केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

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

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

Kala Amb Valley, Sirmour District Himachal Pradesh

उत्तरी हिमालयी क्षेत्र, धर्मशाला

Northern Himalayan Region, Dharamshala

केंद्रीय भूमि जल बोर्ड,

जल संसाधन नदी विकास और गंगा संरक्षण विभाग,

जल शक्ति मंत्रालय,भारत सरकार

Central Ground Water Board,
Department of Water Resources, River Development and Ganga Rejuvenation,
Ministry of Jal Shakti, Government of India

काला अंब घाटी, जिला सिरमौर की

जलभृत मानचित्रण एवं प्रबंधन योजना

हिमाचल प्रदेश

Aquifer Mapping & Management Plan in Kala Amb Valley of District Sirmour Himachal Pradesh

उत्तरी हिमालयन क्षेत्र, धर्मशाला

Northern Himalayan Region, Dharamshala

काला अंब घाटी, जिला सिरमौर की जलभृत मानचित्रण एवं प्रबंधन योजना, हिमाचल प्रदेश

Aquifer Mapping & Management Plan in “Kala Amb Valley” of District Sirmour, Himachal Pradesh

केन्द्रीय भूमिजल बोर्ड/**Central Ground Water Board**

उत्तरी हिमालयन /**Northern Himalayan Region**

जल शक्ति विभाग/**Ministry of Jal Shakti**

जल संसाधन, नदी विकास और गंगा सरंक्षण विभाग

Department of Water Resources, River Development & Ganga Rejuvenation

June 2022

कार्यकारी सारांश / **Executive Summary**

हिमाचल प्रदेश उत्तर भारत के प्रमुख पहाड़ी राज्यों में से एक है और पश्चिमी हिमालय का हिस्सा है।जलभृत मानचित्रण अभ्यास का प्राथमिक उद्देश्य "अपने जलभृत को जानो, अपने जलभृत का प्रबंधनकरो" के रूप में अभिव्यक्त किया जा सकता है।वार्षिक कार्य कार्यक्रम 2012-13 के तहत हिमाचल प्रदेश के कांगड़ा-चंबा के कुछ हिस्सों में जलभृत मानचित्रण अध्ययन किया गया।ये सर्वेक्षण अन्वेषणात्मक ड्रिलिंग, गुणवत्ता के साथ जल स्तर की निगरानी, वसंत निगरानी (निर्वहन और गुणवत्ता), पंपिंग परीक्षण, घुसपैठ परीक्षण के साथ-साथ गुणवत्ता और मात्रा के संदर्भ में भूजल घटना, उपलब्धता और उपयोग के परिदृश्य पर जानकारी को एकीकृत करने के लिए किए जाते हैं। यह प्रतिवेदन अध्ययन क्षेत्र के झरनों, हैंडपंपों और सतही जल के भूजल परिदृश्य को सामने लाता है, जो पीने का मुख्य स्रोत है और वैज्ञानिक तरीके से भूजल के बेहतर प्रबंधन योजना का सुझाव देता है।

रिपोर्ट का कार्यकारी सारांश इस प्रकार है:

- अध्ययन क्षेत्र (पोंटा घाटी और काला अंब घाटी, 793 वर्ग किमी) सिरमौर जिले में पड़ता है जिसे एएपी 2015-16 से एक्वीफर मैपिंग अध्ययन के लिए लिया गया है। काला अंब घाटी 81 वर्ग किमी के क्षेत्रफल में 30°29.5'N और 30°37'N अक्षांश और 77°07'E और 77°10'E देशांतर के बीच आती है।
- एएपी 2015-16 में, कला अंब घाटी के लिए एक्वीफर मैपिंग के तहत अध्ययन किया गया था, जिसमें 81 वर्ग किमी क्षेत्र शामिल है, जिसमें केवल 2.5 वर्ग किमी घाटी क्षेत्र है, शेष क्षेत्र पहाड़ी क्षेत्र है।
- यह क्षेत्र तीनों प्रकार की भूआकृति विज्ञान में समान रूप से विभाजित है। क्षेत्र का पांवटा घाटी भाग पेडी मैदानों के अंतर्गत आता है। काला अंब घाटी अनाच्छादित पहाड़ियों से आच्छादित है। प्रमुख वन क्षेत्र संरचनात्मक पहाड़ियों के अंतर्गत है।
- मारकंडा और घग्गर नदी काला अंब क्षेत्र की जल निकासी बनाती है
- काला अंब क्षेत्र का लिथोलॉजी मुख्य रूप से शिवालिक बलुआ पत्थर से बना है। उत्तरी भाग शिवालिक शैलों से बना है। 2.5 वर्ग किमी क्षेत्र हाल के जलोढ़ से बना है
- पांवटा घाटी का डिजिटल एलिवेशन मैप 335 amsl से 1518amsl तक की ऊंचाई को दर्शाता है। उत्तरी भाग को छोड़कर अधिकांश क्षेत्र नीचा है। काला अंब घाटी 342 से 812 मीटर एएमएसएल दिखा रही है। अधिकांश क्षेत्र उच्च एमएसएल 408 मीटर से अधिक एमएसएल में गिर रहा है,
- खड़ी ढलानों वाले पहाड़ी और पहाड़ी हिस्से मुख्य रूप से अपवाह क्षेत्र बनाते हैं और इनमें भूजल की क्षमता कम होती है। घाटी और निचले इलाकों में, गैर-समेकित/अर्ध-समेकित संरचनाएं अच्छे संभावित जलभृत बनाती हैं।

- वर्तमान में काला अंब उद्योगों के लिए एक उभरता हुआ शहर है क्योंकि यह कागज, धातु, रसायन, धागा मिलों और एयर-कंडीशनर के लिए उत्पादन इकाइयों की मेजबानी करता है;
- 81 वर्ग किमी का अध्ययन क्षेत्र भूविज्ञान के आधार पर दो जल भूवैज्ञानिक इकाइयों में हो सकता है।
- गैर-समेकित/घाटी भरण, जो लगभग 2,5 वर्ग किमी का होता है, मध्यम से उच्च उपज देता है, केवल उन घाटी क्षेत्रों को छोड़कर जहां मिट्टी की प्रधानता होती है, जो 10-15 लीटर उपज देती है। शेष क्षेत्र जो अर्ध-समेकित है, में शिवालिक बलुआ पत्थर शामिल है, जो क्षेत्र के प्रमुख भाग को कवर करता है। इन क्षेत्रों में यिल्ड अधिक है, यदि नदी के निक्षेपों से अधिक बोझ है, जो की लगभग 15 lps,के आस पास बनती है
- जिला सिरमौर में एनएचएस निगरानी स्टेशनों की संख्या 13 है, जिनकी भूजल स्तर और गुणवत्ता के लिए नियमित रूप से निगरानी की जा रही है, जिनमें से केवल 2 काला अंब घाटी में पड़ता है।
- सीजीडब्ल्यूबी द्वारा घाटी के हिस्से में नेशनल हाइड्रोग्राफ मॉनिटरिंग स्टेशन तय किए गए हैं। जल स्तर की गहराई अधिक भिन्नता नहीं दिखाती है। प्री-मानसून अवधि (मई 2014) के दौरान यह अगस्त 2015 में 2.00 से नीचे से 20.00 मीटर बीजीएल से अधिक नहीं होती है, गहराई से जल स्तर परिदृश्य में बहुत अधिक अंतर नहीं होता है।
- जल स्तर और समय और स्थान के संबंध में उसके व्यवहार को जानने के लिए गहरे जलभृत के लिए पीजोमीटर के जल स्तर का विश्लेषण किया गया। यह आंकड़े सिंचाई एवं जन स्वास्थ्य विभाग, हिमाचल प्रदेश सरकार से प्राप्त हुए हैं। स्वचालित जल स्तर रिकॉर्डर से कुल 10 पीजोमीटर की निगरानी की गई है। दिखाया गया जल स्तर गहरा है, 60m . से अधिक दिखाया गया है
- अध्ययन क्षेत्र में पानी की गुणवत्ता को समझने के लिए विभिन्न स्रोतों जैसे खोदे गए कुओं, नलकूपों और हैंडपंपों से नमूने एकत्र किए गए। NAQUIM के दौरान खोदे गए खोजी कुओं से पानी के नमूने भी एकत्र किए गए थे। सभी का विश्लेषण रिज़ल्ट पेरमिससीबले लिमिट्स के अंदर ही पाया गया।
- राष्ट्रीय जलभृत मानचित्रण कार्यक्रम के तहत, हिमाचल प्रदेश के 10 जिलों में भूभौतिकीय प्राथमिक डेटा उत्पादन वैपकोस लिमिटेड को सौंपा गया था। जिला सिरमौर में, वैपकोस ने विभिन्न स्थानों पर 22 वीईएस किया है।
- अध्ययन क्षेत्र में घाटी क्षेत्र/औद्योगिक क्षेत्र 2.5 वर्ग किमी है। 2011 से 2.5 वर्ग किमी का क्षेत्र ओई है। शेष क्षेत्र पहाड़ी है और ढलान> 20% है, कोई संसाधन

अनुमान नहीं किया गया है। भूजल निर्वहन / अमूर्त> पुनर्भरण। गहरा जलस्तर, नलकूप जलस्तर कम होने के कारण खराब हैं।

- जलवायु परिस्थितियों के आधार पर, क्षेत्र की स्थलाकृति, जल-भूविज्ञान, वर्षा जल संचयन के लिए उपयुक्त संरचना और भूजल के कृत्रिम पुनर्भरण की योजना और कार्यान्वयन की आवश्यकता है।
- कुल ड्राफ्ट और कुल GW उपलब्धता के 70% के बीच का अंतर 2.94 MCM है जिसके लिए पुनर्भरण संरचनाओं को लिया जाना है
- 13 स्थलों पर पुनर्भरण संरचनाओं की पहचान प्रस्तावित की गई थी, जो 0.25 एम.सी.एम. पानी का पुनर्भरण कर सकती हैं।
- काला अंब एक औद्योगिक शहर है और इसमें बहुत सारे उद्योग हैं। प्रत्येक उद्योग में बहुत बड़ा छत क्षेत्र है। इसलिए, उद्योगों को अपने परिसर में पुनर्भरण संरचनाओं का निर्माण करके छत के वर्षा जल को संचय करने के लिए निर्देशित किया जा सकता है क्योंकि क्षेत्र में उचित मात्रा में वर्षा होती है।
- घरेलू उपयोग के लिए पहाड़ी की चोटी पर रहने वाले लोगों की मांग को पूरा करने के लिए छत पर वर्षा जल संचयन को प्रभावी ढंग से अपनाया जा सकता है।
- स्प्रिंग शेड क्षेत्र ,पहाड़ी क्षेत्रों और शहरी क्षेत्रों में छत के ऊपर वर्षा जल संचयन प्रथाओं को अपनाया जा सकता है, क्योंकि जिले में उचित मात्रा में वर्षा होती है। सभी नए निर्माणों में छत पर वर्षा जल संचयन संरचनाओं का निर्माण अनिवार्य किया जाए और ग्रामीण क्षेत्रों में वर्षा जल संचयन को बढ़ावा दिया जाए।
- पारंपरिक जल भंडारण प्रणालियों को पुनर्जीवित करने की आवश्यकता है। पहाड़ी क्षेत्रों में संभावित पुनर्भरण संरचनाएं चेक डैम और उपयुक्त स्थानों पर गेबियन संरचनाएं हैं।
- स्प्रिंग शेड प्रबंधन के लिए क्षेत्र विशिष्ट उपाय किए जा सकते हैं। कंटूर ट्रेंचिंग और वृक्षारोपण के लिए स्प्रिंग्स के अपस्ट्रीम कंटूर को लिया जा सकता है।
- अध्ययन क्षेत्रों के ढलानों के साथ-साथ कंटूर के साथ बंधन किया जा सकता है।
- सिंचाई और दैनिक कार्यों के लिए छोटे-छोटे खेतों में वाटर हार्वेस्टिंग टैंक बनाए जा सकते हैं। इन संरचनाओं को छत के ऊपर वर्षा जल संचयन प्रणाली या लिफ्ट सिंचाई तकनीक से संरक्षित पानी से भरा जा सकता है
- वर्षा जल संचयन और उथले जलभृतों के पुनर्भरण के लिए इनका उपयोग करने के लिए तालाबों, टैंकों, तालाबों जैसी पारंपरिक जल संचयन संरचनाओं की रक्षा करने की आवश्यकता है।
- झरनों का समुचित विकास आवश्यक है क्योंकि यह देखा गया है कि जिले के अधिकांश झरनों में संग्रह कक्ष या टैंक नहीं हैं जहां से गुरुत्वाकर्षण के तहत पानी वितरित किया जा सकता है। स्प्रिंग डेवलपमेंट का उद्देश्य भूमिगत बहते पानी को

इकट्ठा करना, सतही संदूषण से बचाना और आपूर्ति के लिए सैनिटरी स्प्रिंग बॉक्स में स्टोर करना होना चाहिए।

- ❖ क्षेत्रों में, अप्रयुक्त और परित्यक्त खोदे गए कुओं का उपयोग वर्षा जल संचयन और भूजल पुनर्भरण के लिए कृत्रिम पुनर्भरण संरचना के रूप में किया जा सकता है, जिसमें भूजल पुनर्भरण के लिए सुरक्षा दिशानिर्देश शामिल हैं।
- ❖ किसी भी प्रकार की विकासात्मक गतिविधियों के लिए लोगों की भागीदारी अनिवार्य है। इसलिए जल संसाधनों के उपयोग और संरक्षण के लिए उचित जागरूकता की आवश्यकता है।

Executive Summary

- ❖ The study area (Paonta Valley (712 sqkm) & Kala Amb valley(81 sqkm) falls in Sirmaur district which is taken up for aquifer mapping study in AAP 2015-16. The NAQUIM area of "Kala Amb valley" have only 2.5 sq km valley area, rest of area is hilly area. Study area falls between latitude 30°29.5'N & 30°37'N and longitude 77°07'E & 77°10'E.
- ❖ The area is divided in all the three types of geomorphology. The Paonta valley portion of the area comes under Pedi plains. Kala Amb valley is covered under denudational hills. Major forest area is under structural hills.
- ❖ River Maarkanda and Ghaggar makes drainage of Kala Amb area
- ❖ Lithology of Kala Amb area is mainly composed of Shiwalik sand stone. Northern part is composed of Shiwalik shales. 2.5 sq km area is composed of recent alluvium.
- ❖ Digital Elevation Map of Paonta valley shows elevation from 335 amsl to 1518 m amsl. Most of area is low lying, except the northern part. Kala Amb valley is showing 342 to 812 m amsl. Most of area is falling in high amsl, more than 408m amsl
- ❖ Hilly and mountainous parts with steep slopes mainly constitute the run off areas and have low ground water potential. In valley and low-lying areas, unconsolidated / semi-consolidated formations form good potential aquifers.
- ❖ At present Kala amb is an emerging town for industries as it hosts production units for paper, metal, chemicals, thread mills and air-conditioners;
- ❖ There are 13 Number of NHS monitoring stations in district sirmour, which are being regularly monitored for ground water level and quality, out of which only 2 falls in kala amb valley.
- ❖ The study area of 81 sq km can be divided in to two hydrogeological units on the basis of geology. Unconsolidated /valley fills, which forms about 2,5 sq km gives moderate to high yield, except the valley areas which have predominance of clay, which yields 10-15 lps. Rest of the area which is semiconsolidated comprises of shiwalik sandstone covers major part of area where yield is high about 15lps, if overburdened with riverine deposits. National Hydrograph Monitoring Stations have been fixed by CGWB, in the valley portion. The depth to water level does not shows much variation. During pre-monsoon period (May 2014) it ranges from below 2.00 to not more than 20.00 m bgl in August 2015, the depth to water level scenario does not differs much.

- To know the water level and its behaviour with respect to time and space, for deep aquifer, water level of piezometers was analysed. This data have been received from Irrigation & Public Health Department, Govt of Himachal Pradesh. A total of 10 piezometers have been monitored from automatic water level recorders. The water level shown is deeper, more than 60m.
- Samples were collected from different sources like dug wells, tube wells and handpumps, to decipher water quality in the study area. Water samples were also collected from Exploratory wells drilled during NAQUIM.
- Under National Aquifer Mapping Programme, the geophysical primary data generation in 10 districts of Himachal Pradesh was entrusted to WAPCOS Ltd. In District sirmour, WAPCOS has done VES at 22 at different places.
- The study area have valley area/Industrial area of 2.5 sq km| The area of 2.5 sq km is Over Exploited since 2011. Rest of area is hilly & slope is >20%, hence no resource estimation is being done. Deep water level, tube wells are defunct due to lowering of water level.
- Based upon the climatic conditions, topography, hydro-geology of the area, suitable structure for rain water harvesting and artificial recharge to ground water need to be planned and implemented.
- Difference between total draft & 70% of net GW availability is 2.94 MCM for which recharge structures are to be taken up.
- Recharge Structures identified at 13 sites were proposed, which can recharge 0.25 mcm water.
- Kala Amb is an industrial town and having lot of industries. Each industry is having very large roof area. Therefore, industries may be directed to harvest the roof top rain water by constructing recharge structures in their premises as the area receives fair amount of rainfall.

AQUIFER MAPPING STUDIES IN KALA AMB VALLEY OF SIRMOUR DISTRICT, HIMACHAL PRADESH.

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REPORT ON AQUIFER MAPPING STUDIES KALA AMB VALLEY OF DISTRICT SIRMAUR, HIMACHAL PRADESH.
AAP (2015-2016)

1. INTRODUCTION

1.1 Introduction of Himachal Pradesh

Himachal Pradesh is one of prominent hilly State of north India and forms part of the western Himalayas. The State has an area of 55,673 sq km. and is located between North Latitude 30° 22’ to 33° 12’and East Longitudes 75° 45’ to 79° 04’. Administratively, the State comprise 12 districts, 76 Teshils, 75 Blocks, 2922 Gram Panchayats, 2623 Villages (Uninhabitated), 57 Towns and 28 Nagar Panchayat.

Himachal Pradesh presents an intricate mosaic of high mountain ranges, hills and valleys with altitude ranging from 350 m to 6500 m amsl. Physiographically, the State is divided from south to north into the *Outer Himalayas or Siwaliks* (350 to 1500 m amsl), the *Lesser Himalayan Range* (1500-5000 m amsl), the *Great Himalayan Range* (5000-6000 m amsl) and Spiti or Tethys Himalayan Range (>6000m amsl).

The major rivers draining the State are Chenab, Ravi, Beas, Sutluj and Yamuna. Most of the rivers are snow fed and perennial in nature. The climatic conditions vary from hot to sub–humid tropical (450-900m), warm to temperate (900-2400m) and cold alpine to glacial (2400 – 4800m). The climate in Lahaul & Spiti and Kinnaur area is of semi-arid, high land type. The state has an average annual temperature of 19°C. The state receives rainfall during southwest monsoon and also during northeast monsoon in winters. The average annual rainfall of the state is 1010 mm with 62 average rainy days. Dharamshala receive the highest rainfall with 3400 mm. Both porous and fissured formations are visualized in the State.

Most of the State is hilly except some intermountain valleys viz., Indora, Nurpur, Bath, Ponta, Kala Amb, Nalagarh, Una and Hum and numerous small valleys. In valley fill areas, ground water occurs under water table and semi confined conditions and extensive ground water development by open wells and tube wells is observed. In hilly areas, springs and *baories* form the major source of water supply, particularly for domestic purpose. State Government in such areas has installed large numbers of hand pumps. In general, ground water quality in the state is good and potable. Fast developing industrial and urban clusters are most vulnerable areas for ground water pollution and require scientific intervention.

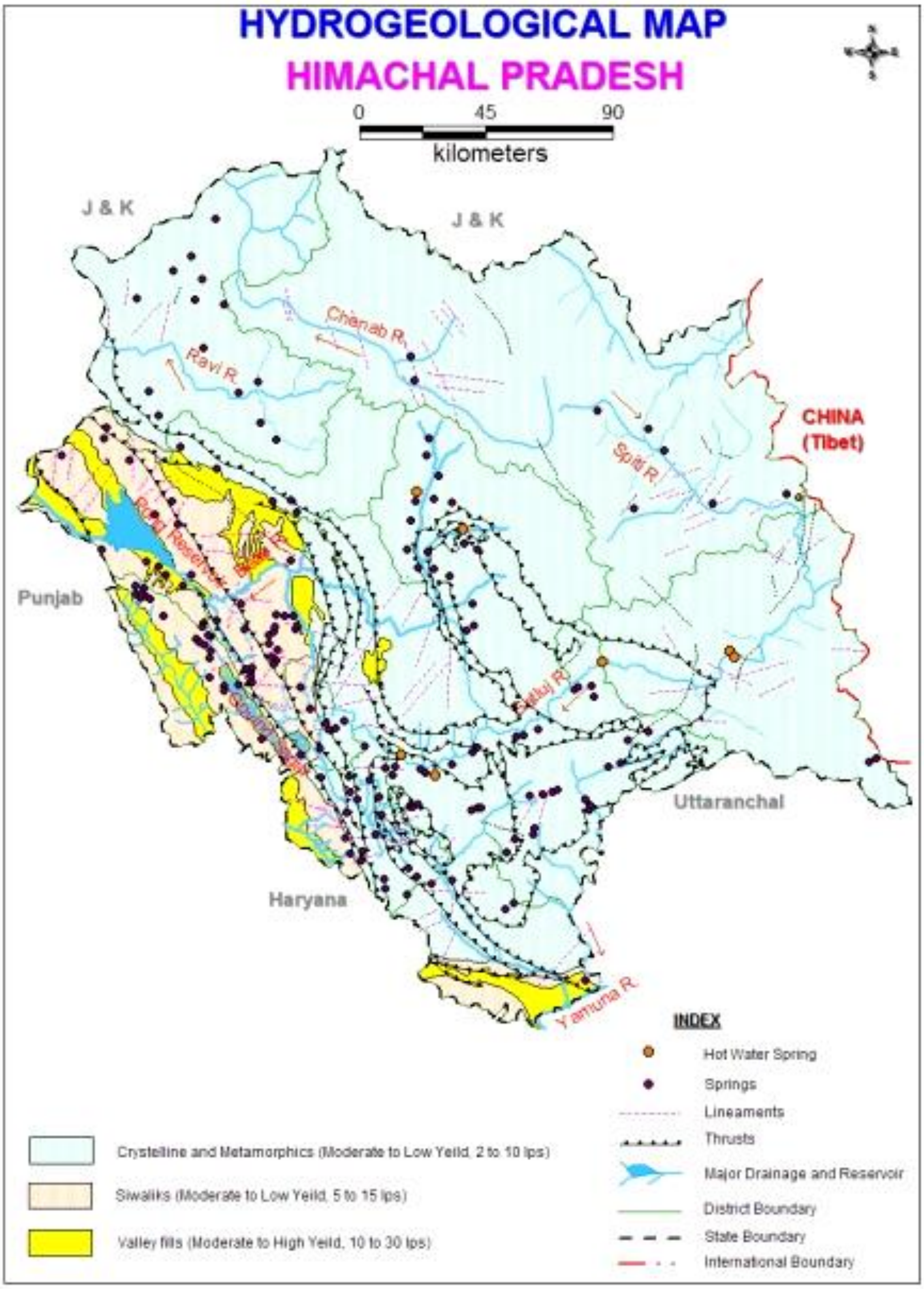


Figure 1: Map of Himachal Pradesh

1.2 Introduction to Aquifer Mapping

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.

1.3 Objectives

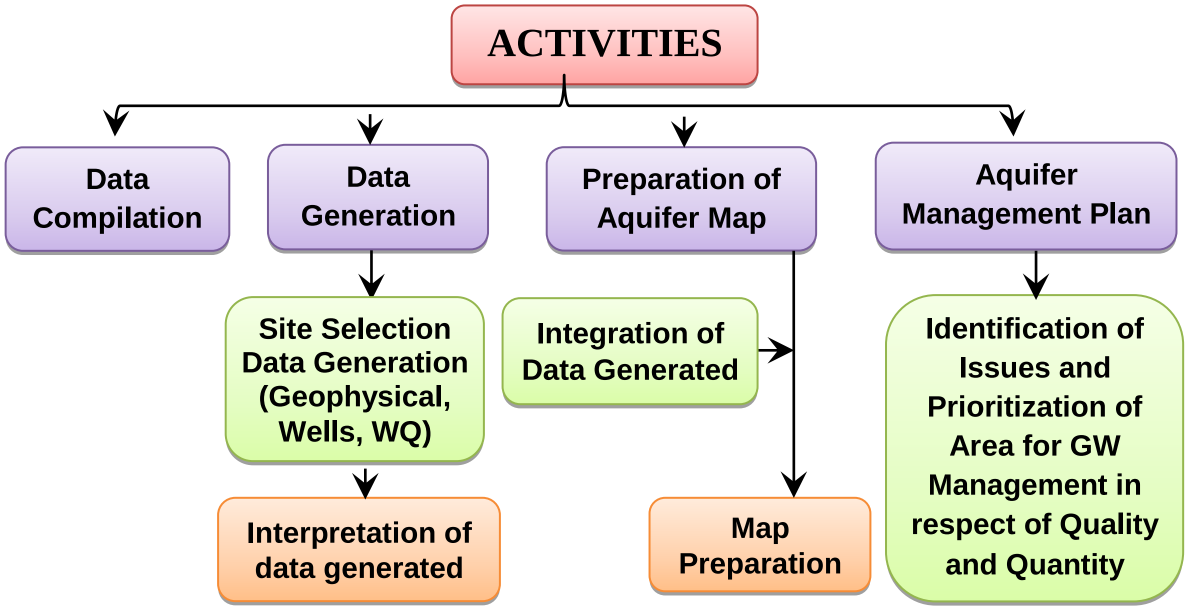
The primary objective of the Aquifer Mapping Exercise can be summed up as "Know your Aquifer, Manage your Aquifer". Demystification of Science and thereby involvement of stake holders is the essence of the entire project. The involvement and participation of the community will infuse a sense of ownership 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 participatorygroundwater management programme. The aquifer mapping approach can help integrate ground wateravailability with ground water accessibility and quality aspects.

With these aims, Aquifer Mapping Study was carried out instudy area i.e. Kala Amb & Paonta valley (81 sq km & 759 sq km) in Sirmaur district.The 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 which results in better management of vulnerable areas.

During this studyof Poanta and Kala Amb valley, in total 21 key observation wells (dugwells), 33 water sampling points & 6 springs were established. Study area of Kala Amb valley is having an area of 81sq km, in which only 2.5 sq km is valley area, which is known as Kala amb valley. Rest of area is hilly area. 3 number of NHS wells are considered for water level monitoring, in the valley. Key observation wells are established for water quality monitoring, which include dug wells and Handpumps. Subsequently, all the available data on ground water from the earlier studies are compiled and integrated with these studies. This report brings out the ground water scenario, of springs, handpumps and surface water of the study area to suggest better management plan of ground water in a scientific manner.

1.4 Methodology

Various activities of NAQUIM are as follows:



1.5 Purpose and scope

In AAP 2015-16, the study was taken under aquifer mapping for Kala Amb valley, comprising of 81 sq km area, in which only 2.5 sq km is valley area, rest of area is hilly area.

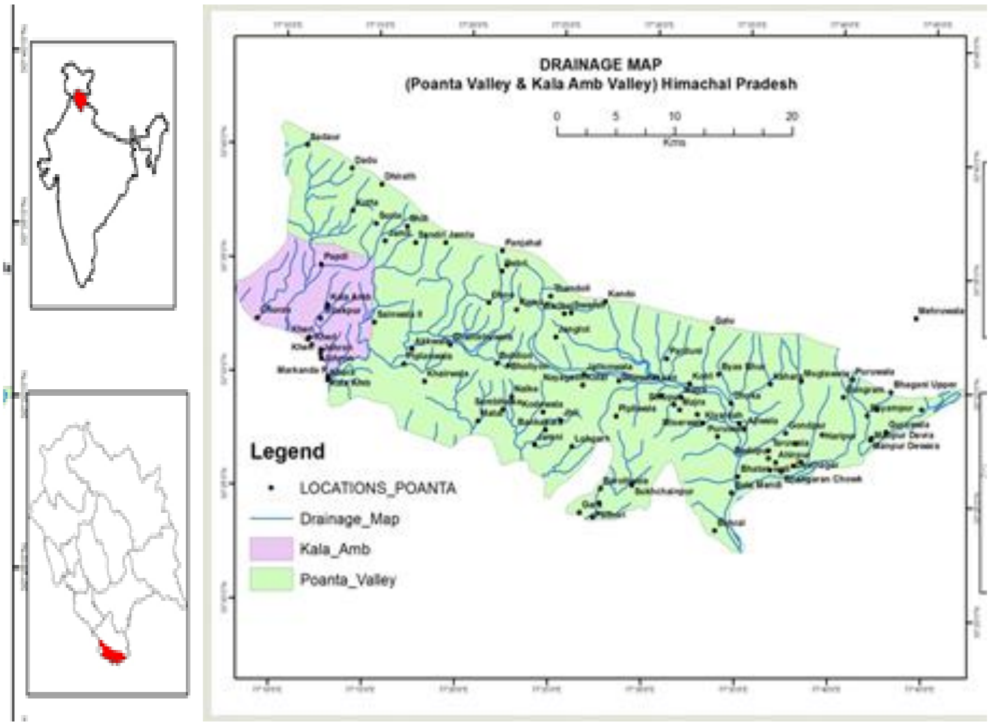


Fig2.: Bird Eye view of Study area (Kala Amb & Paonta Valley)

1.6 Location, Extent & Accessibility

Sirmaur district is one of the densely populated districts, located in the southern part of Himachal Pradesh. The district lies between the North latitude 30^{0}22’30” & 31^{0}01”20”and East longitude 77°01’12” & 77^{0}49’40” and falls in Survey of India degree sheet Nos. 53E and 53F covering an area of 2825 sq km. Sirmaur district with its head quarter at Nahan comprises of three-sub divisions, six tehsils and three sub-tehsils (Table-1 & Fig. 1). For developmental purposes, the district is divided into five community development blocks. There are 228 panchayats and 968 villages in the district.

Table 1.1: Administrative Divisions, District Sirmaur

Sub division	Tehsil	Sub-tehsil	Towns
Nahan	Nahan		Nahan
PaontaSahib	PaontaSahib		PaontaSahib
Rajgarh	Puchad	Nohra	
	Rajgarh	Ronhat	Rajgarh
	Renuka	Dadahu	
	Shalai		

1.7 Administrative Divisions and Demography

The study area (Paonta Valley & Kala Amb valley, 793 Sq. Km) falls in Sirmaur district which is taken up for aquifer mapping study since AAP 2015-16. The Kala Amb valley having an area of 81 sq. km falls between latitude 30°29.5’N & 30°37’N and longitude 77°07’E &

77°10'E. The area is selected for aquifer mapping as maximum population settled in valley area and ground water level is declining as Kala Amb valley has already reached in over exploited stage, as per Ground water resource estimation of Kala Amb valley.

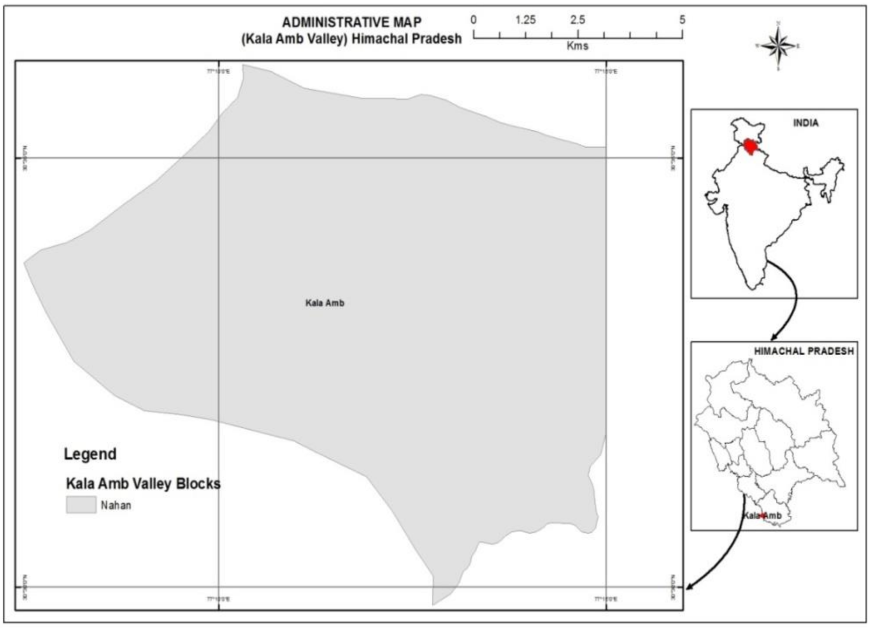


Fig:3 The Administrative Division of the Kala Amb Valley, District Sirmaur

1.8 Geomorphology

The geomorphological map was interpreted from survey of India topographic sheets and IRS P6 LISS - IV satellite imagery. The geomorphic units as below

The area shows mainly 3 types of geomorphology

- Denudational Hills
- Pediplains
- Structural Hills

The area is equally divided in all the three types of geomorphology. The Paonta valley portion of the area comes under Pedi plains. Kala Amb valley is covered under denudational hills. Major forest area is under structural hills.

