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PRELIMINARY REPORT ON THE ASSESSMENT OF LANDSLIDE SITES IN SHIMLA DISTRICT, HIMACHAL PRADESH

Submitted

to

STATE DISASTER MANAGEMENT AUTHORITY

GOVERNMENT OF HIMACHAL PRADESH, SHIMLA

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ACKNOWLEDGEMENTS

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Date: 29-02-2024 **BR Thakur**

CONTENTS

1. INTRODUCTION

Landslides and related mass movement processes are common hazards in hilly terrains. An estimate by Guzzetti (2023) reveals that landslides occur in about 17.1% of the landmasses and about 8.2% of the global population is exposed to this hazard. The Indian Himalayan region is one of the major landslide hotspots, where landslide magnitude varies from a single rock fall (Sarkar et al. 2018) to the collapse of the entire mountain slope (Pradhan et al. 2019). Occurrences of landslides in this mountain often caused extensive economic damage and loss of life. An estimate by the National Disaster Management Authority (NDMA) (2019) reveals landslides caused a monetary loss of Rs. 150 crore per annum in India. In the recent past Indian Himalayan region has witnessed some catastrophic rainfall-induced landslide (RFIL) disasters, including Kedarnath event in 2013 (Martha et al. 2015), Kotropi landslide in 2017 (Pradhan et al. 2019), Batseri landslide in 2021 (Sharma et al. 2022), Dima Hasao event in 2022 (Das et al. 2022) and Tupul landslide in 2022 (Baruah et al. 2023). Following these events, some cascading hazards such as landslide dam formation, and valley blocking incidents are also observed (Martha et al. 2015; Sharma et al. 2022).

Himachal Pradesh with 55673 km^2 and supporting about 7 million people lies in North-western Himalaya-environmentally fragile and ecologically vulnerable. Increasing incidences of disasters like cloudbursts, flashfloods, landslides and avalanches, all attributed to anthropogenic activities and climate change are giving Himachal Pradesh a new catchphrase ‘Land of Disasters’. Fragile ecology of the state, coupled with large variations in physio-climatic conditions, makes it susceptible to climate issues and natural disasters. Physiographically, the State is divided into three main units: Lower Himalaya, Middle Himalaya and Great Himalaya. Each unit faces distinct hazards based on rock types, soils and local climate. Monsoon is vital for the young, vulnerable Himalayan region, but it also poses risks. It destabilizes slopes, causing loss of life and property damage.

Intense, short-duration rainfall events, known as 'cloudbursts,' are a common occurrence in the Himalayas and a major cause of annual monsoon-related damage in various parts of the state. During the monsoon season of 2023, the state experienced substantial damage, resulting in financial losses exceeding ₹9,500 crore and the loss of more than 500 human lives (Emergency Operation Centre, Government of HP, 2023). Central Himachal Pradesh has been the hardest-hit region, with severe losses in terms of human lives, livestock and property. Significant losses in the state occurred during two distinct monsoon depressions. The first, coinciding with a Western Disturbance from July 9th to 11th, 2023, caused extensive damage. Second spell from August 13th to 16th, 2023 brought continuous heavy precipitation and accentuated further damage and a series of slope failures in various districts of Himachal Pradesh including Shimla.

It is in this backdrop, the State Disaster Management Authority (SDMA), Government of Himachal Pradesh vide letter no. Rev (DMC) (F) 11-09/2021-L M dated September 21, 2023, approached the Department of Geography and University Institute of Technology (UIT), Himachal Pradesh University, Shimla, to conduct preliminary studies of 15 landslides in Shimla district. However, the investigation at the Dabarink site in Dodrakawar could not be conducted due to road blockage caused by snowfall. This report presents the findings of these investigations and proposes short- and long-term mitigation measures for 14 selected landslide and land subsidence sites in Shimla district, Himachal Pradesh.

2. DATA BASE AND METHODS OF STUDY

The preliminary study used both primary and secondary data. Primary information, including landslide history, population and affected infrastructure, was gathered from local residents and nearby areas during field visits conducted in December 2023. The rocks were identified in the field based on physical properties observed in hand specimens. The measurements of foliation, joints (discontinuous plane), other structural orientation and slope face (direction of slope face and its inclination) at each site were determined using a Brunton Compass with the zero-zero method. The regional geological setup was studied using a geological map from the Geological Survey of India.

To conduct a topographic survey of each landslide, a DJI Mini 2 UAV (Drone) was used to capture highly accurate aerial images from multiple points. The 2-D images taken from different points were then post-processed using the JDIFLY application to create a panoramic view of each landslide. A differential global positioning system (DGPS) survey was conducted at each landslide site to create contours at 1-meter interval. This survey helped in visually understanding the topographic makeup of each landslide and subsidence incident. The detailed and highly accurate contour plans of each landslide will aid in designing and implementing mitigation measures at each site.

During the field visit, adequate soil samples were collected from each landslide site and analyzed at an ISO certified and NABL accredited soil testing laboratory in Solan. To analyze the geotechnical properties of the soils at each landslide site, grain size analysis (IS: 2720 Part 4:1985) was conducted to determine particle sizes ranging from 0.075 mm to 100 mm. Atterberg's Limits (IS: 2720 Part 5:1985) have been used to establish the liquid and plastic limits of the soil. Bulk density & dry density (IS: 2132:1986) have been employed to calculate soil moisture on a volume basis, with bulk density playing a critical role in this calculation. Specific gravity (IS: 2720 Part 3:1963) has been determined to understand the phase relationships of soils, such as void ratio and degree of saturation. Direct shear (IS: 2720 Part 13:1986) test has been conducted to experimentally determine the shear strength of soil materials, which represents the maximum resistance to shearing. Permeability (IS: 2720 Part 17:1986) has also been measured to assess how quickly water can pass through the soil. Besides, hydraulic conductivity is then determined, as it describes the soil's ability to transmit water and its impact on slope failure.

Besides, the relevant information relating to the landslides has been gathered from the existing literature. Local residents were also interviewed to gather additional information about occurrence of landslips and local knowledge-based mitigation measures. This information was then combined with scientific insights.

3. GEOLOGY OF HIMACHAL PRADESH

The geological landscape of the Himachal Himalayas reveals a variety of terrains, each playing a part in the complex and ever-changing geological history. The Himachal Himalayas consist of four main parts which include the outer Himalayas, lesser Himalayas, higher Himalayas and Tethys Himalayas. Each has its own unique features and geological history. Towards the south of Himachal Pradesh, the Indo-Gangetic plains sprawls across the foothills of the outer Himalaya, the outer Himalaya is separated by the HFT from the alluvium deposited by the Himalayan rivers. The Outer Himalayan geological formations are marked by the presence of sandstone, mudstone, shale and conglomerates, painting a vivid picture of the geological evolution of the Himalayas. **Fig. 1** shows the geological map of Himachal Pradesh.

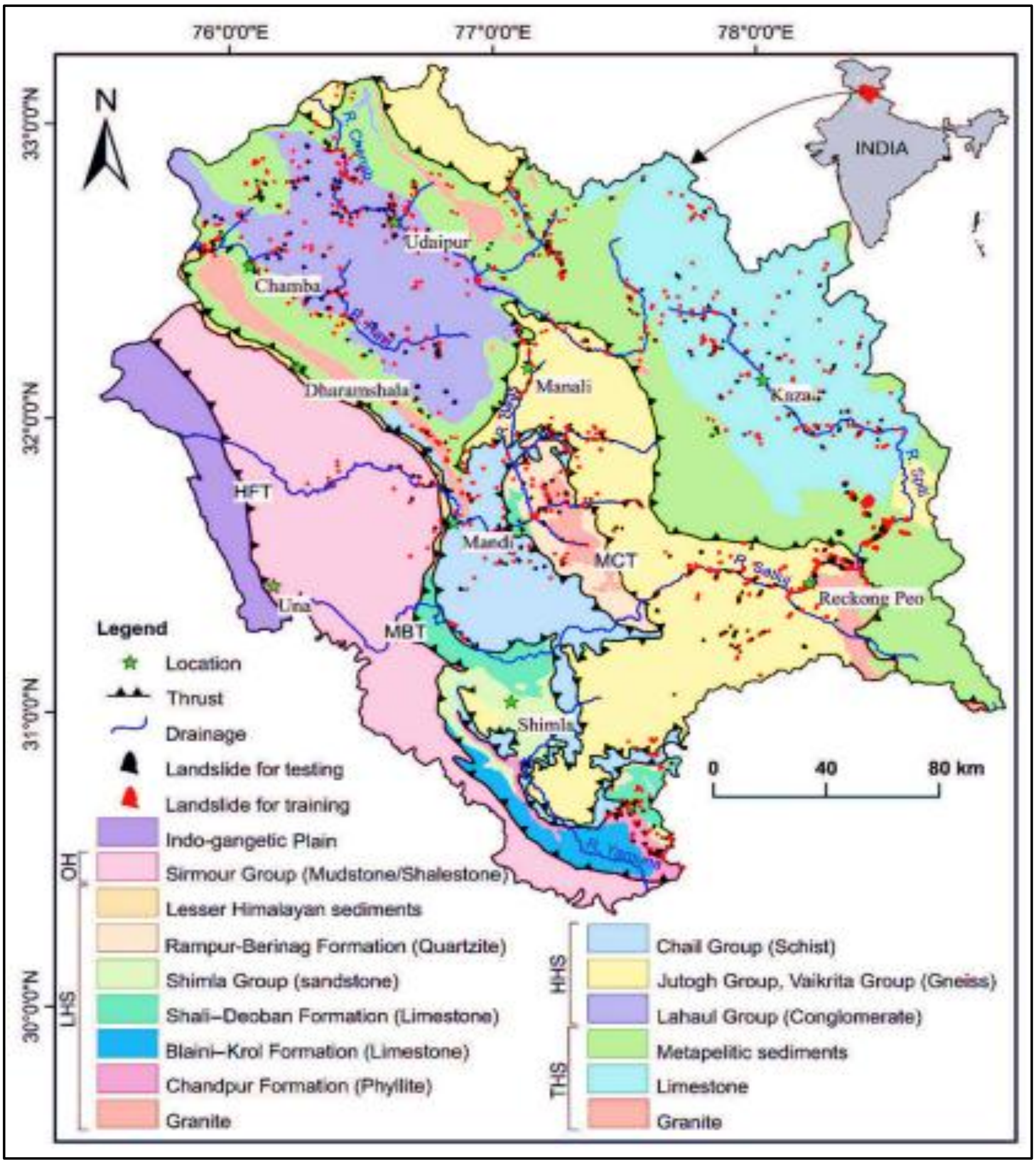


Fig. 1 Geological map of Himachal Pradesh marked with various lithostratigraphic units, regional structures, landslides and major rivers originating from the Himalayas (modified after GSI, 1996).

Moving further north, the Lesser Himalaya is bounded by the Main Boundary Thrust (MBT) in the south and the Main Central Thrust (MCT) towards the north. Traversing northwest into the Satluj valley, the thickness of the Lesser Himalaya gradually diminishes. Within this region, an array of lithologies unfolds, which are divided into different groups and formations, the Rampur–Berinag Formation, Shimla Group, Shali–Deoban Formation, Chandpur Formation, Blaini, Krol and Tal formations. Besides, the Klippen units of the Chail Crystalline and Jutogh groups make the geological setting more complex.

The Higher Himalaya, thrusts over the Lesser Himalaya along the MCT, locally known as the Jutogh Thrust. The Higher Himalaya is comprised of gneiss, schist and granitoids. In the Beas and Satluj valleys, this geological entity is further classified into the Chail, Jutogh and Vaikrita groups. Toward the west, the Lahaul Group adds further geological complexity to the Himachal Himalaya. Heading further north, the Tethys Himalaya is a geological realm known for its granites, metapletic sediments and limestones. This northernmost stretch completes the geological panorama of the Himachal Himalaya, contributing its unique geological features to the overall landscape.

Himachal Pradesh's geology is fragile due to its location in an active tectonic zone. This is compounded by population growth and expanding urban areas, leading to increased construction. As per National Disaster Management Authority’s post disaster needs assessment (PDNA) report (2023), Himachal Pradesh is vulnerable to 25 out of 33 types of hazards identified by the High Powered Committee (HPC) of Government of India and classified into 5 subgroups including geologically related disasters such as landslides. Landslides in Himachal Pradesh occur due to a combination of factors, including the tectonically unstable terrain, monsoons and high-intensity earthquakes. The Himalayan region's steep slopes and geological instability further enhance the vulnerability to landslides. Unsustainable human activities like deforestation, road construction, terracing and changes in agricultural practices have increased the susceptibility of the region to landslides. Himachal Pradesh's hilly areas face ongoing threats from landslides, resulting in loss of life, property damage, soil erosion and disruptions to infrastructure (National Disaster Management Authority’ Report) (2023):p.165).

3.1. GEOLOGICAL SET-UP OF SHIMLA DISTRICT

The geological setting of the Shimla district is characterized by meta-sedimentary and associated granitic rocks, forming part of the lesser Himalaya. The district comprises major groups such as the Jutogh, Shimla, Jaunsar, Rampur and Shali groups, along with the Bandal-Jeori Wangtu gneissic complexes. The Bhandal–Rampur–Wangtu–Karcham gneissic complex comprising migmatite, schists, gneisses and granitoid rocks was dated 2030 Ma. The Rampur Quartzite, occurring as a “window” framed by the higher tectonic level rocks, frame this gneissic complex and forms part of a larger window constituting the Rampur window and the Bhandal–Rampur–Wangtu–Karcham gneissic complex. This gneissic complex is the oldest sequence so far known from the Himachal Himalaya.

Jutogh Group comprises Panjerli, Manal, Bhotli, Khirki, Taradevi, Kanda, Naura, Badrol, Rohru, Chirgaon and Jaknoti formations comprising a thick sequence of carbonaceous phyllite, quartzite, slate, phyllite, schist and gneisses. There are two granitoid gneissic complexes exists. These are the Bandal Granitoid Gneisses in the NW and Jeori-Wangtu Granitoid Gneiss exists and comprised of granitic gneiss, augen gneiss, gneiss, granite, schist and amphibolite. The Rampur Group is divisible into three formations: Bhalan, Banjar, and Manikaran Formation. The Bhalan is a sequence of slate, greenish phyllite with interbands of flaggy quartz arenite and subordinate metabasics. The Banjar Formation is a thick dark-green phyllite (metabasalt). The Manikaran Formation comprises quartzite with bands or bodies of metabasic rocks as exposed in Rampur area. Rampur Group is exposed NW of Jeori-Wangtu Gneissic complex with thrusted contact at Jhakri also known as Munsiari Thrust/MCY-I. Simla Group includes Basantpur, Kunihar, Chahaosa and Sanjauli formations which consist of quartzite, shale, limestone, dolomite, sandstone, siltstone and conglomerate. The Jaunsar Group is primarily found in the Deoban belt, with a smaller presence in the Shimla Hills. The Jaunsar Group has been divided into three formations, namely Mandhali, Chandpur, and Nagthat. Mandhali Formation has a lithological assemblage of limestone, argillite, arenite and conglomerate. The Chandpur Formation is characterized by the occurrence of an alternating sequence of argillite and arenite. The Nagthat Formation consists of sandstone, arenite, grit, conglomerate, shale, slate and phyllite. Shali Group comprises of shale, siltstone, limestone, dolomite and quartzarenite.

It is evident from the foregoing discussion that landslides and subsidence are common in this region due to the geological formations, which include highly fractured rocks such as schist and gneiss and the presence of weak zones created by fault lines and foliation planes. Besides, the steep slopes and high rainfall in the area contribute to the instability of the terrain, leading to frequent landslides and subsidence events.

4. LANDSLIDE INCIDENCES IN SHIMLA DISTRICT

The present study focuses on selected landslides in Shimla district, Himachal Pradesh, which is prone to landslides due to its rugged terrain, steep slopes, unplanned construction activities and heavy monsoon rainfall. The geology of the district, characterized by fractured rocks like schist and gneiss, adds to the slope instability, while dense vegetation and soil composition increase erosion risks. Accessibility in the district is challenging due to mountainous terrain and narrow roads, including NH-5. Despite a well-developed road network, landslides during the 2023 monsoon season blocked access to remote villages, hampering relief efforts. **Fig. 2** shows a location map of 14 surveyed landslide/subsidence sites in Shimla district. These sites are as under: i) NH-707B near Fedizpul, Chopal, ii) Tangnu, Rohru, iii) PWD Resthouse, Nerwa, iv) Near Police Station, Kupvi, v) Lambakhatal, Rohru, vi) Ploutidhar, Jubbal, vii) Labrot, Jubbal, viii) Titrikyar, Kotkhai, ix) Rahighat-Kyartu Link Road, Theog, x) Marni-Kanhar, Kumarsain, xi) Kachighati, Shimla, xii) Uchi, Rampur, xiii) Kot, Rampur and xiv) Saryarla-Barshol, Rampur.

