, the ground water scenarios are different in various parts of the districts.

2) Drying of Springs

    - Majority of the springs in the area are losing discharge, especially during lean season. The man culprit behind drying of springs is Energization nearby groundwater abstraction structures to cope with the increasing demand, Change in land use pattern in the watershed as well as recharge area of he springs and ecological degradation caused by human activities.

3) Low Stage of Ground Water Development

    - Ground water development in study areas is very low. It is mainly due to reason that groundwater potential in the area is low to moderate.

7.0 AQUIFER MANAGEMENT PLAN

An outline of the Aquifer Management Plan includes details regarding population, rainfall, average annual rainfall, agriculture and irrigation, water bodies, ground water extraction and water level behavior.

Plans for Sustainable Management of the Resource

Broad outline of management plan is as follows:

Sr. No	GW Related Issues in Area	Suggested Solution
1.	Low Groundwater Potential	Check runoff thorough various surface storage type recharge structure
3.	High Degree of Runoff	Surface water storage structures i.e. dams/ponds, NB, Gabions structures etc,
4.	Drying of Springs	A program similar to Dhara Vikas Spring Rejuvenation in Sikkim, India
5	Low Stage of Groundwater Development	Promoting Irrigation through TW/DW in valley areas/ potential zones

For sustainable ground water management in area, following additional suggestion should also be considered:

- The lahaul Valley falls under the shadow zone of Himalayan ranges and remains cut from other parts of the country from November to April because of Heavy snowfall. The climate of the area is arid cold to semi arid.
- The valley is drained mainly by Bhaga and Chandra rivers which meets at Tandi to form Chandra Bhaga river. In Jammu & Kashmir this river is known as Chenab River. Main tributaries to this area Milang, Jhankar, Beling lengpa, thirat & Shansha rivers. All these rivers flow from snow melt.
- The Geology of the Lahaul valley is fairly complicated. Predominant formations belong to Precambrian consisting of schist, phyllites, slates, quartzite, limestone etc.
- In general the thickness of glacio-fluviatile sediments is very much limited with thickness ranging upto 100m. these formations occur as discontinuous valleys along the streams varing in width from 0.00 to 3.00 Km. these valley fills are most suitable for the development of ground water through either open well or tubewells.
- In the area, irrigation requirement is only for a limited period of about four months. When abundant snow melt is available through gravity in plenty for the irrigation purpose. During the rest of period valley remains covered by snow and cut off from rest of the country. Perpetual snow cover exists as glaciers.
- The spring water and snow fed water streams for irrigation purposes has two main problems mainly turbidity and low temperature.the cold natures of water affects the fertilization of seeds. for this very reason this water

is generally stored in tanks and afterwards it is applied for irrigation water after warming it. To over come this problem

- There is need to protect traditional water harvesting structures like ponds, tanks, talavs to utilized these for rain water harvesting and recharging shallow aquifers.
- In hilly and mountainous terrain, traditional ground water sources viz., springs, *bowries* etc needs to be developed and protected for better health and hygiene with proper scientific intervention.
- Proper development of springs is essential as it is observed that most of the spring in the district does not have collection chamber or tanks from where water can be distributed under gravity. The objective of spring development should be to collect the flowing water underground, to protect it from surface contamination and store it in sanitary spring box for supply. Similarly, seepage springs along hill sides also need to develop for harnessing ground water in such areas.
- Roof top rainwater harvesting practices can be adopted in hilly areas and urban areas, since the district receives fair amount of rainfall. Construction of roof top rain water harvesting structures should be made mandatory in all new construction and rain water harvesting in rural areas should be promoted. Traditional water storage systems need to be revived.
- People's participation is a must for any type of developmental activities. So proper awareness for utilization and conservation of water resources is required.
- Constrictions of bore well near to spring source in hilly area should be avoided as this could lead to drying of the natural water sources.
- Recharge structures feasible in hilly areas are check dams, Gabion structures and staggered contour trends at suitable locations.

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