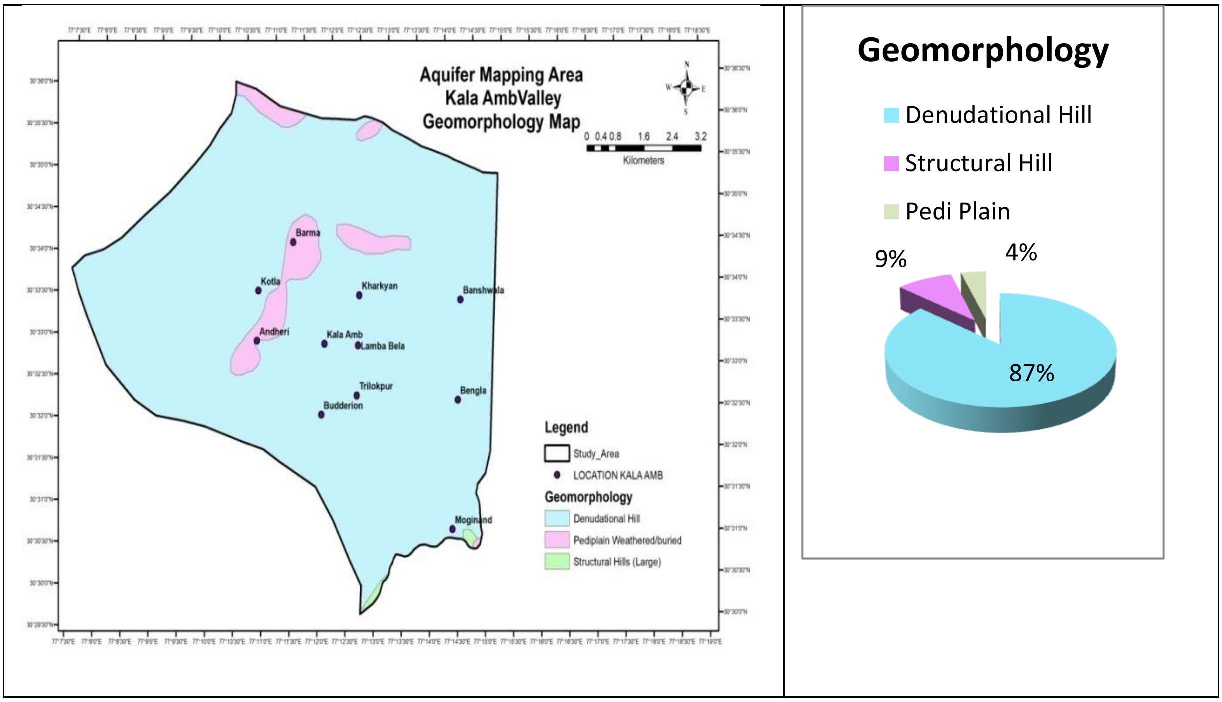


Fig 4(B): The Geomorphology Map of Paonta-Kala Amb Valley, Sirmaur District

1.9 Physiography& Drainage

The entire territory is mountainous with the exception of the valley, in the Paonta tehsil commonly called Paonta Valley (Kayarda-Dun valley). This valley is roughly 40 km long and 10 km to 21 km broad, is mostly flat and plan. Apart from the lie of the land, and the hill ranges called ***dhars***, the rivers determine the natural divisions. This valley is situated in the South – Eastern corner of the state It is also known as ‘Paonta valley’ after the town which lies in the valley. This is located in the Markanda and Dharti ranges. Jamunariver separates it from Dehra-Dun. A greater part of Kiarda-dun valley which is plain falls within the Cis-Giri division and a very small part in a corner spreading across the Girifalls in to the trans-Giri division. The Giri river enters the district and flows length wise from one end to other, dividing the whole territory into two almost equal parts, the Cis-Giri (Giri- war), and the trans (Giri-par). Trans Giri division are more widely and more highly mountainous than the Cis-Giri division.

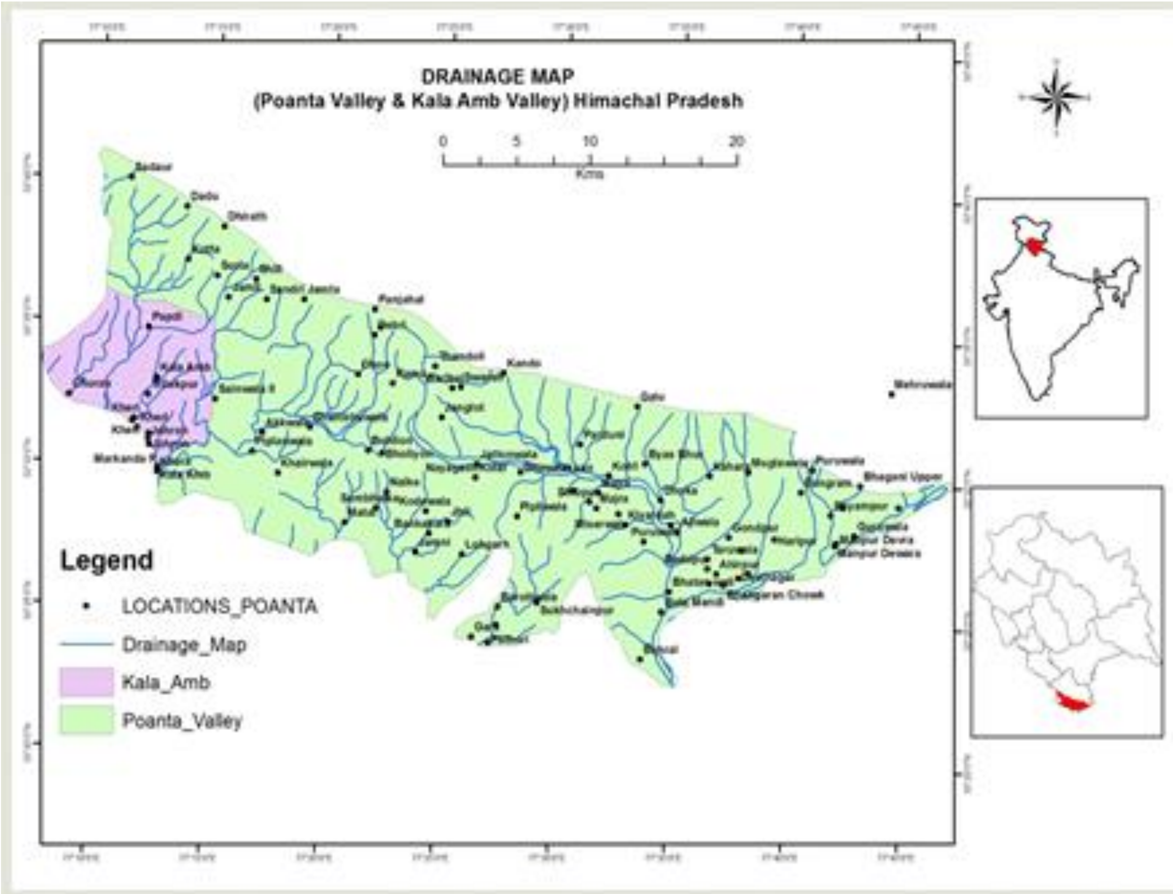


Fig 5(A): The Drainage Map of Paonta-Kala Amb Valley, Sirmaur District

Drainage of Kala Amb Area

The drainage pattern in the area is dendriatic.

The Ghaggar -The river originates in Shiwalik hills of Himachaql Pradesh,from village Lawasa in this district. It flows in the westerly direction and whole of the southern slope of Dharthidhar up to Lawasa drains into this river. It flows for about 12.8 km in Pachhad tehsil of this district before it enters the Haryana near Prit Nagar.

The Markanda – A tributary of River Ghaggar. It rises at Baraban in the hill of Katasan pass below a temple of Keratins Devi. This is a small river of Nahan area. River enters in kala amb at Bikram Bagh and leaves at Sadhora Bridg. After flowing from southeast to southwest for a distance of about 24 km within the district, irrigating Bajora area it passes on to the Ambala district of Haryana at Kala Amb.

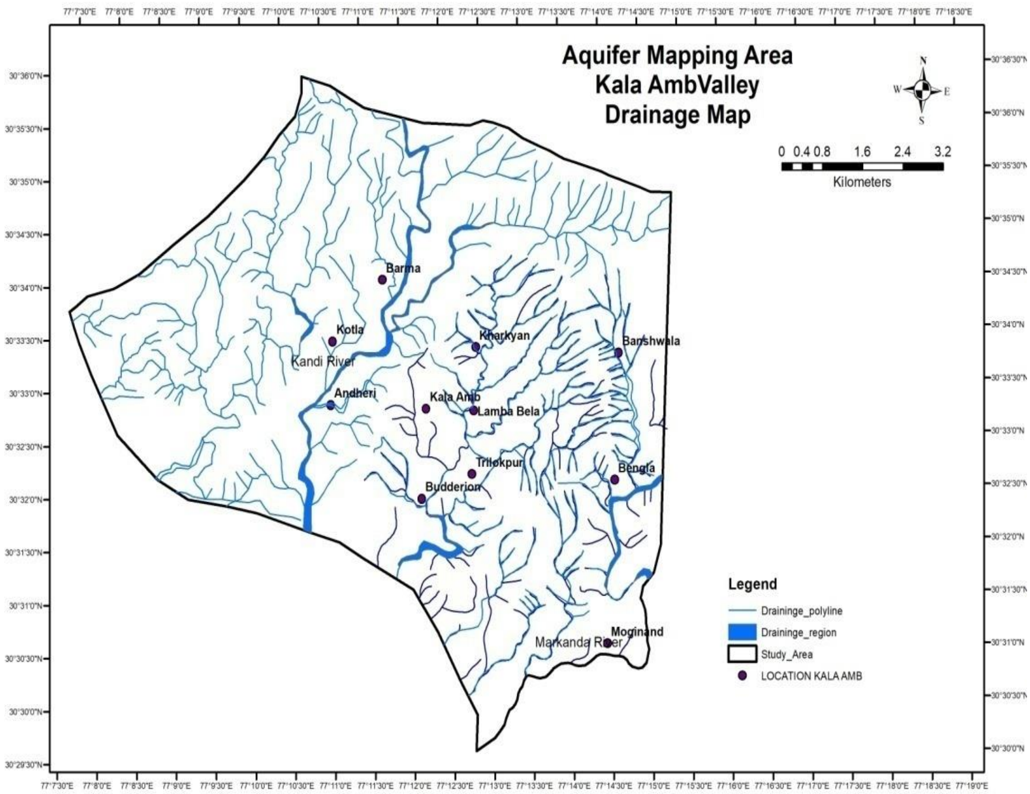


Fig 5(B): The Drainage Map of Kala Amb Valley, Sirmaur District

1.10 Geological Setup

Outer Himalayan Zone

The study area of Kala amb falls in zone Indo gangetic alluvium and Shiwalik or the foothill zone, which consists mainly of Tertiary formations extending from northwest to southeast. This system comprises of great thickness of cobbles, pebbles, detrial rocks, clays and conglomerates. The Nahans are separated from the Eocene beds of the lesser Himalayas by the main boundary thrust, which probably measures the whole length of the Himalaya from Assam to the Beas demarcating the northern boundary of the Shiwalik series.

On paleontological grounds the Shiwalik can be subdivided into three groups; upper, middle and the lower. Thickness in the lower section of the Shiwalik varies between 1,800 m to 2,700 m. The Sirmour group has also three formations namely Kasauli, Dagshai and Subathu and is separated by a fault from the Shiwalik. The Subathu formations have greenish grey shale with bands of limestone and sandstone. The Sirmour group is perfectly continuous and formations lying conformably over each other. In study area generally formationis Alluvium, Fluvioglacial deposits of Recent to Sub-Recent age group comprising of sand caly& boulders and Siwalik formation of Boulder, Conglomerate & Sandstone.

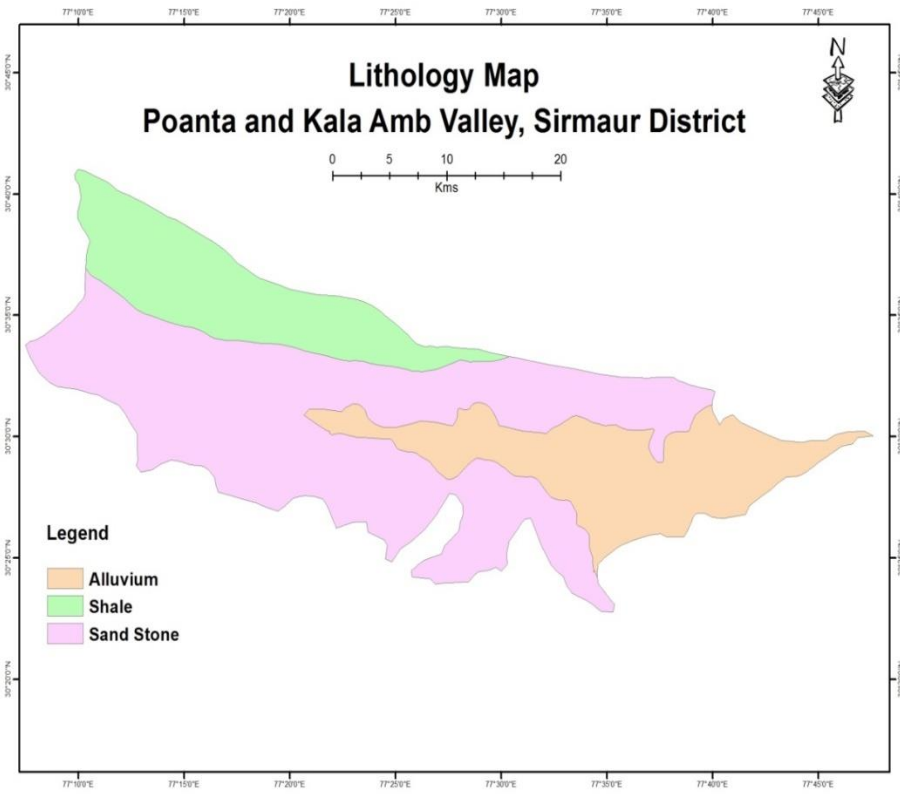


Fig 6(A): Lthology Map of Kala Amb Valley, Sirmaur District

Lithology of Paonta valley and kala amb valley mainly comprises of three formations, Alluvium, Shale and Sandstone. Most of the area is covered under Shiwalik sand stones (Lower pliestoce to middle miocenes). The NAQUIM study area of 81 sq km Kala amb valley comprises of 2.5 sq km of Alluviom, mainly composed of predominave of clay on the western part of valley. Rest of the area is under shiwalik sand stone.

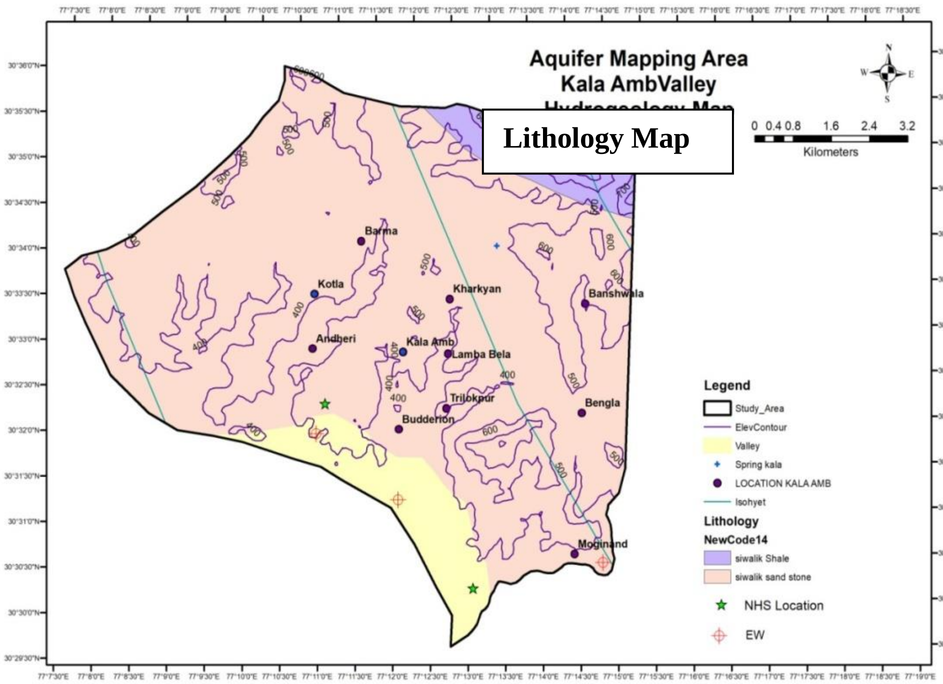


Fig 6(B): Lthology Map of Kala Amb Valley, Sirmaur District

1.11DEM

Digital Elevation Map of Paonta valley shows elevation from 335 amsl to 1518amsl. Most of area is low lying, except the northern part. Kala Amb valley is showing 342 to 812 m amsl. Most of area is falling in high amsl, more than 408m amsl.DEM of areas are shown below.

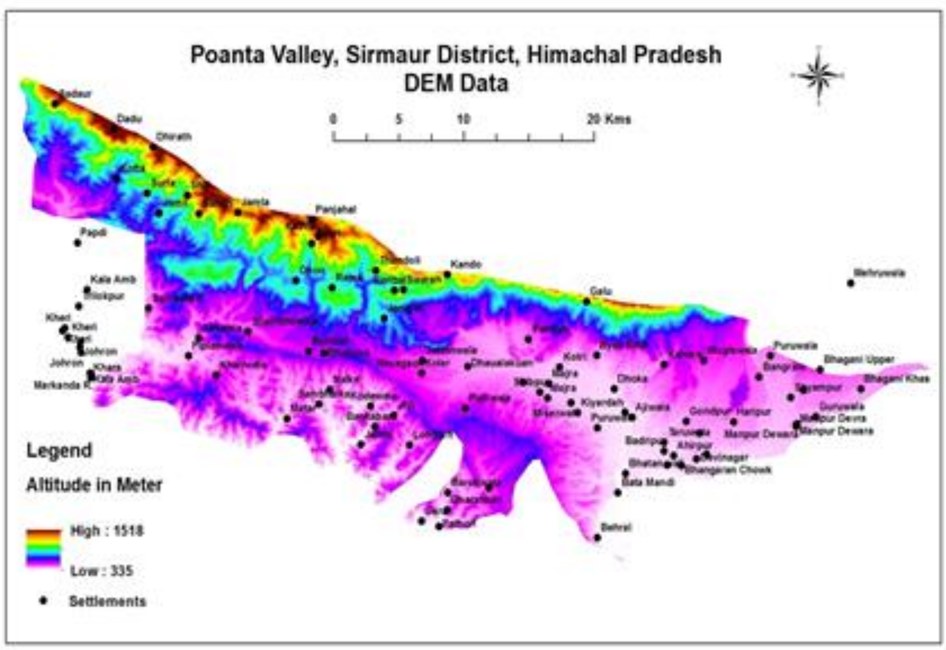


Fig 7(A): DEM of Paonta & Kala Amb Valley

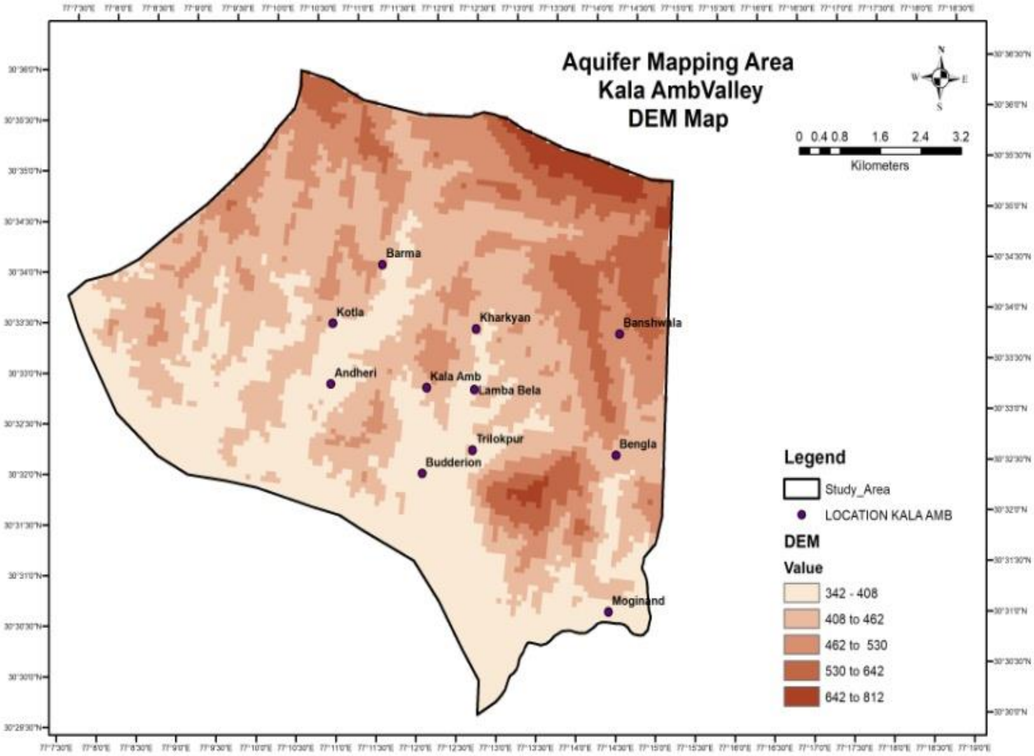


Fig 7(B): DEM of Paonta & Kala Amb Valley

1.12 Hydrogeological Framework

Hilly and mountainous parts with steep slopes mainly constitute the run off areas and have low ground water potential. In valley and low-lying areas, unconsolidated / semi-consolidated formations form good potential aquifers.

Table 1.2 : Geological Formation & their yield potentials

Formation	Yield Potential
Unconsolidated (Alluvium / valley fills of Quarternary age group)	GW under water table & semi confined condition Moderate to High yield (10 to 25lps)
Semi consolidated (Siwaliks, Subathu, Dagshai of Tertiary age group)	GW under water table & semi confined condition Moderate to low yield to 15 lps)

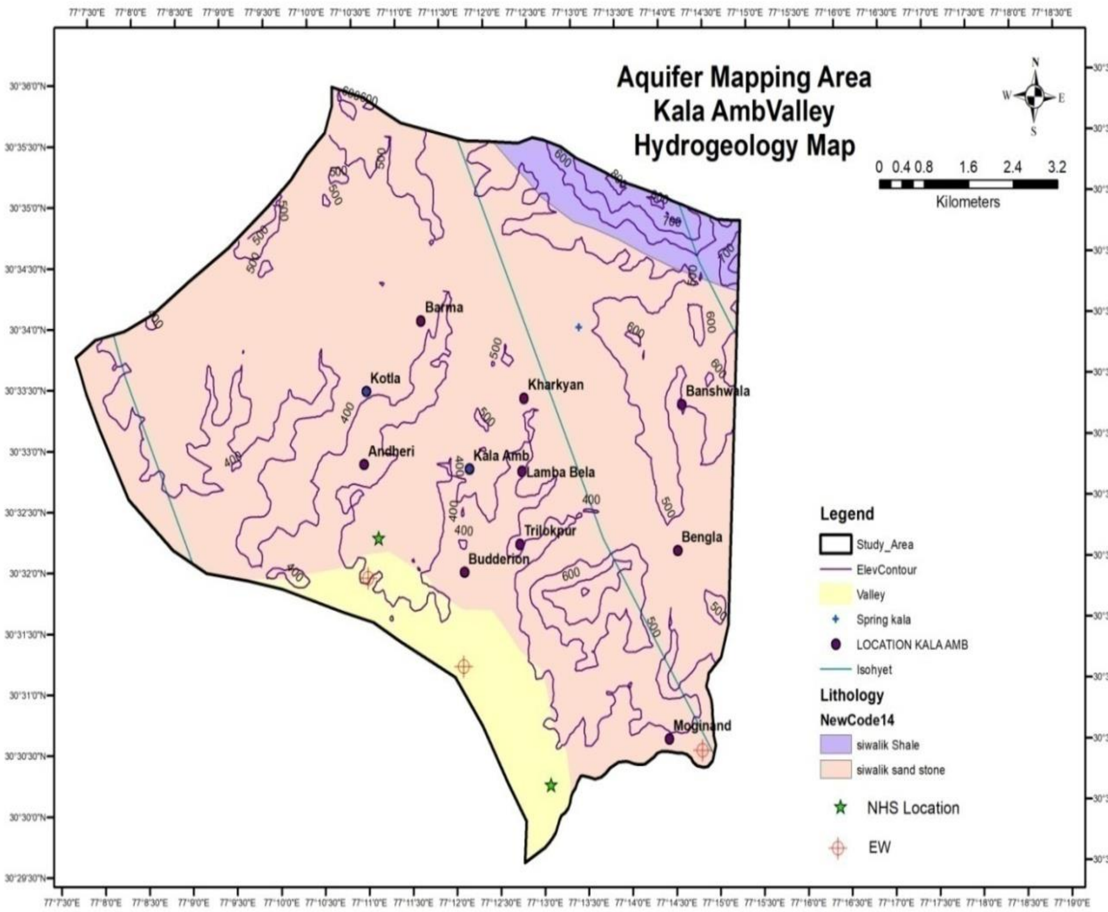


Fig 8: Hydrogeology Map of Kala Amb Valley, Sirmaur District

1.13 Irrigation and Cropping Pattern of the District

Sirmour district is spread in three agro-ecological zones. Majority of farmers (87 %) in this district are marginal and small farmers and average size of land holding is 2.28 ha. In the district, agriculture is done mainly in valley areas of the district. The major source of irrigation in the district is the "*kuhls*" (artificially made water channel). Only 12 % of the net cropped area of the district is irrigated and sizeable part of the cultivated area of the district is not having the assured irrigation facilities and the farmers have to depend on the rainfall. Under various plans, the construction of Kuhls and lift irrigation schemes are being carried out in the district. The lift irrigation has been introduced and shallow wells have been dug by Irrigation and Public Health (I&PH) department. CGWB and other State agencies have installed tube wells in the district which are being used for irrigation. The land utilization particulars in Sirmaur district are given in Table below.

Table 1.3: Land Utilization Pattern in Sirmaur District

Land Use	Area(Hectares)	Percentage of total area
Total geographic area of the district	282500	
Total Reported area	224752	
Total forest area	48704	22
Barren and uncultivated area	8781	4
Land put to non agricultural use	10401	5
Net area sown	42488	19
Area sown more than once	35794	16
Cultivable waste land	14264	6
Current fallows	9045	20
Other fallows	1666	0.7
Total cropped area	78282	35
Total irrigated area	26363	12
Total orchards area	61200	27

The Kharif and the Rabi are the two principal crops. The kharif crops largely depend on the rainfall. Very limited area is irrigated by the assured irrigation water supply. The area covered under food grain crops is given in table below:

Table 1.4: Cropping Pattern, District Sirmaur

Crops	**Area (Hectares)**	**Crop Production (Tones)**
Wheat	25834	31594
Maize	22563	65866
Rice	5383	8729

Barley	2716	2314
Sugar	800	790
Pulses	3983	1764
Ragi	348	317
Common Millets	122	123
Chillies	307	69
Ginger	1187	9170
Oil seeds	1189	270

Source: Department of Agriculture

1.14(A)Land Use & Land Cover of Study Area

The landuse / land cover map was prepared using Survey of India topographic sheets and IRS P6 LISS – III satellite imagery. The Landuse and land cover features in the study area Dense Forest, Land with scrub, Plantation and River . Similarly Forest Area map was prepared with the help of processed satellite imagery, the same has been shown. In the study area, the map shows that the area is mostly forest cover, having barren rocky type of topography and land without scrub at few places. The urban part is restricted to the eastern and western side of the study area. The crop land which is mainly found near rivers and in major part of the valley portion of Paonta valley.

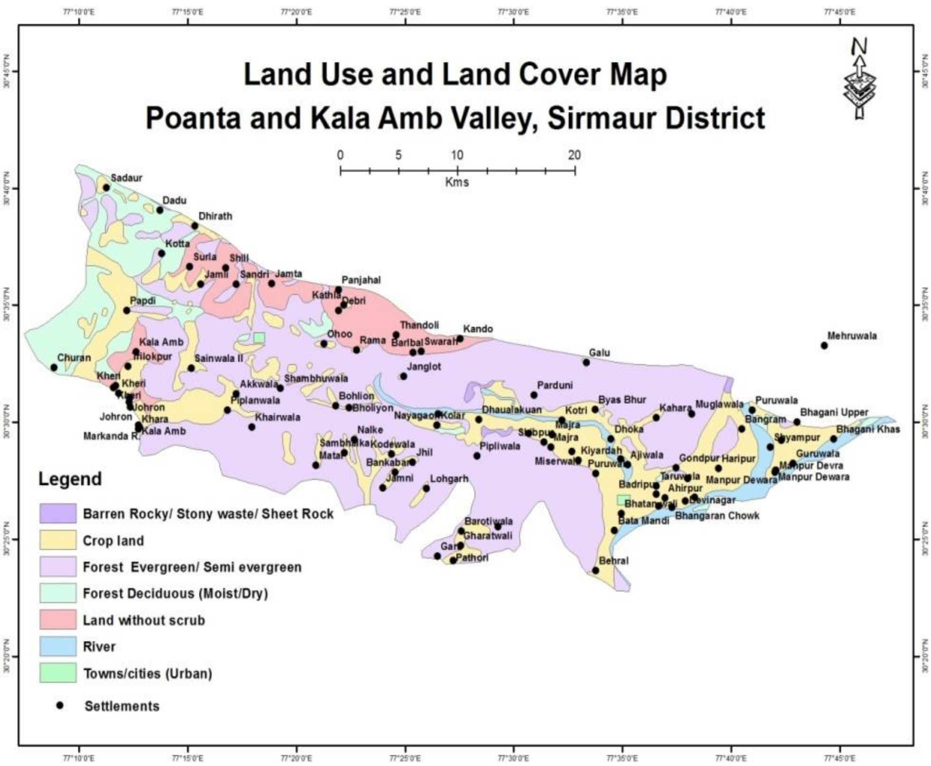
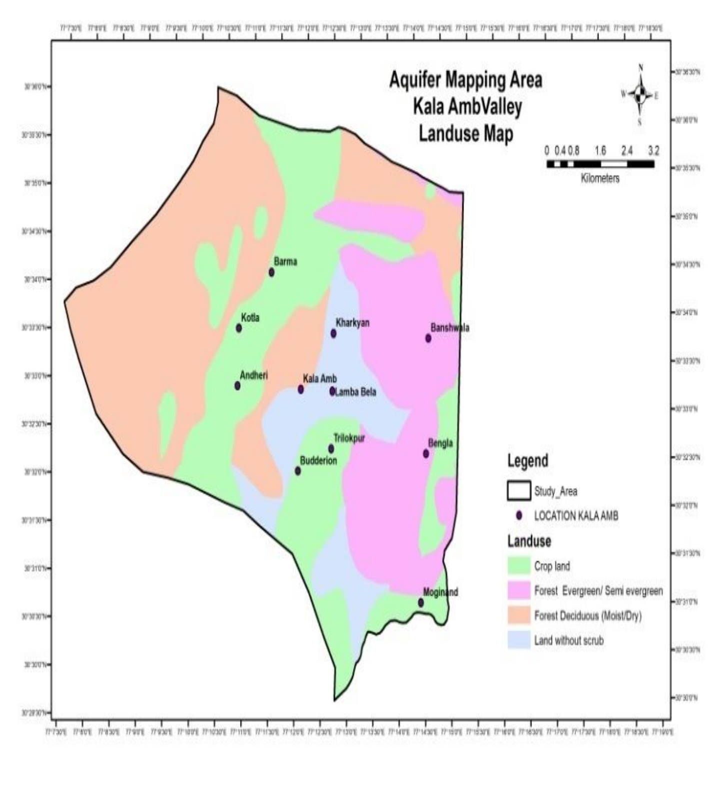


Fig 9 (A)The Land Use, Map of Paonta & Kala Amb Valley, Sirmaur District



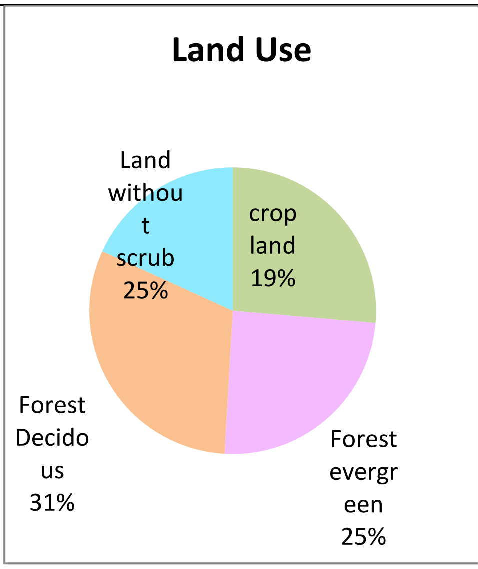


Fig 9 (**B**)The Land Use, Map of Kala Amb Valley, Sirmaur District

The study area of Kala amb mainly can be devided in to forest, land without scrub and crop land. About 19% of the area is covered under crop land.

(B) Forest cover of the Study area

Most of the area under study shows, moderately dense and open forest. Densely forest area are also shown in some places. Non forest cover area is the main valley part of Sirmaur district.