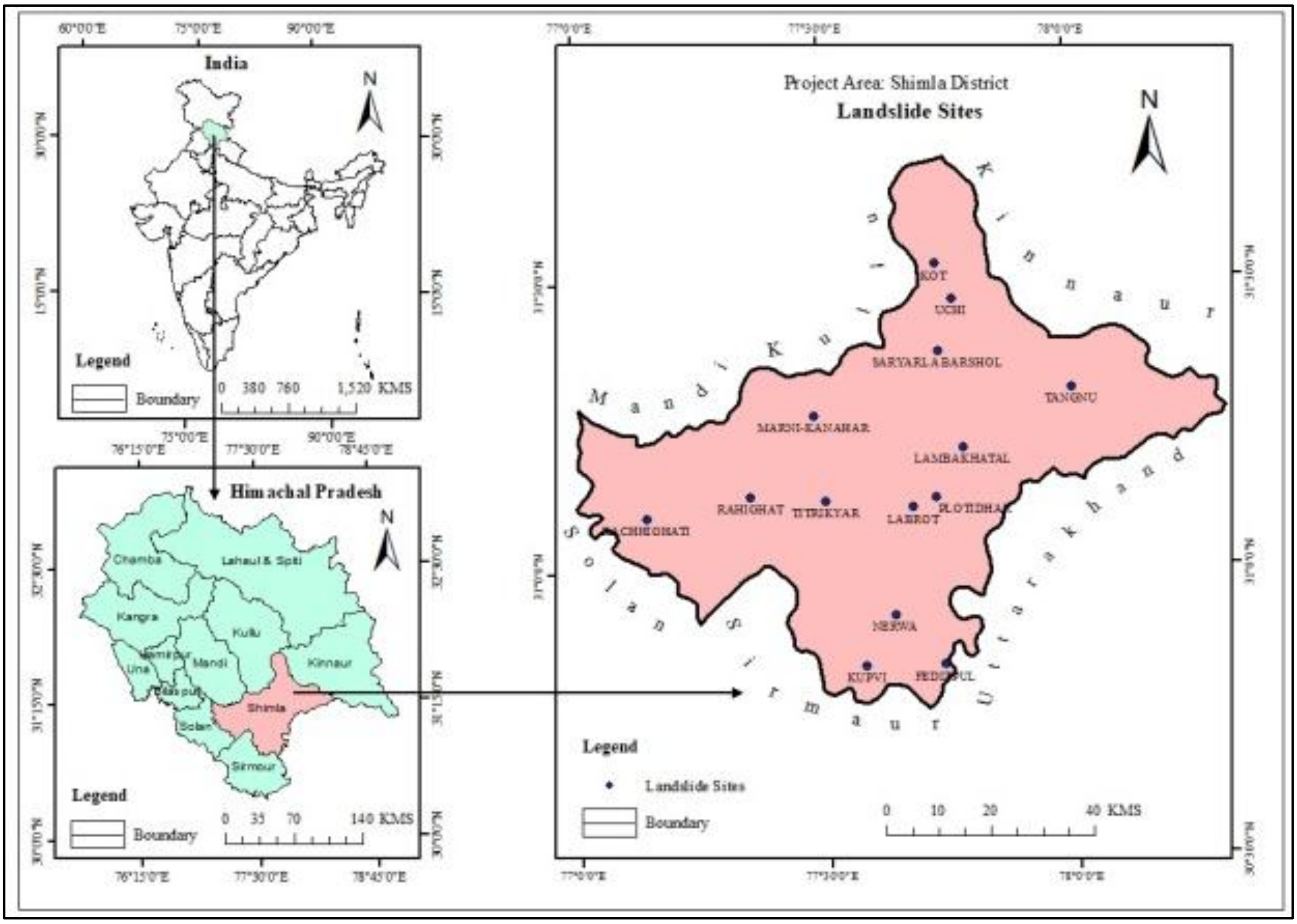


Fig. 2 Location map of landslide/subsidence sites located in the Shimla district

5. TRENDS IN RAINFALL

The rainfall data from 2019 to 2023 for six areas in Shimla district i.e. Shimla city, Kotkhai, Kumarsain, Rampur, Rohru and Theog has been graphically shown in detailed charts **(Fig. 3 to Fig. 8),** illustrating the precipitation patterns (Source: IMD, Regional Centre, Shimla). The bar diagrams illustrate the rainfall data for Shimla district from May to November for the years 2019 to 2023. Unlike the previous four years (2019-2022), there has been an unprecedented increase in rainfall, particularly in July 2023, across all six locations within the district. It is evident from the bar diagrams that Rohru experienced the highest rainfall at 1046 mm in July 2023, while the minimum was recorded at 403 mm at Kumarsain in the same month. This significant increase in rainfall in July-August 2023 has implications for the occurrence of landslides and subsidence in different villages within Shimla district. The heightened precipitation can saturate the soil, increasing its susceptibility to erosion and slope instability. Villages situated on steep slopes or with poor drainage systems are particularly at risk as observed during field investigations also. The data presented in the bar charts can help identify areas that are more vulnerable to landslides and subsidence, allowing for better preparedness and mitigation measures. By understanding the relationship between rainfall patterns and geological features, such as slope inclination and soil type, it is possible to anticipate and mitigate landslides in the future.

During the field investigation and interactions with the population affected by landslides, it became evident that the intense rainfall during the monsoon season of 2023 may have been a key factor in triggering the landslides in Shimla district. **Fig. 3** to **Fig. 8** depict the month-wise variations in rainfall for the locations of Shimla city, Kotkhai, Kumarsain, Rampur, Rohru and Theog during the years 2019 to 2023.

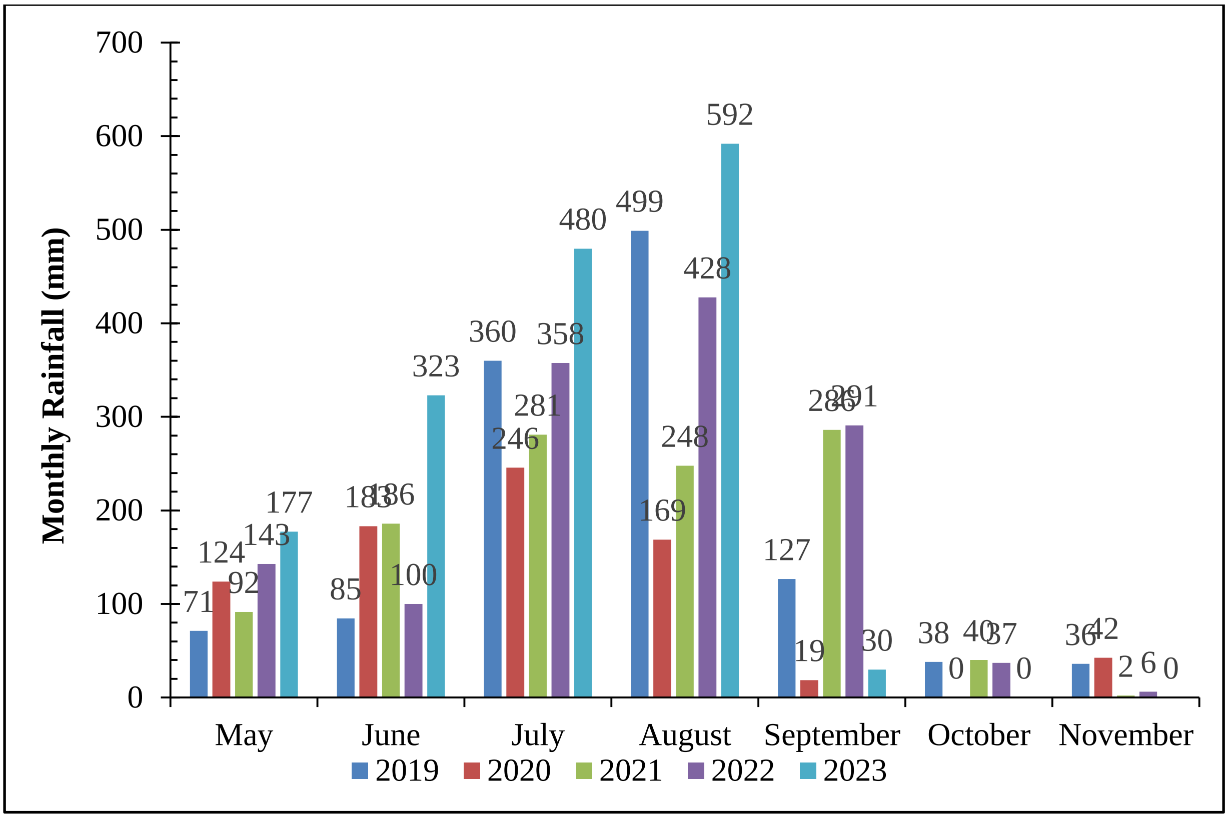


Fig. 3 Monthly rainfall data for the year (2019-23), Shimla city, district Shimla (**Source**: IMD, Regional Centre, Shimla)

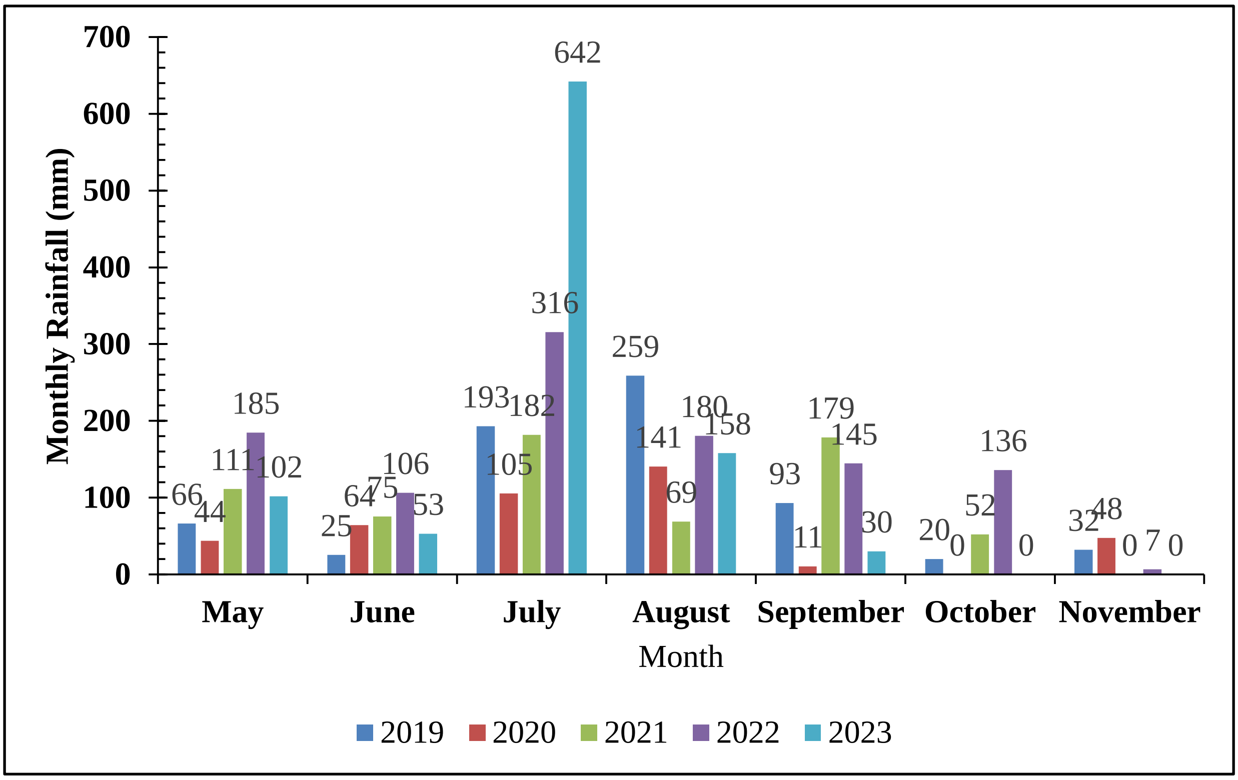


Fig. 4 Monthly rainfall data for the year (2019-23), Kotkhai, district Shimla

(**Source**: IMD, Regional Centre, Shimla)

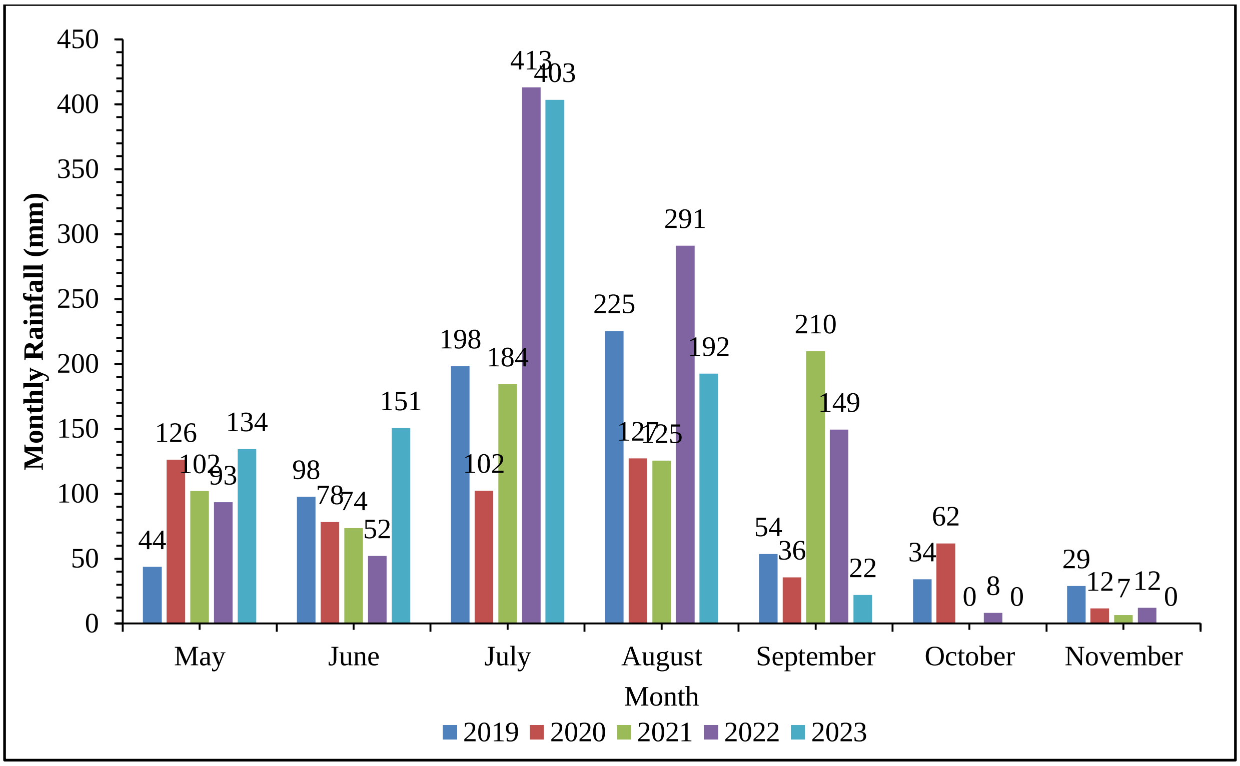


Fig. 5 Monthly rainfall data for the year (2019-23), Kumarsain, district Shimla

(**Source:** IMD, Regional Centre, Shimla)

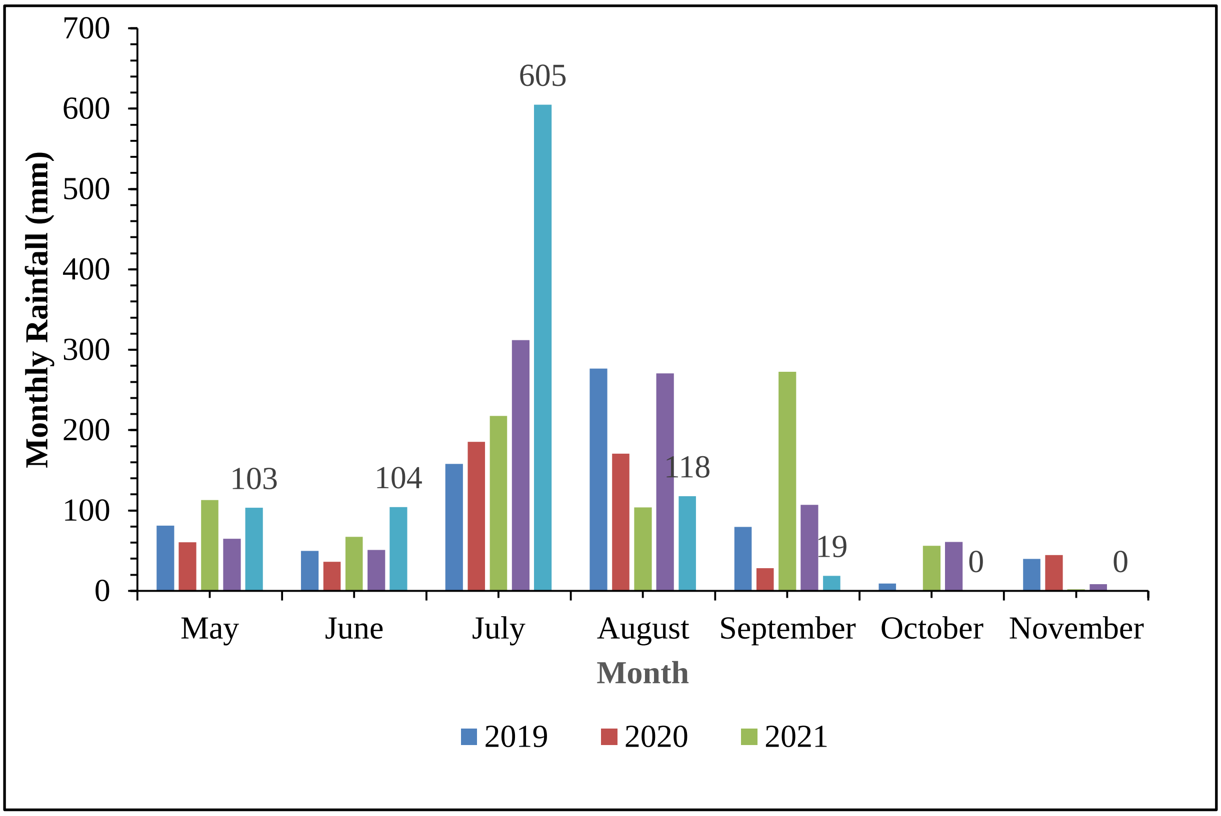


Fig. 6 Monthly rainfall data for the year (2019-23), Rampur, district Shimla

(**Source:** IMD, Regional Centre, Shimla)

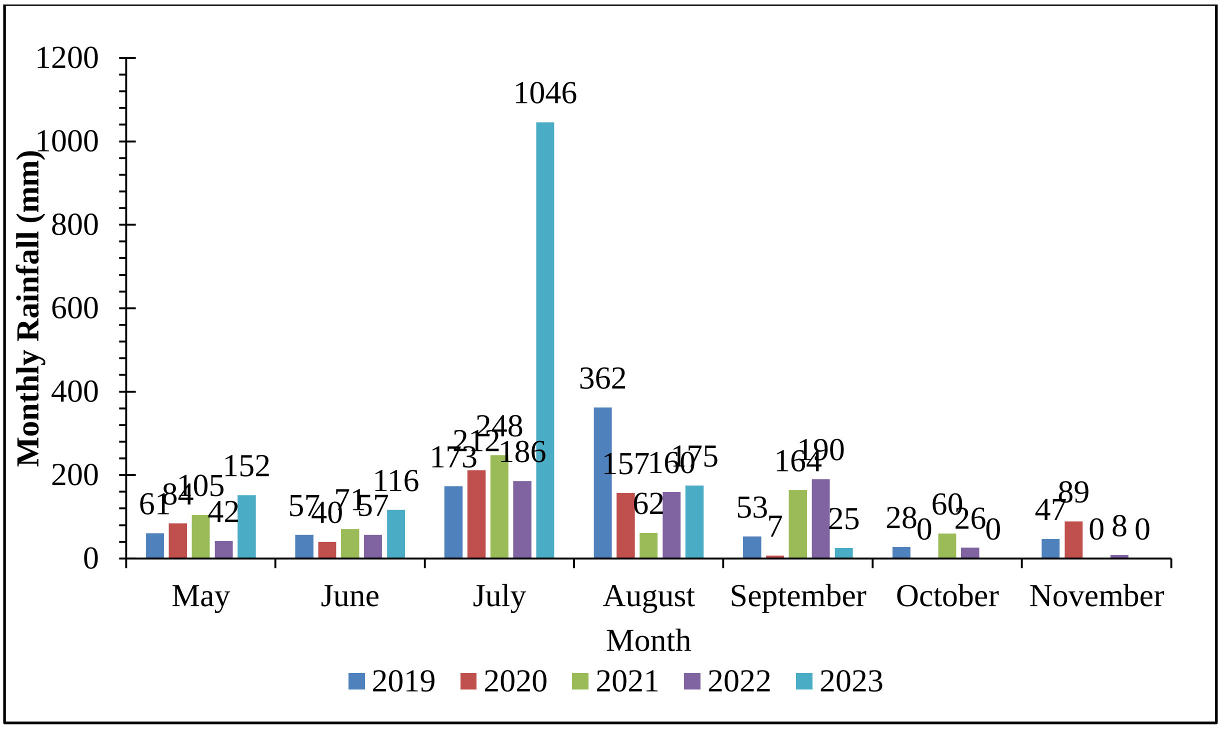


Fig. 7 Monthly rainfall data for the year (2019-23), Rohru, district Shimla

(**Source:** IMD, Regional Centre, Shimla)