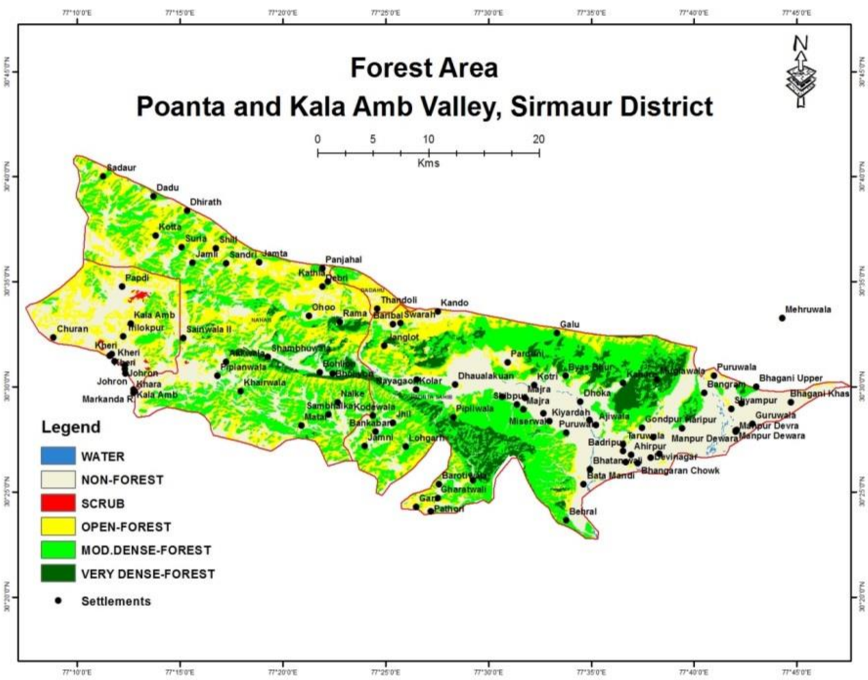


Fig 10 (**A**): Forest cover Map of Paonta-Kala Amb Valley, Sirmaur District

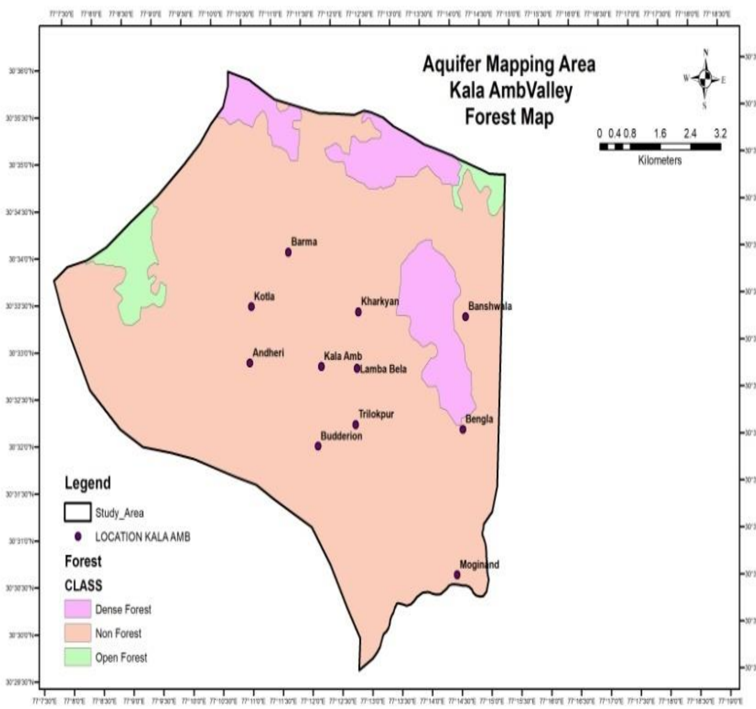


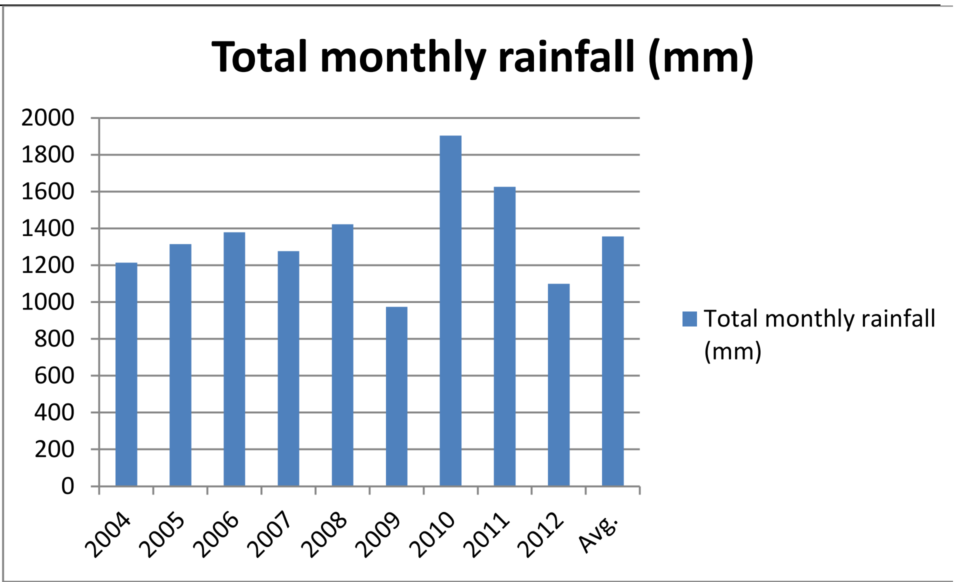
Fig 10 (B): Forest cover Map of Paonta-Kala Amb Valley, Sirmaur District

Majority of the area is covered under Non forest area, other than dense forest and open forest area, which is found at few places.

1.15 Climate & Rainfall

The climate of the district is sub-tropical to temperate depending upon the elevation. Four major seasons that is the winter season extends from Nov to February; summer season from March to June followed by the monsoon period extending from July to September end. Maximum precipitation in the form of rain occurs during July to September.

Year	Total monthly rainfall (mm)
2004	1214
2005	1313.9
2006	1378.2
2007	1276.3
2008	1422.1
2009	974.9
2010	1903.9
2011	1624.9
2012	1099.6
Avg.	**1356.4**



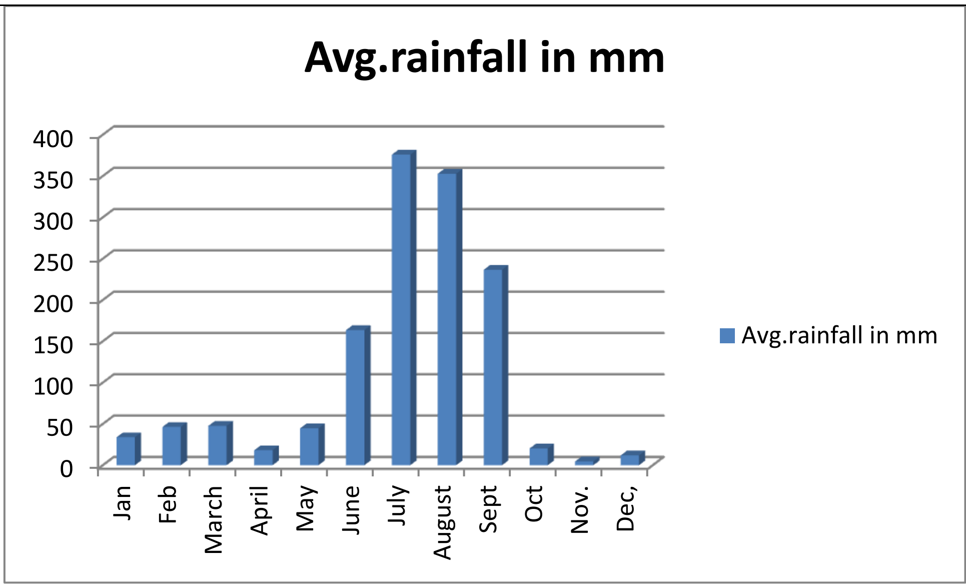
Average annual rainfall in the district is about 1356.4 mm, out of which 83.2% occurs during monsoon season. In the non monsoon season precipitation as snowfall also occurs in the higher reaches above 1500 m amsl, the peaks of Choordhar remains covered by snow. During winter period rainfall also occurs in lower hills and valleys parts. Mean maximum and minimum temperature of 30°C and -0°C respectively. The district wise monthly rainfall is as under.

Table 1.5:Monthly Rainfall (mm)

Year	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov.	Dec,	Total
2004	98.5	6	0	31.7	55.5	147.7	150.2	542.9	77.6	97.5	2.7	3.7	1214.0
2005	63.5	96.9	87.7	3.3	29.4	105.6	477	127.5	323	0	0	0	1313.9
2006	42.7	1.3	125.4	6.4	104.6	123.4	538.4	322	64.4	20	10.8	18.8	1378.2
2007	0	179.7	166	15.2	24.8	186.9	199.6	399	80.8	13.3	0	11	1276.3
2008	29.4	33.1	0	41.9	64	320.6	305.7	366	255.1	5.3	1	0	1422.1
2009	1.3	24.1	24.9	16.6	37.1	40.7	313.3	112.7	365.1	26.3	12.8	0	974.9
2010	8.1	31.4	1.2	4.4	24.6	90.3	566.7	509.5	597.1	13.4	12.3	44.9	1903.9
2011	11.4	32.7	15.2	17.7	61.4	415.4	456.2	399.3	196.7	7	0	11.9	1624.9
2012	49.9	12.2	8.3	26.6	0.7	41.3	375.9	396.6	169	0.2	2.2	16.7	1099.6
Avg.	**33.9**	**46.4**	**47.6**	**18.2**	**44.7**	**163.**	**375.**	**352.8**	**236.**	**20.**	**4.6**	**11.9**	**1356.**

						5	**9**		**5**	**3**			**4**

Source: IMD data

Average rainfall in the area can be seen in the bar char, which shows there is maximum rainfall occurs between July to September months.	

1.16 Soil Types

For the preparation of the soil map, the soil atlas of the Himachal Pradesh, prepared by C.G.W.B. Northern Himalayan Region is used as the primary source and then updated with satellite imagery. The different soil types are shown below.

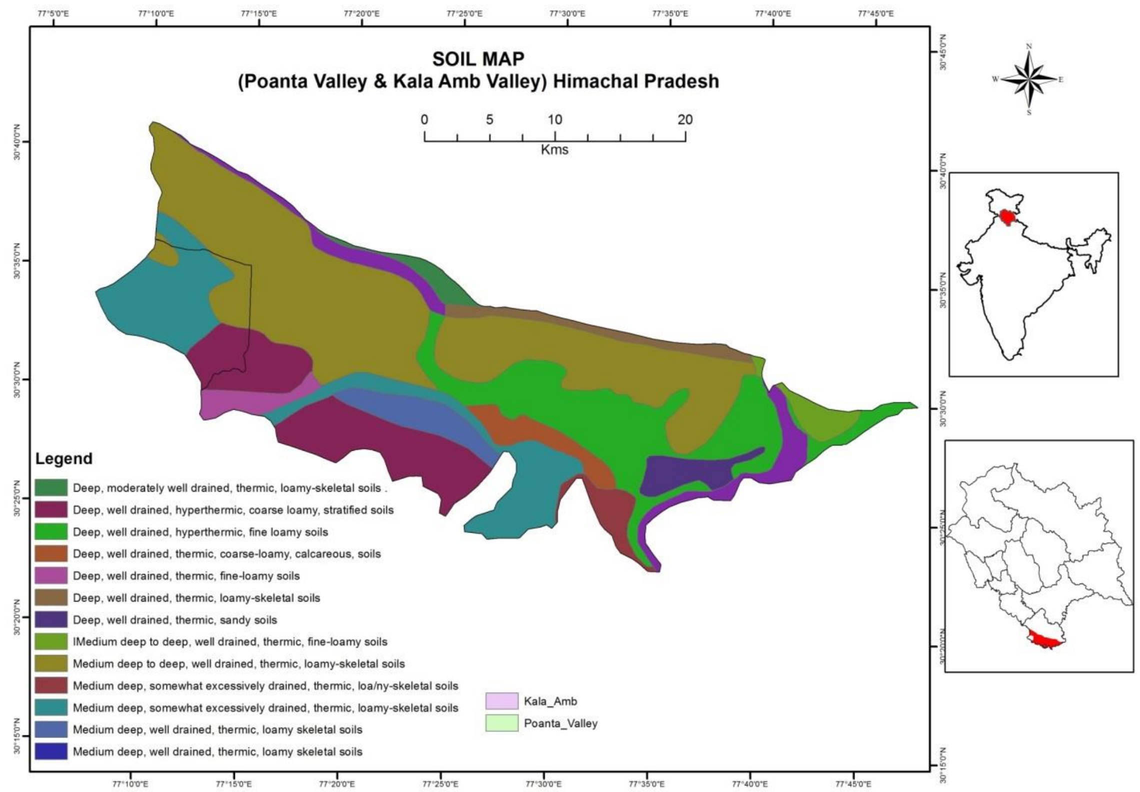


Fig. 11 : Soil Map of Paonta-Kala Amb valley Valley, Sirmour District

In the paonta and kala amb valley, a number of soils are found, mainly can be devided in two broad catogories, medium well drained and deep well drained soils. In the study area of kala amb major type of soil found is medium to deep excessively drained loamy soil, fine and coarse grained.

1.17 Industries and Mining activities

The Industrial Area(I.A) of Kala Amb was developed &established by DIC, Sirmaur in 1991 in a stretch of 221.03 bighas. Total 67 industrial plots were developed in the Industrial area All plots are allotted to total no. of 52 entrepreneurs. Apart from these allotted plots in developed I.A. of Kala Amb few entrepreneur’s setup their industries in nearby area outside I.A. Kala Amb. In all there are 404 industrial units establishes in & around Kala Amb. There are total 134 units are operating in the Industrial area and nearby area. Out of total 134 units 2 units are manufacturing Paper are discharging huge quantum of Effluent are excluded from list. From list of remaining 132 Units 110 Units are located in Industrial area and remaining 22 units in nearby area. (source: executive summary, http://environmentclearance.nic.in/writereaddata)

At present Kala amb is an emerging town for industries as it hosts production units for paper, metal, chemicals, thread mills and air-conditioners; thus air pollution is quite a concern here. This town is on the border of Himachal Pradesh and Haryana, hence half of the town falls in Haryana, However the industrial area is situated in Himachal only. Kala Amb is increasing in area due to an increase in industrialization. Now the boundaries of the town have reached until the village Trilokpur which is famous for Bala Sundri Temple in northern India. List of Industries are given in annexure.

1.18 Previous Work and Present Status of Data

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 Sirmaur district during various field seasons. Central Ground Water Board, NHR, Dharamshala has also carried out preliminary Pollution studies in Urban clusters of Kala Amb and Paonta Sahib of Sirmaur District and ground water exploration studies in the area. CGWB NHR, Dharamshala is monitoring ground water levels from National Hydrograph Network observations and aquifer mapping wells (Table 1.13) since 1977 in all valleys of Himachal Pradesh four times a year in the months of, May, August, November and January. The ground water quality is being studied by CGWB once in a year from the samples collected from those observation wells during the month of May.

In the study area, only 2 NHS are being monitored, Trilokpur and Kala Amb.

Table 1.6 : National Hydrograph Network Stations of Kala Amb&Paonta Valley, Sirmaur District, Himachal Pradesh

S.No	Location details	Block	Lat	Long	type of well	Depth	Estt date	MP	RL
1	TIRLOKPUR	Nahan	30.54	77.204	Dug well	16.5	1981	0.89	366.01
2	KALA AMB	Nahan	30.498	77.212	Dug well	14.5	1974	0.72	340.18
3	SHAMBHU-WALA	Nahan	30.524	77.321	Dug well	13	1975	0.42	482.42
4	KIYARDA	Paonta sahib	30.473	77.549	Dug well	14.55	1975	0.56	408.49
5	KOLAR	Paonta sahib	30.498	77.441	Dug well	29.95	1974	0.85	501.77
6	NAYAGAON	Paonta sahib	30.498	77.441	Dug well	20	1974	0.6	422.5
7	SHIBPUR	Paonta sahib	30.486	77.523	Dug well	30.5	1975	0.36	450.72
8	DHAULAKUAN	Paonta sahib	30.502	77.473	Dug well	13	1974	0.38	442.08
9	BADRIPUR	Paonta sahib	30.449	77.609	Dug well	13.5	1990	0.38	394.81
10	NARIWALA	Paonta sahib			abandoned	45	1981	0.38	469.41
11	AJIWALA	Paonta sahib	30.47	77.587	Dug well	8.65	1981	0.56	391.62
12	KHODAWALA	Paonta sahib	30.487	77.705	Dug well	20.5	1990	0.2	445.09
13	AKKWALA	Paonta sahib	30.52	77.287	Dug well	22.0	1975	0.45	485.00

2. DATA-GAP ACQUISITION & METHODOLOGY

The different data to be collected for aquifer mapping are:

A. Administrative Boundaries.
B. Demography.
C. Agriculture and irrigation.
D. Land use and land cover.
E. Hydrometeorological data.
F. Hydrological data.
G. Soil.
H. Geological data.
I. Hydrogeological data.
J. Ground Water Exploration data.
K. Pumping Test data.
L. Geophysical data.
M. Well census data.
N. Ground Water Resources Estimation.
O. Hydro-geochemical Data.
P. Data on springs.
Q. Mining/ Industry present in the area.
R. Data on salinity hazard in coastal areas.

A. Administrative Boundaries

First different maps of the study area such as district, taluka / block and village boundary has to be collected from concerned state government department. This will be helpful in delineation of the aquifer boundary and collection of other relevant data.

B. Demography

Demographic data from population census and district agencies can be collected. From population data one can know the present water utilization pattern of the area and future demand can also be worked out.

C. **Agriculture and irrigation**

Agriculture and irrigation data has to be collected from concerned state government department. Whether it is ground water or surface water agriculture is the largest user. Data on cropping pattern and irrigation has to be collected from state government agencies. These data can be collected from irrigation, minor irrigation department etc.

D. Land use and land cover

Land use and land cover data can be collected from district statistical hand book and from the concerned block/taluka. This data shall be useful to know the detailed land utilization pattern of the area such as forest, barren and uncultivable land etc.

E. Hydrometeorological data

Data on rainfall, temperature, humidity, wind velocity and potential evapo-transpiration of the study area has to be collected. Monthly rainfall data can be collected from Indian Meteorological Department (IMD) as well as state government agencies. This shall be helpful to estimate the surface run off and the recharge by rainfall into the aquifer system. Drought analysis of rainfall data can be done to know the frequency of droughts. If data on infiltration rate of the soil is available, it can also be collected.

F. Hydrological data

Data on measurement of flow in streams/ water bodies has to be collected. If available data on drainage patterns/ order of streams such as length and breadth of 1^{st}, 2^{nd} and 3^{rd} order streams would be collected. Data on water bodies Tanks/Ponds and other water conservation structures are to be collected from different agencies.

G. Soil

Soil is the thin layer on the surface of the earth where living beings survive. It is the weathered product of bed rocks occurring in the area. The data on different types of soil their geochemical characteristics occurring in the area has to be collected. The type of soil controls the rate of infiltration of rainfall and runoff.

H. Geological data

Lithology and structure controls the occurrence and movement of ground water in crystalline rocks. In alluvial formation, occurrence of porous material like sand, gravel forms very good aquifers. Geological map can be collected from Geological Survey of India. It gives detailed information on lithology of the area. Detailed information on structure like lineament, fault, fold is available in the geological map. Detailed report on geology is also available with different state geological department which can also be collected.

I. Hydrogeological data

Different state agencies like state ground water department etc. used to do hydrogeological survey of the state. Data like pre and post-monsoon depth to water level and detailed hydrogeological report can be collected. Data available with Central Ground Water Board on Systematic Hydrogeological Survey, Ground Water Management studies can also be collected. Data on well yield, areal extent and aquifer disposition has also to be collected.

J. Ground Water Exploration data

State ground water department & Public Health and Engineering Department is engaged in drilling activities for different purposes. Data on depth of weathered zone, detailed borehole lithology, depth of occurrence of fracture zones, well yield of individual fractures can also be collected. Ground water exploration data available with Central Ground Water Board can be collected and compiled.

K. Pumping Test data

A pumping test is performed to find out the behaviour of aquifer as well as the well in response to the stress applied in the form of pumping. The pumping tests are generally conducted to determine:

a. Yield and sustainability of well (Yield Tests).

b. Performance and efficiency of the well (Well Performance Tests).

c. Hydraulic properties of the aquifer (Aquifer Performance Tests).

The aquifer parameters are required for planning ground water development and management. These are required for planning the type and nature of wells to be constructed for various purposes. These are also required for developing a mathematical model for any area, which in turn helps in designing ground water management strategies. The different parameters to be collected are Hydraulic Conductivity or Permeability (K), Transmissivity (T or KD), Specific Yield (Sy), Storativity or Storage Coefficient (S), Hydraulic Resistance (C), Leakage Factor (L) etc.

L. Geophysical data

By geophysical investigation one can know the anomalies or signatures of the physical properties of material beneath the earth surface. Geophysical measurements made remotely or insitu, characterize subsurface geology, geological structures based on lateral and vertical mapping of physical property variations. Geophysical data of the aquifer available with state department has to be collected to know the lateral as well as vertical extent of the aquifer. A variety of methods exists for collection of geophysical data of the aquifer, viz., Schlumberger, Wenner, dipole-dipole etc. By geophysical studies one can get the depth of weathered zone thickness, occurrence of fracture zone etc.

All available Vertical Electrical Sounding (VES) data has to be compiled and analysed from which different geo-electric layers can be deciphered. Available sub-surface logging data has to be interpreted. 2-D imaging data, and Heliborne survey data can be acquired from NGRI. From these studies vertical and lateral extent of different layers such as clay can be determined.

M. **Well Census data**

Well census data regarding total number of ground water structures such as dug wells, bore wells has to be collected. Data on well yield, depth and diameter has to be collected. Ground water draft data of all the ground water structures available has to be collected.

N.Ground Water Resources Estimation

Ground water resources are estimated assessment unit wise. The assessment unit is watershed in the states occupied predominantly with hard rocks. This is because the ground water balance equations recommended in GEC-1997 can be better applied in the assessment units with hydrologic/ hydrogeologic boundaries. The ground water recharge is estimated season-wise both for monsoon and non-monsoon season. The following recharge and discharge components are assessed in the resource estimation. Recharge from rainfall, recharge from canal seepage, return flow from irrigation, recharge from water tanks & ponds and recharge from water conservations structures and discharge through ground water draft. Ground Water Resource Estimation data available should also be collected.

O. Hydro-geochemical Data

There are two major objectives of water quality studies:

1. To ensure safe water for various types of uses
2. As a tool for understanding, characterization and quantification for various natural processes and parameters. The different chemical data available with the organisation, state ground water department and other agencies can be collected which will be helpful in delineation of chemical quality problem areas like fluoride, arsenic, nitrate. On the basis of the data future sampling in the entire aquifer can be done.

P. Data on springs.

A spring is a localized natural discharge of ground water issuing on the land surface through well-defined outlets. The discharge may vary from a trickle to a stream. Data on springs, auto-flow wells present in the area has to be collected.

Q. Mining/ Industry present in the area.

All data regarding mines both open cast and underground of the area has to be collected. Any mining activities like coal etc affect the aquifer. By mining activities the ground water of the surrounding aquifer is affected. So data on mine dewatering are to be collected.

R. Data on salinity hazard in coastal areas.

Salinity hazard is mostly common in coastal areas and in some inland areas. So data on areas affected with salinity hazard has to be collected. All the collected data has to be compiled and various thematic maps will be prepared. On the basis of these thematic maps further studies will be carried out.

2.1 METHODOLOGY AS PER EFC

Table 2.1: Tentative norms of activities to be taken for Aquifer Mapping as per EFC

S.No	Activities	Unit	Per toposheet (700 Sq.km)
1	Micro level hydrogeological data including quality monitoring	Nos	174
2	GW monitoring (4 times in a year for 2 years)	Nos	70
3	Geophysical survey (VES)	Nos.	25
4	Borehole logging	Nos	Need based
5	2 D imaging	Line km	Need based
6	Ground TEM (Transient Electromagnetic)	Nos	Need based
7	Heliborn TEM	Line km	Need based
8	Water quality (Basic & heavy metals)	Nos.	105
9	Water quality (Pesticides, Bacteria, Arsenic & fluoride)	Nos	10
10	Carbon-14	Nos	1
11	Isotope study – stable & other isotopes	Nos	15
12	Soil infiltration rate	Nos	33
13	Core drilling in Arsenic & fluoride affected area with geochemical analysis	Nos	Need based
14	Slug test	Nos	6
15	Specific yield determination	Nos	6
16	GW exploration (EW & OWs)	Nos	6 – 12 , Avg-9

2.2. AS PER GUIDELINES FOR HILLY AREAS

a. Exploratory data 1.

Data Required

i. Desirable spatial scale should be 5" x 5" grids and 100 m depth depending upon the area attributes.

ii. In hilly areas 10*EWs* and 10 OW"s should be constructed (wherever possible) at suitable locations, preferably one in central quadrant and one each in the four corner quadrants for establishing aquifer geometry and determining aquifer parameters. (Fig-Dl)

iii. For the first aquifer 3-4 pumping test are be carried out in dug wells/ if possible in shallow bore wells.

iv. Aquifer performance test shall be conducted at all the ten EWs tapping different aquifers to estimate the aquifer parameters/ hydraulic characteristics and water quality.

2. Data adequacy and Data gap analysis

1. Assessment of Data Adequacy (Adequacy of available sub-surface information for deciphering aquifer geometry at the desired vertical&horizontal scale) is to be done based on recommended and available information.
2. Aquifer parameter availability upto the desired depth should be presented in form of square diagram for each quadrant. (Fig-D2)
3. Quadrant wise recommended and existing EW/OW/PZ/SH should be depicted using square diagram and the additional EW/OW/PZ/SH etc. required for aquifer geometry delineation should be assessed (Fig-D3).

b. Geophysical Data

1. Data Required

i. Desirable spatial scale should be 5" x 5" grids and 100 m depth depending upon the site attributes.(wherever possible)

ii. It is recommended that 2 Profiling/VES/TEM soundings having 100 meter interpretation depth should be carried out in each of the nine quadrants of the toposheettotaling to 18 nos. in each sheet to decipher aquifer geometry (Fig-D4).

iii. It is recommended that all the Exploratory Wells should be e-logged and the data should be tabulated.

Sample-Geophysical data required for aquifer in Hilly areas (Quadrant wise)		
2 Profiling/ VES/TEM	2Profiling/ VES/TEM	2 Profiling/ VES/TEM
2 Profiling/ VES/TEM	2 Profiling/ VES/TEM	2 Profiling/ VES/TEM
2Profiling/ VES/TEM	2 Profiling/ VES/TEM	2 Profiling/ VES/TEM

2.Data adequacy and Data gap analysis

1. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-D5)
2. Quadrant wise recommended and existing VES/TEM profiling data should be depicted using square diagram and the additional Profiling/ VES/TEM required for aquifer
3.

c. Ground Water Monitoring Data

1.*Data Required*

i. Desirable spatial scale should be 5"x 5" grids and 100 m depth.

ii. One open/dug well is recommended for each quadrant of a toposheet. (Fig-12)

iii. All the spring sheds in a toposheet

Sample-GW monitoring data required for the aquifer in hilly area		
1stAq - 1	1stAq - 1	IslAq - 1
1stAq - 1	1stAq - 1	1stAq - 1

should be demarcated and only sustainable spring sheds are to be taken for discharge and quality monitoring. iv. Minimum four times monitoring annually is recommended as per the state specific schedule of monitoring.	1stAq - 1 | 1stAq - 1 | 1stAq - 1

4. geometry delineation should be assessed (Fig-D6)

d. Ground Water Quality Data

i. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-08)

ii. Quadrant wise recommended and existing DW/PZ should be depicted using square diagram and the additional DW/PZ required for ground water monitoring should be assessed (Fig-D9).

1.Data Required

i. Desirable spatial scale should l be 5".x 5"grids and 200 m depth.

ii. For I[5]'aquifer (un-confined/Phreatic) one .sample from open/dug wells isrecommended for each quadrant of a toposheet. (Fig-DIO)

iii. Quality of available springs should be monitored.

iv. Minimum two times monitoring initially is recommended for qualitymonitoring.

2.Data adequacy and Data gap analysis

i. Assessment of Data Adequacy is to be done based on recommended and available information and depicted as in Fig-D 11.

ii. Quadrant wise recommended and existing quality monitoring stations should be depicted using square diagram and the additional quality monitoring stations required should be assessed (Fig-012)

Sample- GW quality data required for the aquifer in hilly area		
IstAq- 1	1stAq - 1	1stAq – 1
1stAq - 1	1stAq - 1	1stAq – 1
1stAq - 1	1stAq - 1	1stAq – 1

3.0 DATA GAP ANALYSIS

3.1 Data Gap Analysis

The Data gap analysis was done on the basis of NAQUIM & EFC guidelines in Aquifer Mapping Study area of Kala Amb Valley (81 sq.kms), District Sirmaur of Himachal Pradesh. The study area falls in Survey of India Toposheets No.53 A/12, A/16, 53 B/9, B/13 and 53 F/1 covering full or partial area of 18 quadrants (Figure -1.2 - Toposheet Index Map). The Data Gap analysis of all the attributes are given in Table.

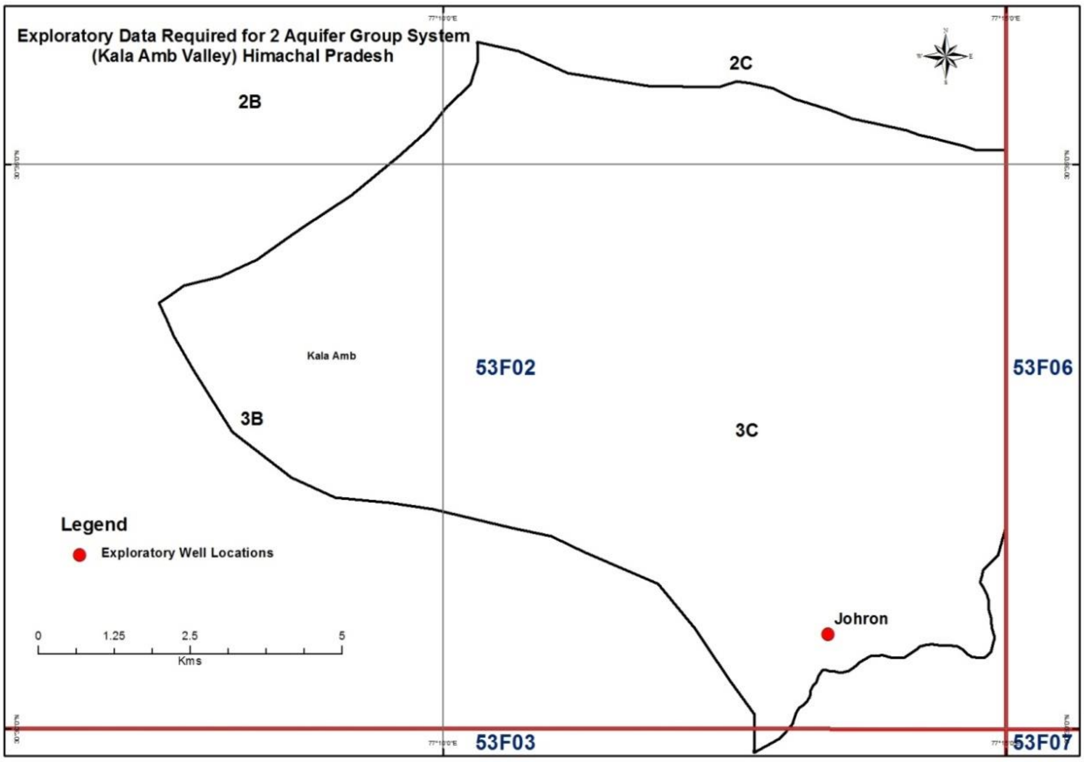


Fig:3.1. The Topo Index map of the Kala Amb Valley, District Sirmaur

3.2 Brief description: Data availability, data adequacy & data gap analysis

Data gap is the required no. of structures – existing structures. Required no. of structures are worked out considering the above norms. The existing structures which fulfil the criteria is taken as available no of structures. Data generation is the creation of additional structure / data. The activity wise & aquifer wise data required, data available & data gap for both the study areas is given below;

Table 3.1: Data Gap Analysis of Kala Amb Valley

Activity	Data required		Data available		Data Gap		Data Gap Filled		Data Gap To be filled	
	1st Aq	2nd Aq	1st Aq	2nd Aq	1st Aq	2nd Aq	1st Aq	2nd Aq	1st Aq	2nd Aq
Exploration wells	2	1	0	0	2	1	2	0	0	1
Observation wells	2	1	0	0	2	1	2	0	0	1
Piezometers	0	0	0	0	0	0	0	0	0	0
WL monitoring Key wells	3	0	0	0	0	0	0	0	0	0
WQ monitoring wells	4	0		0	4	0	0	0	0	0
VES for Resistivity	0	3	0	0	0	3	0	0	0	3
Soil Infiltration test	4	0	0	0	4	0	0	0	4	0
Spring discharge monitoring	2 number of springs were identified and monitored in NAQUIM area									

3.2.1 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-1.6.1

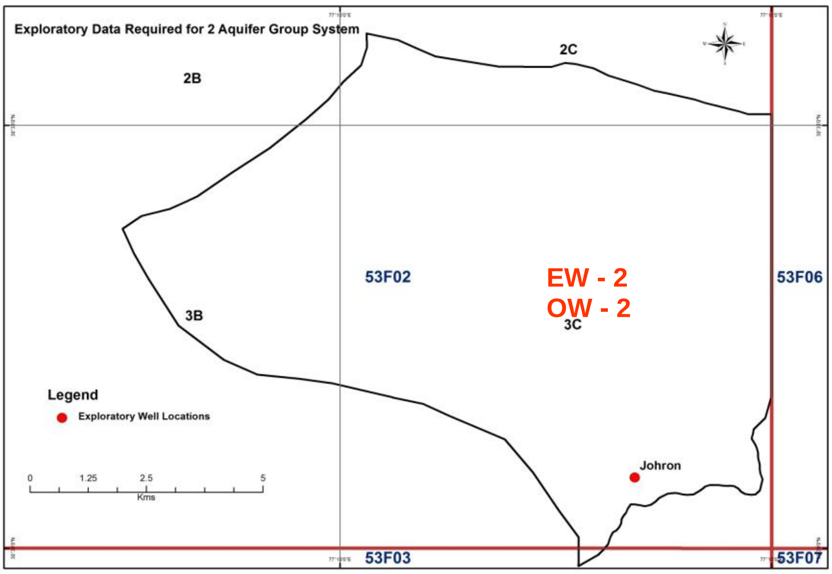


Fig.3.2 Exploratory Data Required Map – Kala Amb Valley, Sirmaur District

3.2.2 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. But for the study area, no VES data is available with CGWB and state agencies. On the basis of data gap analysis, the required 3 no.of VES is requiredfor Kala amb valley. The quadrant-wise existing and recommended VES sites is presented and shown as square diagram in the following figures.

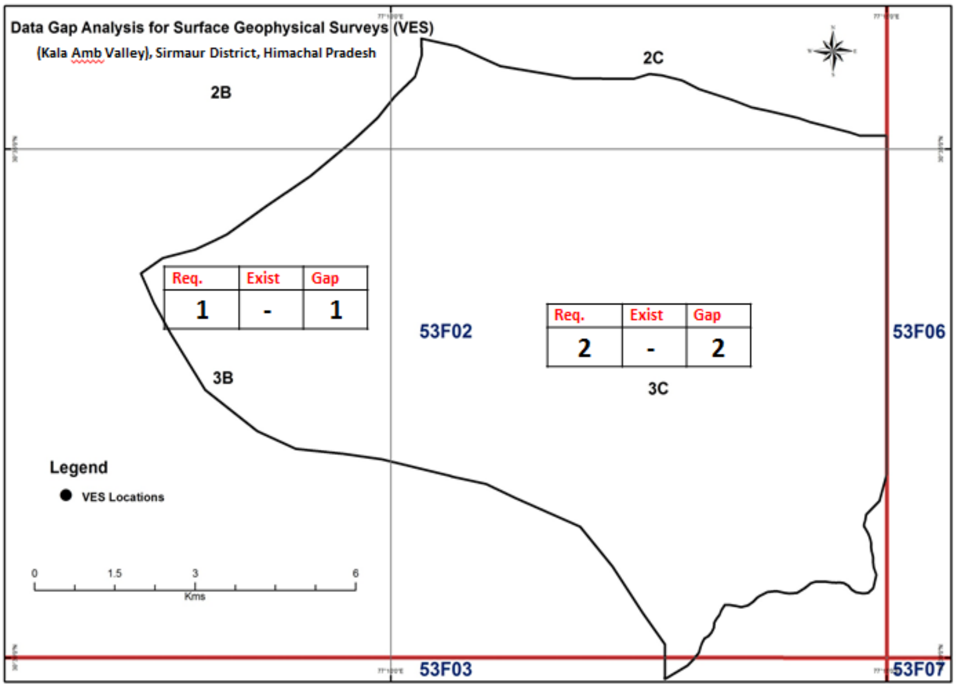


Fig.3.3 Data Gap Analysis of Surface Geophysical Surveys Kala Amb Valley,

3.2.3 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 -

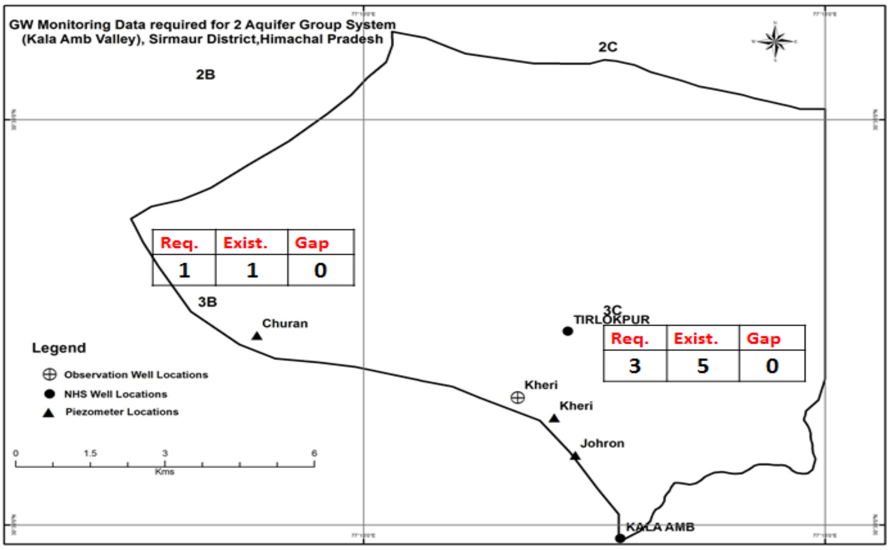


Fig. 3.4 Data Gap Analysis for Ground Water Monitoring Kala Amb Valley, Sirmaur District

3.2.4 Ground Water Quality Monitoring Stations (GWQMS)

Most of the ground water quality monitoring NHS and Key well observation stations in the area tap 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. On the basis of data gap analysis, at few places, additional GWQMS are required; rest will be monitored through NHS,Key well observation stations, hand pumps, existing and proposed E/Ws, and Pzs. The quadrant-wise and aquifer-wise existing and recommended ground water quality monitoring stations are shown as square diagram in the figure -1.6.4

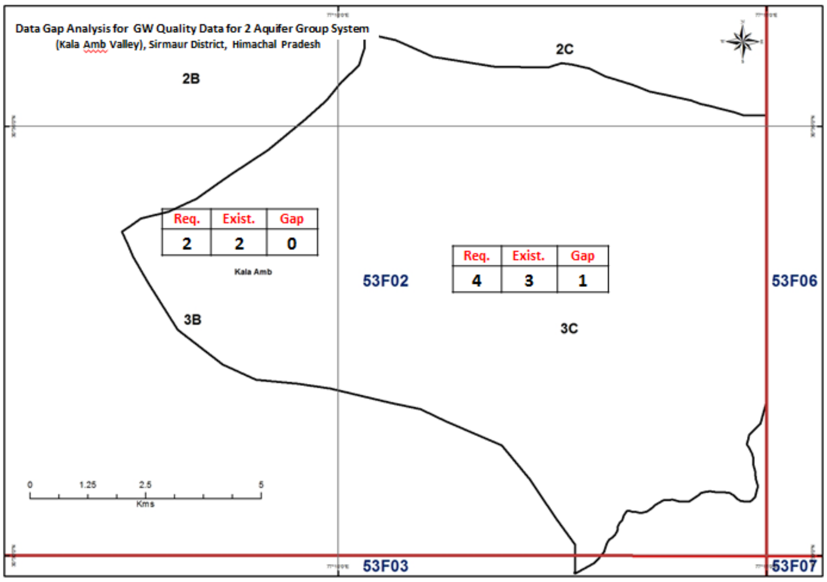


Fig.3.5 Existing Ground Water Quality Locations - Kala Amb Valley

3.2..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 -1.6.5.

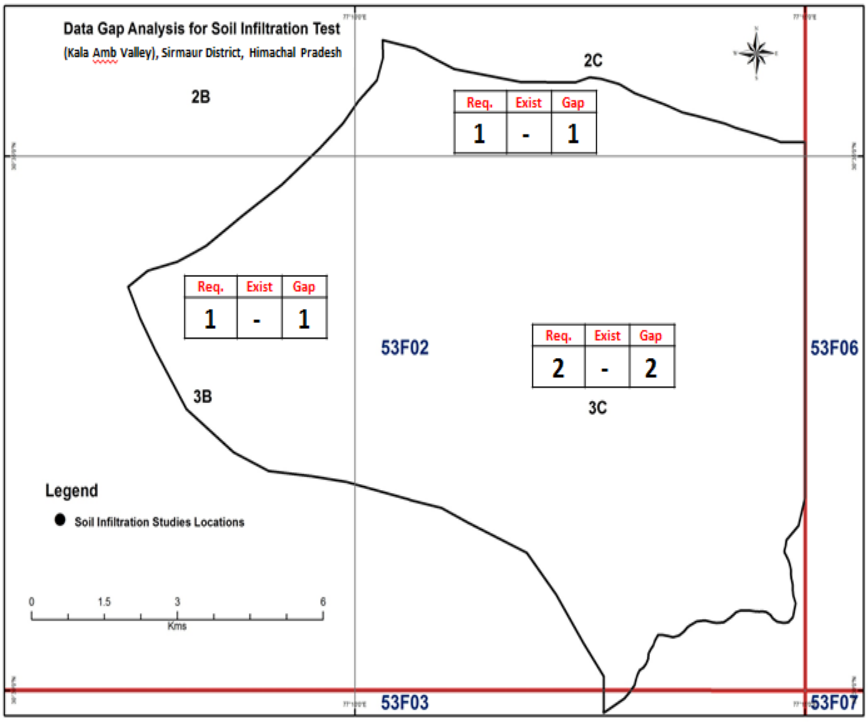


Fig.3.6 Data Gap Analysis for Soil Infiltration Studies - Kala Amb Valley, Sirmaur District

3.2.6 spring monitoring

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, 4 springs have been located.

3.0 DATA COLLECTION,GENERATION & INTERPRETATION

3.1 Hydrogeological Data

Hydrogeological data was generated by pinpointing the sites for exploratory wells. The sites were pinpointed in the valley area of Kala Amb because of accessibility issue.

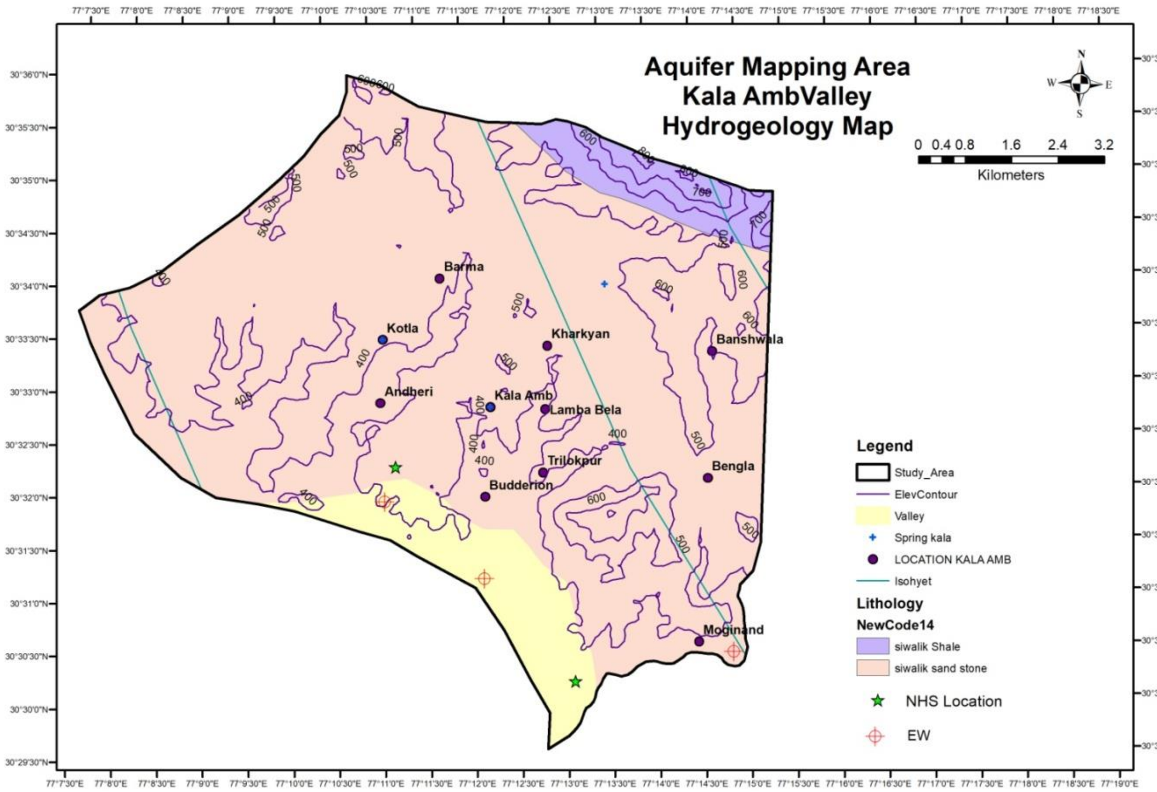


Fig 3.1: Hydrogeology Map

The study area of 81 sq km can be in to two hydrogeological units on the basis of geology. Unconsolidated /valley fills, which forms about 2,5 sq km gives moderate to high yield, except the valley areas which have predominance of clay, which yields 10-15 lps. Rest of the area which is semiconsolidated comprises of Shiwalik sandstone covers major part of area. Yiled is high in these areas about 15lps, if overburdened with riverine deposits. The details are shown in tables below:

Table:3.1: Hydrogeological distribution with yield potentials

Hydrogeological Unit	Distribution	Yield Potential
Unconsolidated (Alluvium / valley fills)	Valley fill/Fluvial/ With predominance of Clay	Moderate to high yield (approx. 35lps) Moderate(approx. 2-4 lps)
Semi consolidated (Siwaliks)	covering hilly areas (over burdened with riverine deposits	Moderate to high yield (approx. 15lps)

As data generation was limited to valley area , the 2D section can be shown as below:

3.22-D of Kala Ambvalley area

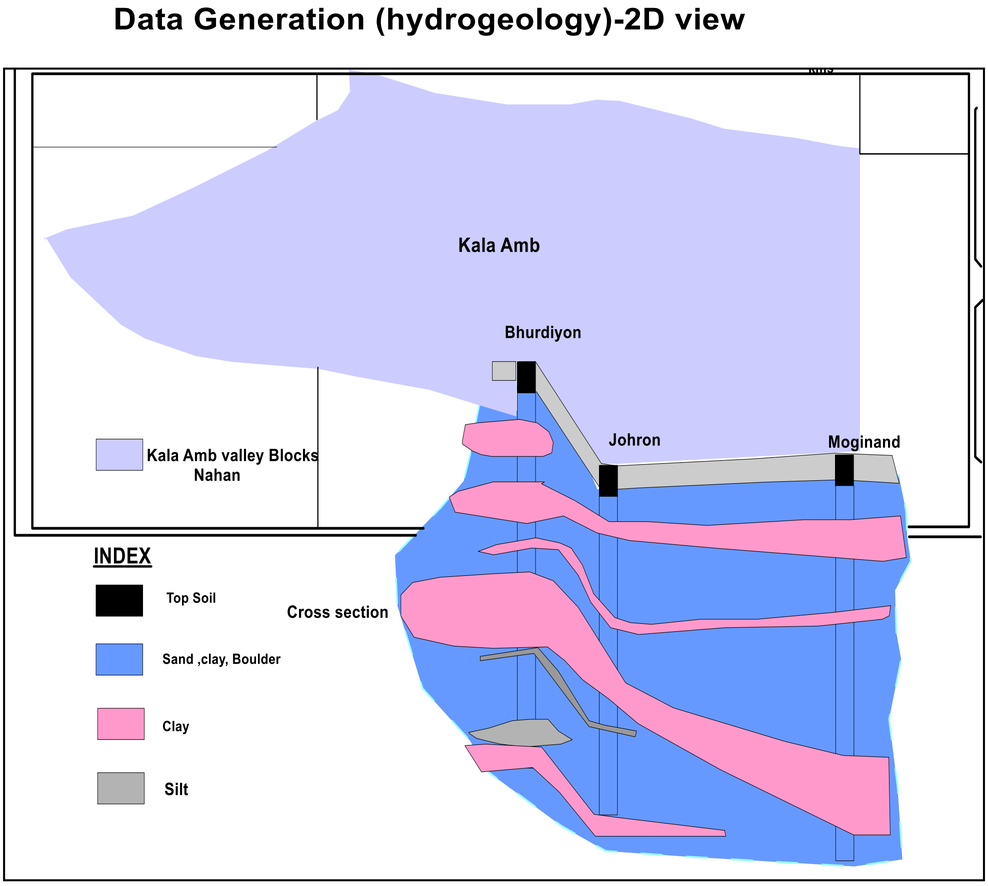


Fig 3.2: 2-D Cross-section fromBhrddiyon, Johron and Moginand

Table3.2 (A) :Aquifer parameters of EWs drilled under NAQUIM in Study area

Location	**Lat**	**Long**	**Type**	**Depth (m)**	**SWL (m)**	**Dis (lpm)**	**d/d (m/lpm)**	**T (m2/d)**
Johron	30.50139	77.22361	valley fill	100	39.5	220		
Moginand	30.5142	77.2395	valley fill	100.5	34	210	18	22.07
Bhurddiyo	30.5358	77.1997	valley fill	98	2.18	210	60	16.85
Dhangwala	30.6042	77.1963	Riverrine /Siwalik	105	3.68	877.55	1.42	1399.75

Table3.2(B) : Aquifer parameters of EWs drilled under NAQUIM in Study area

Exploratory Well	**T (m2/day)**	**Specific Capacity (lpm/m)**	**Discharge (lpm)**	**Well Depth**
DhangwalaGurudwara	1399.75	635.43	870.55	120
Mogi Nand	22.075	11.58	210	100
Bhurridiyon	16.8535	1.7	210	100

3.2.1. Water Level Behaviour (NHS): To know the water level and its behaviour with respect to time and space, 13 dug wells have been inventoried for Ground Water Management Studies all over the area. The dug wells are located in and around Kala amb and Paonta valley. The water levels were taken during the month of May and November, 2015 & 2016 and on the basis of these data, pre-monsoon, post monsoon and seasonal fluctuation map have been prepared for the Paonta valley area. The hydrogeological data of the inventoried dug wells are given below

Table 3.3 NHS locations in Paonta-Kala Amb Valley

S. No	**Location details**	**Block**	**Lat**	**Long**	**Well Type**	**Depth**	**Estt date**	**MP**	**RL**
1	TIRLOKPUR	Nahan	30.54	77.204	Dug well	16.5	1981	0.89	366.01
2	KALA AMB	Nahan	30.498	77.212	Dug well	14.5	1974	0.72	340.18
3	SHAMBHU-WALA	Nahan	30.524	77.321	Dug well	13	1975	0.42	482.42
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6	NAYAGAON	Paonta sahib	30.498	77.441	Dug well	20	1974	0.6	422.5
7	SHIBPUR	Paonta sahib	30.486	77.523	Dug well	30.5	1975	0.36	450.72
8	DHAULAKUAN	Paonta sahib	30.502	77.473	Dug well	13	1974	0.38	442.08
9	BADRIPUR	Paonta sahib	30.449	77.609	Dug well	13.5	1990	0.38	394.81
10	NARIWALA	Paonta sahib			abandoned	45	1981	0.38	469.41
11	AJIWALA	Paonta sahib	30.47	77.587	Dug well	8.65	1981	0.56	391.62
12	KHODAWALA	Paonta sahib	30.487	77.705	Dug well	20.5	1990	0.2	445.09
13	AKKWALA	Paonta sahib	30.52	77.287	Dug well				

Kala Amb valley acquires only 2.5 sq km area of the total 81 sq km study area. Only 2 National Hydrograph Monitoring Stations have been fixed by CGWB, in the valley portion. The depth to water level does not showsmuch variation. During pre-monsoon period (May

2014) it ranges from below 2.00 to not more than 20.00 m bgl in August 2015, the depth to water level scenario does not differs much.

Table 3.4DTW of May14, August14, Nov 14 & Jan15

District	Sirmour	Latitude	Longitude	dtw may 14	dtwaug 14	dtwnov 14	dtwjan 15
1	Ajiwala	30.47	77.59	5.66	3.94	3.41	5.28
2	Akkawala	30.52	77.61	12.40	11.04	10.42	11.44
3	Badripur	30.44	77.62	12.82	10.24	10.60	12.52
4	Dhaulakuan	30.45	77.64	6.35	3.08	3.52	5.45
5	Kala-Amb	30.5	77.22	14.12	11.89	15.00	13.24
6	Khodawala	30.49	77.73	15.47	12.91	15.60	15.97
7	Kiyarda	30.48	77.55	10.71	2.74	6.05	9.26
8	Kolar	30.55	77.43	12.81	8.03	13.15	11.48
9	Nayagaon	30.49	77.52	10.35	4.57	9.35	11.99
10	Shambuwala	30.53	77.32	8.66	7.59	9.20	8.53
11	Shibpur	30.48	77.67	19.21	25.56	20.10	11.99
12	Trilokpur	30.54	77.21	2.02	1.36	1.80	1.88

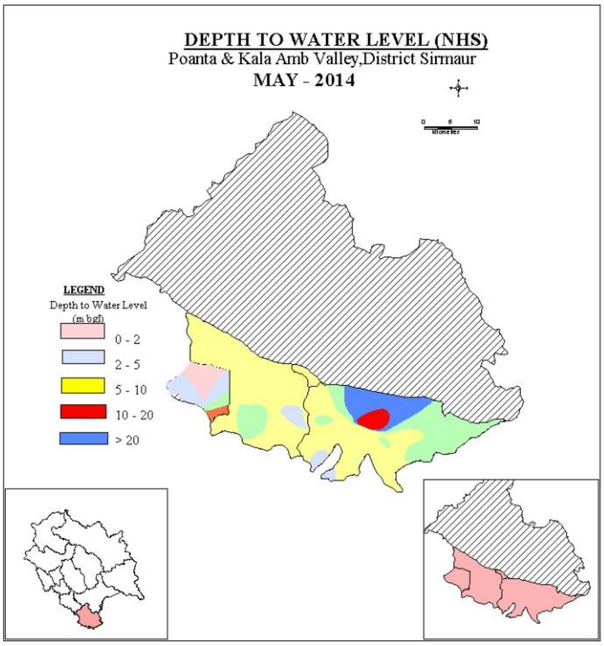


Fig:3.3 (A) Map showing DTW from NHS (May 2014)

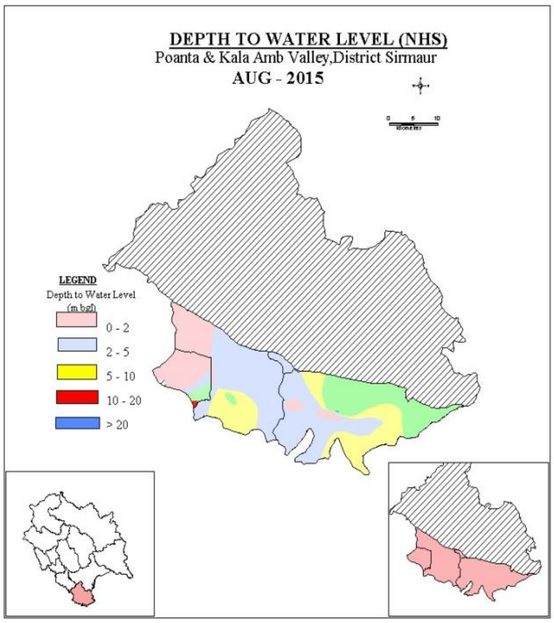


Fig:3.3 (B) Map showing DTW from NHS (Aug 2015)

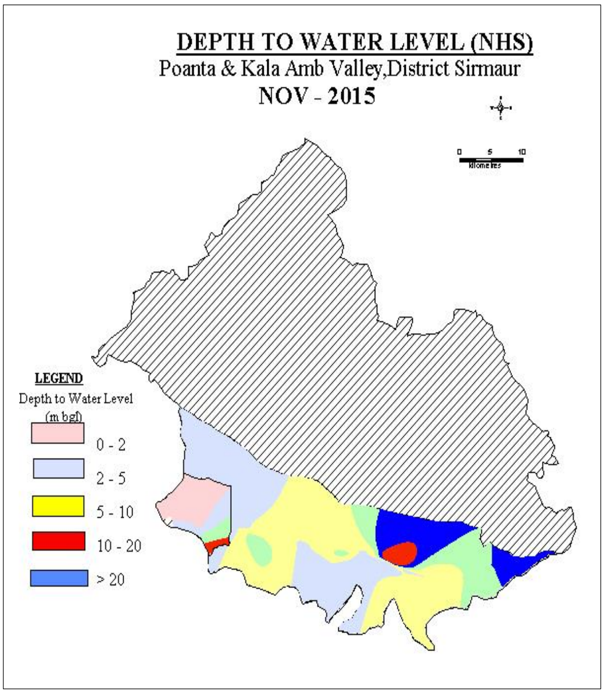


Fig:3.3 (C) Map showing DTW from NHS (Nov 2015)

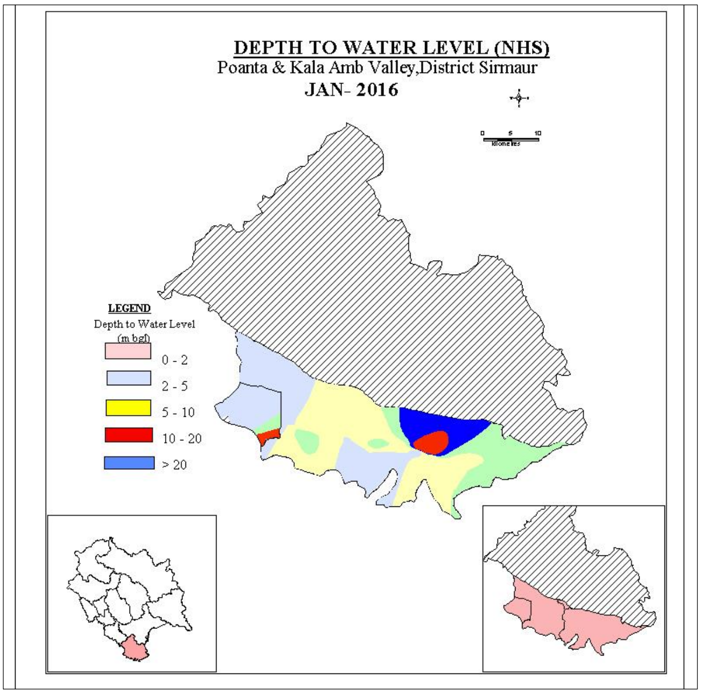


Fig:3.3 (D) Map showing DTW from NHS (Jan 2016)

Table 3.5 Water level data from NHS locations in Kala Amb Valley

	2014-15	**Depth to Water Level**				**Seasonal Fluctuatn**	**Annual Fluctuation**		**Decadal Fl**
Sr. No	NHS Locations	May 14	Aug 14	Nov14	Jan15	(May-Nov 14	May 13-14	Nov 13-14	2004-13, wrt may 14
1	Kala Amb	14.12	11.89	15.00	13.24	0.88	-0.66	-1.9	0.76
2	Trilokpur	2.02	1.36	1.80	1.88	0.14			
	2015-16	**Depth to Water Level**				**Seasonal Fluctuatn**	**Annual Fluctuation**		**Decadal Fl**
Sr. No	NHS Locations	May 15	Aug 15	Nov15	Jan16	(May-Nov 15	May 14-15	Nov 14-15	2005-14, wrt may 15
1	Kala Amb	13.80	10.70	12.35	13.60	1.45	0.32	2.65	-0.24
2	Trilokpur	1.80	0.82	1.69	2.12	0.11	0.22	0.11	0.74
	2016-17	**Depth to Water Level**				**Seasonal Fluctuatn**	**Annual Fluctuation**		**Decadal Fl**
Sr. No	NHS Locations	May 16	Aug 16	Nov16	Jan17	(May-Nov 16	May 15-16	Nov 15-16	2006-15, wrt may 16
1	Kala Amb	16.75	13.30	15.20	15.60	1.55			-3.04
2	Trilokpur	2.33	1.35	2.00	2.25	0.33	-2.95	0.53	0.17

Hydrographs of two NHS wells, in the study area are shown below:

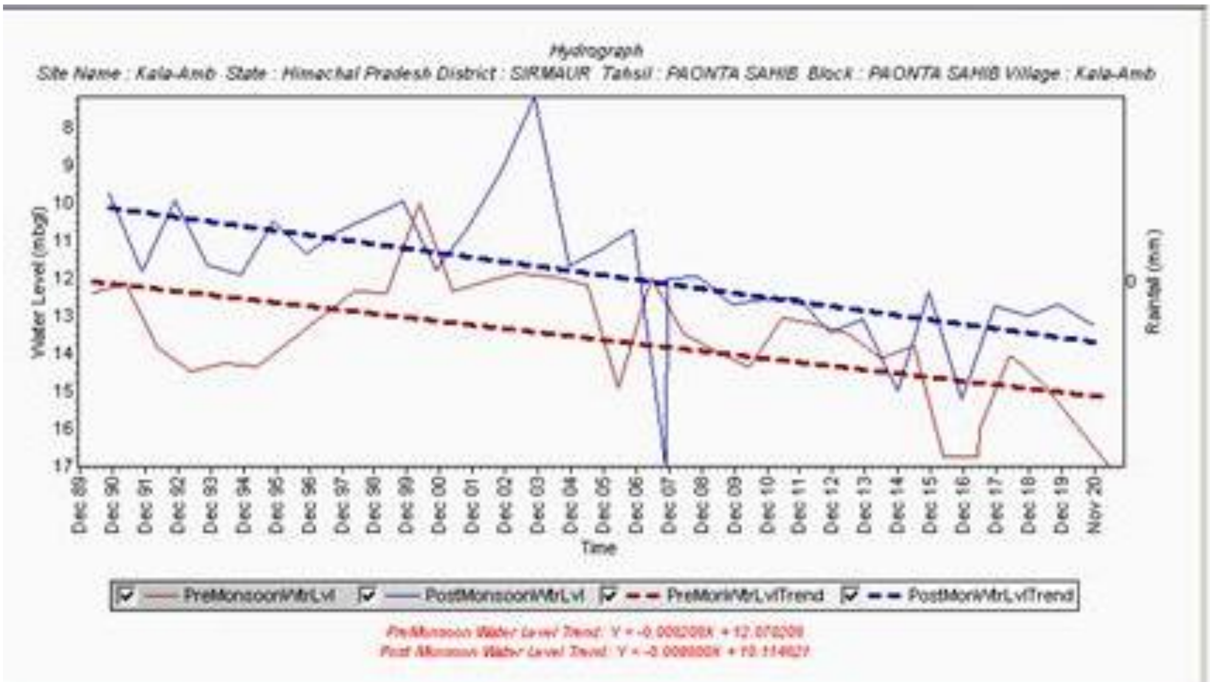


Fig: Hydrograph of NHS well Kala Amb

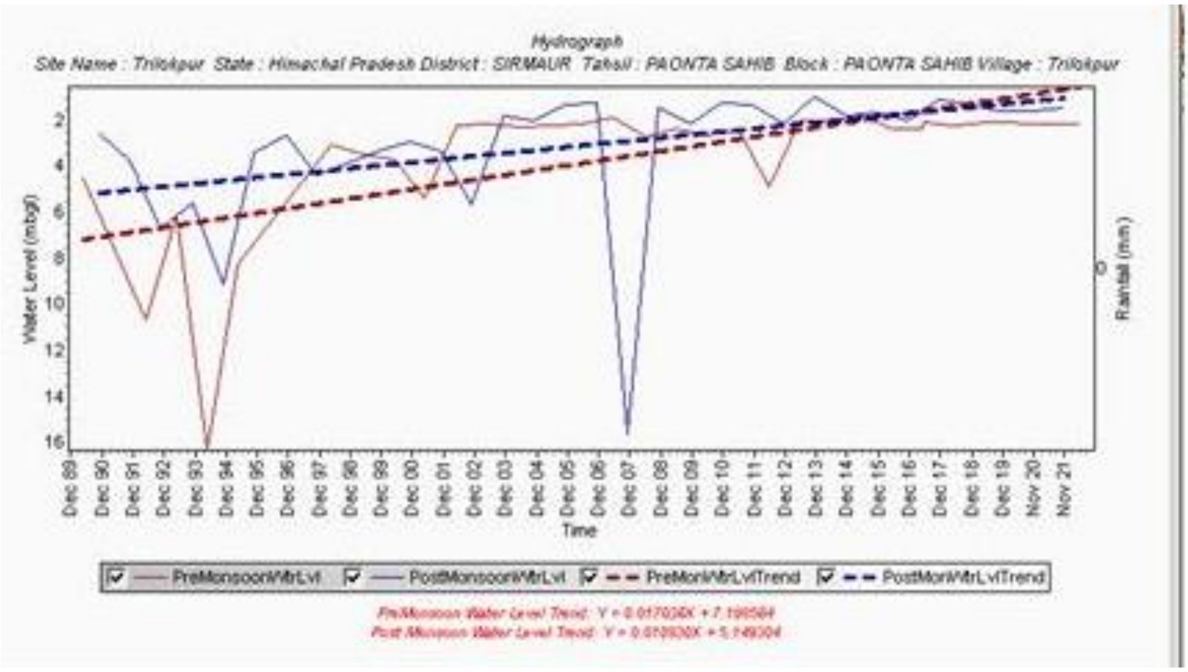


Fig: Hydrograph of NHS well Trilokpur

3.2.2. Water Level Behaviour (PIEZOMETERS):

To know the water level and its behaviour with respect to time and space, for deep aquifer, water level of piezometers was analysed. This data have been received from Irrigation & Public Health Department, Govt of Himachal Pradesh. A total of 10piezometershave been monitored from automatic water level recorders. The detail peruse of maps are shown below:

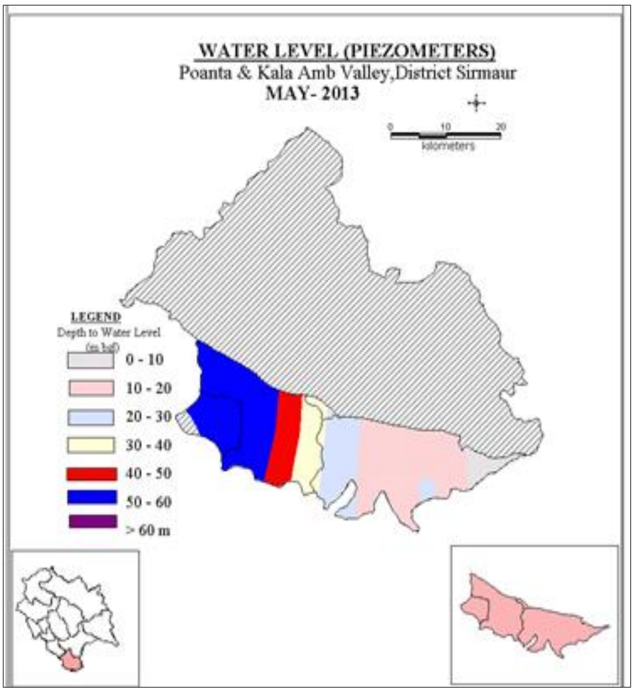


Fig:3.4 (A) Pre monsoon Map showing DTW from Piezometers (May 2013)

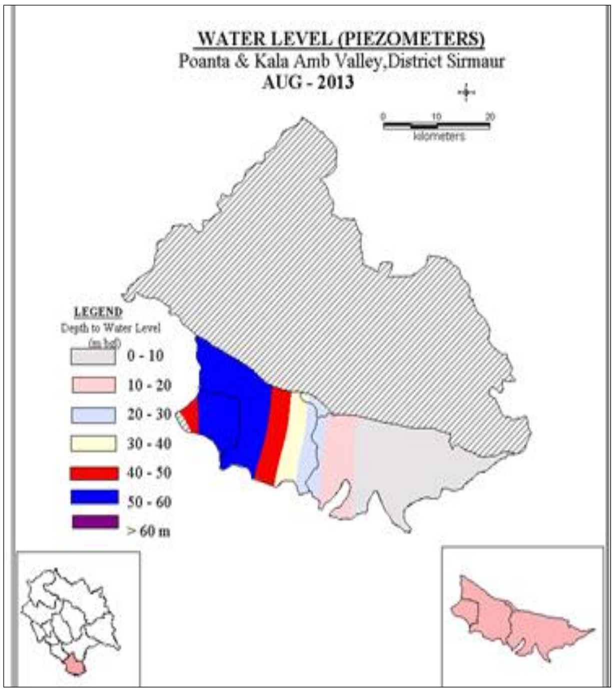


Fig:3.4 (B) Map showing DTW from Piezometers (Aug 2013)

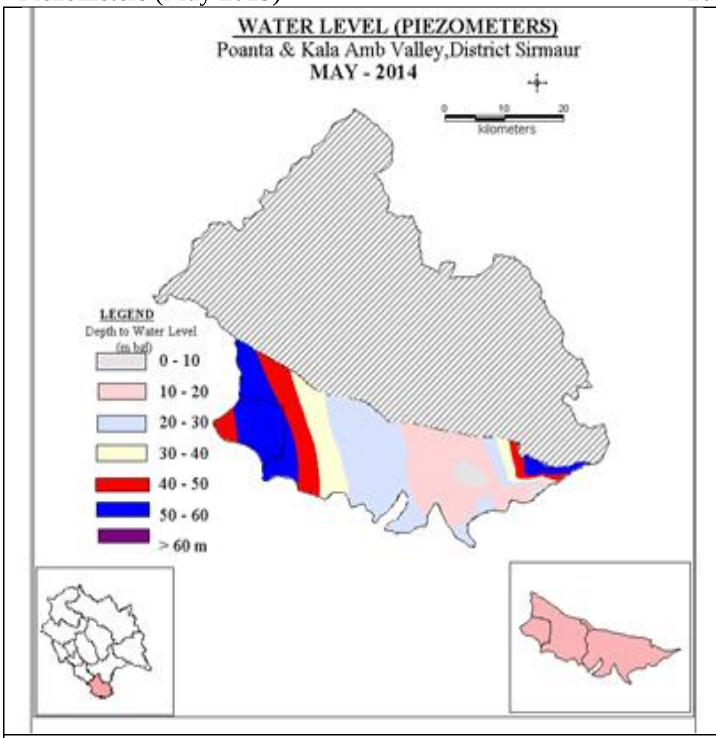


Fig:3.4 (C) Pre monsoon Map showing DTW from Piezometers (May 2014)