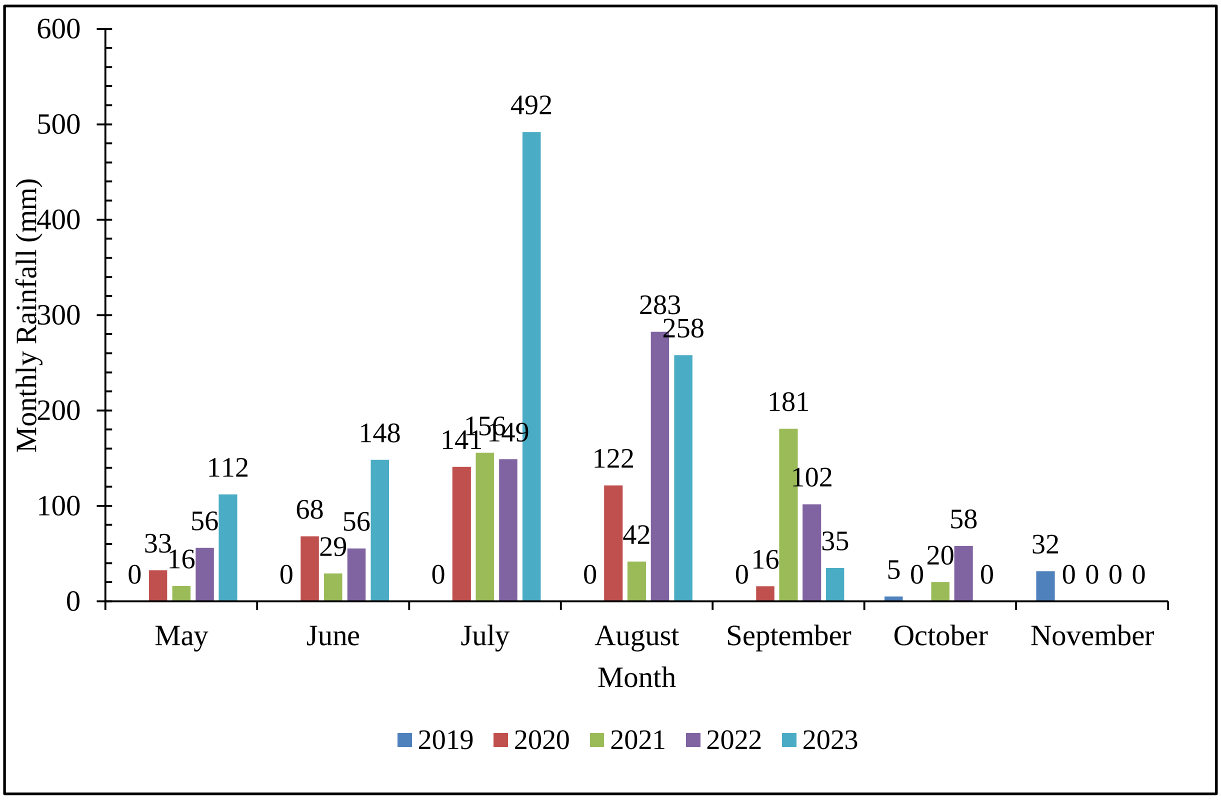


Fig. 8 Monthly rainfall data for the year (2019-23), Theog, district Shimla

(**Source**: IMD, Regional Centre, Shimla)

6. RESULTS AND DISUCSSION

6. 1 NH-707B NEAR FEDIZPUL, CHOPAL LANDSLIDE

The landslide site at NH-707B near Fedzipul, located in the Chopal Panchayat of Shimla district, Himachal Pradesh, experienced a significant landslide event on July 10, 2023. The landslide site falls in the Survey of India toposheet 53E/9 at 1:50,000 scale. This incident, occurring on the right bank of Shalvi Khad, primarily resulted from intense rainfall and impacted the roadway connecting Fedzipul with Paonta Sahib. The aftermath resulted in a two-week closure of the road, with subsequent restoration allowing for the passage of traffic through a single lane. Fortunately, there were no reported casualties, but a canal that transported water from Fediz to Kiarla Village was lost as a consequence of the landslide. The site's geological setting is within the Lesser Himalayas and the valley is structurally controlled. The area's geology predominantly features limestone with three discontinuity planes (J_1, J_2, and J_3), and damp to wet groundwater conditions. The slope faces 45^0 in N043^0 direction, with J_1 and J_2 planes forming a wedge inclined at 42^0 in N 0270 direction, indicating a high probability of wedge failure, especially during monsoon rains.

The grain size analysis of soil reveals that this site has shown highest (76%) of sand content. Due to highest percentage of sand and gravel moisture holding capacity of soil is restricted to very low (about 2%). The site has absence of clay soil thus, accelerating the soil detachment while silt and grain size is less than 15% of the total **(Table 1).** The site falls in non-plastic class with small dry density values. On the shear parameters, the site was recorded in low cohesion category with high coefficient of permeability indicating susceptibility to slope failure.

Fig. 9 presents the contour map of the NH- 707B near Fedzipul landslide prepared at an interval of 1 m. It describes a complex terrain with steep slopes, especially near the crown where the angles are close to vertical, transitioning to a consistent incline of 45^0 along the main body of the slide. The contours' delineation indicates a steep gradient and a high degree of slope instability. **Fig. 10** and **Fig. 11** portray the panoramic view and the field photograph of the site respectively. **Fig. 11** illustrates the toe cutting by the Shalvi Khad and loose material. **Fig. 12** displays the disintegrated rock mass, with boulders of various sizes, alongside a 145-meter-long RCC protection wall that has been erected as a mitigation measure by the National Highway authorities. **Fig. 13** and **Fig.** 14 depict the extent of debris runout and the distribution of loose slide material from the identified landslide, providing valuable insights into the dynamics and characteristics of the event.

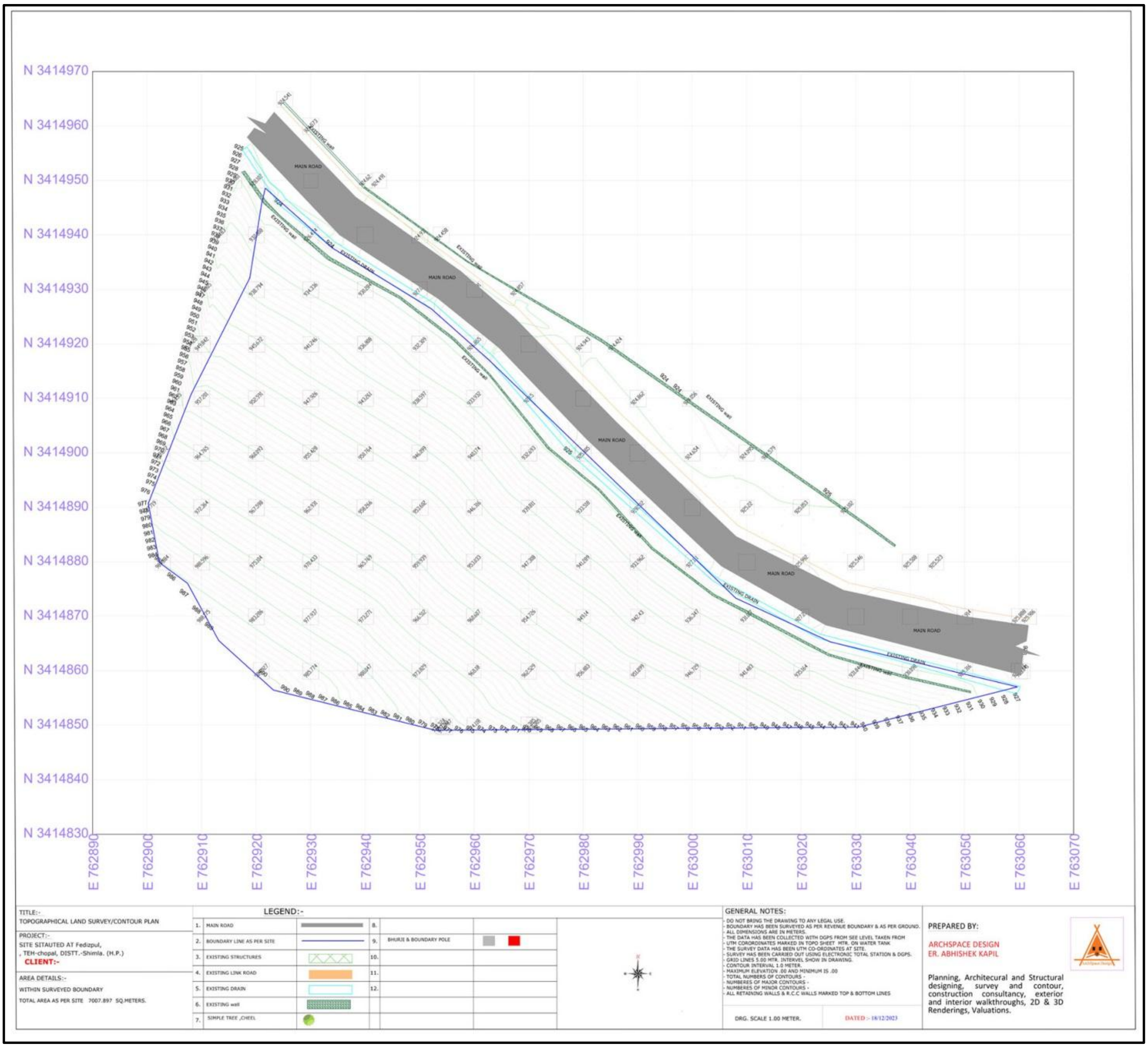


Fig. 9

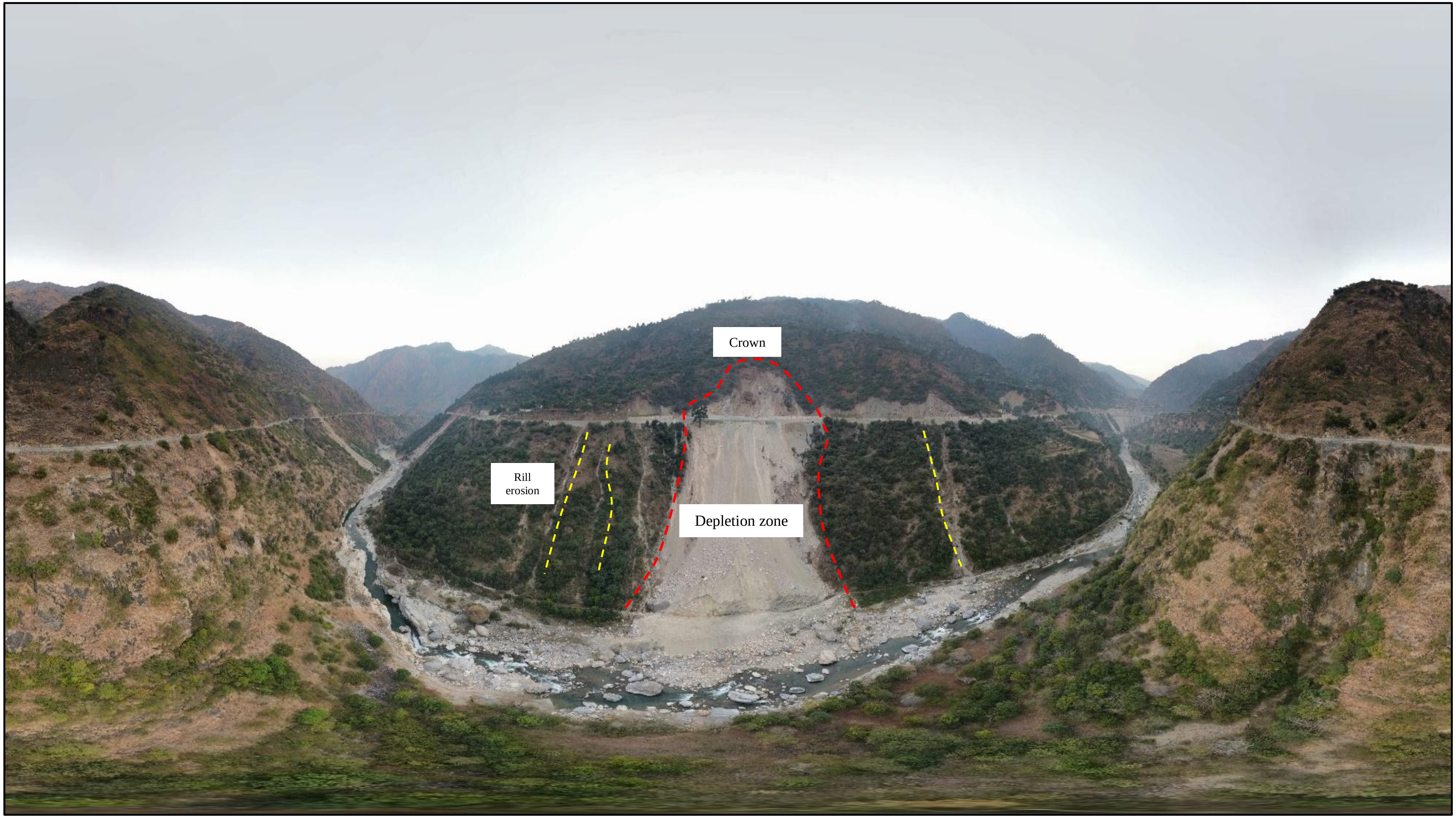


Fig. 10 A panoramic view of NH-707B landslide site near Fedzipul, Chopal, Shimla district

Fig. 11 Toe Cutting by Shalvi Khad

Fig. 12 Disintegrated rock mass and mitigating concrete retaining wall

Fig. 13. Debris runout

Fig. 14. Loose debris slide material

Causative Factors

- The slope failed due to a combination of wedge failure and movement of overlying debris, likely triggered by the excavation for road widening.
- Heavy rainfall during the monsoon further weakened the already unstable slope, leading to the landslide.

Short Term Measures

- The required solutions have already been implemented by the National Highway Authorities.
- A RCC protection wall spanning approximately 145 meters has been erected, along with a 145-meter-long crash barrier.
- For slope stabilization, the implementation of geocell with hydroseeding and Hedge Brush Layering has been adopted.

Long-Term Solutions

- Bioengineering methods should be extended to both the upper and lower areas of the active landslide site/ road to ensure continued effectiveness in mitigating the ongoing risk.
- Continuous monitoring of the site to ensure the effectiveness of existing reinforced structures and bioengineering measures and to promptly address any changes in the geological or structural integrity.

6.2 TANGNU, ROHRU LANDSLIDE

On July 14, 2023, Tangnu village, situated on the right bank of the Pabbar River in the Shimla district, experienced a devastating landslide induced by heavy rainfall. The landslide site falls in the Survey of India toposheets 53E/15 at 1:50,000 scale. This historic village, with an 800-year history and home to around 350 residents in 55 households, blends agricultural and residential land use. The village has a scanty evidence of land subsidence, dating back to 1992 when a significant rockfall occurred on the left bank of the Pabbar River, resulting in the formation of a temporary lake This event altered the river's course, leading to toe erosion and partially contributing to the ongoing subsidence of the village. Currently, a portion of the Pabbar River flows through private land along the toe area now occupied by the river. Presently, Tangnu is grappling with a sinking phenomenon affecting the entire village. The primary contributors to the village's sinking are the absence of proper drainage and sewerage systems, creating damp to perennial waterflow conditions. Tangnu is underlain by both surface and subsurface water, with the village appearing to be situated on water surfaces. The village is characterized by around six perennial natural springs, increasing to 20 during the rainy season.

Houses are built on the upper slope, while the landslide under analysis is situated below the road on the lower slope, where apple orchards are grown. The upper slope in the village exhibits multiple seepages and flowing water, along with visible tension cracks. The signs of land and footpath subsidence and few structures are present at several locations. These tension cracks are found on the land, measuring approximately 3m in length, 5-6cm wide/open, and 2-6cm deep. These cracks indicate the active nature of the landslide and its extension, contributing to land failures that affect the lower slope.

Notably, the landslide and subsidence is trans-rotational in nature, posing a threat to approximately 400 apple trees if mitigation measures are not promptly adopted. The landslide has already resulted in the loss of approximately 30 Bigha of agricultural and horticultural land. The predominant land-use pattern in Tangnu is a combination of agriculture and built-up areas. The village features various trees such as Walnut, Apple, Apricot (locally known as *Chuli*) and Vehmi trees.

Geologically, the area, a part of the Lesser Himalayas under the Jutogh Group, is known for its metamorphic rocks. The village is bounded by Shanaulti Khad and Devra Nala, with Sundru Khad forming a valley to its left. The Pabbar River, flowing through deep gorges and active landslide areas, signifies the valley's structural control. Deep gorges and vertically dissected hill slope in the valley and active landslides evident that the valley is structurally controlled. **Fig. 15** presents the contour map of the Tangnu landslide. The 1-meter interval contour mapping of the Tangnu landslide depicts a slope angled around **45^0**, nearly mirroring the foliation plane, signaling substantial risk for landslides. The contours hint at zones of deformation and instability, where tension cracks and subsidence are prevalent, crucial for developing a digital elevation model (DEM) that will facilitate the analysis of slope stability and the formulation of corrective measures while preparing detailed project report.

The soil analysis reveals that this site is dominated by about half of the total soil content as sand. Absence of clay and about $1/3^{rd}$ of the soil content being composed of silt material indicating susceptibility to runoff water. The site reported 10% of the moisture content with absence of clay soil thus, accelerating the soil detachment. The site falls in non-plastic class with small dry density values. On the shear parameters, the site was recorded in low cohesion values with high permeability coefficient indicating proneness to landslides **(Table 1).**

Fig. 16 shows the panoramic view of the site. The whole village, flanked by Pabbar river in the south and the village road connecting Tangnu, is experiencing significant sinking. The slanting walnut trees, known as "drunken trees," **(Fig. 20)** suggest that the village is sinking. The consequences included a loss to apple orchards, damage to approximately 4-5 houses (tilting and cracks) and concrete pathways accompanied by cracks in farmlands as shown in **Fig. 17** to **Fig. 21.** Interactions with the locals **(Fig. 21)** revealed psychological concerns regarding the subsiding landmass and structures in Tangnu village indicating the urgent need for intervention and resolution.