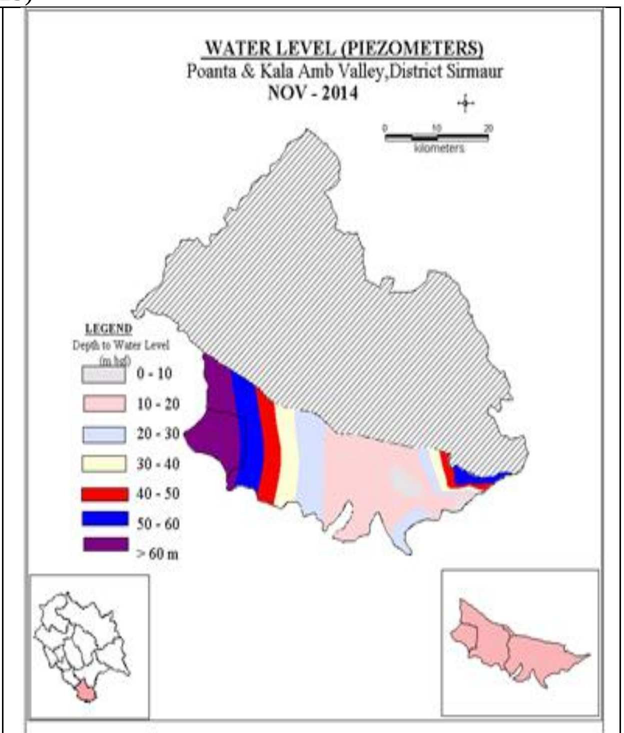


Fig:3.4 (D) Post Monsoon Map showing DTW from Piezometers (Nov 2014)

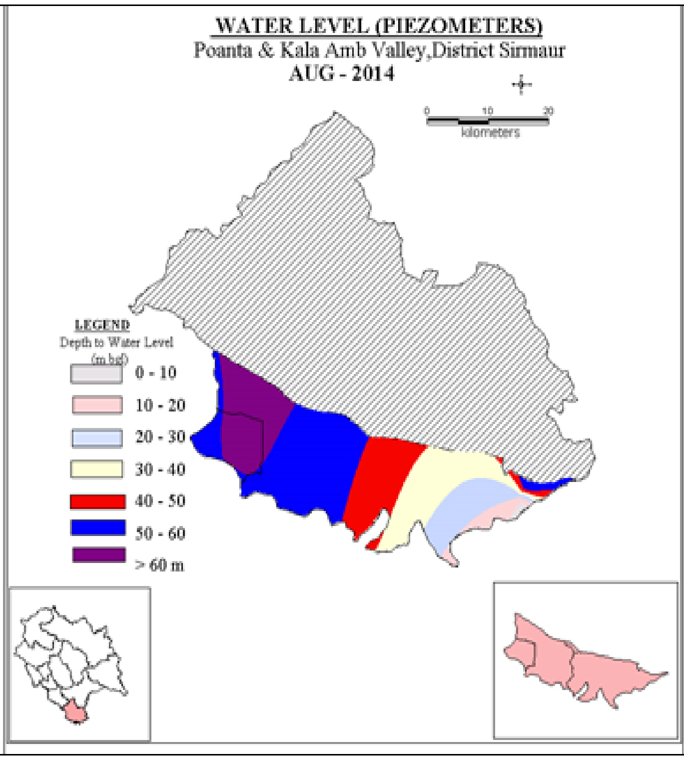


Fig:3.4 (E) Map showing DTW from Piezometers (August 2014)

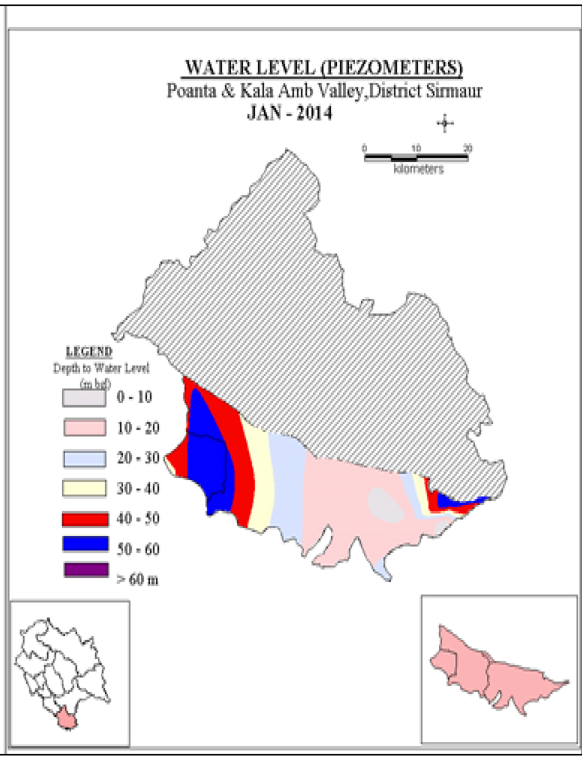


Fig:3.4 (F) Map showing DTW from Piezometers (Jan 2014)

Table 3.6 Water level data from State Piezometers in District Sirmour

Location	**District**	**Pre Monsoon 2010**	**Post Monsoon 2010**	**Pre Monsoon 2011**	**Post Monsoon 2011**	**Pre Monsoon 2012**	**Post Monsoon 2012**
Majra	Sirmour	16.97	12.12	16.32	11.05	15.59	10.15
ManpurDeara	Sirmour	8.6	8.6	8.85	8.7	7.95	8.75
Bhagani Upper	Sirmour	62.1	43.85	58.15	48.95	59.45	53.7
Gulabgarh	Sirmour	2.65	0.5	2.25	0	2.05	0
Toruwala	Sirmour	22	NA	NA	NA	NA	NA
Jattonwala	Sirmour	26.1	13	25	17.05	25.4	19
Johron	Sirmour	67.15	66.05	65.05	66.4	67.05	70.75
Kheri	Sirmour	54.37	54.24	54.31	56.43	57.4	61.53
Churan	Sirmour	NA	NA	44.12	45.6	46.25	49
Bohlion	Sirmour	NA	NA	0	0	0	0

Location	**Pre Monsoon 2013**	**Post Monsoon 2013**	**Pre Monsoon 2014**	**Post Monsoon 2014**	**Pre Monsoon 2015**	**Post Monsoon 2015**	**Pre Monsoon 2016**
Majra	15.85	11.31	14.64	14.00	NA	NA	19.6
ManpurDeara	8.86	8.67	9.17	8.54	8.92	8.61	8.78
Bhagani Upper	NA	NA	59.93	60.09	NA	NA	NA

Gulabgarh	1.86	0	2.39	1.99	2.89	2.32	3.94
Toruwala	20.25	15.55	20.17	19.51	21.15	NA	22.81
Jattonwala	24.37	15.04	21.31	17.28	21.95	NA	29.6
Johron	NA	NA	NA	NA	NA	NA	75.2
Kheri	59.46	59.75	56.85	62.65	NA	NA	65.9
Churan	38.11	39.75	44.12	50.66	47.87	51.22	51.79
Bohlion	0	0	0	0.00	0	NA	0

Source: IPH Department, HP

3.3 Water Quality Data

Samples were collected from different sources like dug wells, tube wells and handpumps, to decipher water quality in the study area. Water samples were also collected from Exploratory wells drilled during NAQUIM. Details of results are shown in tables belowTo assess the impact of industrial pollution on ground water quality, 24 numbers of water samples from Poanta Sahib and 7 numbers of water samples from Kala Amb were collected. Samples were collected from all the sources of water including phreatic aquifer, shallow and deep aquifer and surface water. From Poanta Sahib, 6 number of samples from surface water, 9 from tube wells (used for public supply), 5 samples from Hand pumps and 5 samples from dugwells. Similarly, one sample was from surface water and 5 samples were collected from tub wells from Kala Amb industrial area. One drain/effluent samples was also taken.

Table 3.7 (A) Water Quality data (2016)of key observation wells established under NAQUIM study

S. No.	Location	Source	pH	Sp Cond ms/cm 25°C	CO_3	HCO_3	Cl	Ca	Mg	Na	K	TH
1	Kala Amb	DW	7.84	570	0	159	50	24	26	65	5	165
2	Johron	TW	7.46	550	0	281	25	66	17	31	2	235
3	Kheri	TW	7.71	540	0	201	25	28	28	52	2.3	185
4	Trilokpur	DW	8.77	1190	54	250	191	16	24	310	17	140
5	Kala Amb	TW	7.39	740	0	195	67	48	30	71	2.4	245
6	Moginand	HP	8.1	740	0	519	18	20	8.5	230	5.4	85
7	Markanda R.	SW	7.98	470	0	226	29	44	15	52	4	170
8	Johron-1	TW	7.18	580	0	232	57	62	16	35	1.7	220

Table 3.7(B)Water Quality data (2015) of key observation wells established under NAQUIM study (shallow aquifer)

S. No.	Location	Source	pH	Sp Cond ms/cm 25°C	CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	Sio2	TH
1	Dhirath	HP	8.75	445	35	203	7.1	20	BDL	BDL	8	0	110	0.5	13	20
2	Banethi	Spring	8.35	190	12	98	3.5	10	BDL	BDL	20	5	20	2.2	14	70
3	Kando	Spring	8.18	199	nil	143	7.1	15	0.78	BDL	32	12	6.9	0.6	16	130
4	Panjahal	Spring	8.35	224	12	96	11	15	6.31	0.05	40	5	7.7	0.4	16	120
5	Kayartu	Spring	8.3	192	12	85	3.5	40	0.1	0.15	36	10	4.5	0.3	10	130
6	Serta	HP	8.8	952	118	406	11	40	0.98	0	8	12	240	1.5	14	70
7	DevkaPurla	Spring	8.44	248	12	96	7.1	62	BDL	0.17	26	23	8.5	0.1	15	160
8	Shaktinagar	HP	8.55	425	23	144	25	45	2.22	BDL	28	22	40	0.8	22	160
9	Akkawala	DW	8.45	278	23	107	11	30	3.4	BDL	28	15	20	3.7	26	130
10	Sketi	HP	8.6	702	23	167	7.1	136	65	BDL	16	15	130	3	15	100

Table 3.7(C) Water Quality data fromNHS wells (2015) in District Sirmour(shallow aquifer)

S. No.	Location	Temp °C	pH	Sp Cond ms/cm 25°C	CO_3	HCO_3	Alkalinity	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	TH	TDS
1	Kala amb	22	7.1	580	0	214	175	43.0	94.89	2.0	0.24	56	20	**50**	**6**	220	302
2	Trilokpur	23	7.42	1050	0	275	225	152.0	89	15.0	0.35	30	12	186.0	12	125	546

S. No	Location	pH*	EC*	CO_3	HCO_3	Cl*	SO_4	NO_3*	F*	PO_4	Ca*	Mg*	Na	K	SiO_2	TH *as $CaCO_3$
1	Sainwala (HP)	8.45	405	23	96	35	65	24	0.12	BDL	24	34	26	0.8	22	200
2	Berma (HP)	8.70	890	59	179	71	84	34	0.29	0.02	20	39	92	43	19	210
3	Kheri (HP)	8.40	309	12	120	21	28	2.13	0.43	0.05	16	15	33	8	19	100

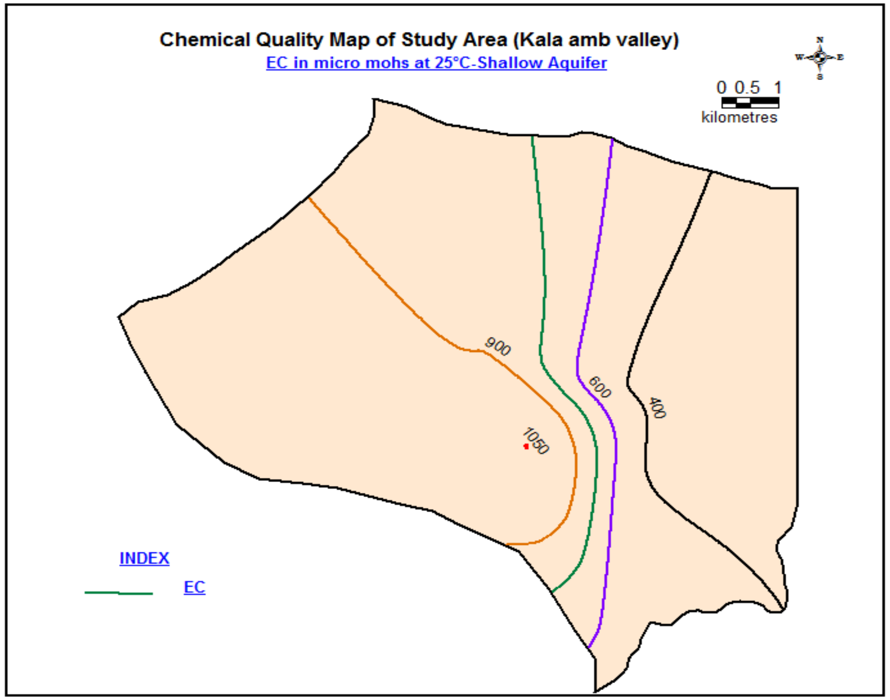


Fig 3.5 (A): EC in shallow aquifer in study area

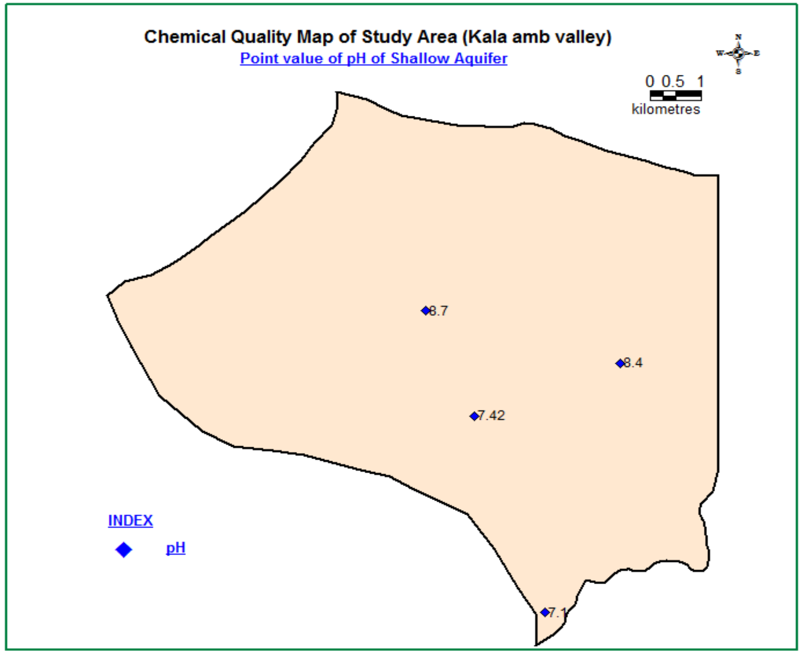


Fig 3.5 (B): pH values in shallow aquifers in study area

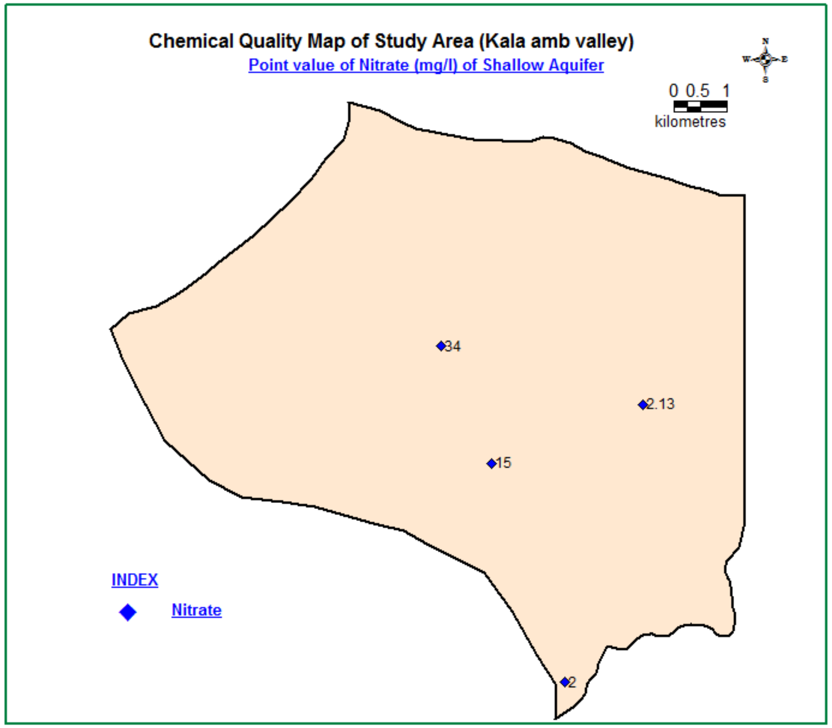


Fig 3.5 (C): Nitrate in shallow aquifer in study area

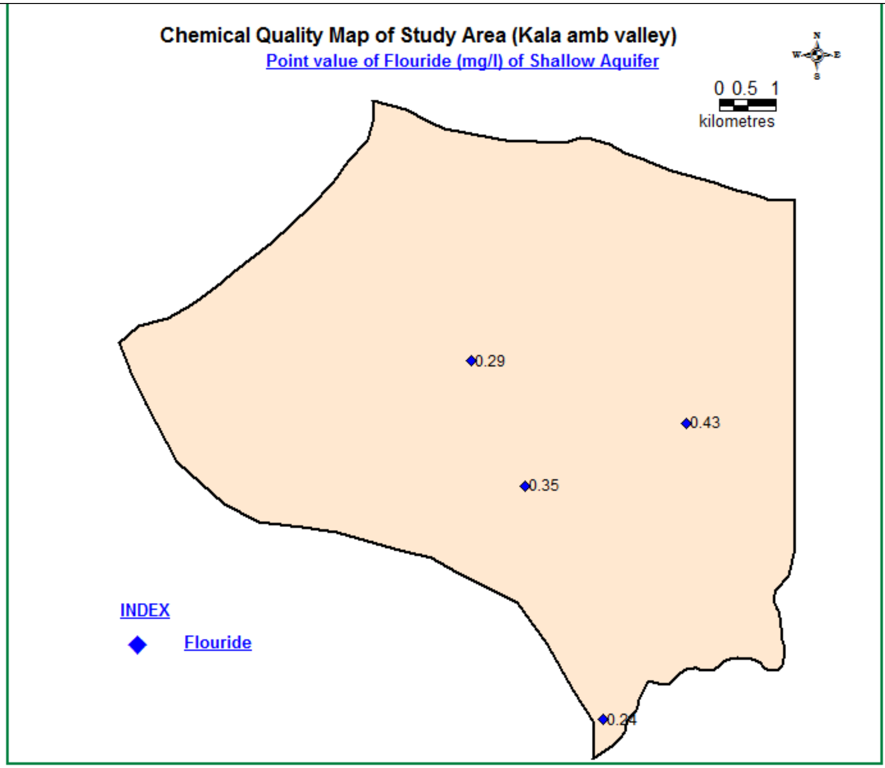


Fig 3.5 (D): Flouride values in shallow aquifers in study area

Table 3.7(E) Water Quality data fromalready existing deep TWs in Kala Amb valley (Deep Aquifer)

Sr. No	Location	Source	Lon	Lat	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	TH
1	Johron	Tube Well	77.20519	30.51733	8.17	350	Nil	189	14	7	11	Tr	38	13	19	1.1	150
2	Kheri	Tube Well	77.19292	30.52456	8.60	490	6	281	14	9	14	0.21	70	11	27	2.3	220

3	Johron	Tube Well	77.20569	30.51072	7.78	550	Nil	250	39	18	20	0.10	86	9.70	19.00	1.50	255.00
4	Kala Amb	Tube Well	77.20997	30.55014	8.07	380	Nil	220	11	5	8.9	0.10	58	7.2	15	1.0	175
5	Khara	Tube Well	77.21219	30.49514	8.65	430	6	226	21	10	4.9	0.10	70	3.6	22	1.7	190
6	Markanda R.	Surface water	77.21308	30.49672	8.20	440	Nil	207	21	46	6.8	0.10	64	11	21	6.9	205

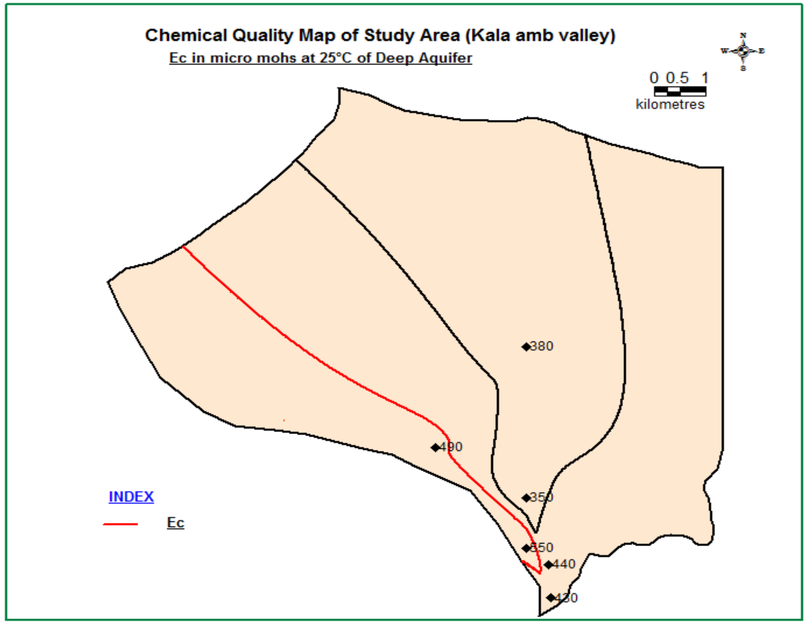


Fig 3.6 (A): EC in Deep aquifer in study area

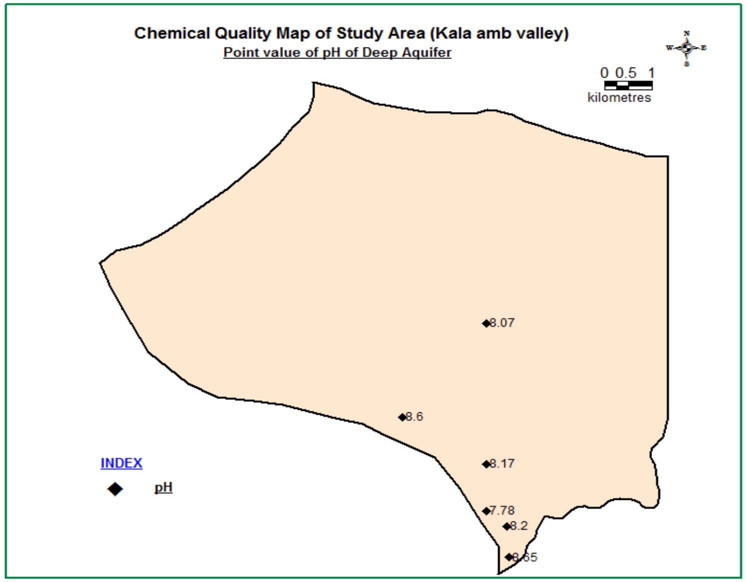


Fig 3.6 (B): pH values in Deep aquifers in study area

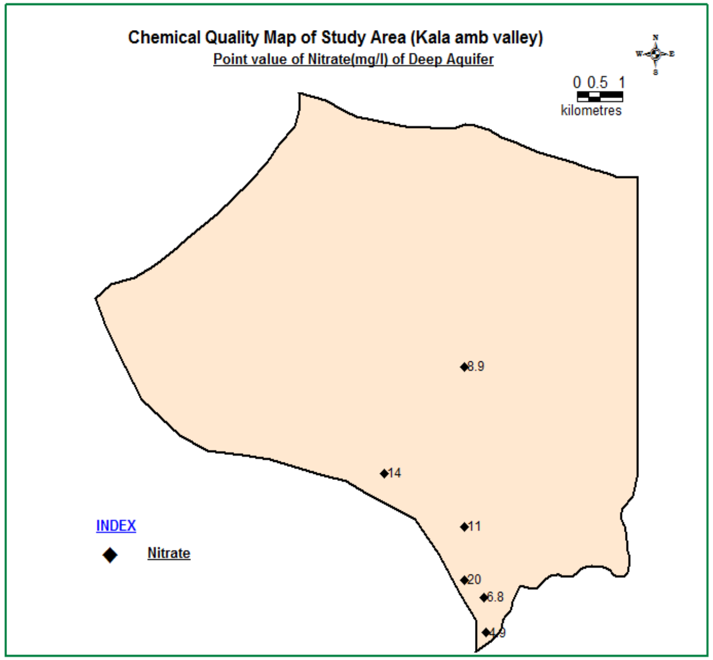


Fig 3.6 (C): Nitrate in Deep aquifer in study area

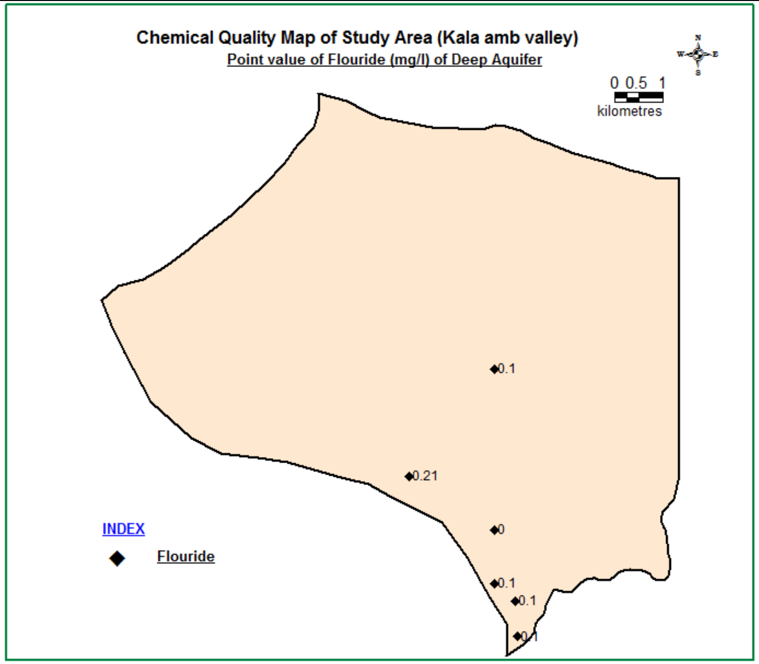


Fig 3.6 (D): Flouride values in Deep aquifers in study area

Table 3.7 (F) Water Quality data of Exploratory wells drilled during NAQUIM

Location	**Bhurrdiyon**	**Dhangqwala Gurudwara**	**Moginanad**
Date of collection	24.8.2016	Jun-16	30.5.2016
temperature	22	Jan-00	22
pH	7.42	7.2	8.35
EC (mS/cm) at 25^0C	1050	102	804
CO_3 mg/l	0	0	54
HCO_3 mg/l	275	30	415
Cl mg/l	152	10	28
NO_3 mg/l	15	12	1.64
F mg/l	0.35	0.2	0.23
Ca mg/l	30	12	14
Mg mg/l	12	5.2	51
Na mg/l	186	6	105
K mg/l	12	2.53	1.9
TH as $CaCO_3$ mg/l	125	130	245
Total Hardness			418

All the collected samples were analysed by adopting Standard methods of analysis (APHA). The heavy metal analysis was carried out by Atomic Absorption Spectrophotometer (ECIL 4141). Location of sampling points with details are given in Annexure I . The location of sampling points are given in figure 2&3.Water quality parameter for springs, Shallow, Deep ground water aquifers and Drain / Effluents samples are discussed below. Minimum & maximum values of water quality parameter for springs, shallow and deep aquifers are summarised below. Data has been compiled from the key observation wells established during NAQUIM study of Kala Amb area of 81sqkm. (Table 3.4A & B).

Table 3.8 : General Range of Water Quality parameters in Kala Amb valley

Sl. No.	**Water Quality Parameters**		
		Min	**Max**
1.	pH	7.18	8.8
2.	EC µmhos/cm at 25°C	190	1190
3.	Carbonate (mg/l)	0	118
4.	Bi carbonate (mg/l)	85	519
5.	Chloride(mg/l)	3.5	191
6.	Nitrate(mg/l)	0.1	65
7.	Fluoride(mg/l)	nm	nm
8.	Sulphate(mg/l)	10	136
9.	Calcium(mg/l)	8	66
10.	Magnesium(mg/l)	0	30
11.	Sodium(mg/l)	7.7	310
12.	Potassium(mg/l)	0.1	17
13.	Total Hardness as $CaCO_3$(mg/l)	20	245

3.4 Vertical Electrical Soundings by WAPCOS

Under National Aquifer Mapping Programme, the geophysical primary data generation in 10 districts of Himachal Pradesh was entrusted to WAPCOS Ltd. by the Central Ground Water Board, Ministry of Jal Shakti, and Govt. of India. Accordingly, WAPCOS initiated the primary data generation activities in Himachal Pradesh

Table 3.9: List of VES in District Sirmour

District	Block	No. of VES Proposed by CGWB	No. of VES Conducted by WAPCOS
Sirmaur	Nahan, PaontaSaheb,	(81-102)22	22

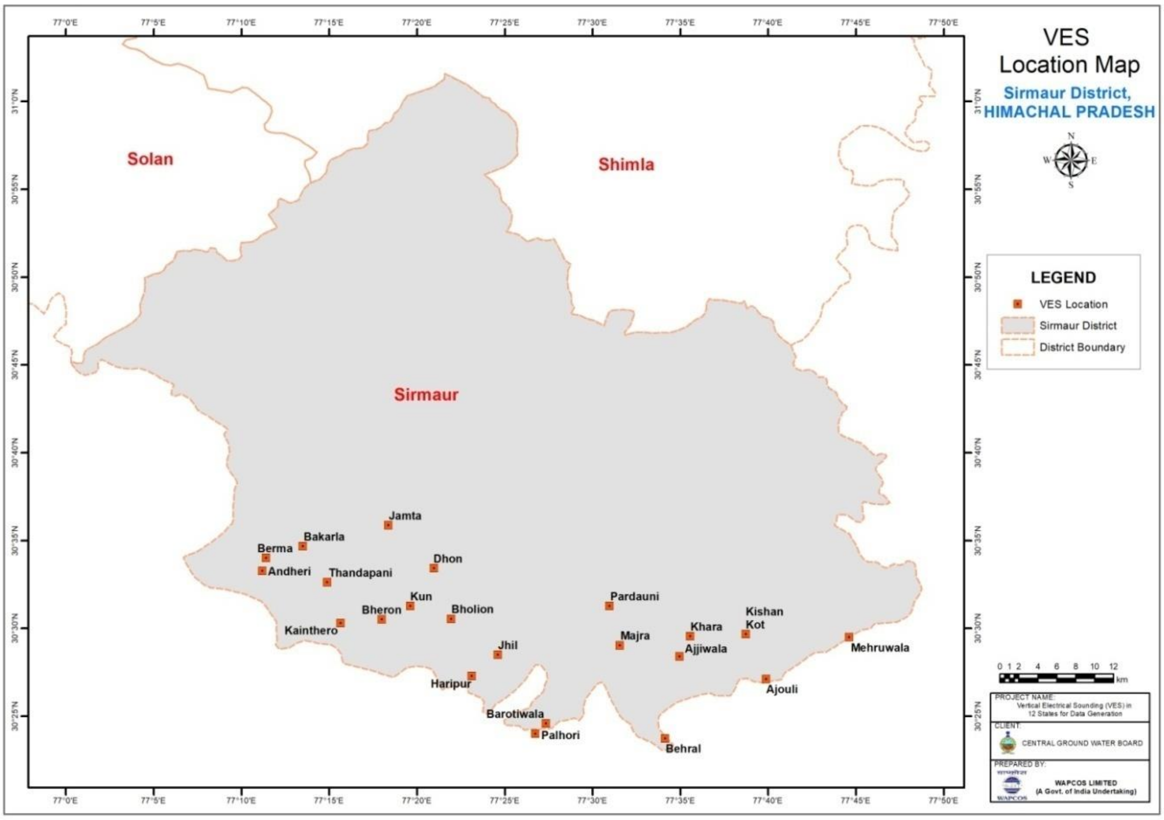


Figure 3.5.1: Map of Sirmaur district showing VES locations

Objectives of the Geophysical Surveys

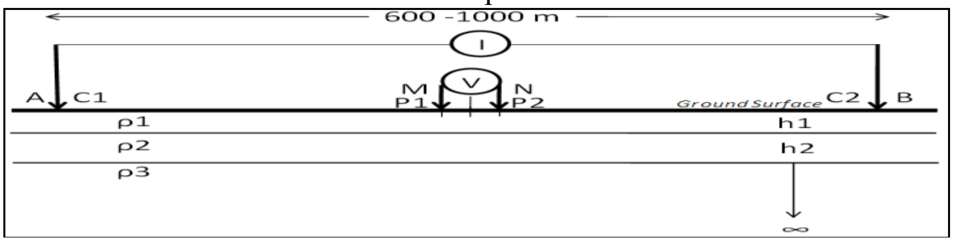
The districts mentioned above are mostly occupied by soft rock comprising sand, clay, sandstone and parts of a few districts are occupied by hard rock, comprising granites and gneisses. In soft rock area granular aquifers are to be identified. The hard rocks are hydrogeologically heterogeneous. Aquifer mapping in these hard rocks demands mapping of aquifers in the weathered zone, and in the underlying saturated fractured zones.

The objectives of geophysical surveys were

- To ascertain sub-surface information and aquifer deposition up to 300m depth in soft rock 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.

3.4.1 Vertical Electrical Sounding (VES)

The Vertical Electrical Soundings (VES) were carried out using Schlumberger configuration (Figure 3.6). 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 3.6:** 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.

3.4.2 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.