EXISTING RIVER
TITLE:-
TOPOGRAPHICAL LAND SURVEY/CONTOUR PLAN
PROJECT:-
SITE SITAUTED AT tangnu,
, TEH-ROHRU, DISTT.-SHIMLA. (H.P.)
CLIENT:-
AREA DETAILS:-
WITHIN SURVEYED BOUNDARY
TOTAL AREA AS PER SITE 59980.489 SQ.METERS.
LEGEND:-
1. MAIN ROAD
2. BOUNDARY LINE AS PER SITE
3. EXISTING STRUCTURES
4. EXISTING LINK ROAD
5. EXISTING RIVER
6. EXISTING wall
7. SIMPLE TREE ,CHEEL
8. EXISTING tempel
9. BHURJI & BOUNDARY POLE
10.
11.
12.
GENERAL NOTES:
- DO NOT BRING THE DRAWING TO ANY LEGAL USE.
- BOUNDARY HAS BEEN SURVEYED AS PER REVENUE BOUNDARY & AS PER GROUND.
- ALL DIMENSIONS ARE IN METERS.
- THE DATA HAS BEEN COLLECTED WITH DGPS FROM SEE LEVEL TAKEN FROM
- UTM CORORDINATES MARKED IN TOPO SHEET MTR. ON WATER TANK
- THE SURVEY DATA HAS BEEN UTM CO-ORDINATES AT SITE.
- SURVEY HAS BEEN CARRIED OUT USING ELECTRONIC TOTAL STATION & DGPS.
- GRID LINES 5.00 MTR. INTERVEL SHOW IN DRAWING.
- CONTOUR INTERVAL 1.0 METER.
- MAXIMUM ELEVATION .00 AND MINIMUM IS .00
- TOTAL NUMBERS OF CONTOURS -
- NUMBERES OF MAJOR CONTOURS -
- NUMBERES OF MINOR CONTOURS -
- ALL RETAINING WALLS & R.C.C WALLS MARKED TOP & BOTTOM LINES
DRG. SCALE 1.00 METER.
DATED :- 18/12/2023
PREPARED BY:
ARCHSPACE DESIGN
ER. ABHISHEK KAPIL
Planning, Architecural and Structural designing, survey and contour, construction consultancy, exterior and interior walkthroughs, 2D & 3D Renderings, Valuations.

Fig. 15

Fig. 16 A panoramic view of Tangnu, Rohru landslide site, Shimla district

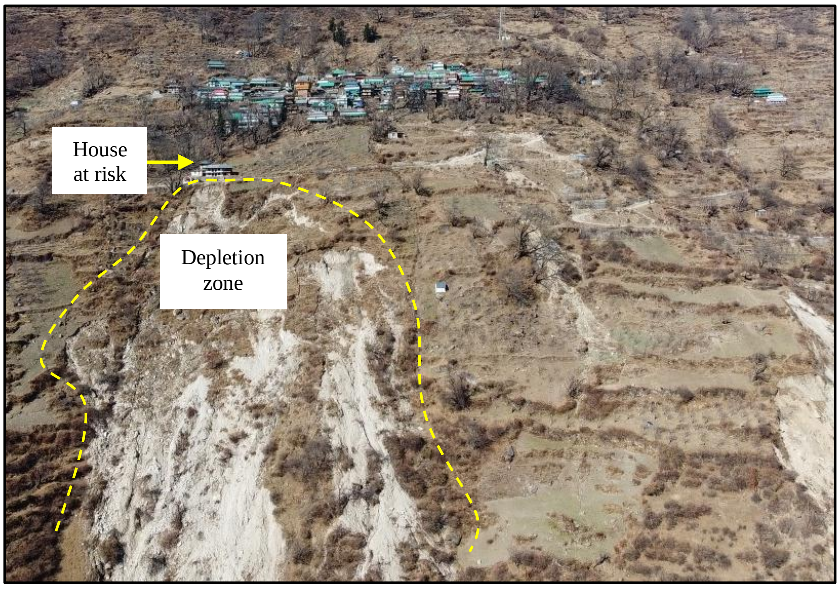


Fig. 17 Depletion Zone below the Tangnu Road

Fig. 18 Cracks in Houses

Fig. 19 Prominent tension cracks due to subsidence

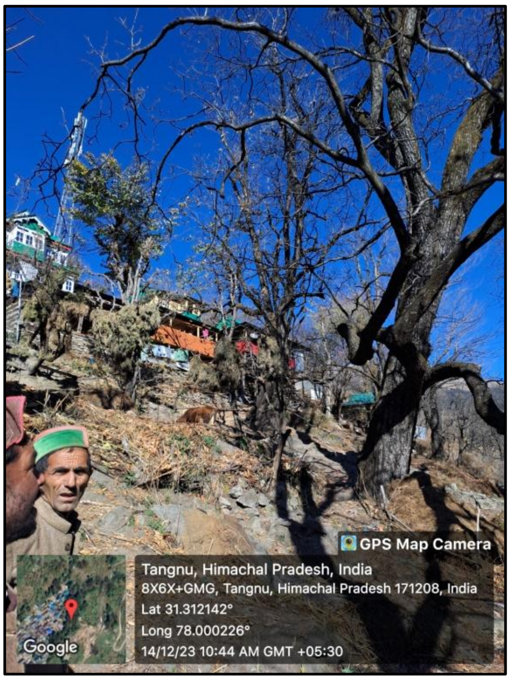


Fig. 20 Slanting Walnut trees indicating village sinking

Fig. 21 Team Members interacting with Villagers

Causative Factors

- Insufficient drainage and sewerage systems leading to persistent damp conditions.
- The geological composition, including surface and subsurface water with numerous natural springs.
- Structural changes in the landscape from historical landslide and alterations in the river course, compounded by a moderately steep to steep slope, a structurally controlled valley, toe erosion and heavy rainfall.

Short-Term Remedial Measures

- Implementing effective drainage management on the upper slopes to address water seepage and flow.
- Immediate erosion control at the slope's toe, possibly through river training and constructing step walls with weep holes.

Long-Term Solutions

- Installation of a comprehensive sewerage system to enhance drainage and mitigate subsidence risk.

- Ensuring new housing constructions meet civil engineering standards for increased resilience against subsidence.
- Adoption of bioengineering strategies like planting Walnut and Silver Oak trees for natural slope stabilization.

Note: ***Given the sinking scale and its impact on the inhabited area, it is essential to prepare a detailed project report (DPR) to address the slope instability/ land subsidence of Tangnu Village.***

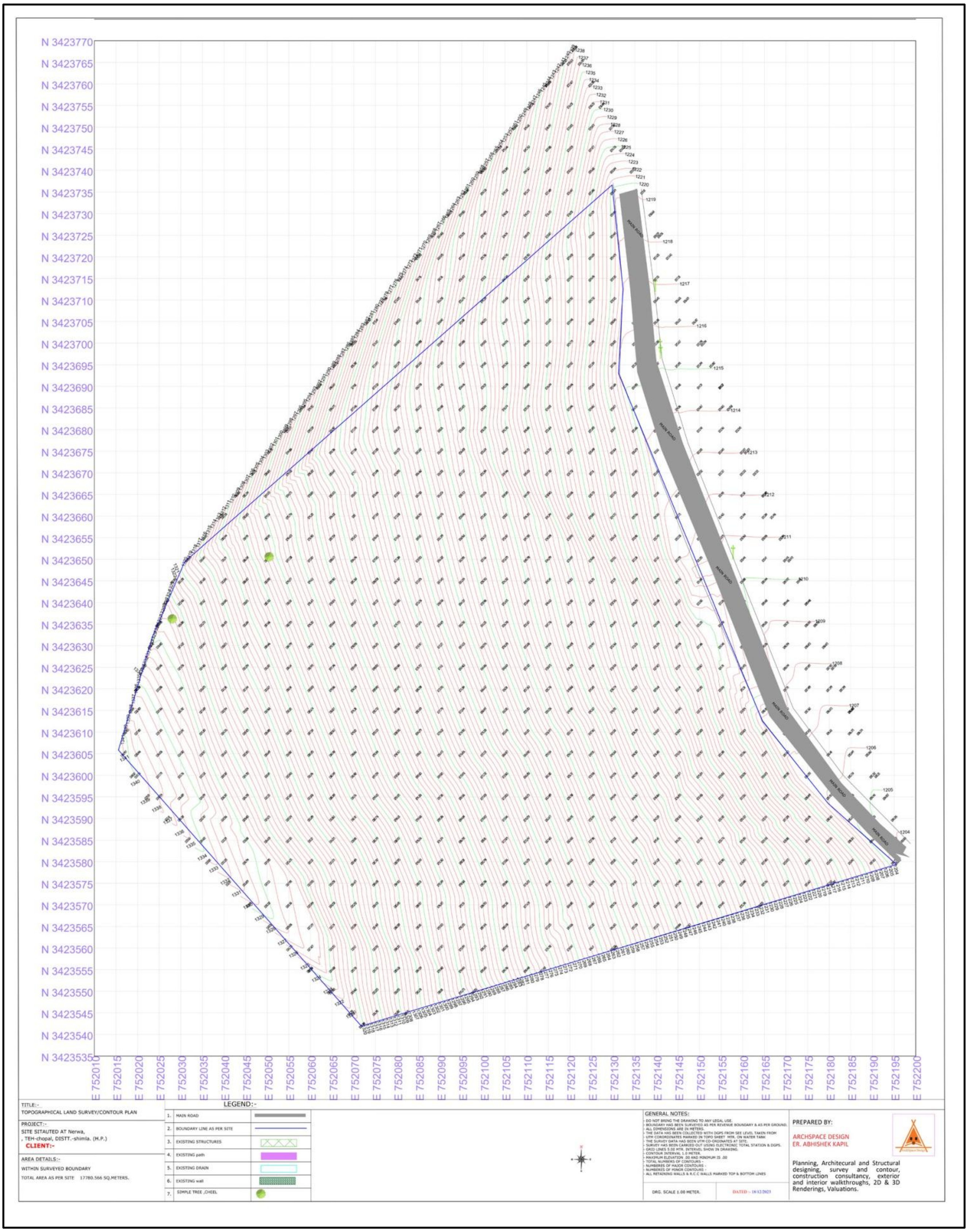
6.3 PWD REST HOUSE, NERWA LANDSLIDE

Between July 10-12, 2023, a landslide occurred on the right bank of Shalvi Khad, a tributary of the Tons River. The landslide site falls in the Survey of India toposheet 53E/9 at 1:50,000 scale. Initially detected in August 2018, this geological phenomenon has evolved into an annual issue, with the latest incident in 2023 resulting in damage to 10 residential and commercial buildings and necessitating month-long evacuations. The landslide directly affected approximately 100 people. Compensation has been disbursed to each affected family directly impacted by the landslide. The potential threat extends to vital local infrastructure including the local bus stand, the transport depot in Nerwa, and Nerwa Public School (NPS), which provides education up to the 10th standard. Without preventative measures, these vital structures face impending danger. Although, the local road has been restored, issues persist, including seepage problems from the road connecting Nerwa-Dehia-Kupvi situated above the landslide. Besides, there are concerns about a blocked culvert and inadequate drainage atop the landslide also. During the rainy season, there is a heightened risk of falling stones and boulders, increasing the overall vulnerability of the affected area.

Fig. 22 presents the contour map of the PWD rest house, Nerwa landslide. The contour map of the landslide site, with 1-meter interval contours, demonstrates a steep topographic profile, indicating a high susceptibility to slope failure. **Fig. 23** and **Fig. 24** illustrate the panoramic and the field photograph of the site respectively. **Fig. 24** depicts the debris runout material and the exposed, vulnerable mass seeking protection, as well as the restored road linking Nerva with Chopal. **Fig. 25** shows the transport depot, Nerwa and other structures that could be impacted if the landslide is not mitigated in the future.

From a geological perspective, the site is situated within the Lesser Himalayas and is part of the Jutogh Group. This region is characterized by metamorphic rocks such as schist, phyllites, slates and quartzite. Specifically, the landslide area is dominated by phyllite, which is highly deformed, jointed and faulted, adding to the site's vulnerability. The phyllite rock mass near the HPPWD guest house displays three sets of discontinuity planes (J0, J1, and J2) and is subject to folding, faulting and shearing **(Fig.26).** The slope faces 070^0 N with varying angles of 44^o, 30^o, and 70^o, further contributing to the complexity and instability of the geological structure. These technical aspects of the site's geology play a crucial role in understanding and addressing the landslide risks.

The soil analysis reveals that this site consists primarily of sand, which accounts for more than half of the total soil content. The absence of clay and the presence of about 18% silt make the site susceptible to runoff. It is also evident from the **Table 1** that the site has a moisture content of 23%, which, combined with the absence of clay, accelerates runoff. The soil properties also exhibit high dry density values. In terms of shear parameters, the site shows lower cohesion values and a medium coefficient of permeability.



MAIN ROAD
TITLE:-
TOPOGRAPHICAL LAND SURVEY/CONTOUR PLAN
PROJECT:-
SITE SITAUTED AT Nerwa,
, TEH-chopal, DISTT.-shimla. (H.P.)
CLIENT:-
AREA DETAILS:-
WITHIN SURVEYED BOUNDARY
TOTAL AREA AS PER SITE 17780.566 SQ.METERS.
LEGEND:-
1. MAIN ROAD
2. BOUNDARY LINE AS PER SITE
3. EXISTING STRUCTURES
4. EXISTING path
5. EXISTING DRAIN
6. EXISTING wall
7. SIMPLE TREE ,CHEEL
GENERAL NOTES:
DRG. SCALE 1.00 METER.
PREPARED BY:
ARCHSPACE DESIGN
ER. ABHISHEK KAPIL
Planning, Architecural and Structural designing, survey and contour, construction consultancy, exterior and interior walkthroughs, 2D & 3D Renderings, Valuations.

Fig. 22

Fig. 23 A panoramic view of PWD rest house, Nerwa landslide site, Shimla district

Fig. 24. A field photograph of PWD rest house, Nerwa landslide site

Fig. 25. Structures likely to be affected by Landslide

Fig. 26. Discontinuity planes and geological features of Phyllite rock mass

Causative Factors

The primary issues contributing to the landslide include heavy rainfall, seepage problems from the Nerwa-Dehia-Kupvi road situated above the landslide site, a blocked culvert, and inadequate drainage. The landslide's severity is heightened during the rainy season due to the increased risk of falling stones and boulders. The geology of the area, part of the Lesser Himalayas and belonging to the Jutogh Group, includes metamorphic rocks such as schist, phyllites, slates, and quartzite. The phyllite rock at the site is highly deformed, jointed and faulted, contributing to the area's geological instability.

Short-Term Solutions

- Installing a comprehensive drainage system on the road and above the landslide area to manage water effectively.
- Implementing bioengineering techniques to provide immediate stabilization to the slope.

Long-Term Solutions

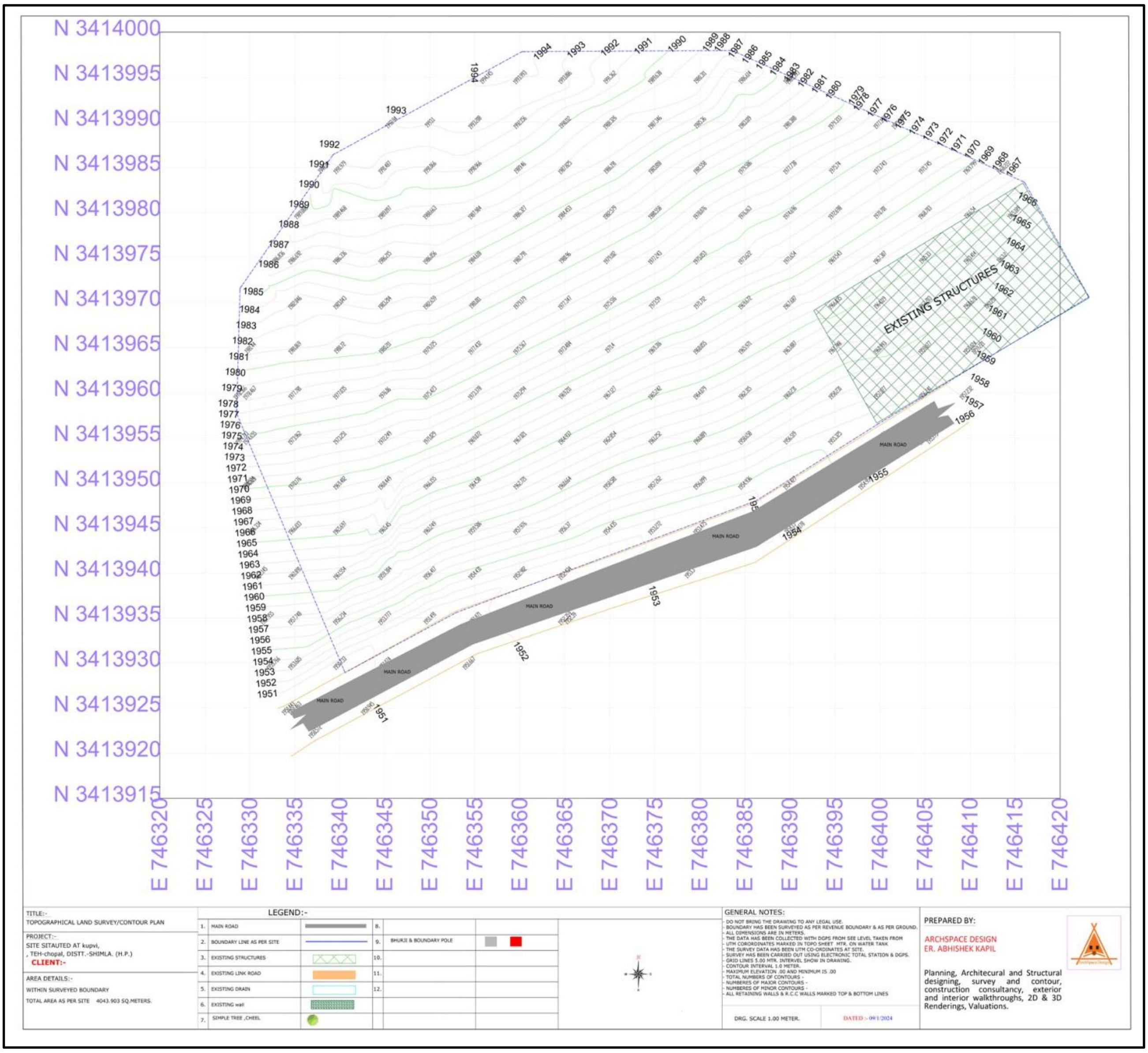
- Managing water seepage on the slope by monitoring and repairing any sources of water leakage.
- Constructing a retaining wall with weep holes is essential to stabilize the slope and manage water seepage on the slope above the crown of the site. This structural solution is crucial for preventing future landslides and safeguarding the local infrastructure, including the area below the road, the nearby PWD Guest house above the road, and the residents.
- Regular monitoring and maintenance of these solutions are imperative to adapt to future geological or climatic changes, ensuring the safety and sustainability of the site.

6.4 NEAR POLICE STATION, KUPVI LANDSLIDE

The landslide near the Kupvi police station, despite its current inactivity, has been a subject of concern, leading to a preliminary study by the district administration. The landslide site falls in the Survey of India toposheet 53E/9 at 1:50,000 scale. This translational landslide, which initially emerged in May 2021 due to continuous rainfall over 2- 4 days, is located on the district road linking Kupvi (Shimla) to Haripur Dhar (Sirmaur). In the May 2021 incident, damage occurred to the private land of Laiq Ram and his family, resulting in the loss of 3 Bigha of agricultural land. The road was closed for approximately 4-5 days, leading to the evacuation of 4-5 houses by the local administration. During the recent monsoon season, no significant losses were reported. However, cracks have developed above the crown of the landslide, posing a potential risk to the residential house of Mr. Kedar Singh, son of Shri Janam Singh. Besides, about 2-3 bigha agricultural land above the landslide is under threat, as well as three recently constructed concrete houses below the road **(Fig.29).**

Fig. 27 portrays the contour map of the near police station Kupvi, landslide. The contour map of the landslide site, featuring 1-meter interval contours, reveals a moderate topographic profile, indicating a moderate susceptibility to slope failure. **Fig. 28 and 29** depict the panoramic view and a field photograph of the site, respectively. **Fig. 29** also highlights the structures and agricultural land affected by the landslide above the road, as well as those likely to be affected by its reactivation below the road in the future. Geologically, the area forms a part of the Lesser Himalayas, characterized by rocks such as phyllites, carbonaceous phyllites, and schists belonging to the Jutogh Group. The schist rock exposed near the site is notably fractured and deformed **(Fig. 30)**, with three sets of joint planes (J_0, J_1, and J_2) weakening the slope. The site's current dry groundwater conditions and the visible tension cracks near the crown suggest a potential for reactivation under heavy and prolonged rainfall. This geological setting indicates a partially stable slope, evidenced by some weed growth, but remains vulnerable to future rainfall events.

The grain size analysis of the landslide site soils indicates that this site contains 56% silt, making it highly susceptible to soil detachment. The moisture content is around 15% and the soil exhibits poor cohesion and a high coefficient of permeability **(Table 1),** indicating its vulnerability to landslide.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E 746390
E 746395
E 746400
E 746405
E 746410
E 746415
E 746420
EXISTING STRUCTURES
MAIN ROAD
TITLE:-
TOPOGRAPHICAL LAND SURVEY/CONTOUR PLAN
PROJECT:-
SITE SITAUTED AT kupvi,
, TEH-chopal, DISTT.-SHIMLA. (H.P.)
CLIENT:-
AREA DETAILS:-
WITHIN SURVEYED BOUNDARY
TOTAL AREA AS PER SITE 4043.903 SQ.METERS.
LEGEND:-
1. MAIN ROAD
2. BOUNDARY LINE AS PER SITE
3. EXISTING STRUCTURES
4. EXISTING LINK ROAD
5. EXISTING DRAIN
6. EXISTING wall
7. SIMPLE TREE ,CHEEL
8.
9. BHURJI & BOUNDARY POLE
10.
11.
12.
GENERAL NOTES:
- DO NOT BRING THE DRAWING TO ANY LEGAL USE.
- BOUNDARY HAS BEEN SURVEYED AS PER REVENUE BOUNDARY & AS PER GROUND.
- ALL DIMENSIONS ARE IN METERS.
- THE DATA HAS BEEN COLLECTED WITH DGPS FROM SEE LEVEL TAKEN FROM
- UTM CORORDINATES MARKED IN TOPO SHEET MTR. ON WATER TANK
- THE SURVEY DATA HAS BEEN UTM CO-ORDINATES AT SITE.
- SURVEY HAS BEEN CARRIED OUT USING ELECTRONIC TOTAL STATION & DGPS.
- GRID LINES 5.00 MTR. INTERVEL SHOW IN DRAWING.
- CONTOUR INTERVAL 1.0 METER.
- MAXIMUM ELEVATION .00 AND MINIMUM IS .00
- TOTAL NUMBERS OF CONTOURS -
- NUMBERES OF MAJOR CONTOURS -
- NUMBERES OF MINOR CONTOURS -
- ALL RETAINING WALLS & R.C.C WALLS MARKED TOP & BOTTOM LINES
DRG. SCALE 1.00 METER.
DATED :- 09/1/2024
PREPARED BY:
ARCHSPACE DESIGN
ER. ABHISHEK KAPIL
Planning, Architecural and Structural designing, survey and contour, construction consultancy, exterior and interior walkthroughs, 2D & 3D Renderings, Valuations.

Fig. 27

Fig. 28. A panoramic view of Near Police Station, Kupvi landslide site, Shimla district

Fig. 29. Structures and agricultural land affected due to landslide

Fig. 30. Disintegrated rock mass, Near Kupvi Landslide site

Causative Factors

The May 2021 landslide damaged 3 Bigha of agricultural land, necessitating a 4-5 day road closure and nearby house evacuations. Concerns now include developing cracks above the landslide, endangering Mr. Kedar Singh's residence, nearby agriculture and three recently built concrete houses. The primary trigger of the landslide has been identified as sustained heavy rainfall, which, along with the fractured and deformed rock structure, weakened the slope.

Short-Term Measures

- Frequent monitoring of the cracks and the areas identified as vulnerable, particularly during the rainy season.
- Installation of temporary support structures to stabilize the slope and prevent further land displacement.

Long-Term Solutions

- The slope appears partially stable, indicated by the growth of weeds. Light bioengineering methods, like planting vetiver grass and other local varieties, can effectively stabilize the slope.

6.5 LAMBAKHATAL, ROHRU LANDSLIDE

On 14th July, 2023, a landslide, triggered by heavy rainfall, took place on the right bank of the Pabbar River, approximately 4 km from Rohru bus stand. This place is known as Lambakhatal. The landslide site is located within Survey of India toposheet 53E/16, mapped at a scale of 1:50,000. The landslide impacted an established road connecting Rohru and Chirgaon villages, a route that has been in use for approximately 50 years. This specific landslide, classified as a translational landslide, had previously occurred in 2021 during a period of heavy rainfall. The area, primarily used for grazing and pasture, is government-owned. The landslide led to a temporary two-day closure of the road between Rohru and Chirgaon villages. Fortunately, there were no reported losses resulting from the landslide.

Fig. 31 portrays the contour map of Lambakhatal landslide. The contour map of the landslide site, with 1-meter interval contours, shows a steep topographic profile, indicating a high susceptibility to slope failure. **Fig. 32** and **Fig. 33** depict the panoramic view and a field photograph of the site, respectively. The field investigation reveals the structures and agricultural land affected by the landslide above the road, with potential reactivation in the future.

Geologically, the site is part of the Lesser Himalayas, with rocks mainly of metamorphic origin belonging to the Jutogh Group. The folded Jutogh Group, overthrusted on the Jhaunsar Group, comprises mainly schists, phyllites, slates and quartzites. At the site, the rock type exposed is quartzite, characterized by fractures and three sets of discontinuous planes (J_0, J_1, and J_2). The slope is steep, with the slope mass primarily formed by debris. Near the landslide's crown, the slope is very steep, while the middle slope has a dip of approximately 40^0.

The soil analysis reveals that this site contains approximately half of its total soil content in the form of silt and sand, with clay comprising a negligible share of 2%. The moisture content is reported to be 8% **(Table 1).** The site exhibits high dry density values and falls into the non-plastic class. In terms of shear parameters, the site demonstrates moderate cohesion and a moderate coefficient of permeability, indicating its susceptibility to slope failure and landslide.

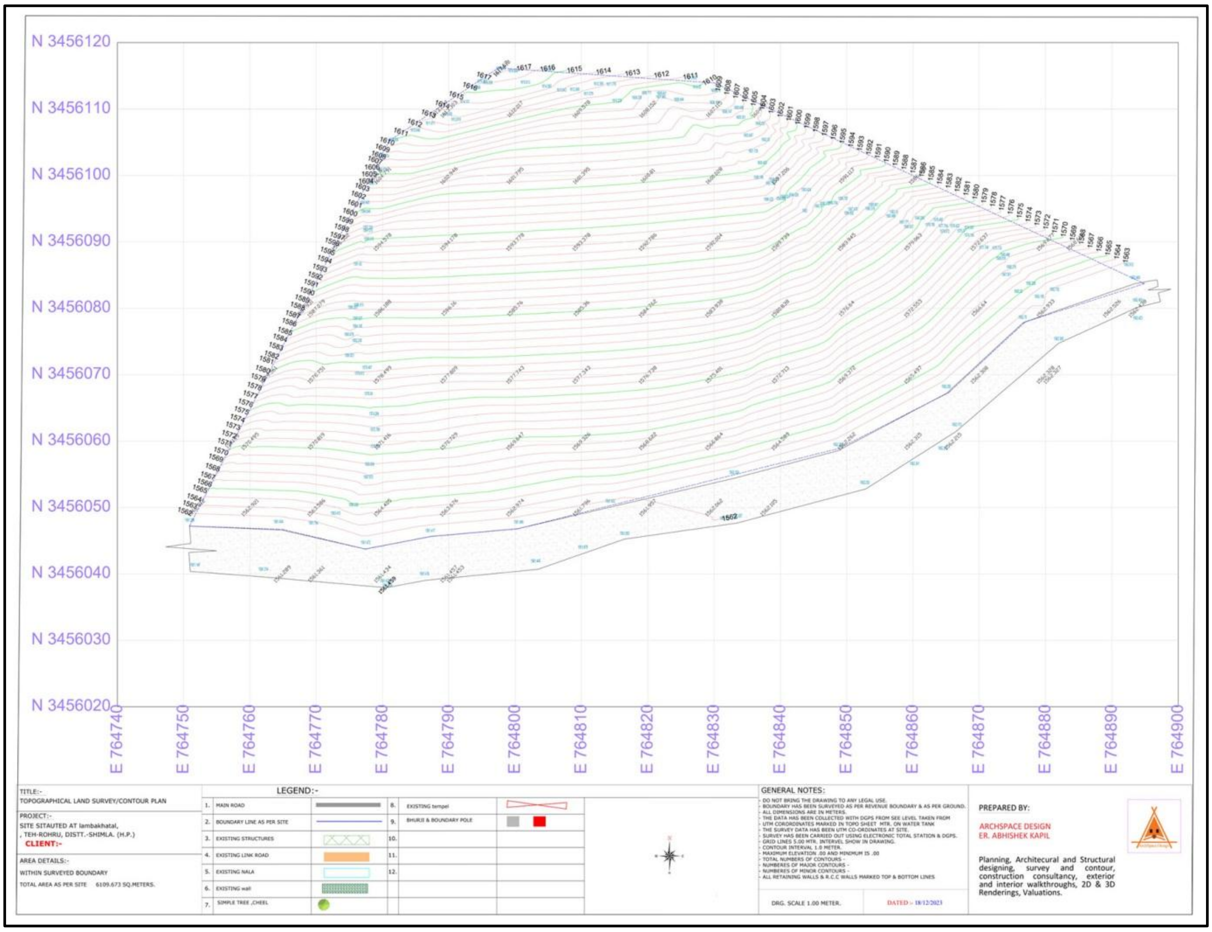

Fig. 31

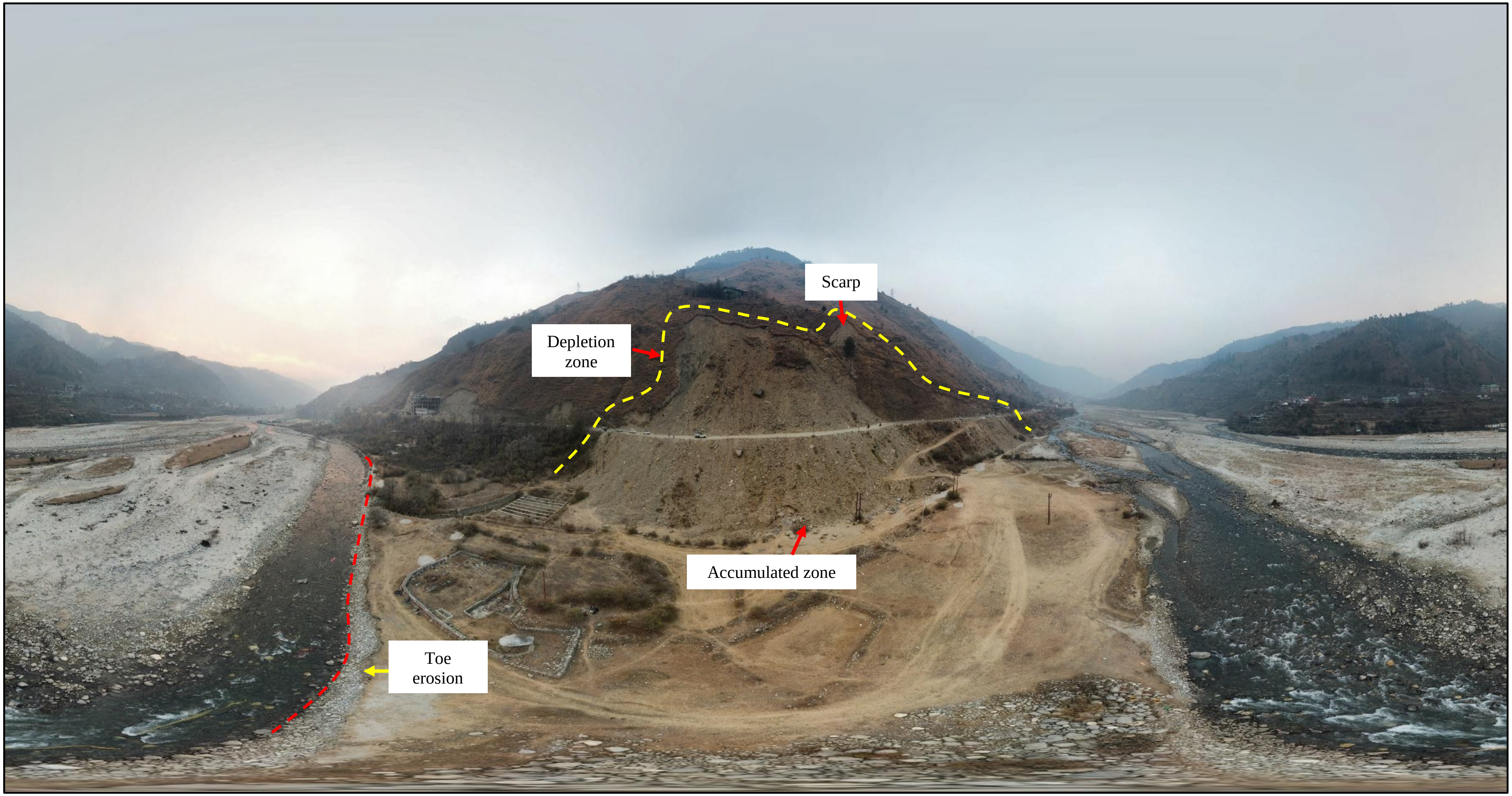

Fig. 32. A panoramic view of Lambakhatal, Rohru landslide site, Shimla district

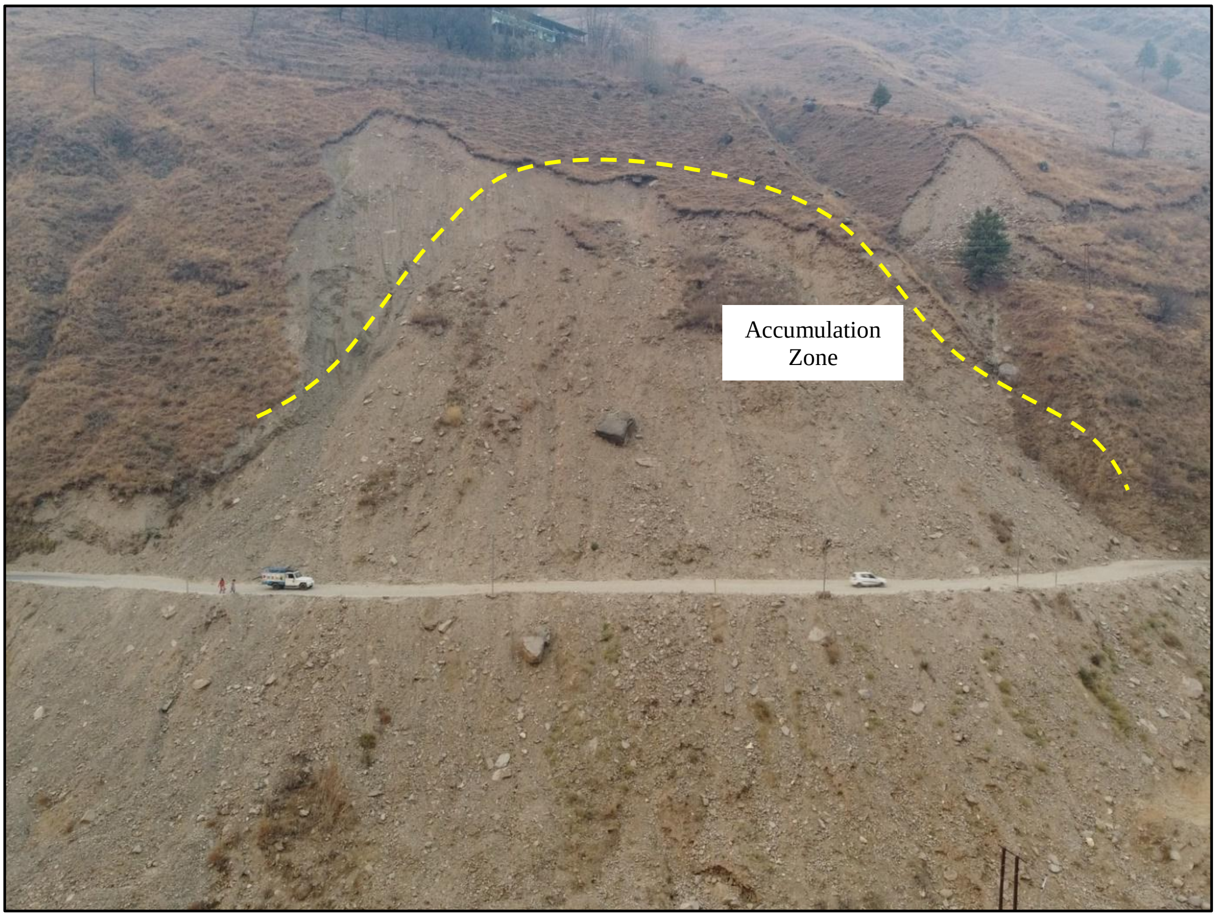

Fig. 33. Debris Runout and Loose Material at the Lambakhatal Landslide Site

Causative Factors

- The landslide was primarily triggered by heavy rainfall, exacerbating the already unstable slope conditions due to the geological and topographical features. The steepness of the slope and the nature of the debris contribute to the area's susceptibility to landslides, especially during the monsoon season.

Short-Term Measures

- Dismantling the large boulder located centrally within the landslide area to reduce its destabilizing impact.

Long-Term Measures

- Construction of a Reinforced Cement Concrete (RCC) Protection Wall to provide structural support and prevent further landslides.
- Introducing ecological solutions, such as planting Robinia trees and other environmentally suitable plant species, to stabilize the slope and enhance soil cohesion.

6.6 PLOUTIDHAR, JUBBAL LANDSLIDE

Between July 8-15, 2023, Ploutidhar, a village in the Shimla district of Himachal Pradesh with a 300-year history, experienced a significant rainfall-induced landslide. The landslide site is located within Survey of India toposheet 53E/12, mapped at a scale of 1:50,000. This subsidence, first noted in 1978 following a cloud burst, has been a recurring issue in the region. Ploutidhar is located along National Highway 705, connecting Theog and Hatkoti villages. The village's landscape features laminar subsurface flow with 4-5 natural springs. The lack of a proper drainage system has resulted in damp to flowing surface and subsurface water conditions. Deforestation and land use changes, such as the conversion of forest land into apple orchards, have significantly altered the natural slope dynamics, increasing vulnerability to land failure.