3.4.3 Standardization of VES Results with Borehole Information

The borehole (BH) at Bhurddiyon (DD: 100 m) is located in Upper Siwaliks at an elevation of 367 m amsl. The nearest VES 99, located about 2.3 km NW of the BH, is also in Upper Siwaliks(Fig. 3.9.3). It is at an elevation of 398 m amsl. The litholog of the BH indicates the presence of sticky clay throughout the depth drilled except a 15 m thick bed of medium to coarse sand in the depth range 70-85 m. However, VES 99 infers the presence of clay (15 ohm.m resistivity) in the depth range 11-49 m. An improvement in resistivity up to 31 ohm.m is observed in the underlying layer in the depth range 49- 101 m. It indicates mixing of sand with clay. Further down, beyond 101 m, the resistivity is 74 ohm.m, that could be associated with medium to coarse sand predominance. The VES indicates that BH drilled up to about 150 m depth may encounter deeper aquifers.

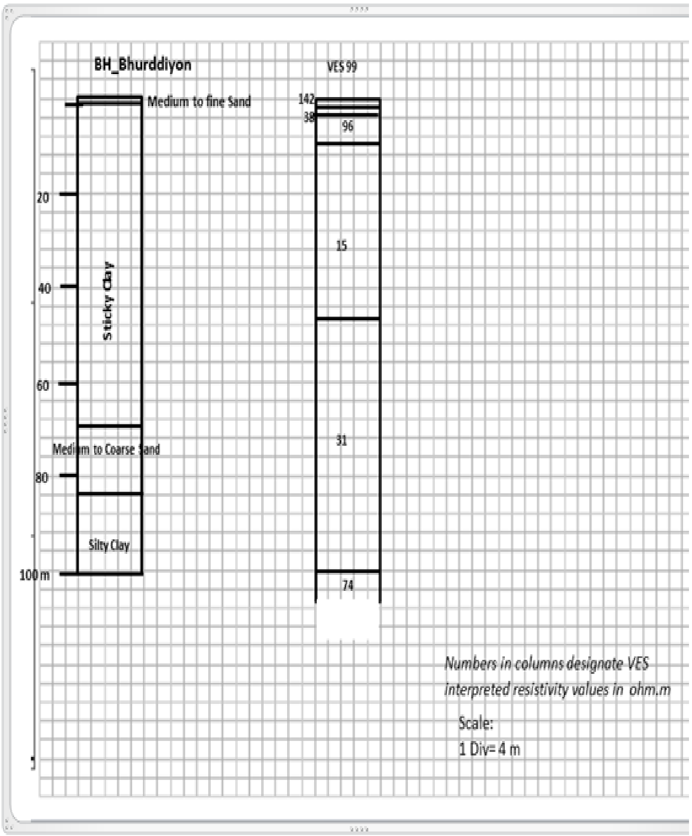


Figure 3.7(A): VES-Borehole LithologCorrelation,Bhurddiyon , Sirmaur Dist.

The BH at Moginand (DD: 100 m) is located in Middle Siwaliks at an elevation of 378 m amsl. The nearest VES 83, located about 2.3 km SE of the BH, is also in Middle Siwaliks(Fig. 3.9.4). It is at an elevation of 384 m amsl. The litholog of the BH indicates the presence of clay and clay mixed sand throughout the depth drilled except two prominent medium to coarse sand zones in 70-90 m depth range (taken from CGWB report; correct quantitative litholog not available). VES 83 infers the presence of clay (19 ohm.m resistivity) in the depth range 5- 25 m. An improvement in resistivity up to 53 ohm.m is observed in the underlying layer in the depth range 25-146m. It

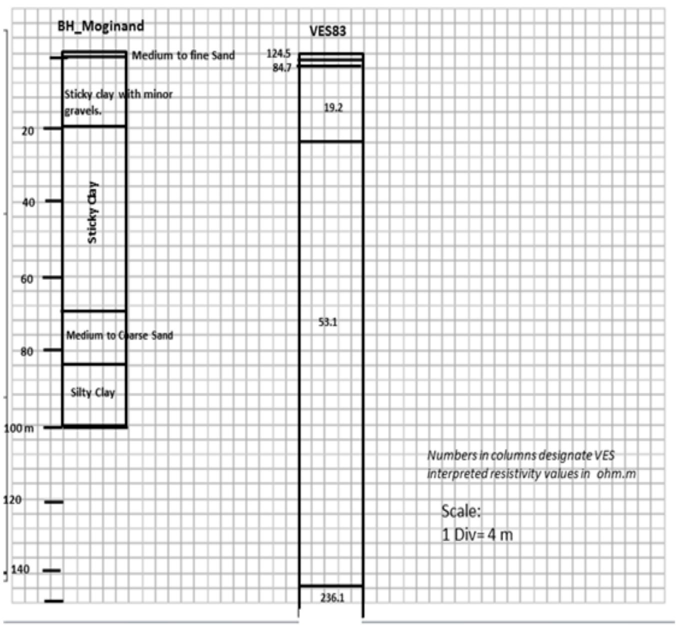


Figure 3.9.4: VES-Borehole Litholog Correlation,Moginand , Sirmaur Dist.

Figure 3.7(B): VES-Borehole LithologCorrelation,moginand , Sirmaur Dist.

indicates predominance of sand. Further down, beyond 146 m, the resistivity is 236 ohm.m, that could be associated with compact sandstone. In this case also, the VES indicates that BH drilled up to about 150 m depth may encounter deeper aquifers.

The BH at DhangwalaGurudwara (DD: 120 m) is at 528 m elevation. It is located near Krol Thrust zone- the contact zone of Lower Siwaliks with older Subathu formation. The BH has encountered pebble, cobble, gravel and boulder (PCGB) either with sand or clay in an alternating bed sequence. The thickest (27 m) PCGB with clay is in the depth range 43-70 m and 93-120 m. The thickest (15 m) PCGB with sand is in the depth range 70-85 m. The nearest VES 102 is at an elevation of 437 m amsl(Fig. 3.9.5). It is located in Lower Siwaliks, about 3.6 km SE of the BH and much south of the Krol Thrust. The VES infers a layer of 28 ohm.m resistivity in the depth range 5-87 m. The resistivity value manifests the presence of sand and clay in this depth range. It is underlain by a resistive layer that could be the compact sandstone.

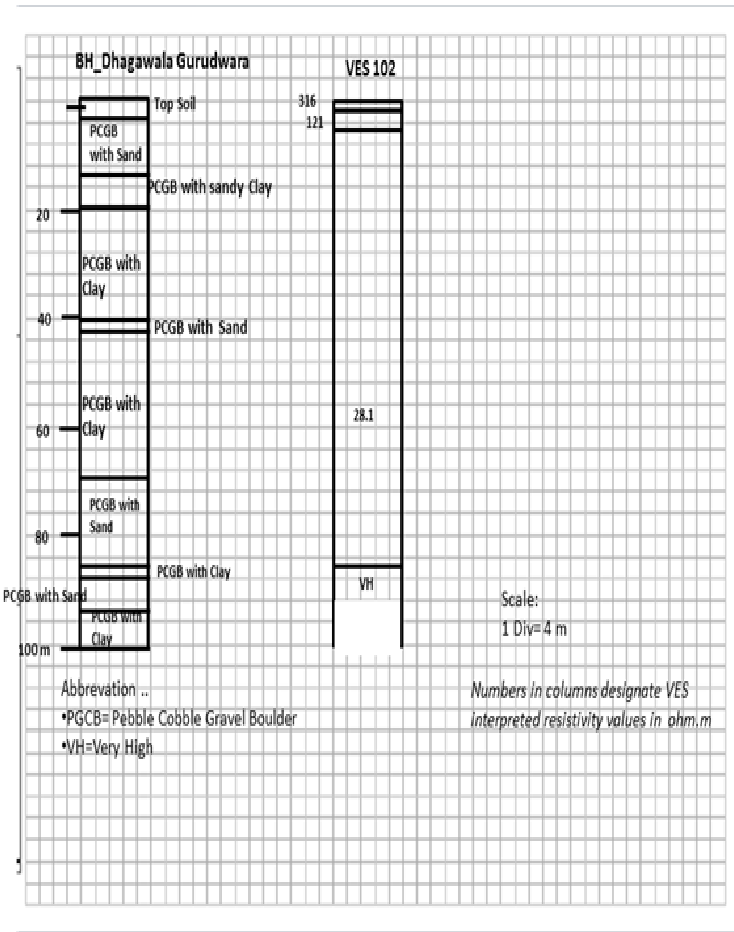


Figure 3.7©: VES-Borehole LithologCorrelation,DhangwalaGurudwara ,Sirmaur Dist.

VES data correlation with Bore hole in Paonta Valley of District Sirmour is as follows:

The BH at Kiyardah (DD: 103 m) is at 412 m elevation. It is located in the alluvium of Paonta Sahib valley. The alluvium is underlain by Upper Siwaliks. The BH encountered clay with sand, gravel and boulder throughout the depth drilled. However, within this the 7-8 m thick sand, gravel and boulder bed without any clay is in the depth ranges 50-57 m and 58-65 m. There are 3 VES-90, 92 and 97 located within 2.5 to 4m from the BH these VES are in alluvium and at elevations 383, 414 and 368 m amsl. All the 3 VES infer a highly resistive (171-241 ohm.m) near surface layer. The highly resistive layer extends to a maximum depth of 69 m at VES 92 and minimum depth of 17 m at VES 90. It indicates thickening of boulder bed towards west. The highly resistivity layer is underlain by a thick (>200 m) layer of resistivity ranging from 50 to 95 ohm.m (Fig. 3.9.6) . It could be a part of Upper Siwalik sediment. The resistivity values manifest the presence of coarse sand and gravel and could form potential aquifer.

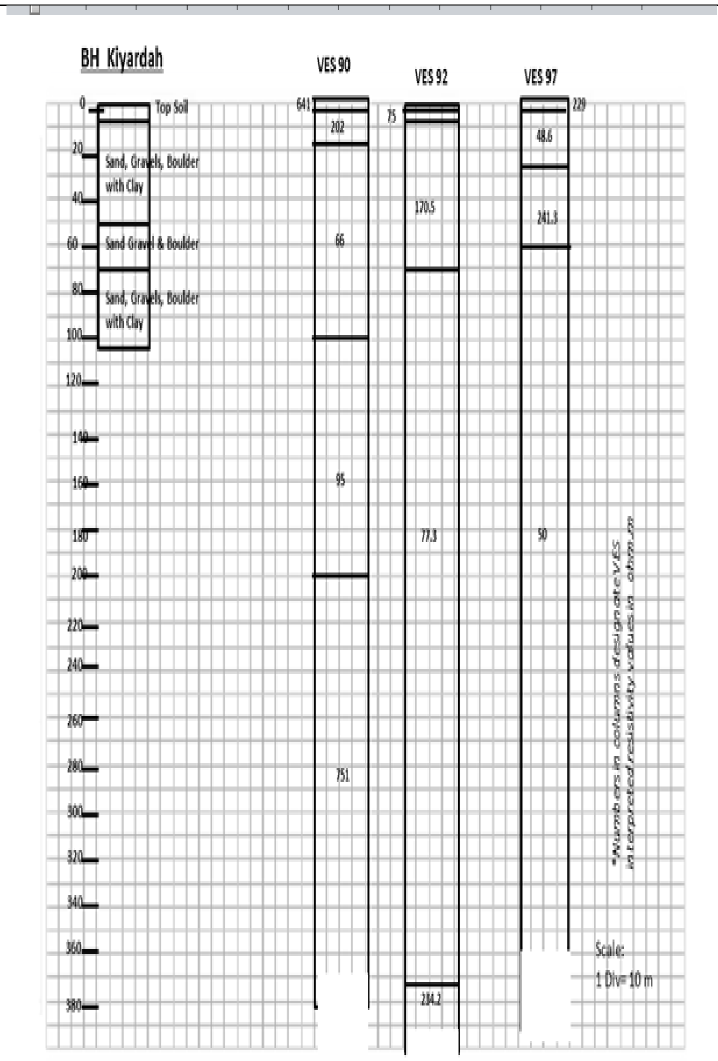


Figure 3.7(D): VES-Borehole Litholog Correlation, Kiyardah ,Sirmaur Dist.

The BH at Rajban Road, Jawalapur (DD: 101 m) is at 470 m elevation. It is located in the alluvium of Paonta Sahib valley, near the confluence of Giri and Yamuna Rivers. The alluvium is underlain by Upper Siwaliks. The BH encountered fine to coarse sand, gravel and boulder throughout the depth drilled. However, within this mixing of clay is observed in the thin depth zones of 40-45 m. VES 95 is located 2.6 km west of the BH and VES 94 is 3.5 km south of the BH. VES 95(elevation 466 m amsl) infers a layer of 57 ohm.m resistivity in the depth range 5-22 m and a layer of 103 ohm.m resistivity in the depth range of 22-52 m. At VES 94 (elevation 362 m amsl) the layer with least resistivity is 138 ohm.m in the depth range 32-149 m. Both the VES infer sand predominance and presence of potential aquifer, but an increase in resistivity beyond 80 ohm.m may not be much suitable because that indicates predominance of gravel and boulder which may not form sustainable aquifer(Fig. 3.9.7).

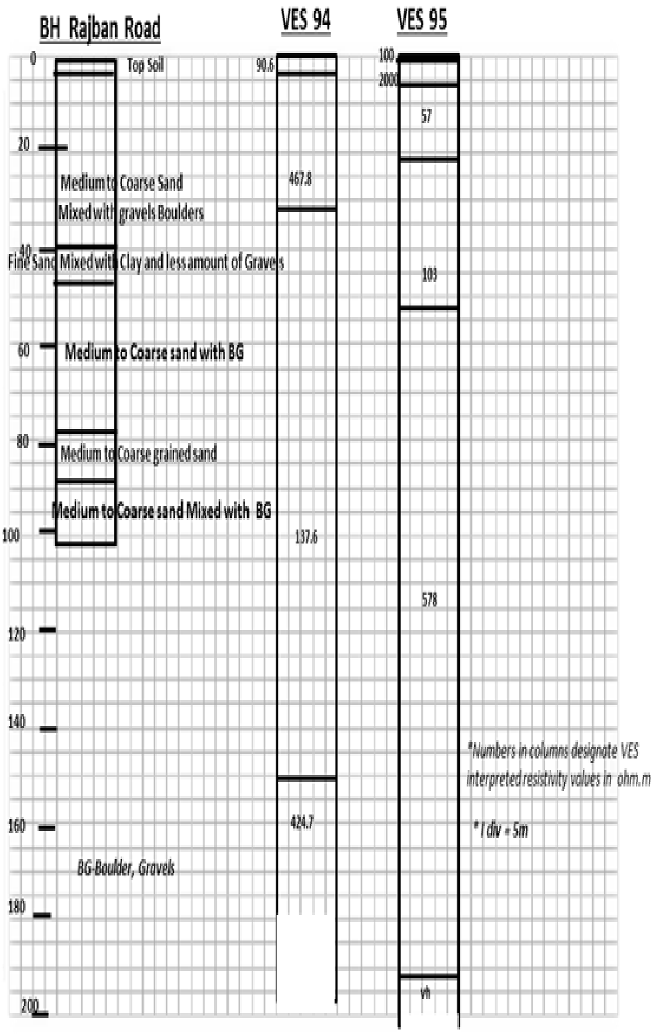


Figure 3.7€: VES-Borehole Litholog Correlation, Rajbanroad ,Sirmaur Dist.

3.5 Interpreted Results of VES

The interpreted results of VES are given in Annexure-I and the hydro-geophysical cross-sections prepared on the basis of VES results are shown fig 3.9.8 (a, b, c &d). The interpreted results are discussed here briefly. The VES 83, 85, 86, 87, 88, and 98 are located in Middle Siwalik hills. The VES spot elevations vary from 429 to 320 m amsl. It is highest in NW at VES 98 and lowest at VES 88 located about 20 km SE of VES 98. All the VES infer the presence of a thick layer of moderate resistivity ranging from 19 to 65 ohm.m. The depth to the bottom of this layer is maximum 300 m at VES 87 and minimum 116 m at VES 98, which is located at the highest elevation of 429 m. The resistivity of this moderately resistive layer is in the range of 19-27 ohm.m in the area between VES 83 and VES 86 which manifests the presence of clay and clay mixing with sand. The resistivity increases to 60-65 ohm.m eastward at VES 87 and 88 indicating predominance of sand as moved eastward. Also, its thickness increases at VES 87 with depth to the bottom at 300 m. A highly resistive layer underlies the moderately resistive layer which represents compact sandstone. The VES sites 87and 88 appear to hold thick aquifers.

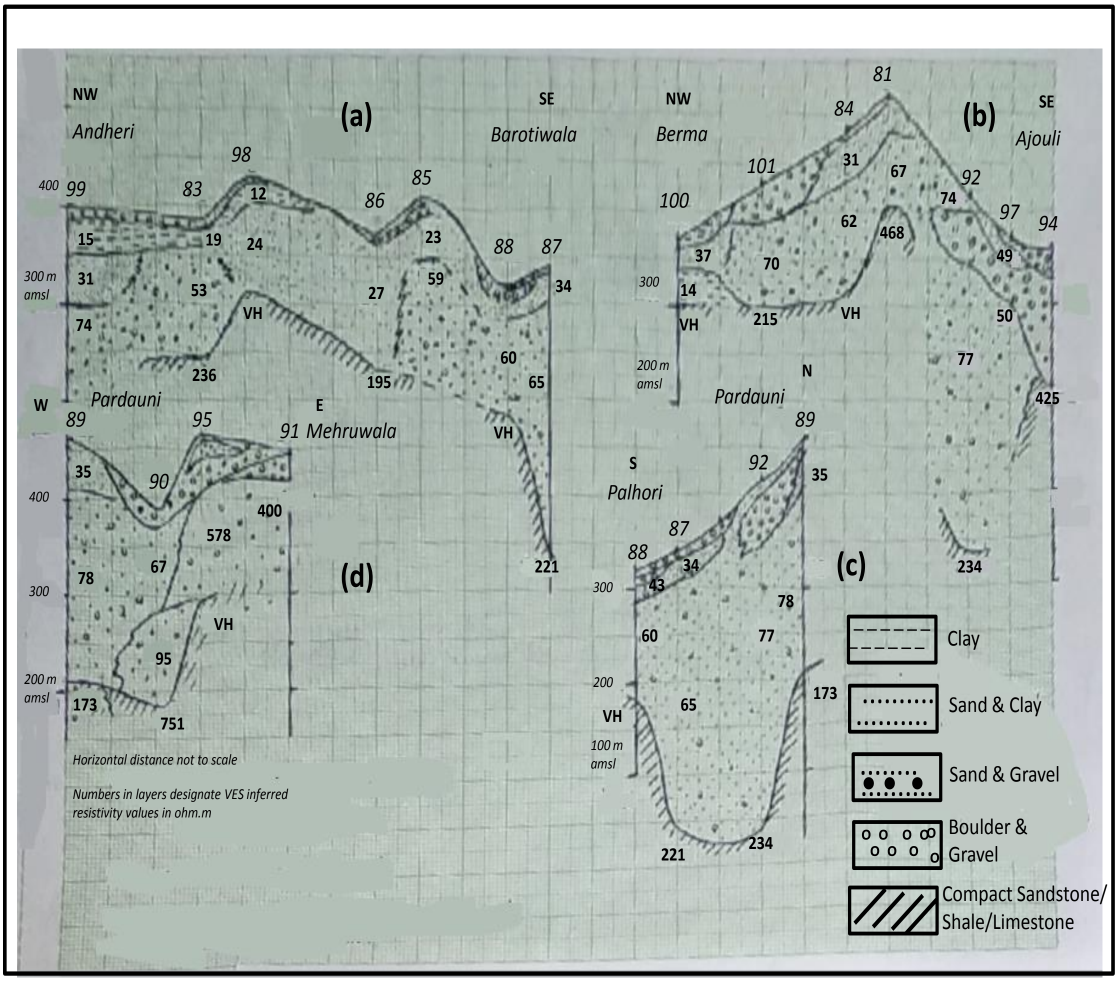


Figure 3.8 HydrogeophysicalCross-Sections ,Sirmaur District, Himachal Pradesh

The VES 99, 100, 101, 84 and 81 are located almost along Nahan Thrust which also forms the contact zone of Upper Siwalik in south with Lower Siwaliks in north of the Thrust and coincides with the course of Bata River. Contrary to the spot elevations of VES on the Middle Siwalik hills, the spot elevations of VES along Nahan Thrust increase from NW to SE. Among these VES, the maximum thickness of moderately resistive (31-61 ohm.m) layers is at VES 84 (elevation: 479 m amsl) with bottom depth 171 m. Similar moderately resistive layer is inferred at VES 101 and 81 also. However at VES 100 located on a local topographic low (elevation 371 m amsl - minimum VES spot elevation), the thickness as well as resistivity of this moderately resistive layer get reduced. The resistivity varies from 14-37 ohm.m and the bottom depth is 70 m. A similar condition exists at VES 99 (elevation 398 m amsl) with resistivity ranging from 15 to 31 ohm.m and bottom depth at 101 m. At VES 100 within 70 m depth, a layer of 37ohm.m is interbedded with layer of 18 ohm.m resistivity overlying it and that of 14 ohm.m resistivity underlying it. While the resistivities of 14-18 ohm.m represent clay predominance, the resistivity of 37 ohm.m indicates improvement in granularity or mixing of sand and clay and resistivities of 60-70 ohm.m manifest sand predominance with possible presence of gravel and pebble. The top clay layer (18 ohm.m resistivity) continues to VES 99 with 15 ohm.m, but the underlying 14 ohm.m resistivity layer at VES 100 is missing here. Instead a layer of 74 ohm.m is delineated at 101 m depth underlying the layer of 31 ohm.m resistivity. Over all, within the surveyed area, along the Nahan Thrust, the presence of clay towards NW is inferred. Though the thick aquifer in sand predominating layers is inferred at SE part, topographic elevation and direction of groundwater movement may have to be considered.

A peculiarity is that at all the VES sites, a resistive to highly resistive layer is delineated at the bottom within the depth of investigation of the VES. It is expected to be the compact sandstone and the variations in elevation of the top of this resistive to highly resistive compact sandstone more or less follow the ground surface topographic elevations. Exception is at VES 87 where the highly resistive deeper layer is at 300 m depth.

Further east, VES were conducted along the courses of Yamuna and Bata Rivers. The VES 89, 90, 95 and 91, located west to east, are at elevations of 460, 383, 466 and 448 m amsl respectively. While VES 89 and 90 are at the margin of alluvium and Lower Siwalik, VES 95 and 91 are in alluvium. The VES 95 and 91 infer highly resistive layers manifesting the possible presence of boulder and gravel bed to a considerable depth (delineated up to 173 m depth at VES 95). A thin near surface layer of 57 ohm.m resistivity is delineated up to 22 m depth at VES 95. However, at VES 89 and 90, where alluvial thickness is expected to be less compared to that at VES 91 or 95, thick moderately resistive (35-78 ohm.m) layers are delineated. Its maximum thickness is at VES 89, with bottom at 248 m. This moderately resistive layer is a part of Siwalik sediments – could be Upper Siwaliks (and not Lower Siwaliks) and form potential aquifer.

The VES 91, 94 and 93 are located on the right bank of River Yamuna at elevations of 448 m, 362 m and 362 m respectively. As already discussed above, VES 91 infers the presence of thick zone holding boulder and gravel brought down by the River Yamuna. VES 94 also infers the presence of thick zone holding boulder and gravel. But at VES 93, located downstream immediate west of the Yamuna Tear Fault a moderately resistive (31 ohm.m) layer is delineated in the depth range 29-208 m. It represents sand and clay beds combined. It is capped by a resistive (196 ohm.m) boulder and gravel bed up to 29 m depth. The moderately resistive (31 ohm.m) thick layer is expected to form potential aquifers in the sand beds.

Only one VES, VES 96 was conducted at an elevation of 1204 m amsl in Subathu Formation (Lower Tertiaries) comprising shale and limestone. The VES infers the presence of resistive and highly resistive layers up to depths beyond 200 m. As such, the site is not expected to hold granular aquifers. Indications of fractured zones were qualitatively picked up in the depth range 65-80 m. Though the fractured zones may be tapped, but in view of the VES spot topographic elevation a detailed study on the structural aspects of the area, lithology and groundwater flow direction is desired.

3.6 Conclusions and Recommendations

In Nahan and Paonta Sahib Valley of Sirmaur district 22 VES were conducted. The VES are mostly located in the Siwalik sediments and in the alluvial capping. A thick moderately resistive (up to 70 ohm.m) layer is delineated at several VES sites. It indicates the presence of sand predominating zone and could form the potential aquifer. A highly resistive near surface layer is delineated. It represents the bed of boulder and gravel brought down by Yamuna, Bata and Giri Riversconfluencing in Paonta Sahib Valley. A highly resistive layer is delineated at depth. It represents compact sandstone/limestone etc. The topography of the top of the deeper resistive layer mostly follows the ground surface topography with exception at a few VES sites. The maximum thickness of sand predominating moderately resistive (65 ohm.m) layer is at VES 87. Its bottom is at 300 m depth. Analysis of VES results along with lithology and the structural controls like folds, faults and the thrust zone is essential to hydrogeologically transform the geophysical layer parameters usefully to get an idea of the aquifers and decide upon the sites for borehole drilling. The details of VES site specific recommendations are given in the interpretation table (Annexure-2).

4.0 GROUND WATER RESOURCES & GROUND WATER RELATED ISSUES

Rainfall is the major source of 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.

Ground water resources and irrigation potential for Kala Amb area of Sirmaur district computed utilizing GEC-97 methodology as on March 2011, March 2013 & GEC-2015 methodology for March 2017 is as below

Table: 4.1 Dynamic Ground Water Resource 2011 , 2013& 2017

S.no	Particulars	Unit	**Kala Amb valley**		
			2011	2013	2017
1	Area of Assessment Unit	Sq. km	2.5	2.5	2.5
2	Ground water draft for all uses	Hect.m	545.32	336.95	411
3	Annual Ground water recharge	Hect. m	101.66	86.33	117
4	Net ground water availability for future irrigation development	Hect. m	0	-8.05	0
5	Stage of ground water development	% age	**564.63**	**410.86**	**350**
6	Categorization of the Assessment Unit	Safe/ unsafe	**OE**	**OE**	**OE**

4.1 GROUND WATER RELATED ISSUES

Ground water issues and problems in the study area are localized in nature and require particular methodology/ technique by taking up the micro level studies. In hilly and mountainous parts of study area, the most common issues related to scarcity of water occurs when dwindling water levels and spring discharges are seen. Rainwater harvesting and awareness for water conservation, protection & scientific development of traditional sources and water harvesting are the measures that need to be adopted.

Presently heavy withdrawal of ground water is observed in industrial belt where fall of groundwater level have been observed. Thus, ground water level depletion and also vulnerability to ground water pollution is major issues in this industrial belt.

In valley area there is large number of khads and most of them are seasonal flowing. High elevated hills adjacent to the valleys don’t contribute much to arrest surface run off during monsoon periods and due to over exploitation of ground water, the depth to ground water level is depleting.

In hilly region, there is a tradition to divert stream flow by making full use of slope for irrigating the fields by short approach channels locally called Kulhs (khul irrigation). In high hill areas, spring water is being utilized for irrigation. Potentiality of spring sources has been diminishing due to degrading climatic factors and haphazard infrastructure development, resulting in disturbance in spring shed area.

Fertile agricultural soils in valleys need prevention of erosion during monsoon period which washes out natural organic top soil contents and affect crops. Thus, there is a need for conservation and augmentation of ground water resource through wide spectrum of techniques which are in vogue. These recharge techniques are decided based on geomorphological, geological and hydrogeological frame work.

Broadly, ground water related problems can be summarized as:

- The study area have valley area/Industrial area of 2.5 sq km
- The area of 2.5 sq km is OE since 2011.
- Rest of area is hilly & slope is >20%, no resource estimation done.
- Ground water discharge/abstraction > recharge.
- Tube wells are gone dry due to lowering of groundwater level.

5.0 AQUIFER MANAGEMENT PLAN & RECOMMENDATIONS

Ground water is the major source for irrigation & domestic water supply in both rural and urban areas. Water level observation data has revealed declining trend in water level in some parts of the district. Though the stage of ground water development in Kala Amb valley is over exploited category, however, in many parts the availability of water during summer is limited particularly in hilly areas in drought/ low rain/snow years. There is thus a general need to conserve and augment water resource. Based upon the climatic conditions, topography, hydro-geology of the area, suitable structure for rain water harvesting and artificial recharge to ground water need to be planned and implemented. Roof top rainwater harvesting is one such solution both for urban & rural areas. Rainwater harvesting in rural area and proper scientific intervention for spring development and revival of traditional water storage is required in water scarce hilly uplandareas

5.1 Management Plan – Kala Amb Valley

An area of 81 sqkmofKalaAmb valley was taken under NAQUIM, area comprises2.5 sq kmofvalley area and its surrounding hills.The valley area, comprisingquaternary alluvium, which is heavily industrialized. Being industrial area, maximum withdrawal of groundwater is taking place in this area of 2.5 sq km. Both Private and Govt industrial area, have their own water supply through tube wells.Department of Industries is also supplying 7 lakh l/day to Govt industrial area and 2.5 lakh l/day to private industrial area. The area other than industrial area have water supply through I&PH department of Himachal Pradesh by 3 no of tube wells and through treated surface water. The details are shown below:

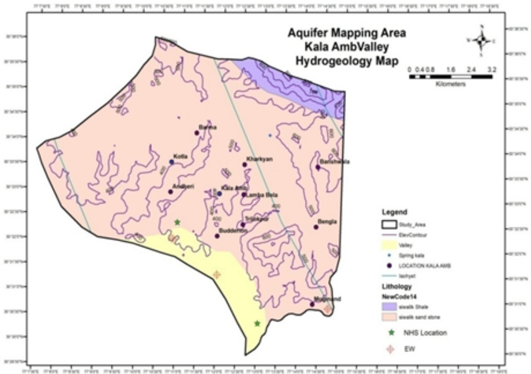
Table 5.1: Details of water supply in Study area

Study Area	Type of Habitation	Water Supply	Details of water supply by Deptt of Industries (HP)
Kala Amb valley (81 sq km)	**Industrial Area (2.5 sqkm)** • Govt Industrial Area (186328 sq m) • Private Industrial Area	Own Water supply & also through department of Industries	**6 no of Tube wells** 7 lakh liters/day 2.5 lakh liters/day
	Rural Area (78 sq km) • Valley area • Hilly Area	IPH deptt	**3 no of Tube wells** (3lakh liters/day) (through treated surface water)

MANAGEMENT PLAN

Dynamic Ground Water Resource of Kala Amb valley

S.no	Particulars	Unit	2017
1	Area of Assessment Unit	Sq. Km	2.5
2	Ground water draft for all uses	mcm	4.11
3	Net ground water availability	mcm	1.17
4	Net ground water availability for future irrigation development	mcm	0
5	Stage of ground water development	%age	350
6	Categorization of the Assessment Unit	Safe / unsafe	OE



- **Total Are=81 sq km**
- **Valley=2.5 sq km**
- **Hilly area having > 20% slope**
- **Demand & Supply**

Demand & Supply

Industrial Area **(own water supply)**

Rural Area **(I&PH) Deptt (through treated surface water**

Private Industrial Area **(own water supply)**

Govt. Industrial Area **(own water supply)**

Fig: 5.1(A): Stage of GW Development & Demand & Supply of Study area

MANAGEMENT PLAN (FACTS)

Dynamic Ground Water Resource of Kala Amb valley

S.no	Particulars	Unit	2017/2020
1	Stage of ground water development	%age	350/27.51
2	Categorization of the Assessment Unit	Safe / unsafe	OE/Safe

- **Total Are=81 sq km**
- **Valley=2.5 sq km**
- **Hilly area having > 20% slope**
- **Demand & Supply**

Demand & Supply

Industrial Area **(own water supply)**

Rural Area(hilly) **(I&PH) Deptt (through treated surface water)**

Private Industrial Area **(No record)**
CGWA has given permission for 26 TW since notified from 2010

Govt. Industrial Area186328 sq m

Rural Area(Valley) **(I&PH) Deptt Through TW (3 lac l/day**

Supply through Deptt. of Industries
6TW=7lac l/day (2.5lac l/day to private industrial area)

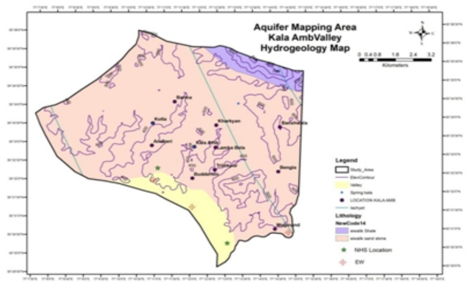


Fig: 5.1(B): Demand & Supply of Study area

5.2 Surplus Runoff

Surplus runoff in the study area.is assessed considering the drainage area, rainfall & runoff coefficient of the area and is about 45.5 mcm.The stage of ground water development in Kala Amb valley area is 564.63% and 350% as on March 2011& 2017 and falls under "*Over Exploited category*".

In Kala Amb valley Annual Ground water recharge is 101.66 Ham & 70% (71.162 ham) of the total recharge can be utilised to keep the valley in safe category, while the total draft is 545.32 ham which is 474.158 ham more than safe category. Difference between total draft & 70% of net GW availability is 4.74 MCM for which recharge structures are to be taken up. To augment the excess withdrawal, there is a need of harvesting the part of the surplus runoff available in the area i.e. 45.5 mcm. Few sites for construction of recharge structures have been identified and few mores are to be identified.

Table5.2 : Site Specific conservative measures

Study Area	Type of Area	Site Specific Conservative Measures to be taken
Management Plan for Kala Amb valley (81 sq km)	1. Hilly Area	• Contour Trenching • Contour Bunding • Check Dams • Plantation/Afforestation
	2. Valley Area	• Artificial Recharge Structures • Use of abandoned TW/HP as recharge structure • Trench with recharge well in river beds • Pond with recharge shaft
	3. Industrial Area	• Roof Top Rain Water Harvesting

The study area comprises of three type of area, identified for various water conservative measures. Most of area under study is hilly and being recharge area for ground water, conservative measures should be taken on priority. Contour trenching/Bunding can be taken up as water and soil conservation. Small check dams can be construction for the same purpose. Impounder water in check dams can be used in agriculture and domestic purposes.

Valley area of 2.5 sq km, which is a growing industrial area also, different type of artificial recharge and conservative measures can be taken. A wide scope of roof top rain water harvesting exists in industrial area.