The consequences of landmass subsidence include the permanent loss of 18 structures and partial damage to 10 others, affecting a total of 25-30 families. Visible evidence of this impact includes noticeable cracks and partially damaged houses throughout the village

(Fig.37). Approximately 50 Bigha land, hosting apple orchards with 1500 trees (including Apple, Apricot, and Devdar varieties), is at risk of subsiding **(Fig.39).** Compensation has already been disbursed, with Rs 1.3 Lakhs provided to each of the 18 families for complete damage and Rs 1 Lakh to partially affected families. Beyond the economic ramifications, the village grapples with psychological challenges arising from the potential collapse and gradual subsidence of residences.

Fig. 34 shows the contour map of the Plouthidhar landslide, with 1-meter interval contours, indicating a moderate to steep susceptibility to slope failure, which is adequate to the village's land subsidence issue. **Fig. 35** and **Fig. 36** depict the panoramic view and a field photograph of the site, respectively. The field investigation highlights the buildings and horticultural land affected by the landslide subsidence. The issue is expected to worsen during future monsoons if left unaddressed. It was observed during the filed visit and discussion with locals that poor drainage, characterized by damp to wet conditions **(Fig. 38)**, coupled with heavy rainfall, is contributing to the land subsidence and slope instability in the village.

Geologically, Ploutidhar lies within the Lesser Himalaya, dominated by rocks of the Jutogh Group, characterized by metamorphic rocks. Schists, particularly mylonitised with a pinching and swelling structure, are exposed on the landslide's right flank. These schists are fractured, showing four sets of discontinuity planes (J_0, J_1, J_2, and J_3). The landslide-affected area features highly disintegrated rocks, with wet to flowing groundwater conditions. The area's hydrogeology is further complicated by the presence of a water channel within the landslide zone and the Giri Ganga river flowing opposite the slope.

Based on laboratory observations, the grain size analysis of soli indicates that this site is composed of approximately 90% sand and silt, with no clay present. The soil is non-plastic, with a moisture content of about 17% **(Table 1),** making it vulnerable to landslide. Shear parameters show moderate cohesion and a high permeability coefficient.

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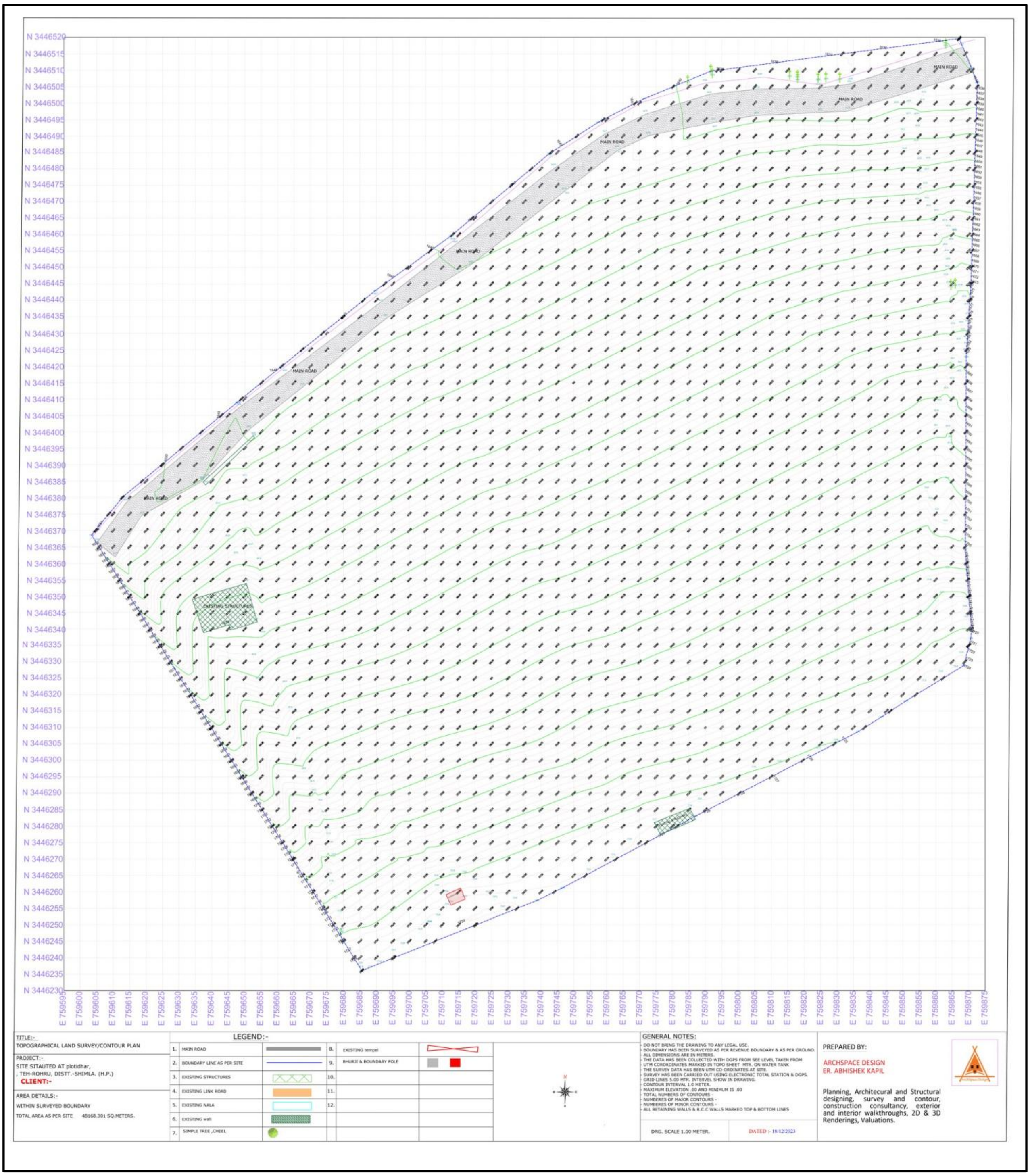


MAIN ROAD
TITLE:-
TOPOGRAPHICAL LAND SURVEY/CONTOUR PLAN
PROJECT:-
SITE SITAUTED AT plotidhar,
, TEH-ROHRU, DISTT.-SHIMLA. (H.P.)
CLIENT:-
AREA DETAILS:-
WITHIN SURVEYED BOUNDARY
TOTAL AREA AS PER SITE 48168.301 SQ.METERS.
LEGEND:-
1. MAIN ROAD
2. BOUNDARY LINE AS PER SITE
3. EXISTING STRUCTURES
4. EXISTING LINK ROAD
5. EXISTING NALA
6. EXISTING wall
7. SIMPLE TREE ,CHEEL
8. EXISTING tempel
9. BHURJI & BOUNDARY POLE
10.
11.
12.
GENERAL NOTES:
- DO NOT BRING THE DRAWING TO ANY LEGAL USE.
- BOUNDARY HAS BEEN SURVEYED AS PER REVENUE BOUNDARY & AS PER GROUND.
- ALL DIMENSIONS ARE IN METERS.
- THE DATA HAS BEEN COLLECTED WITH DGPS FROM SEE LEVEL TAKEN FROM
- UTM CORORDINATES MARKED IN TOPO SHEET MTR. ON WATER TANK
- THE SURVEY DATA HAS BEEN UTM CO-ORDINATES AT SITE.
- SURVEY HAS BEEN CARRIED OUT USING ELECTRONIC TOTAL STATION & DGPS.
- GRID LINES 5.00 MTR. INTERVEL SHOW IN DRAWING.
- CONTOUR INTERVAL 1.0 METER.
- MAXIMUM ELEVATION .00 AND MINIMUM IS .00
- TOTAL NUMBERS OF CONTOURS -
- NUMBERES OF MAJOR CONTOURS -
- NUMBERES OF MINOR CONTOURS -
- ALL RETAINING WALLS & R.C.C WALLS MARKED TOP & BOTTOM LINES
DRG. SCALE 1.00 METER.
DATED :- 18/12/2023
PREPARED BY:
ARCHSPACE DESIGN
ER. ABHISHEK KAPIL
Planning, Architecural and Structural designing, survey and contour, construction consultancy, exterior and interior walkthroughs, 2D & 3D Renderings, Valuations.

Fig. 34

Fig. 35. A panoramic view of Ploutidhar, Jubbal landslide site, Shimla district

Fig. 36. Houses and Horticultural Land in Peril

Fig. 37. Houses Affected by Land Subsidence in Plothidhar

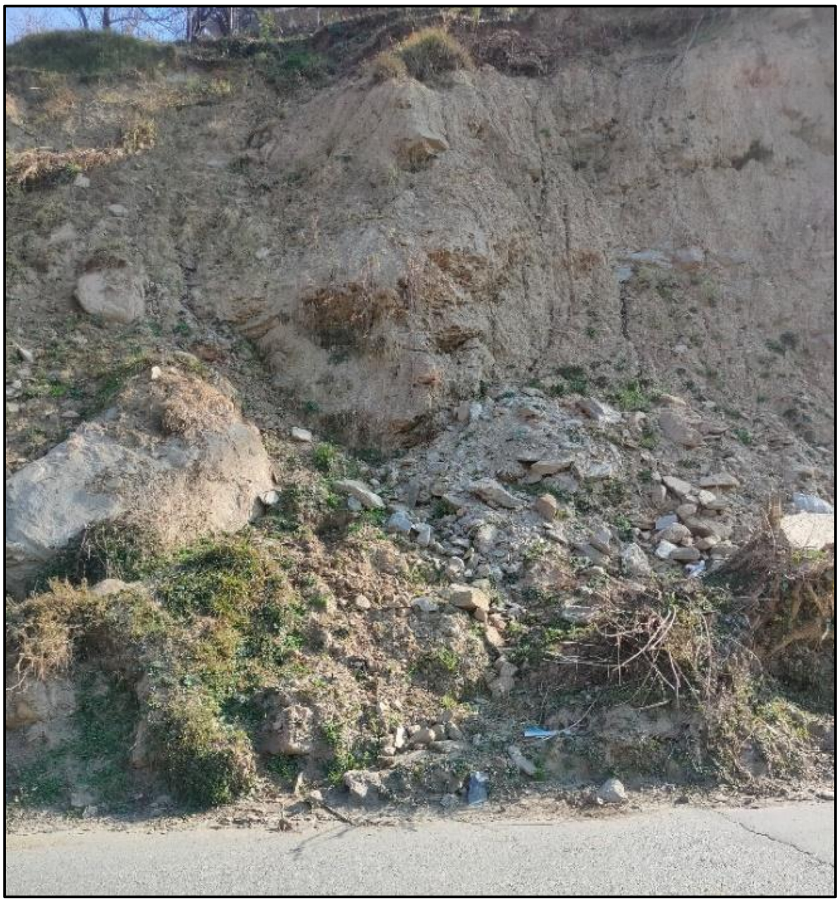


Fig. 38. Debris Material Exhibiting Damp to Wet Conditions

Fig. 39. Cracks in Apple Orchards Caused by Land Subsidence

Causative Factors

- Heavy rainfall and the lack of a proper drainage system have led to damp to flowing surface and subsurface water, contributing to the land subsidence.
- Deforestation, especially converting forest land to apple orchards, has altered the natural slope, increasing susceptibility to land failure.
- The fractured rocks with four sets of discontinuous planes (J0, J1, J2, and J3), along with disintegrated rocks on the slid land, worsen the situation.
- Groundwater conditions on the slope range from wet to flowing, compounding the issue.

Short-Term Measures

- Installation of a temporary drainage system to manage surface and subsurface water flow.

Long-Term Solutions

- Design and implementation of an effective, comprehensive drainage system.
- Construction of a robust underground water system to manage the groundwater flow.
- Constructing retaining walls with weep holes to provide structural support and manage water seepage, designed to suit the area's unique landslide problem.

Note: Given the sinking scale and its impact on the apple rich inhabited area, it is essential to prepare a detailed project report (DPR) to address the issue of land subsidence of Plothidhar village.

6. 7 LABROT, JUBBAL LANDSLIDE

The Labrot area in Jubbal, Shimla District, Himachal Pradesh, witnessed a significant landslide between 12-14 July, 2023. The landslide site is located within Survey of India toposheet 53E/12, mapped at a scale of 1:50,000. This village, with a history dating back around 250 years, has faced recurrent subsidence issues, with initial instances in 1978 and more recent events in 2008 and 2010, all triggered by heavy rainfall. Positioned along National Highway 705, the village connects Theog and Hatkoti villages. The consequences of land subsidence are tangible, affecting five families and causing the destruction of five structures. The visible evidence of this impact includes noticeable cracks and partial damage to houses in the village. A potential risk looms over 25 Bigha land, which houses apple orchards and approximately 300 fruit-bearing trees, at risk of subsiding. Based on on-site observations, a significant economic setback is anticipated, with an estimated annual revenue loss ranging between 30-35 Lakhs. Beyond the economic implications, the village is grappling with psychological concerns stemming from the potential collapse and gradual subsidence of residences.

Fig. 40 shows the contour map of Labrot, a village experiencing land subsidence, with 1-meter interval contours indicating a moderate to steep susceptibility to slope failure, which is critical to the village's land subsidence issue. **Fig. 41** and **Fig. 42** depict the panoramic view and a field photograph of the site, respectively. A small land subsidence/landslip incident has also occurred on the Labrot village link road connecting to the NH-705. A protection wall has now been erected to support upslope structures and mitigate the impact of landslides **(Fig. 44).** The field investigation highlights the buildings **(Fig. 43)** and horticultural land affected by the landslide subsidence. If left unaddressed, the issue is expected to worsen during future monsoons. Poor drainage, characterized by damp to wet conditions, coupled with heavy rainfall, is contributing to the land subsidence and slope instability in Labrot village, as observed during the field visit and discussions with locals.

Geologically, the Labrot area is a part of the Lesser Himalayas, specifically within the Jutogh Group known for its metamorphic rock formations. The site's geological composition is dominated by sandy clay without significant rock outcrops. Near the landslide's crown, there is a scarp indicating recent subsidence of about 52cm. The site exhibits tension cracks approximately 7m in length, 8-9cm wide, and 10-15cm deep, signaling ongoing instability. The slope is further characterized by being part of a landslide-affected area resting over an underground water channel, influencing the overall stability of the slope. The toe of the slope is wet to dripping, indicating poor drainage conditions.

The grain size analysis of the soils indicates that this site consists of about 87% sand and silt, with gravel contributing about 10% to the total. The high percentage of sand and gravel limits the soil's ability to hold moisture, resulting in low moisture retention capacity. The soil at the site is classified as non-plastic, with low dry density values and approximately 14% moisture content **(Table 1).** In terms of shear parameters, the soil exhibits low cohesion values and a high coefficient of permeability, indicating susceptibility to landslide.

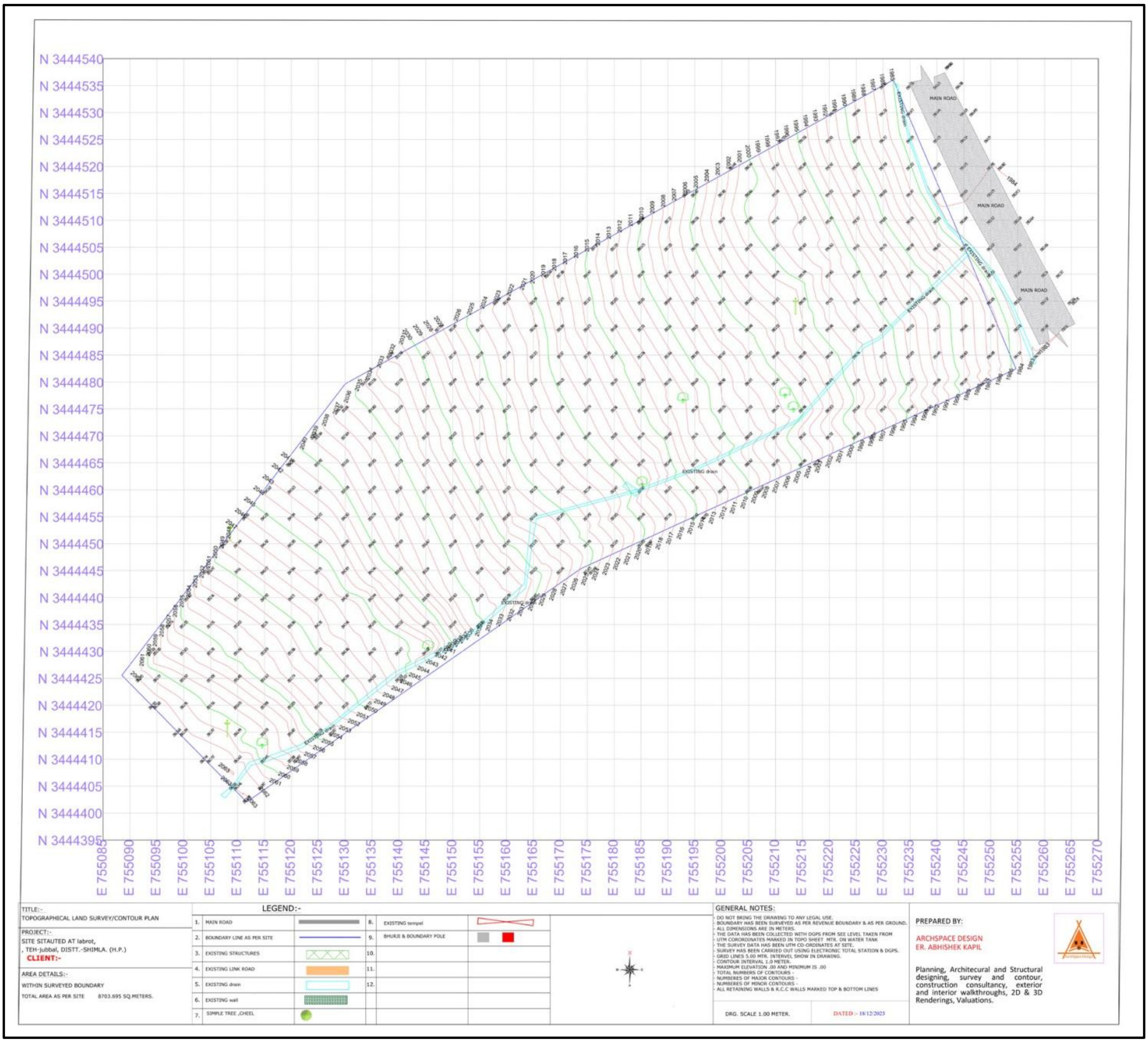

TITLE:-
TOPOGRAPHICAL LAND SURVEY/CONTOUR PLAN
PROJECT:-
SITE SITAUTED AT labrot,
, TEH-jubbal, DISTT.-SHIMLA. (H.P.)
CLIENT:-
AREA DETAILS:-
WITHIN SURVEYED BOUNDARY
TOTAL AREA AS PER SITE 8703.695 SQ.METERS.
LEGEND:-
1. MAIN ROAD
2. BOUNDARY LINE AS PER SITE
3. EXISTING STRUCTURES
4. EXISTING LINK ROAD
5. EXISTING drain
6. EXISTING wall
7. SIMPLE TREE ,CHEEL
8. EXISTING tempel
9. BHURJI & BOUNDARY POLE
GENERAL NOTES:
- DO NOT BRING THE DRAWING TO ANY LEGAL USE.
- BOUNDARY HAS BEEN SURVEYED AS PER REVENUE BOUNDARY & AS PER GROUND.
- ALL DIMENSIONS ARE IN METERS.
- THE DATA HAS BEEN COLLECTED WITH DGPS FROM SEE LEVEL TAKEN FROM UTM CORORDINATES MARKED IN TOPO SHEET MTR. ON WATER TANK
- THE SURVEY DATA HAS BEEN UTM CO-ORDINATES AT SITE.
- SURVEY HAS BEEN CARRIED OUT USING ELECTRONIC TOTAL STATION & DGPS.
- GRID LINES 5.00 MTR. INTERVEL SHOW IN DRAWING.
- CONTOUR INTERVAL 1.0 METER.
- MAXIMUM ELEVATION .00 AND MINIMUM IS .00
- TOTAL NUMBERS OF CONTOURS -
- NUMBERES OF MAJOR CONTOURS -
- NUMBERES OF MINOR CONTOURS -
- ALL RETAINING WALLS & R.C.C WALLS MARKED TOP & BOTTOM LINES
DRG. SCALE 1.00 METER.
DATED :- 18/12/2023
PREPARED BY:
ARCHSPACE DESIGN
ER. ABHISHEK KAPIL
Planning, Architecural and Structural designing, survey and contour, construction consultancy, exterior and interior walkthroughs, 2D & 3D Renderings, Valuations.