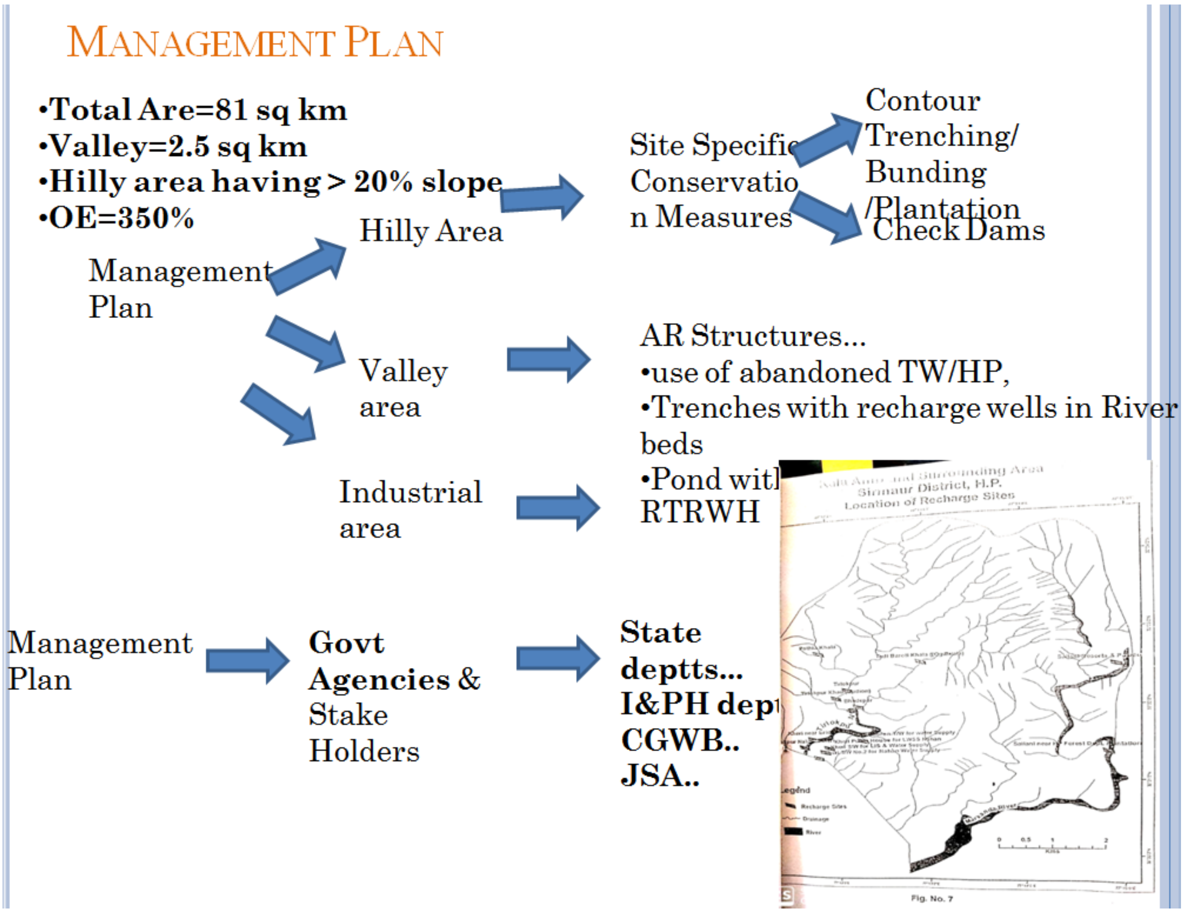


Fig: 5.2Site specific conservation measures of Study area

5.3 Proposed Intervention based on aquifer management Plan

As the study area includes hilly area, valley area and industrial area, management plan can also be divided in to site specific management plan.

Catchment area	81 Sq. km
Average annual rainfall	1405 mm
Surplus Runoff assessed	45.5 MCM
Runoff Recharge	4.74 mcm out of 45.5 mcm
Area of Assessment Unit	2.5 Sq. km
Net GW availability (70% of Annual Recharge)	1.17 MCM
Ground water draft for all uses	4.11 MCM
Difference between total draft & 70% of net GW availability, **for which recharge structures are to be taken up**	2.94 MCM

A Valley Area Interventions

In the valley area, 13 number of artificial recharge sites were selected in a joint visit made by CGWB & I&PH Officers. The Details are as follows:

A joint visit was made by CGWB & I&PH Officers on dated 7.12.2013 and by CGWB on 8.12.13 for identification of feasible artificial recharge sites for augmentation of ground water resource in the Kala Amb Valley area. Sites are identifiedconsidering the geology of the area, depth to water level and other criteria's. All the parameters recorded during field visit are compiled and tabulated below. The locations of the proposed recharge sites in and around the Kala Amb valley area are marked on map.By construction of these structures, about0.25 MCM water is expected to recharge to ground water in the area, annually.

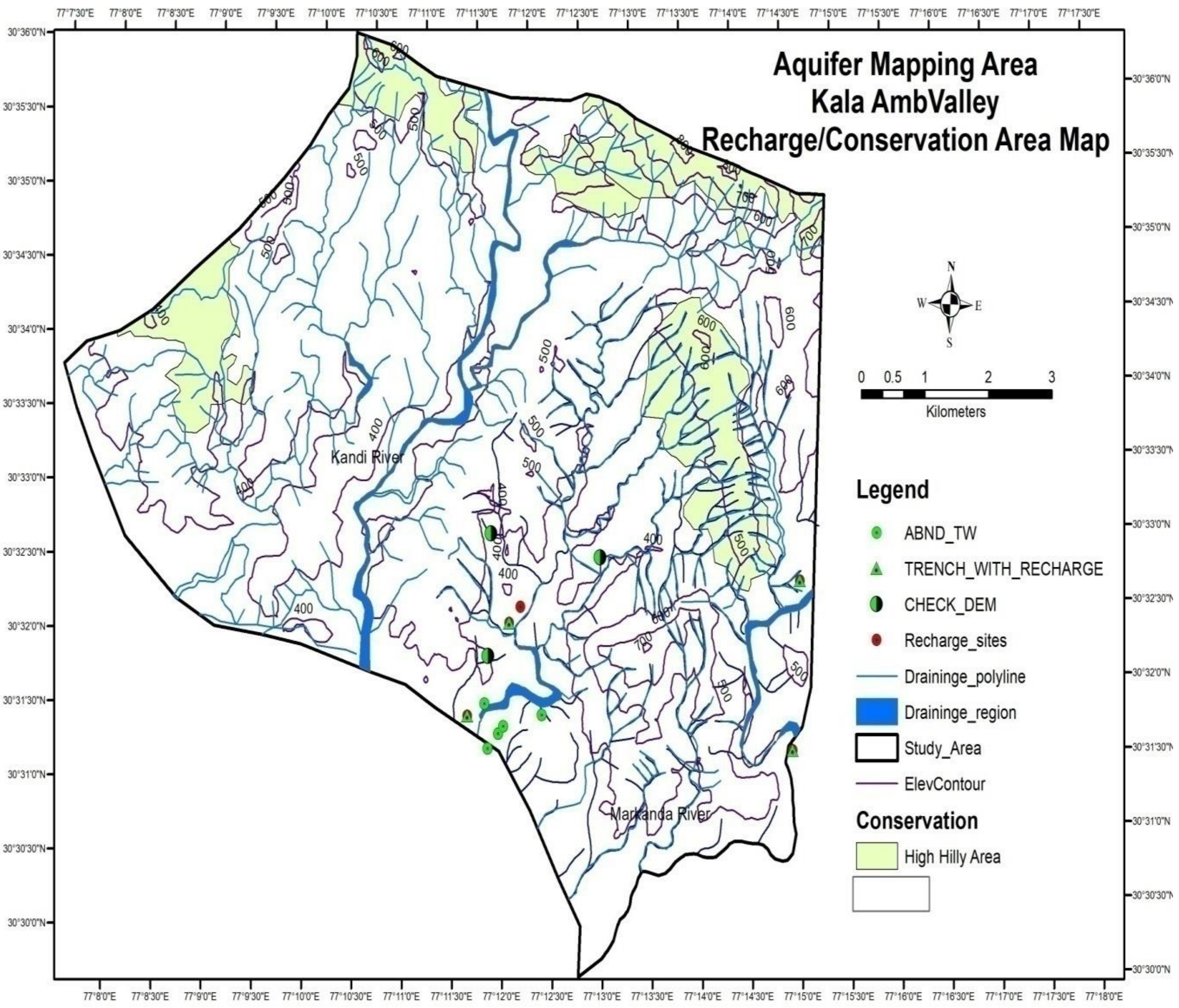


Fig 5.4 : Location of recharge sites in study area

The site photographs of the individual artificial recharge sites are given below along with details.

Table 5.3(A) : Recharge Site photographs from S. No. 1-4, with details

S.No	Site	Latitude	Longitude	Proposed AR structures
1	Jhoron T/W for water supply	30^0 31’ 32.6”	77^0 12’ 19.5”	Abandoned T/W may be used as recharge structure as per design given in fig. and runoff of the surrounding buildings having 1196 sq. m area may be diverted for recharge
2	Kheri T/W for LIS & water supply	30^0 31’ 24.2”	77^0 11’ 53.9”	The design of recharge structure is given in fig. below and runoff of the surrounding buildings/area (2576 sq. m) may be diverted for recharge.
3	Kheri T/W No. 2 for Nahan water supply	30^0 31’ 18.1”	77^0 11’ 47.7”	Abandoned T/W may be used as recharge structure as per design given in fig. below and runoff of the surrounding buildings/area (1850 sq. m) may be diverted for recharge.
4	Kheri Pump House for LWSS Nahan	30^0 31’ 27.4”	77^0 11’ 56.8”	The design of recharge structure is given in fig. below and runoff of the surrounding buildings/area (2380 sq. m) may be diverted for recharge.

Fig 5.4(A) : Photograph of recharge sites 1-4

Table 5.3(B) : Recharge Site photographs from S.No. 5-8, with details

S.No	Site	Latitude	Longitude	Proposed AR structures
5	TirlokpurNala in Kheri	30^0 31' 30.9"	77^0 11' 35.3"	2 to 3 trenches is proposed at a spacing of 100 m inside the stream bed and 0.15 m above the lowest stream bed level to avoid entry of industrial waste water during lean period into the trenches. The design of recharge structure is given in fig. below.
6	TirlokpurKhad (Budion)	30^0 32' 9.3"	77^0 11' 58.7"	5 to 6 trenches is proposed at a spacing of 100 m inside the lowest stream bed as per design given in fig. below.
7	PothiaKhala	30^0 32' 45.0"	77^0 11' 46.6"	A check dam of 5 m height is proposed for storage cum recharge structure. The stored water may be utilised for agriculture use.
8	Bhadepar	30^0 31' 55.5"	77^0 12' 10.8"	A check dam of 1 m height is proposed in the narrow stream with 4" dia outlet and 3 to 4 trenches in the wider stream at a spacing of 100 m in the lowest stream bed as per design given in fig.below.

Fig 5.4 (B) : Photograph of recharge sites 4-8

Table 5.3 : Recharge Site photographs from S. No. 9-12, with details

S.No	Site	Latitude	Longitude	Proposed AR structures
9	TadiBarotiKhala (Ogalwala)	30^0 32’ 37.3”	77^0 12’ 52.1”	Four check dams of 2 m height each are proposed at a spacing of 300 m for storage cum recharge structure and for direct agriculture use.
10	Tirlokpur	30^0 32’ 16.0”	77^0 12’ 05.2”	Three check dams of 1 m height each are proposed at a spacing of 200 m with 4” dia outlet for supply of water to d/s for recharge through trenches already proposed in the same nala at Sr. no. 6. The stored water may also be utilised for direct agriculture use. The schematic design of the outlet is given in fig.below

11	Kheri near Bridge	30^0 31’ 36.2”	77^0 11’ 45.1”	The runoff of the road / adjoining buildings having about 7500 sq.m area may be utilised for recharge. The design of the recharge structure is given in fig. below
12	Sailani near HP Forest Deptt. Plantation	30^0 31’ 22.7”	77^0 14’ 50.2”	2 to 3 trenches at a spacing of 100 m inside the stream bed and 0.15 m above the lowest stream bed level to avoid entry of industrial waste water during lean period into the trenches. The design of recharge structure is given in fig. below

Fig 5.4 © : Photograph of recharge sites 9-12

Table 5.3 : Recharge Site photographs, S.No. 13, with details

S.No	Site	Latitude	Longitude	Proposed AR structures
13	SailaniResorts& Palace	30^0 32' 31.5"	77^0 14' 51.8"	6 trenches (2 X 3) at a spacing of 100 m u/s of bridge at the lowest stream bed as per schematic plan given in fig. no. 14 and design in fig.below.

Fig 5.4(D) : Photograph of recharge sites 9-12

In the study area 13 sitesare identified for construction of recharge structures, out of which 4 sites are for construction of check dams and 9 sites for construction of recharge trenches with bore well. By implementing such structures on large scale in the area, it will not only contribute to ground water recharge but also help in reducing the declining rate and improving the ground water quality.

5.4 Design of Artificial Recharge Structures:

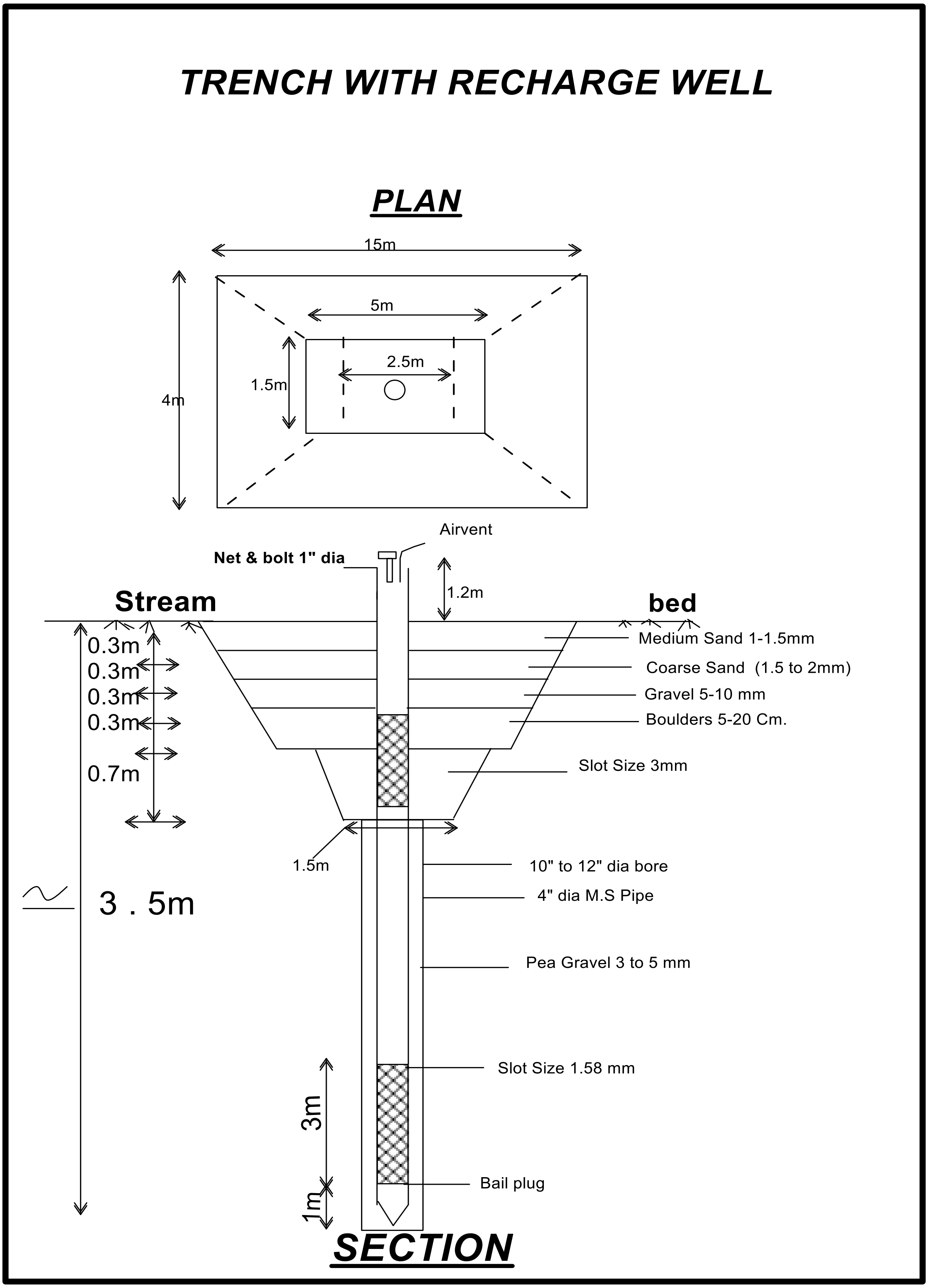


Fig 5.5(A) : Design of Recharge structures

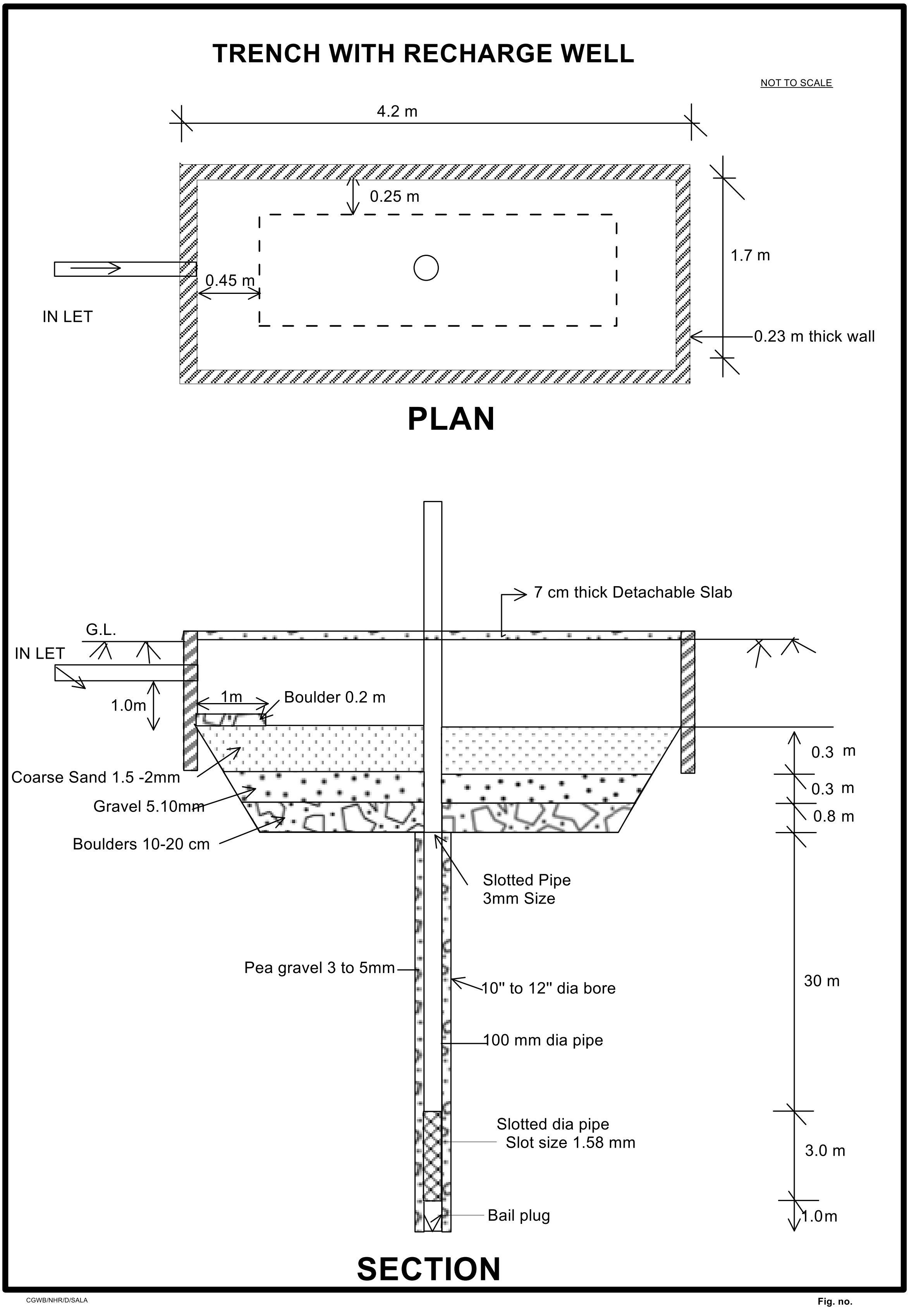


Fig 5.5(B) : Design of Recharge structures

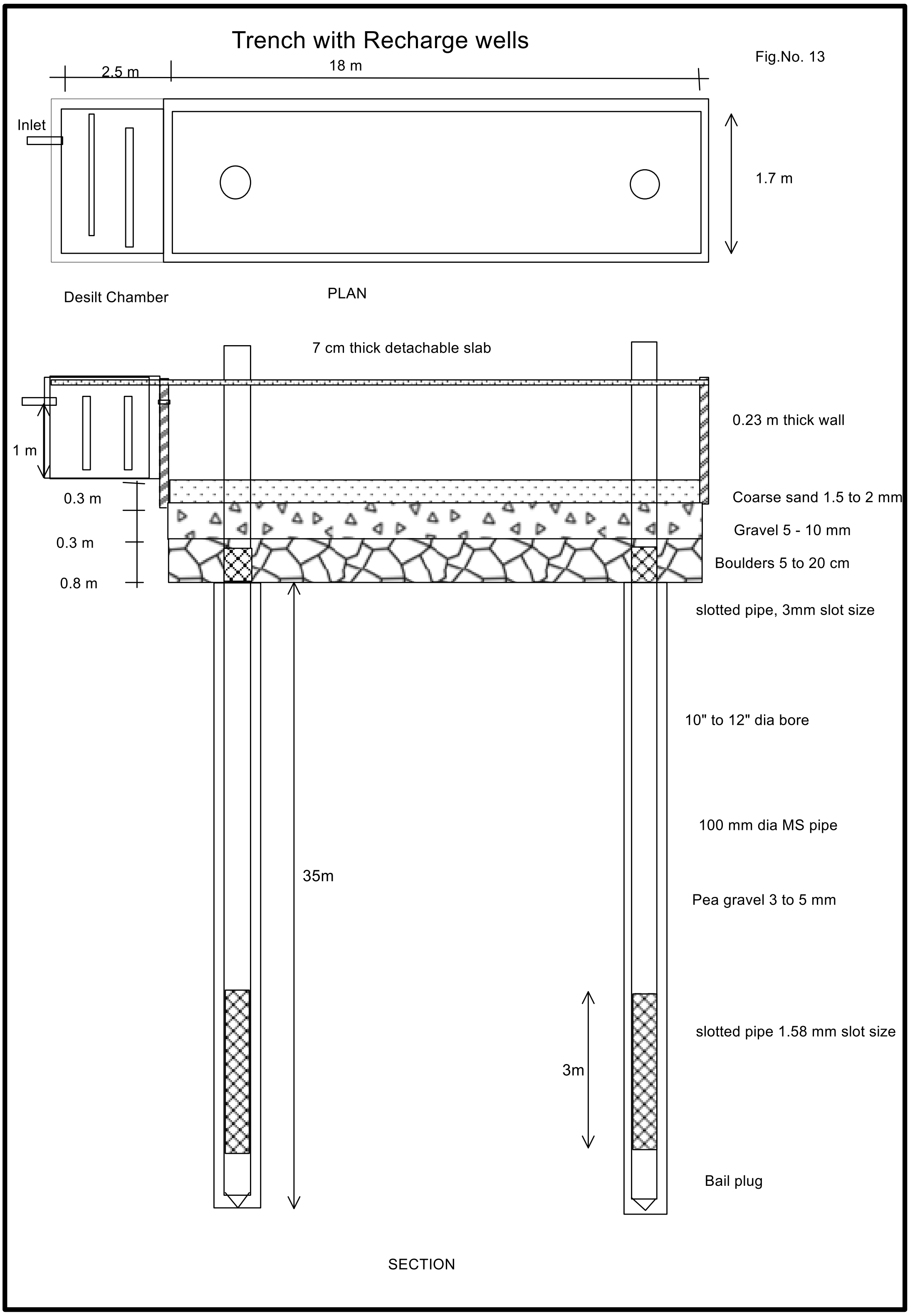


Fig 5.5(C) : Design of Recharge structures

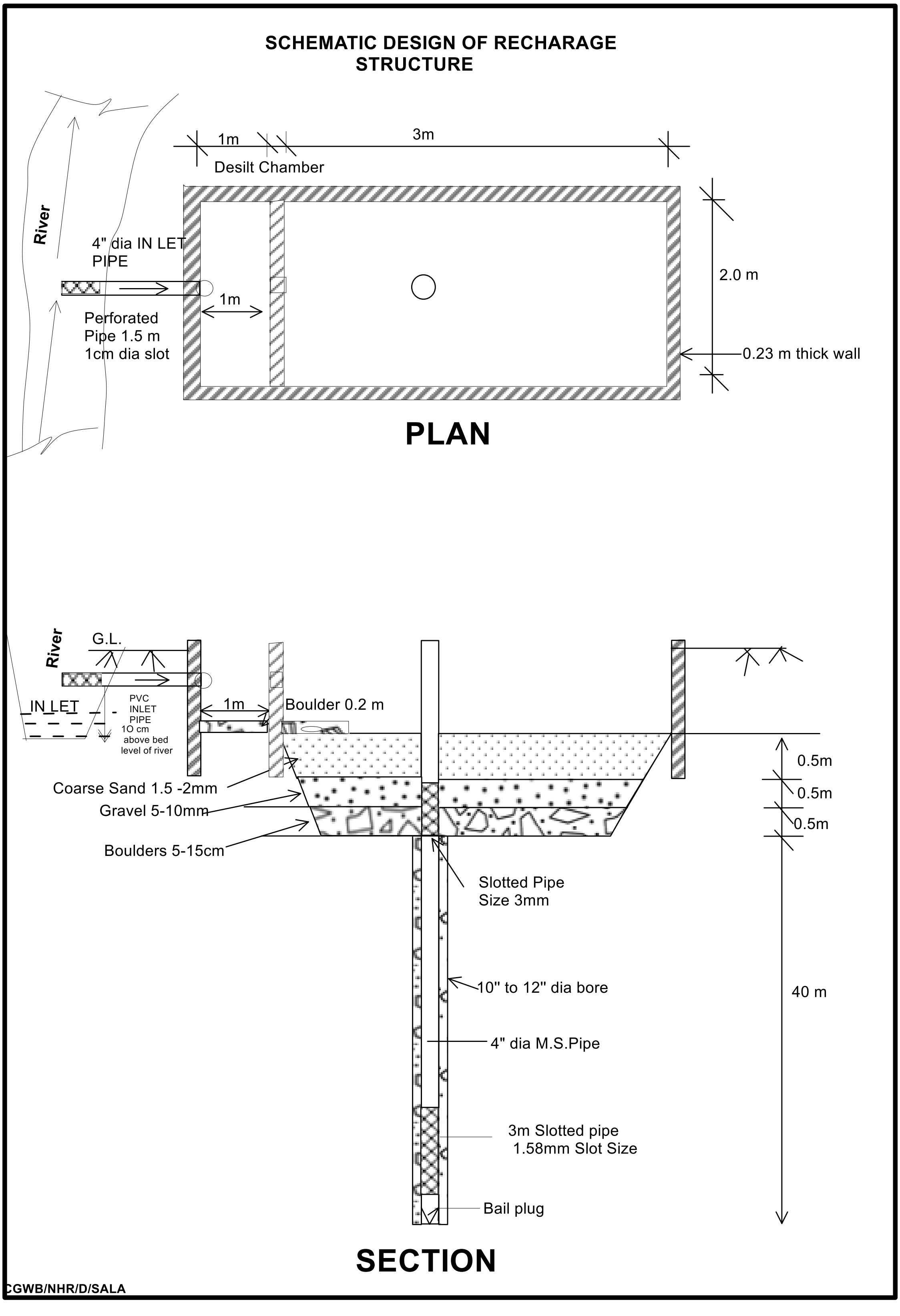


Fig 5.5(D) : Design of Recharge structures

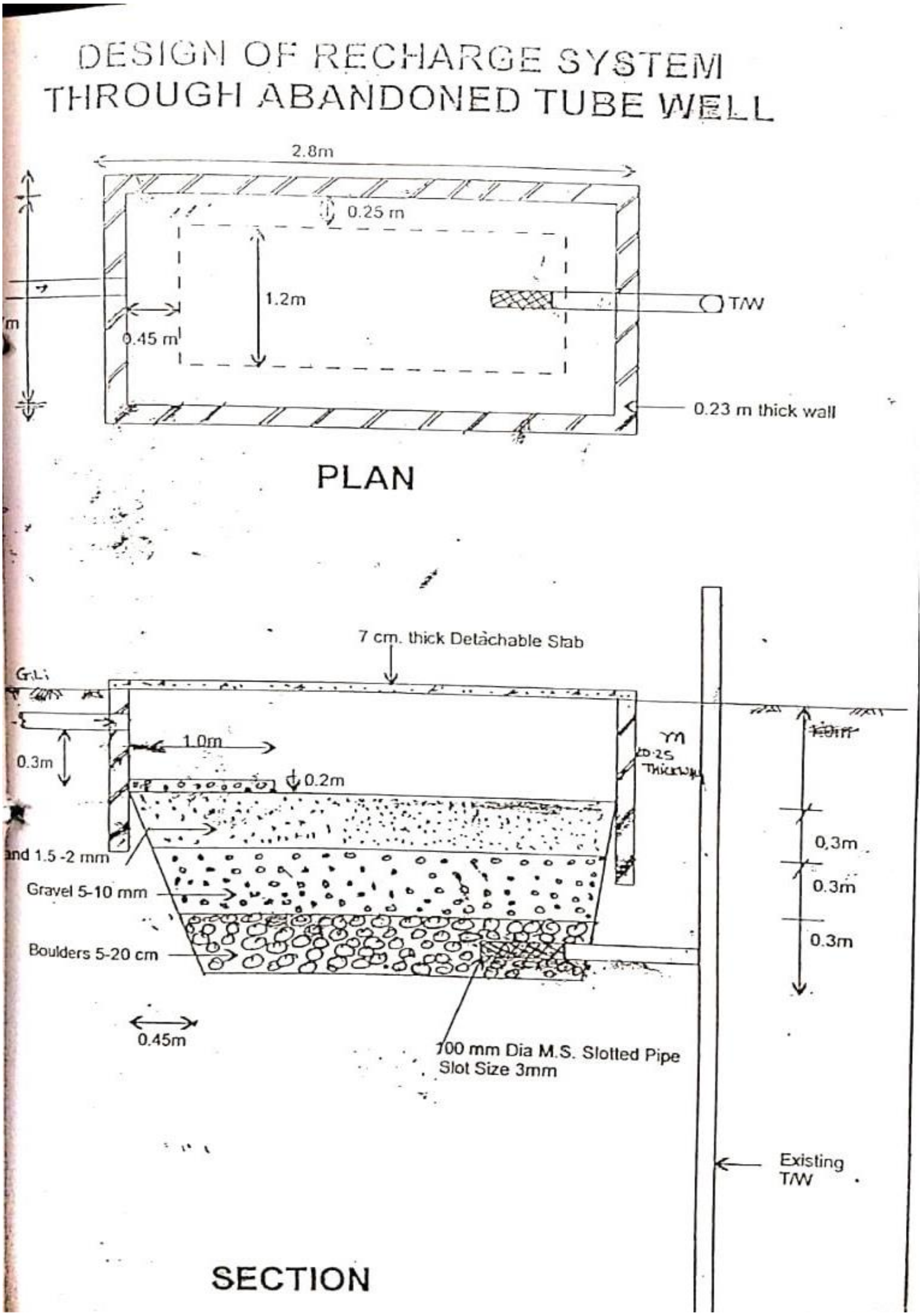


Fig 5.5(E) : Design of Recharge structures

Fig. no.