Fig. 40

Fig. 41. A panoramic view of Labrot, Jubbal landslide site, Shimla district

Fig. 42. Field photograph of land sinking area, Labrot, Jubbal

Fig. 43. Structural damage from land subsidence

Fig. 44. Protection wall erected to support upslope structures and mitigate landslide impact

Causative Factors

Key factors contributing to the subsidence at Labrot include natural springs, an inadequate sewerage system, and an undefined underground water drainage network. The presence of apple orchards cultivated in step farming fashion on the unstable slopes enhances the risk. The tension cracks and prolonged rainfall increase pore water pressure, leading to slope failures. The open cracks on the slope also suggest a high risk of further land subsidence in future rainy seasons.

Short-Term Measures

- A protection wall has already erected to support upslope structures and mitigate landslide impact
- Immediate sealing of the open tension cracks to prevent water infiltration and reduce landslide risk and further subsidence.
- Implementation of an emergency drainage management plan to address current water flow issues, especially before the rainy season.

Long-Term Solutions

- Developing a robust sewerage system to manage water flow effectively and reduce land subsidence risks.
- Establishing an efficient underground water drainage system to ensure slope stability and prevent further ongoing sinking.

Note: ***Given the sinking scale and its impact on the apple rich inhabited area, it is essential to prepare a detailed project report (DPR) to address the issue of land subsidence of Labrot village.***

6.8 TITRIKYAR, KOTKHAI LANDSLIDE

On July 14, 2023, a landslide caused by heavy rain occurred on Baghi Road, connecting Shimla. The Survey of India toposheet 53E/8, scaled at 1:50,000, includes the landslide site. This landslide, triggered by rock and wedge failure, was a result of vertical cutting done back in 1970. Mr. Sushil, whose 2 Bigha apple orchard land was destroyed, was directly affected. The landslide led to the closure of the road for a week, affecting connectivity for about 20 nearby villages. The flow of the Giri Ganga river was blocked for three days until the Himachal Pradesh Public Works Department (HPPWD) stepped in to restore it. There's a concern about the possibility of a recurrence, which could affect Sushil Chauhan's horticultural land. The initial observation points to the unscientific vertical cutting done during the road construction.

Fig. 45 shows the contour map of the Titrikyar landslide, featuring 1-meter interval contours indicating a steep slope susceptible to failure, critical to further land subsidence. **Fig. 46 and Fig. 47** depict the panoramic view and a field photograph of the site, respectively, with the latter showing the depletion and accumulation zone of the landslide along with the restored road. The movement of vehicles on the road is also visible. The field investigation highlights the dominance of loose and unconsolidated material as a trigger for the Titrikyar landslide **(Fig. 48).**

Geologically, the area is part of the Lesser Himalaya. The rocks in the region are mainly of metamorphic origin, belonging to the Jutogh Group. The folded Jutogh Group is thrust over the Jaunsar Group and mainly comprises schists, phyllites, slates, and quartzites. The predominant rock type at the site is quartzite, which is highly fractured. Three sets of joints (J_0, J_1 and J_2) are visible, with J_2 and J_3 forming wedges trending N $193^0/81^0$, while the slope is inclined N $190^0/85^0$. These conditions meet the criteria of Markland's test for wedge failure. The type of landslide is rockfall, and the mode of failure is wedge failure. Groundwater conditions on the slope are dry.

Based on laboratory observations, the grain size analysis reveals that this site consists of approximately 50% sand and silt, with gravel accounting for the remaining 50%. The high proportion of sand and gravel limits the soil's ability to retain moisture, resulting in a low moisture holding capacity. The site is classified as non-plastic, with low dry density values and an approximate moisture content of 11% **(Table 1).** In terms of shear parameters, the site exhibits low cohesion values and a high coefficient of permeability, indicating susceptibility to landslide.

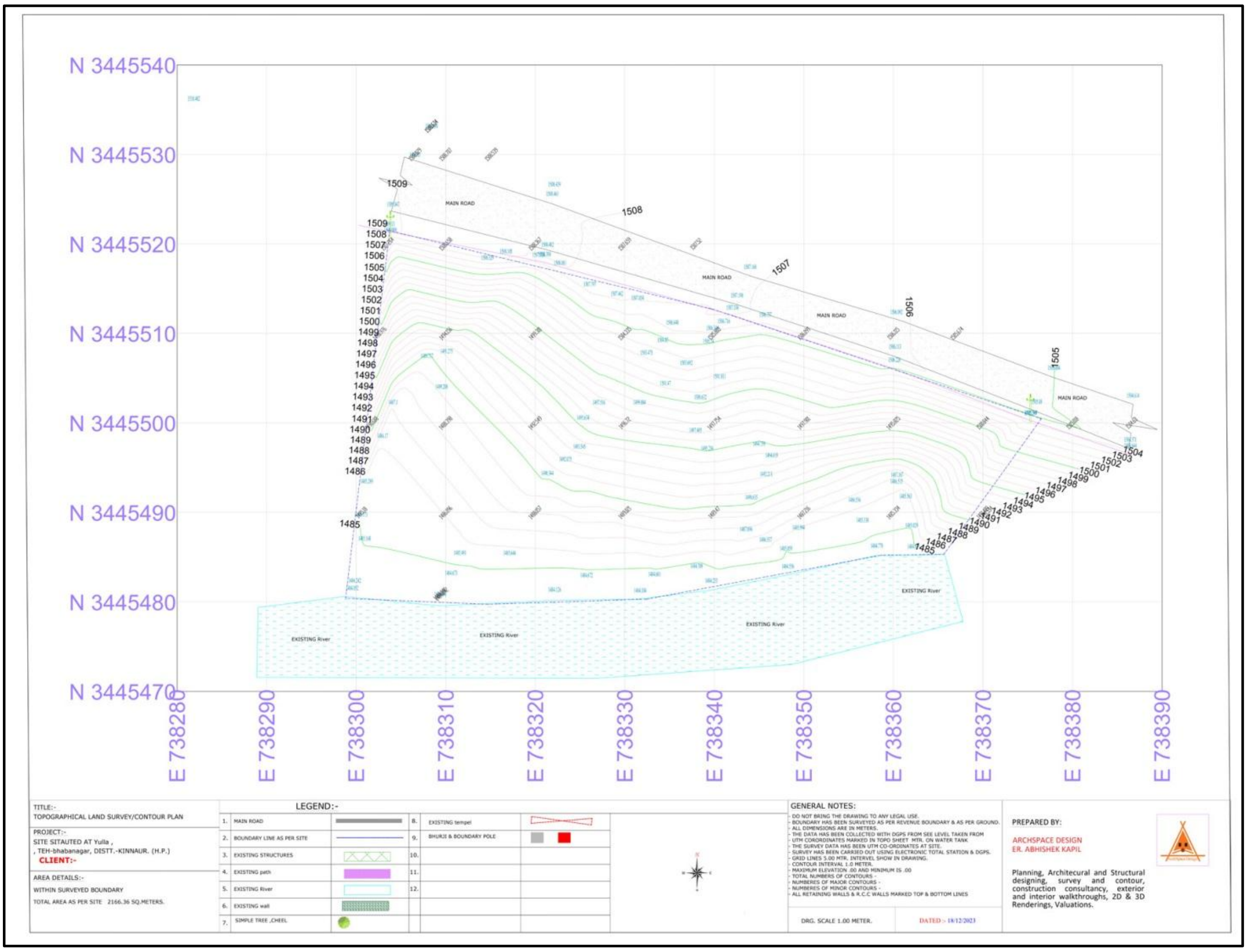


Fig. 45

Fig. 46. A panoramic view of Titrikyar, Kotkhai landslide site, Shimla district

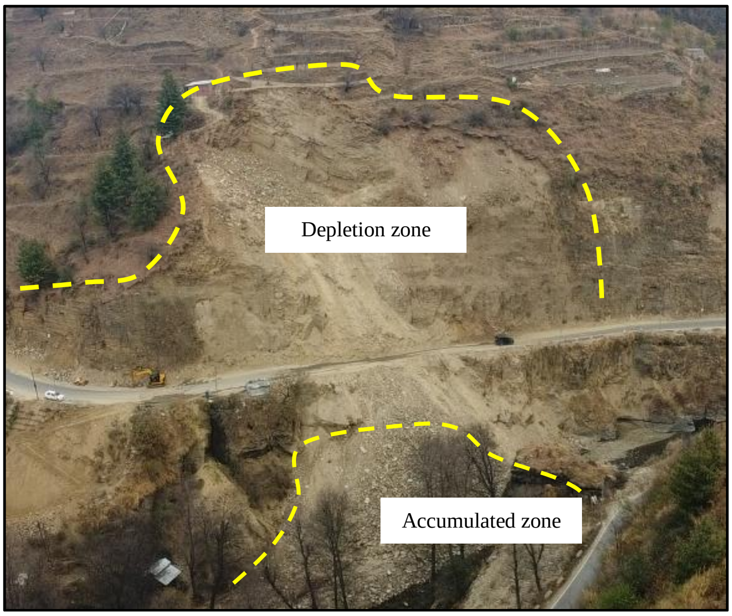


Fig. 47. Titrikyar landslide showing depletion and accumulation zone of the site

Fig. 48. Titrikyar landslide depicting the loose debris slide

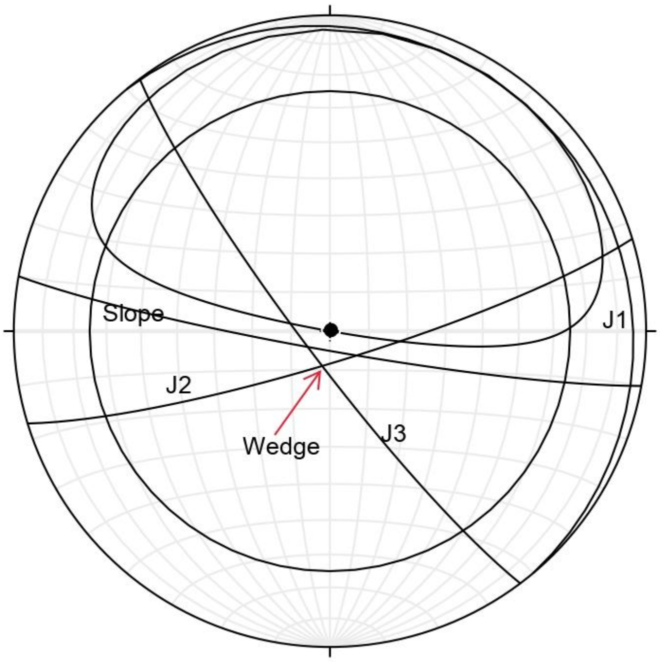


Fig. 49. Stereoplot showing the planar failure along the foliation plane (J_0) at the Titrikyar landslide location

Causative Factors

- Excessive rainfall is one of the most significant contributing factors of the landlside.
- The main geological cause of this failure is the presence of discontinuities and steep slope **(Fig.49).**
- Cut slope and steep slope along the roadside are known to be problematic and has contributed to the present landslide.

Short-Term Remedial Measures

- The road has been restored to ensure the connectivity of affected villages.
- To address the aftermath and prevent future incidents, small restoration work has also been initiated.

Long-Term Solutions

- Remedial measures such as using wire mesh, shotcrete and slope modification can be implemented at this site.
- Adoption of bioengineering strategies like planting locally suitable trees for natural slope stabilization.

6.9 RAHIGHAT KYARTU LINK ROAD, THEOG LANDSLIDE

The Rahighat-Kiyartu Road landslide site is located approximately 500 meters from Theog bus stand. The Survey of India toposheet 53E/8, scaled at 1:50,000, includes the landslide site. This area has experienced repeated landslide events, initially occurring in 2015 and then again in 2018. The most recent landslide event took place on 14 August, 2023, triggered by heavy rainfall during the monsoon season. This landslide resulted in the disruption of road connectivity to approximately 10 villages. The affected area includes the crown of the landslide, which is part of the old NH-5. The lack of a proper sewerage and drainage system in the area has led to surface water flowing onto the highway and into the nearby nalla (stream). This influx of water, combined with heavy rainfall, has been identified as the main cause of the landslide.

The landslide has caused significant damage, including the permanent destruction of an MC toilet and partial damage to two MC shops. Government Primary School in Rahighati has been forced to close. One house has been evacuated due to safety concerns. Local residents have reported that the Sundari colony area, which houses approximately 10 houses, has subsided by about 3 feet. Furthermore, cracks and fractures have been observed in nearby houses as a result of the landslide.

Fig. 50 shows the contour pattern of the Rahighat-Kiyartu Road landslide site, with 1-meter interval contours indicating a steep to very steep slope prone to failure, which is crucial for understanding the landslide. **Fig. 51** and **Fig. 52** show a panoramic view and a field photograph of the site, respectively. The field investigation reveals the impact on vegetal cover, remnants of a damaged retaining wall **(Fig. 53)** due to the landslide, and damp underground conditions caused by the area's inadequate drainage system, which contributed to the said landslide. The site is affected by debris failure due to excessive rainfall.

Geologically, the area is from the part of the Lesser Himalayas. Rocks in the region are mainly of metamorphic origin which belongs to the Jutogh Group. Phyllites outcrop at the site near the left flank of the landslide and are highly fractured and thinly foliated with very low compressive strength. Three sets of joints (J_0, J_1 and J_2) are visible.

This site consists of approximately one-fifth of the total soil content in the form of silt, while sand comprises more than one-third, with clay accounting for only 2%. The high proportion of sand and gravel results in a very low water holding capacity of about 8% **(Table 1).** The site is classified as non-plastic, with low dry density values. In terms of shear parameters, the site exhibits low cohesion values and a high coefficient of permeability, indicating susceptibility to slope destabilization.

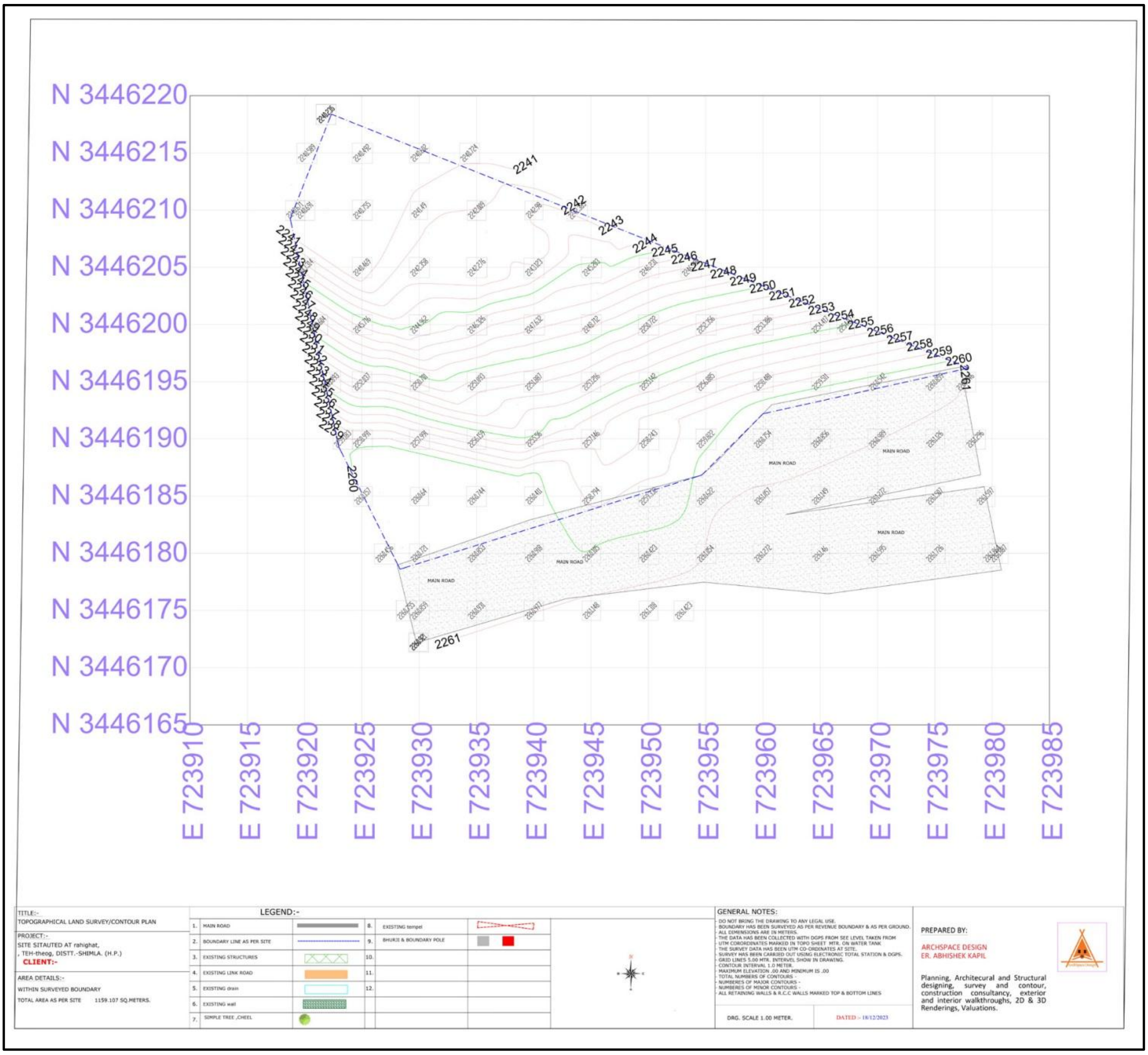


Fig. 50

Fig. 51 A panoramic view of Rahighat Kyartu Link Road, Theog landslide site, Shimla district