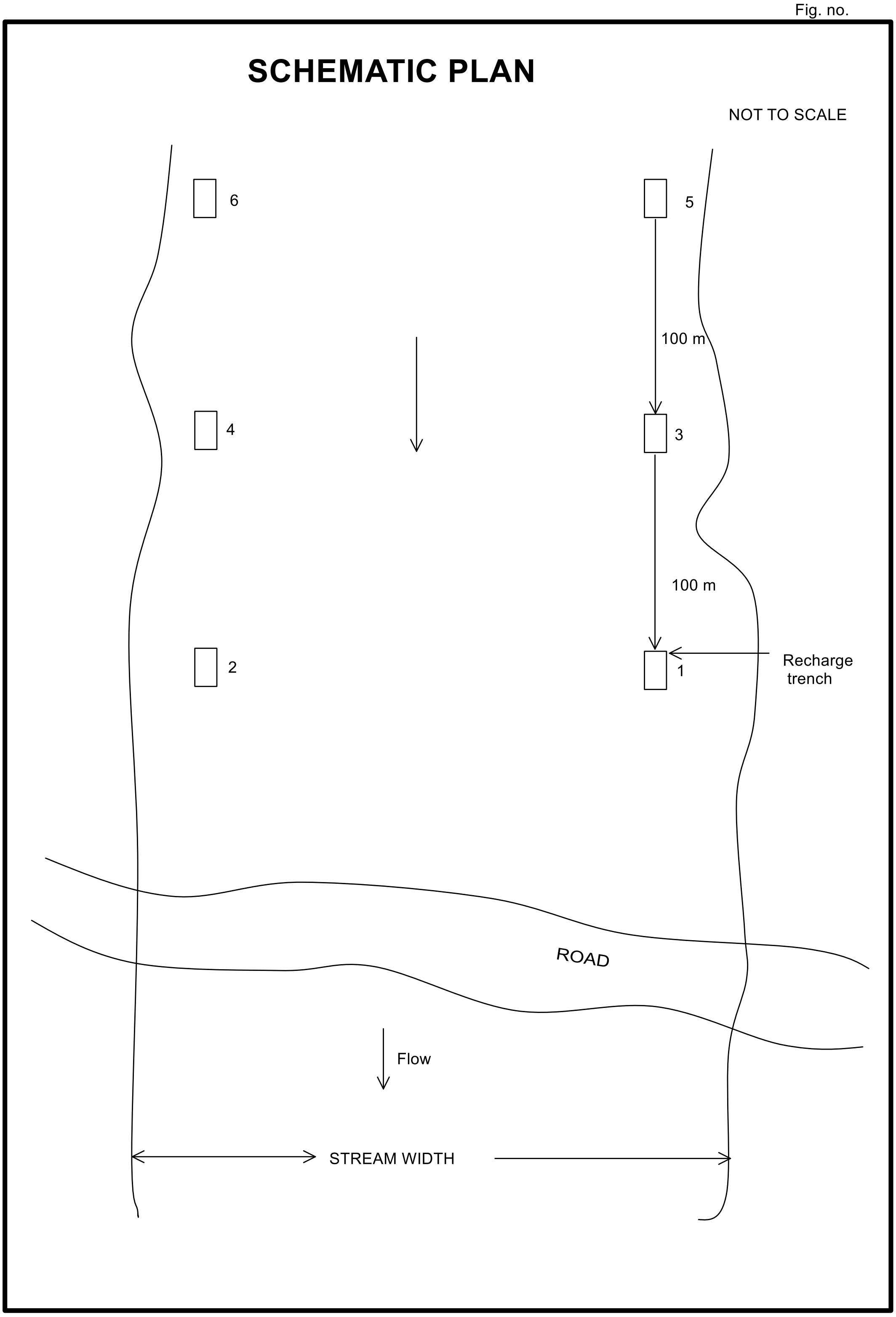
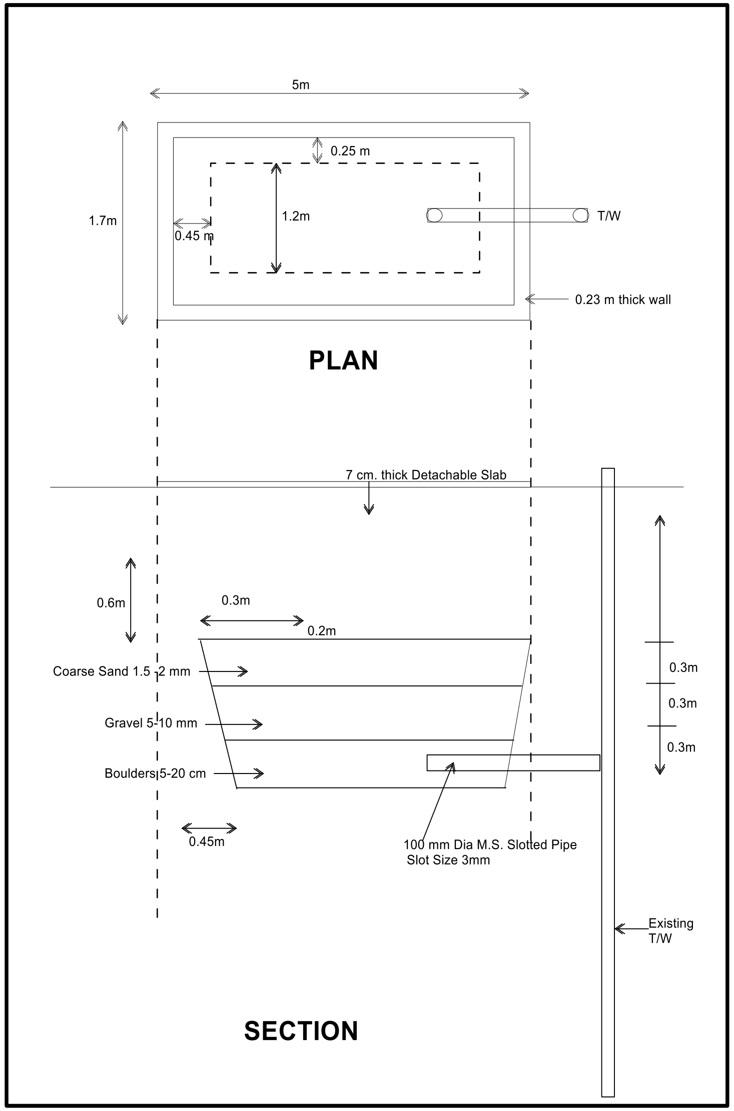


Fig 5.5(F) : Design of Recharge structures



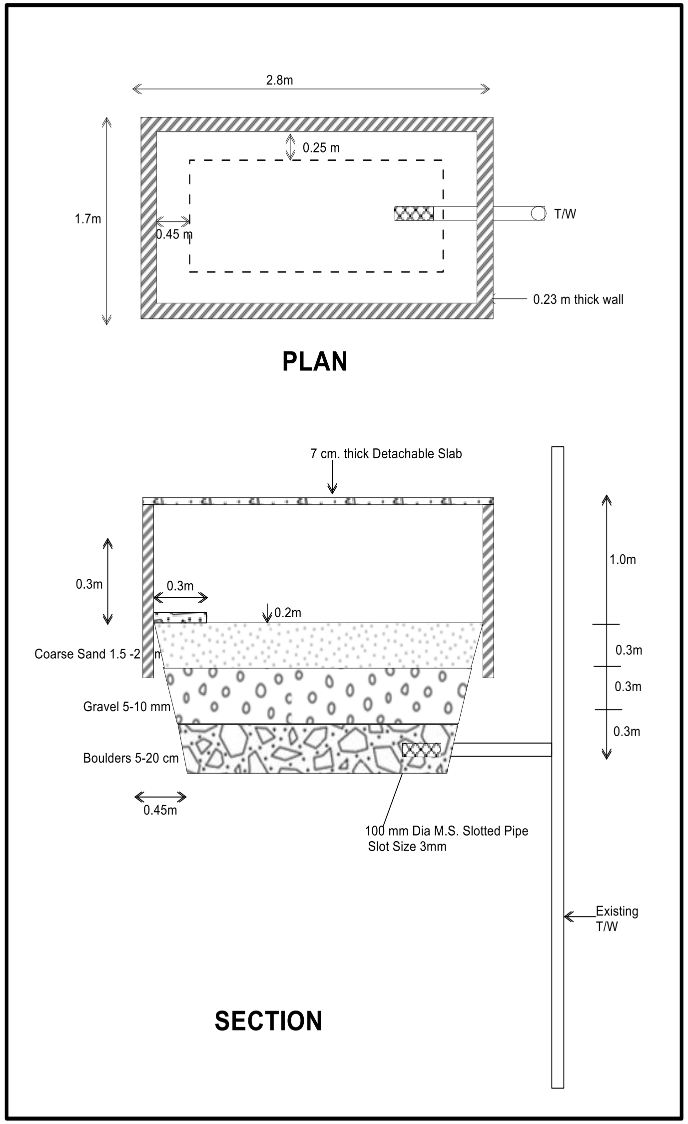


Fig 5.5(G) : Design of Recharge structures

C. Hilly Area Interventions

Hilly areas which covers most of the study area, specific measures should be taken for water and soil conservation.

- Mapping & geo-tagging of all springs should be done, using advance technology.
- Recharge areas of springs/spring shed areas may be identified
- Rejuvenation of springs must be taken up trough interventions like contour trenching &contour bunding.

Details of construction, cost estimate and amount of water conservationof contour trench are as follows:

Contour trenches can be made 1 m length, with 1m/0.6m width and 1m/0.6m height.One contour trench with a length of 1m can be made in a gap of 2 mts. Therefore, in stretch of 1 km, 330 trenches can be made, with gap of 2 mts. Being undulating topography,500 m stretch or less can be taken for making contour trenches, with 1m length and 2m gap. If 1m*0.6m*0.6m contour trench is made, it costs about Rs.375/- per trench. So, a total 330 contour trenches are made in a stretch of 1km.

MANAGEMENT PLAN (FOREST LAND/ SPRINGSHED)

contour trenching	Item of work	L rate (2009)	T rate	total cost(2020)
Cost Estimate	1m*.6m*.6m	167.5	180.5	375

Source-PWD norms

- Cost of proposed contour trenching with stretch of 1 Km
- If 1m*.6(b)*.6(d)=360lit=0.36 cubic m (0.10cubic m @30%recharge =108 lit)
- 1m (l) trench with gap of 2m in between=330 trenches in 1 km, @375/-
- =330*375=Rs.1.23lakh
- **Total amount of water conserved (in 2 slope contours)**
- 108 lit*30(rainy days)=3240 lit/trench
- 3240 liter *700 trenches=22,68,000 lit/year
- =2268 cubic m/year =2.26 mcm/year
- **Total Cost of Intervension**
- 1.23 lakh*660 trenches= Rs 8.11Cr

cost of water conserved=3240/375= 0.08 lit./paise

- ***Areas identified(on the basis of landuse-landcover***
- *Siwalik(hilly area other than habitation)*

Fig5.6: Details of Contour Trenching

Table 5.4: Details of water conservation in contour trench

volume of water holded in 1*.6*.6 m contour trench	360 litre (0.36 cubic m)
30 % recharge of holded water	0.10 cubic m
No of rainy days	30
Volume of water holded per trench	108 litre
Total volume of water for 30 rainy days in 1 trench	108*30=3240 liter/trench
No of trenches (with a gap of 2 mts) in 1 km stretch	330
If trenches made for 2.5 km with slope (two slopes)	700 trenches
Total volume of water for 30 rainy days in 1650 trench	3240*700=2268000 lit/year =2268 cubic m =2.26 mcm/year

Table: 5.5 Management Plan : Proposed strategy : Demand Side Management

Catchment area	81 Sq. km
Average annual rainfall	1405 mm
Surplus Runoff assessed	45.5 MCM
Runoff Recharge	4.74 mcm out of 45.5 mcm
Area of Assessment Unit	2.5 Sq. km
Net GW availability (70% of Annual Recharge)	1.17 MCM
Ground water draft for all uses	4.11 MCM
Difference between total draft & 70% of net GW availability, **for which recharge structures are to be taken up**	2.94 MCM
Deficit in demand & supply	2.94 mcm
RTRWH in industrial area of Kala Amb (RTRWH)	0.449 mcm
Structures identified at 13 sites which can recharge	0.25 mcm@ 7.41 cr
Additional resources created	0. 699 mcm
Volume of water conserved through contour trenching (660 no of trenches)	2.26 mcm
Total proposed conservation	Demand side + supply side 0.699 mcm +2.26 mcm =2.95 mcm

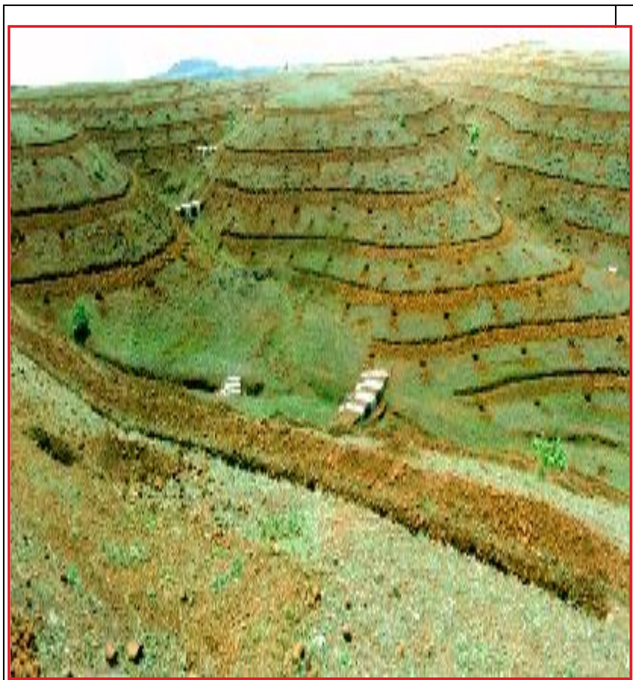
If we can increase the number of trenches and check dams, more amount of water can be recharged.

5.4 Recommendations

The dimensions of the Check dams are will be decided based on the survey of each site and accordingly, the changes may be incorporated. Similarly, based on the general geology of the area, the depth of recharge well is recommended. The recharge well should end in the permeable formation which may vary from site to site, therefore, as per site condition; the minor changes in the depth of well may be incorporated. The Recharge wells should be properly developed after construction for effective recharge.

Where the recharge trenches are proposed inside the stream bed and 0.15 m above the lowest stream bed level, it should be precociously implemented as per design given ,to avoid contamination of ground water due to entry of industrial waste water into the trenches especially during lean period.

Where the recharge trenches are proposed indownstream of check dam, an outlet of 4" dia is proposed in the check dam at a height of about 0.5 m above stream bed as per schematic design for continuous supply of water to recharge trenches for recharging to ground water.



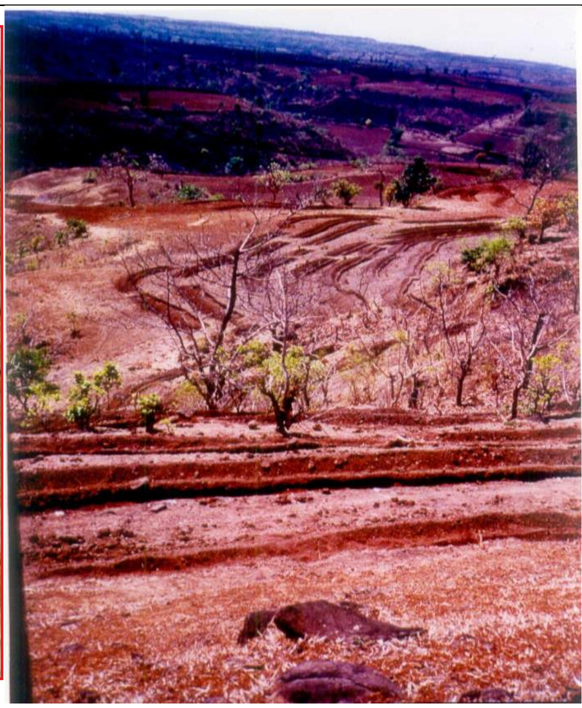


Fig5.7 (A): Continuous Contour Trenches

Fig5.7 (B): Staggered Contour Trenches

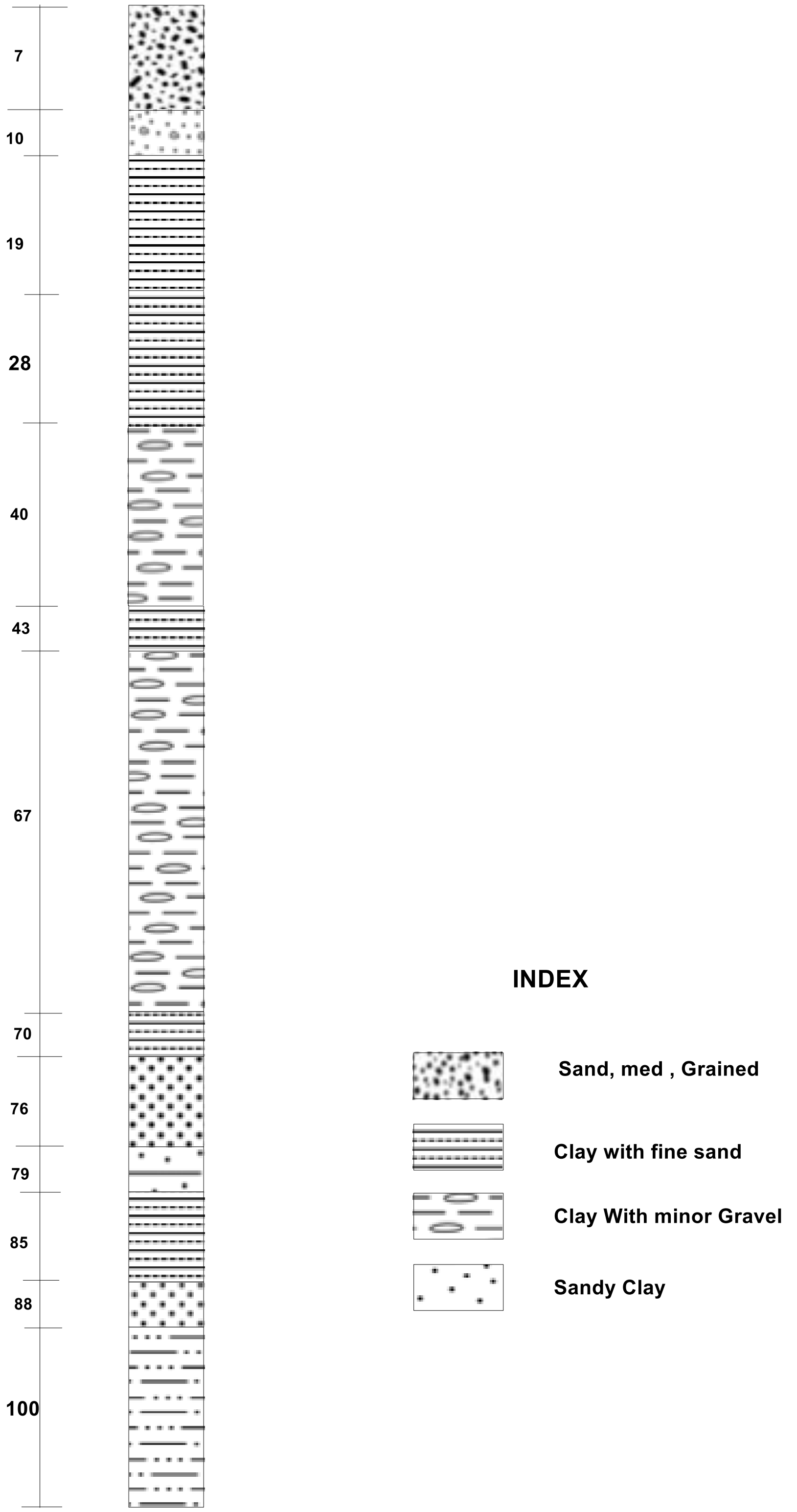
The other recommendations are:

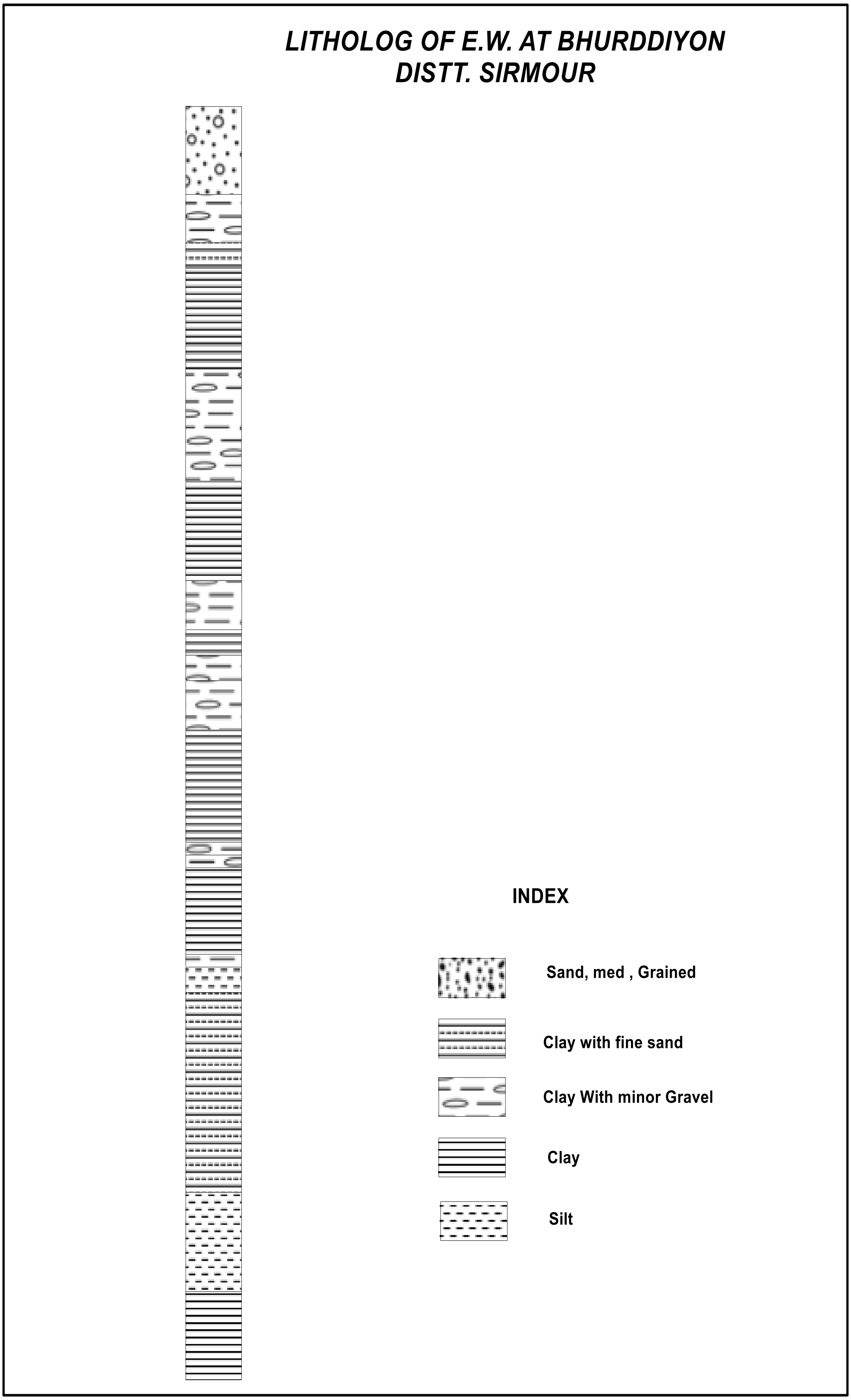
- Kala Amb is an industrial town and having lot of industries. Each industry is having very large roof area. Therefore, industries may be directed to harvest the roof top rain water by constructing recharge structures in their premises as the area receives fair amount of rainfall.
- Industries effluents and domestic & sewage water should not be discharged in the natural streams and surrounding areas, because it will not only contaminate the ground water but also reduce the further scope of recharge to ground water due to reduction of space and fresh water for recharge.
- The industrial units particularly dye and pharmaceuticals discharge highly toxic effluents, due to which such areas are highly prone and vulnerable to surface and ground water pollution; thus close network of water quality monitoring is essential.
- Proper waste/effluent disposal measures are required to be adopted by industrial units and state authorities to check the pollution.
- Industries may be directed for recycle / reuse the waste water after treatment and also for using the water conserving technologies in their industries.

- Industries may be encouraged for implementation of ETPs either individually or collectively and it should be regularly checked by the state agencies.
- There is a need for creating awareness among masses through Mass Awareness Programmes for conservation and protection of water quality.
- Kala Amb valley is an over-exploited valley. It should be notified and restricted by State Ground Water Authority (SGWA) for further ground water development
- and management point of view and no well should be constructed in the valley area without the permission of SGWA.
- In agriculture sector also, farmers may be educated for implementation of water conservation techniques i.e. sprinkler & drip irrigation system for irrigating their fields.
- There is a need to protect traditional water harvesting structures like ponds, tanks, *talavs* and to utilize 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.
- Springs needs to be inventoried & studied for optimum utilisation and development of their discharge either by fracturing, horizontal drilling or by constructing galleries etc.
- Roof top rainwater harvesting practices can be adopted in hilly 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 constructions having roof area more than 100 sq.m. Rain water harvesting in rural areas should also be promoted.
- People’s participation is a must for any type of developmental activities. So proper awareness for utilization and conservation of water resource is required.

Annexure-1

LITHOLOG OF E.W. AT MOGINAND DISTT. SIRMOUR




LITHOLOG OF E.W. AT BHURDDIYON
DISTT. SIRMOUR
INDEX
Sand, med , Grained
Clay with fine sand
Clay With minor Gravel
Clay
Silt

ANNEXURE 2

S.No	District	Village	Block	VES_No	General Geology	Easting	Northing	Elevation amsl	Layer	Resisitivity	Thickness (m)	Depth (m)	Inferred Formation Characteristics	Qualitatively Inferred	Recommendations for Drilling	Remarks
								INTERPRETATION OF VES LAYERS	Direct interpretion of VES layer							
70	Sirmaur	Bholion	Nahan	81	Siwaliks	727021	3377578	514	1	82.7	1	1	Top Soil	NA	100 m	The VES 81 to 102 in Sirmaur disrict are located in Siwalik sediments (Upper, Middle and Lower) The Siwaliks are characterized by coarsening upward sedimentation cycles and therefore upper part is dominated by coarse sand/sandstone with pebble and gravel and the lower part with sand/sandstone and clay. The sandstones belonging to Lower Siwalik are reported to be indurated, which may increase their resistivity. While the top part of Upper Siwalik is conglomeratic The lithological inferences drawn are qualitative and not standardized through borehole lithologs
					Tertiary Sediments				2	54.9	3.3	4.3	Sand			
					Upper Siwalik				3	37.1	30.1	34.4	Sand & Clay	Aquifer		
									4	66.9	72.7	107.1	Sand	Aquifer		
									5	468			Compact Formation (Sandstone ?)			
71	Sirmaur	Dhon	Nahan	82	Siwaliks	725329	3382879	739	1	158.3	2	2	Top Soil	NA	Not Recomme	
					Tertiary Sediments				2	13.1	3.9	5.9	Clay			
					Lower Siwalik				3	81.6	10.2	16.1	Sand	Aquifer		
									4	13.5	18.5	34.6	Clay/Clay stone			
									5	587			Compact Formation (Sandstone ?)			
72	Sirmaur	Kainther	Nahan	83	Siwaliks	716954	3376911	384	1	124.5	0.6	0.6	Top Soil	NA	150 m	
					Tertiary Sediments				2	84.7	4.2	4.8	Sand			
					Middle Siwalik				3	19.2	20.4	25.2	Clay			
									4	53.1	120.6	145.8	Sand	Aquifer		
									5	236.1			Compact Formation (Sandstone ?)			
73	Sirmaur	Kun	Nahan	84	Siwaliks	723262	3378854	479	1	175.6	2	2	Top Soil	NA	170 m	
					Tertiary Sediments				2	78.9	3	5	Sand			
					Upper Siwalik				3	31	40.9	45.9	Sand & Clay	Aquifer		
					Close to Nahan Thrust				4	61.9	125.2	171.1	Sand	Aquifer		
									5	vh			Compact Formation (Sandstone ?)			
													a			
74	Sirmaur	Jhil	Nahan	85	Siwaliks	731364	3373889	408	1	45	0.6	0.6	Top Soil	NA	100 m	
					Tertiary Sediments				2	39.6	5.1	5.7	Sand & Clay			
					Middle Siwalik				3	58.9	10.1	15.8	Sand	Aquifer		
									4	23.3	43.7	59.5	Sand & Clay			
									5	59.4			Sand	Aquifer		

75	Sirmaur	Haripur	Nahan	86	Siwaliks	729014	3371595	373	1	130	0.6	0.6	Top Soil	NA	Not Recomme			
					Tertiary Sediments				2	79.4	3.7	4.3	Sand					
					Middle Siwalik				3	171.9	7.4	11.7	Sand & Bouldery Formation					
									4	26.8	130.9	142.6	Sand & Clay	Aquifer (?)				
									5	195			Compact Formation (Sandstone ?)					
76	Sirmaur	arotiwa	onta Sa	87	Siwaliks	735876	3366744	342	1	271	0.6	0.6	Top Soil	NA	200 m			
					Tertiary Sediments				2	1402	5	5.6	Bouldery Formation					
					Middle Siwalik				3	34	24.9	30.5	Sand & Clay	Aquifer				
									4	65	269.5	300	Sand	Aquifer				
									5	221			Compact Formation (Sandstone ?)					
77	Sirmaur	Palhori	onta Sa	88	Siwaliks	734947	3365671	320	1	2100	4.4	4.4	Top Soil	NA	135 m			
					Tertiary Sediments				2	112	11.5	15.9	Sand & Bouldery Formation					
					Middle Siwalik				3	42.7	14	29.9	Sand	Aquifer				
									4	60.1	105.6	135.5	Sand	Aquifer				
									5	vh			Compact Formation (Sandstone ?)					
78	Sirmaur	Pardaun	onta Sa	89	Siwaliks	741403	3379241	460	1	127.6	0.7	0.7	Top Soil	NA	200 m			
					Tertiary Sediments				2	171.3	6.9	7.6	Sand & Bouldery Formation					
					(Alluvium Covered)				3	34.6	40	47.6	Sand & Clay	Aquifer				
									4	77.7	200.4	248	Sand	Aquifer				
									5	172.5			Compact Formation (Sandstone ?)					
79	Sirmaur	Khara	onta Sa	90	Siwaliks	748822	3376243	383	1	229	0.5	0.5	Top Soil	NA	> 100 m			
					Tertiary Sediments				2	641.8	3.3	3.8	Sand & Bouldery Formation					
					(Alluvium Covered)				3	202.3	12.7	16.5	Sand & Bouldery Formation					
									4	66.6	82.3	98.8	Sand	Aquifer				
									5	94.9	100	198.8	Sand & Gravel	Aquifer (?)				
									6	751			Compact Formation (Sandstone ?)					
80	Sirmaur	ehruwa	onta Sa	91	mla Group	763343	3376473	448	1	93.2	0.8	0.8	Top Soil	No FZ indic	Not Recommended			
					Formation				2	237.5	3.4	4.2	Less Compact/Boulder bed					
					(Slate, Sandstone & Quartzite)				3	4752	25.3	29.5	Highly Compact/Boulder bed					
					Close to Yamuna river bed				4	402			Less Compact/ Metamorphics					

81	Sirmaur	Majra	onta Sa	92	Siwaliks	742427	3375127	414	1	45	0.6	0.6	Top Soil	NA	200 m			
				Tertiary Sediments					2	107.8	3.1	3.7	Sand & Bouldery Formation					
				(Alluvium Covered)					3	74.4	6	9.7	Sand					
									4	170.5	58.8	68.5	Sand & Bouldery Formation					
									5	77.3	305.6	374.1	Sand	Aquifer				
									6	234.2			Compact Formation (Sandstone ?)					
82	Sirmaur	Behral	onta Sa	93	Siwaliks	746801	3365430	362	1	141	1.4	1.4	Top Soil	NA	200 m			
				Tertiary Sediments					2	30	5	6.4	Sand & Clay		Low Priority			
				Upper Siwalik					3	196	22.5	28.9	Sand & Bouldery Formation					
									4	31.1	179.1	208	Sand & Clay	Aquifer (?)				
									5	vh			Compact Formation (Sandstone ?)					
83	Sirmaur	Ajouli	onta Sa	94	Siwaliks	755856	3371894	362	1	90.6	2.9	2.9	Top Soil	NA	Not Recommended			
				Tertiary Sediments					2	467.8	29.3	32.2	Sand & Bouldery Formation					
				(Alluvium Covered)					3	137.6	116.5	148.7	Sand & Bouldery	Aquifer (?)				
				Yamuna River Bed					4	424.7			Sand & Bouldery Formation					
84	Sirmaur	ishan K	onta Sa	95	Siwaliks	753891	3376551	466	1	100	0.1	0.1	Top Soil	NA	50 m			
				Tertiary Sediments					2	2000	4.9	5	Bouldery Formation					
				(Alluvium Covered)					3	57	16.9	21.9	Sand					
									4	103	30.2	52.1	Sand & Gravel	Aquifer (?)				
									5	578	120.6	172.7	Compact Formation (Sandstone ?)					
									6	vh			Compact Formation (Sandstone ?)					
85	Sirmaur	Jamta	Nahan	96	athu Forma	721093	3387310	1204	1	124.7	0.7	0.7	Top Soil	65-80	Not Recomme	FZ indications in the depth range 65-80 m. Therefore borehole up to 80 m depth may be attempted on low priority		
				Shale & Limestone					2	2000	2.7	3.4	C ompact Formation/Bouldery Formation					
									3	158.6	52.4	55.8	Sand & Bouldery	Aquifer (?)				
									4	409	90.6	146.4	Compact Formation					
									5	961			Compact Formation					
86	Sirmaur	Ajjiwala	onta Sa	97	Siwaliks	747901	3374064	368	1	50	1	1	Top Soil	NA	100 m			
				Tertiary Sediments					2	228.6	2.7	3.7	Sand & Bouldery Formation					
				(Alluvium Covered)					3	48.6	23.2	26.9	Sand	Aquifer				
									4	241.3	32.5	59.4	Sand & Bouldery Formation					
									5	50.4			Sand	Aquifer				

87	Sirmaur	Bheron	Nahan	98	Siwaliks	720693	3377386	429	1	336.5	1.1	1.1	Top Soil	NA	Not Recomme	The resistivity of the layer in		
					Tertiary Sediments				2	18.7	6.1	7.2	Clay			the depth range 27-116 m is		
					Middle Siwalik				3	12.3	19.4	26.6	Clay			24 ohm.m only, indicating		
									4	23.5	89.6	116.2	Clay & Sand			presence of sand and clay with		
									5	vh			Sand & Bouldery Formation			predominance of clay		
88	Sirmaur	Andheri	Nahan	99	Siwaliks	709706	3382277	398	1	141.9	0.7	0.7	Top Soil	NA	150 m	The resistivity of the layer in		
					Tertiary Sediments				2	37.9	3.5	4.2	Sand & Clay			the depth range 49-101 m is		
					Upper Siwalik				3	95.9	6.7	10.9	Sand & Gravel			31 ohm.m , indicating		
									4	15	38.4	49.3	Clay			presence of sand and clay .		
									5	30.5	51.4	100.7	Sand & Clay	Aquifer (?)		The resistivity of the last layer		
									6	74.2			Sand	Aquifer (?)		beyond 101 m depth is 74		
89	Sirmaur	Berma	Nahan	100	Siwaliks	710040	3383646	371	1	849	2.6	2.6	Top Soil		50 m	The VES is located towards		
					Tertiary Sediments				2	18.3	6.9	9.5	Clay			west of Nahan Thrust The		
					Upper Siwalik				3	37.4	19.4	28.9	Sand & Clay	Aquifer		layer with resistivity 37		
									4	14.1	41.3	70.2	Clay			ohm.m in the depth range 10-		
									5	vh			Compact Fomation (Sandstone ?)			30 m may form shallow		
90	Sirmaur	mandapa	Nahan	101	Siwaliks	715657	3381190	432	1	453	2	2	Top Soil		130 m			
					Tertiary Sediments				2	130	37.4	39.4	Sand & Bouldery Formation			The VES is located between		
					Lower Siwalik				3	70.4	91.1	130.5	Sand	Aquifer		Nahan and Krol Thrust		
									4	215.3			Compact Formation (Sandstone ?)					
91	Sirmaur	Bakarla	Nahan	102	Siwaliks	713344	3384950	437	1	316	0.7	0.7	Top Soil			The VES is located between		
					Tertiary Sediments				2	121	3.8	4.5	Sand & Bouldery Formation			Nahan and Krol Thrust		
					Lower Siwalik				3	28.1	82.2	86.7	Sand & Clay	Aquifer (?)		Comparison of VES 101 and		
									4	vh			Compact Formation (Sandstone ?)			102 reveals that though both		
																the VES the resistivity of the		
					(Neo terminal proterozoic)				2.0	1980	6.8	7.8	Compact formation					
					Shale, Phyllites and Quartzites				3.0	617	46.6	54.4	Less compact formation					
									4.0	249	57.2	111.7	Less compact/fractured formation					
									5.0	1078			Compact formation					
Note	1. NA: FZ delineation not possible or not required																	
	2. Geology is taken from published maps, reports and papers																	

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