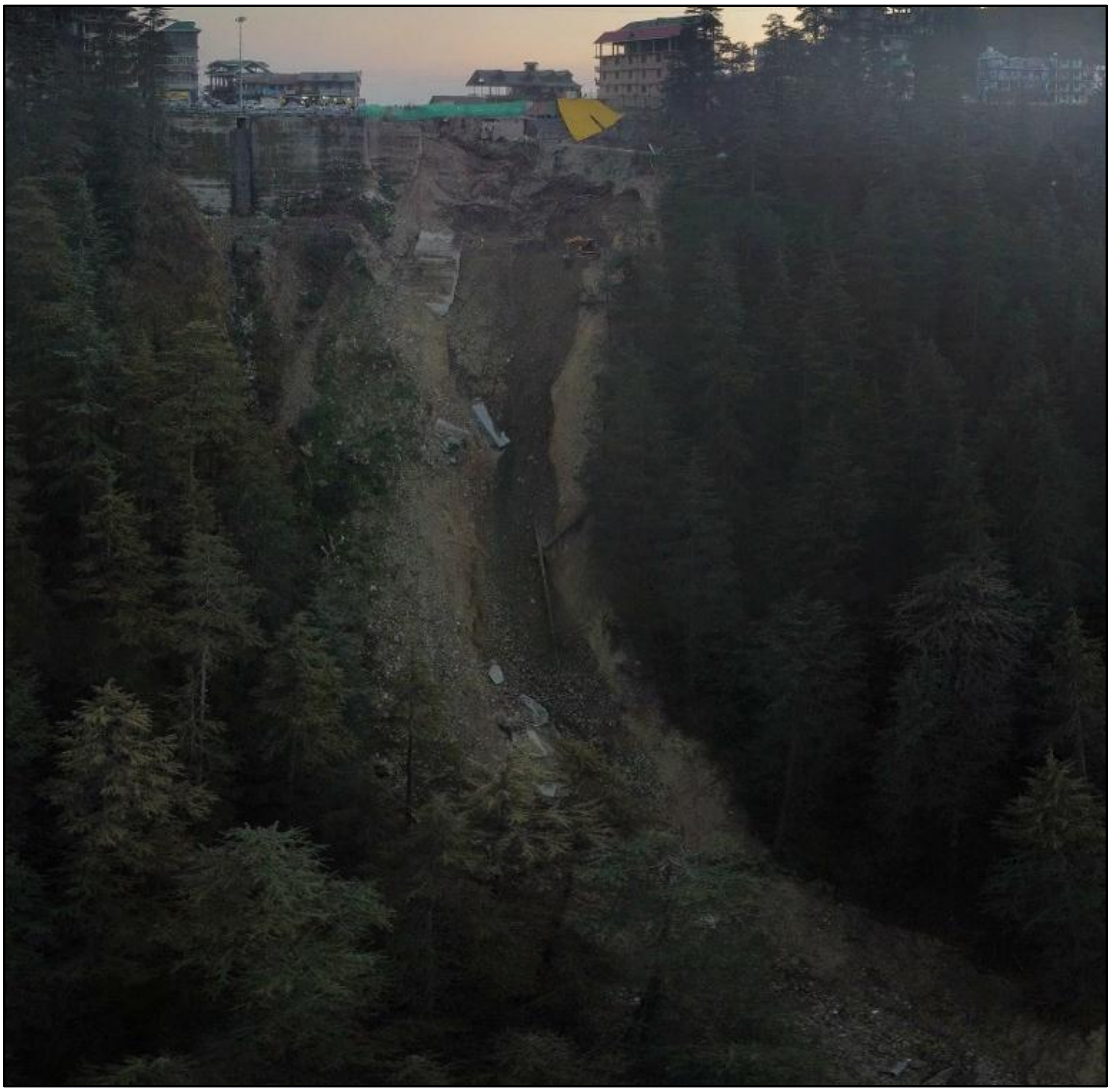


Fig. 52. Field photograph of Rahighat Kyartu Link Road, Theog landslide site, Shimla

Fig. 53. Vegetal cover loss and damp underground conditions

Causative Factors

The damp groundwater condition at the site, coupled with factors such as poor wastewater drainage, unsealed septic tanks, weak geology and steep slopes, contributed to the slope's weakening and Rahighat Kyartu Link Road, landslide.

Short-Term Remedial Measures

- The Public Works Department has initiated restoration work at the site.
- A RCC retaining wall, costing Rs. 2.32 crore, is being constructed as per the initial survey.
- Efforts are being made to restore the damaged properties.

Long- Term Solutions

- Successful and timely construction of the ongoing RCC retaining wall with weep holes.
- Given the various factors involved, there is an urgent need for a comprehensive drainage plan, including wastewater management, for the site.
- Implementing suitable bio-engineering measures in consultation with the forest and public works departments is another sustainable solution.

6.10 MARNI-KANHAR, KUMARSAIN LANDSLIDE

Marni-Kanahar is an active landslide first observed during July-August 2022 and reactivated on 12-13 July 2023 due to heavy rainfall. The landslide is situated along the right bank of Marni Nallah. The Survey of India toposheet 53E/7, scaled at 1:50,000, includes the landslide site. The total population of the Marni hamlet is approximately 40 persons spread over 15 families, all located above the crown of the landslide. The slide blocked the road connecting Oddi village with Bithal village for about two weeks, but it has since been successfully restored by the State Public Works Department.

The landslide has resulted in the loss of horticultural land of 4 families, including about 100 apple trees. The main residential area is situated about 20-30 meters above the crown of the landslide and is at potential risk of collapse and further sliding if the site remains unaddressed before the onset of the next monsoon. The landslide occurred in a dense vegetal area dominated by oak, pine, and other local species. There is a possibility of toe erosion by Marni Nallah acting as one of the triggers.

Fig. 54 portrays the contour map of Marni-Kanahar landslide, a site characterized by ongoing land subsidence, with 1-meter interval contours indicating a moderate to steep slope susceptible to failure, crucial to understand slope destabilization process. **Fig. 55** and **Fig. 56** present a panoramic view and a field photograph of the site, respectively, with the latter highlighting the depletion zone and threatened apple orchards above the crown of the landslide. **Fig. 57** showcases the debris runout and the protective measure of an RCC protection wall, erected to support upslope structures and mitigate landslide impact. The field investigation identifies cracks measuring about 10 inches to 1 foot **(Fig. 58)** caused by landslide subsidence. Without intervention, the situation is expected to worsen during future monsoons. **Fig. 59** illustrates the debris runout material of various sizes.

Geologically, the terrain at this site is composed of rocks from the Rampur Group, consisting of meta sedimentaries and quartzites. These rocks have undergone severe deformation in the thrust zone and are mylonitised at some locations. The site experienced a debris translational retrogressive landslide during the last monsoon, triggered by prolonged and heavy precipitation. It is a reactivated landslide with a slope dipping at 40^0 in the $N344^0$ direction. The rocks at the site are highly fractured and exhibit three sets of discontinuities (J_0, J_1 and J_2).

The grain size analysis of the soils indicates that this site comprises approximately one-fifth of the total soil content as silt, while sand accounts for more than one-third, with clay making up only 2% **(Table 1)**. Due to the high proportion of sand and gravel, the soil's water holding capacity is very low, at about 8%. The site is classified as non-plastic, with low dry density values. In terms of shear parameters, the site exhibits low cohesion values, indicating chances of slope failure.

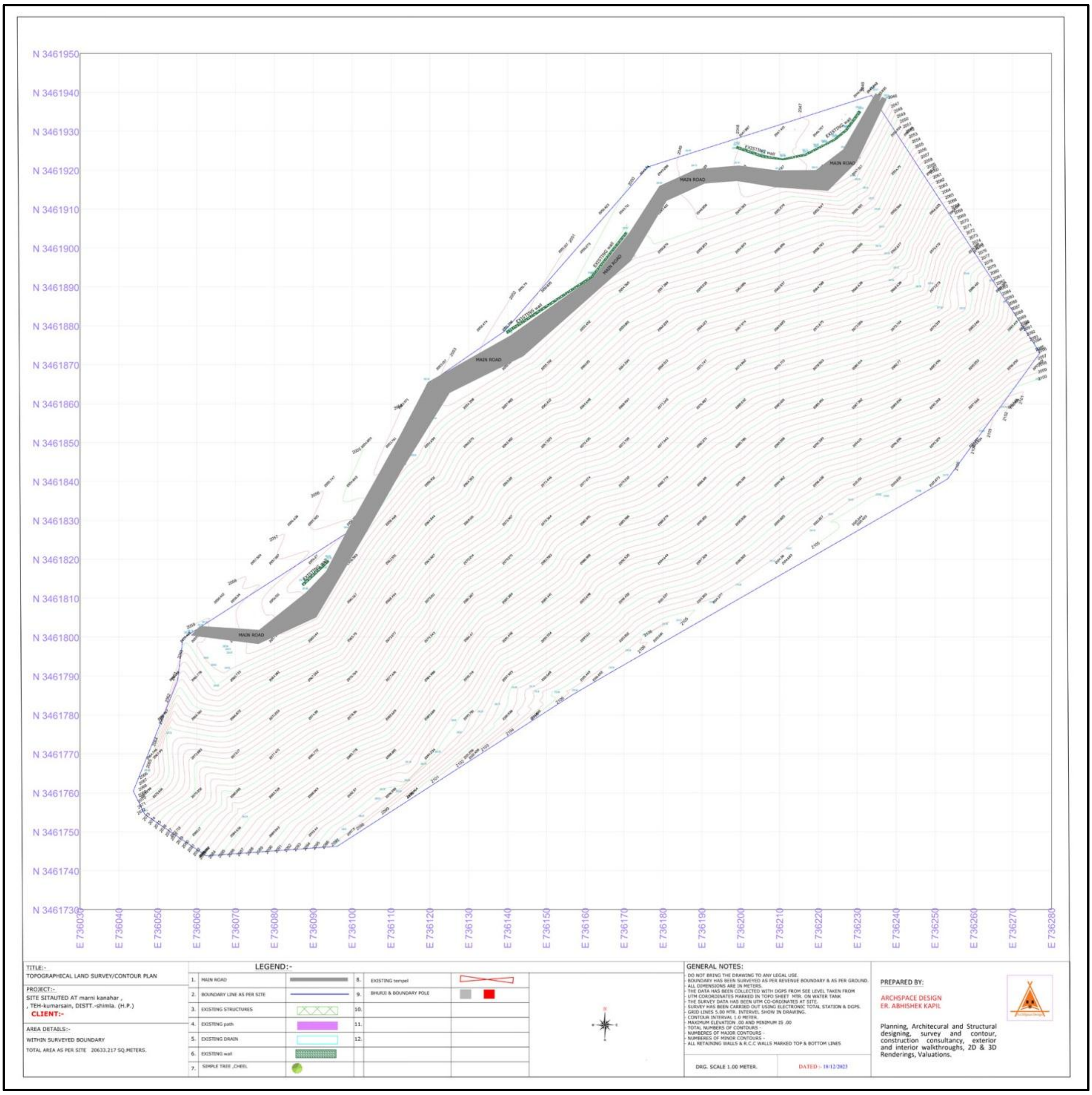

TITLE:-
TOPOGRAPHICAL LAND SURVEY/CONTOUR PLAN
PROJECT:-
SITE SITAUTED AT marni kanahar ,
, TEH-kumarsain, DISTT.-shimla. (H.P.)
CLIENT:-
AREA DETAILS:-
WITHIN SURVEYED BOUNDARY
TOTAL AREA AS PER SITE 20633.217 SQ.METERS.
LEGEND:-
1. MAIN ROAD
2. BOUNDARY LINE AS PER SITE
3. EXISTING STRUCTURES
4. EXISTING path
5. EXISTING DRAIN
6. EXISTING wall
7. SIMPLE TREE ,CHEEL
8. EXISTING tempel
9. BHURJI & BOUNDARY POLE
GENERAL NOTES:
- DO NOT BRING THE DRAWING TO ANY LEGAL USE.
- BOUNDARY HAS BEEN SURVEYED AS PER REVENUE BOUNDARY & AS PER GROUND.
- ALL DIMENSIONS ARE IN METERS.
- THE DATA HAS BEEN COLLECTED WITH DGPS FROM SEE LEVEL TAKEN FROM
- UTM CORORDINATES MARKED IN TOPO SHEET MTR. ON WATER TANK
- THE SURVEY DATA HAS BEEN UTM CO-ORDINATES AT SITE.
- SURVEY HAS BEEN CARRIED OUT USING ELECTRONIC TOTAL STATION & DGPS.
- GRID LINES 5.00 MTR. INTERVEL SHOW IN DRAWING.
- CONTOUR INTERVAL 1.0 METER.
- MAXIMUM ELEVATION .00 AND MINIMUM IS .00
- TOTAL NUMBERS OF CONTOURS -
- NUMBERES OF MAJOR CONTOURS -
- NUMBERES OF MINOR CONTOURS -
- ALL RETAINING WALLS & R.C.C WALLS MARKED TOP & BOTTOM LINES
DRG. SCALE 1.00 METER.
DATED :- 18/12/2023
PREPARED BY:
ARCHSPACE DESIGN
ER. ABHISHEK KAPIL
Planning, Architecural and Structural designing, survey and contour, construction consultancy, exterior and interior walkthroughs, 2D & 3D Renderings, Valuations.
MAIN ROAD
EXISTING wall

Fig. 54

Fig. 55. A panoramic view of Marni-Kanhar, Kumarsain landslide site, Shimla district

Fig. 56. Field photograph showing depletion zone and threatened apple orchards

Fig. 57. Debris runout and protective measure

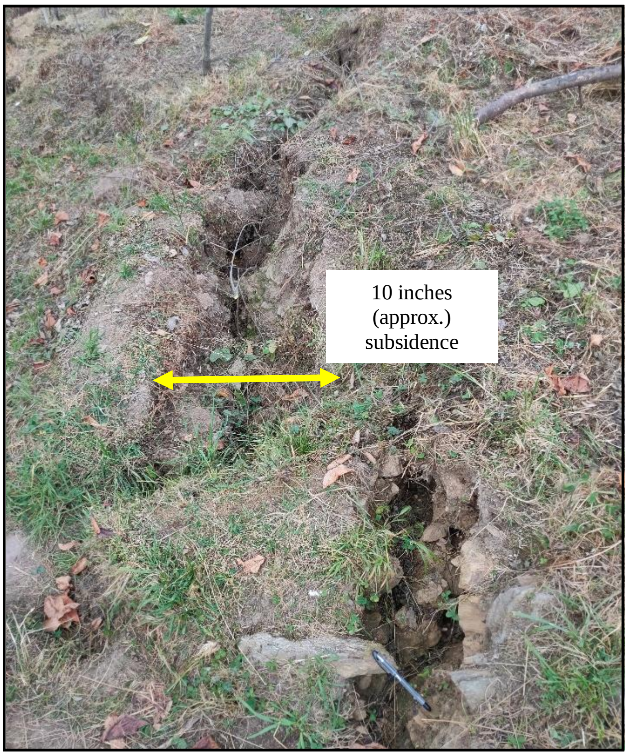


Fig. **58.** Cracks as a risk for future land subsidence

Fig. 59. Debris runout material of various sizes

Causative Factors

- The debris translational retrogressive landslide was triggered by prolonged and heavy precipitation during the monsoon.
- The moderate to steep slope of the area makes it susceptible to slope failure
- The rocks in the area, belonging to the Rampur Group, have undergone severe deformation and are highly fractured, contributing to the instability of the slope.

Short-Term Remedial Measures

- The RCC retaining wall has already been constructed below the road, and a breast wall has been erected above the road.
- Proper drainage management is crucial for preventing water accumulation and erosion, reducing horticultural landslide risk, and ensuring slope stability of Marni hamlet.

Long- Term Solutions

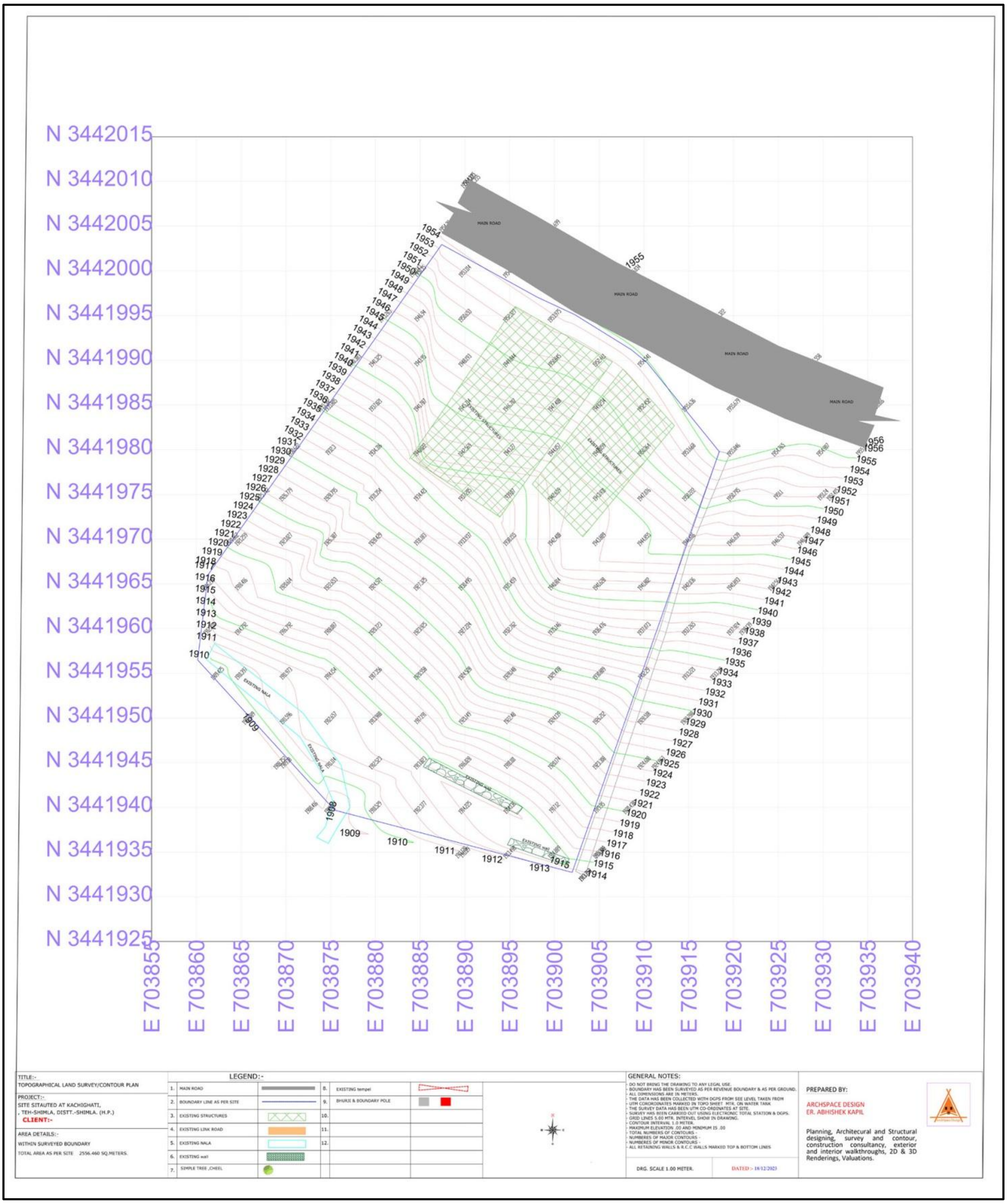
- Constructing and reinforcing retaining wall with weep holes can support slope stabilization and prevent soil from sliding.
- Creating terraces on slopes can reduce the slope angle, making it less prone to further landslide and village subsidence
- Bioengineering measures in consultation with forest and Public works departments can be implemented to stabilize the slope and prevent further sliding of the village.

6.11 KACHIGHATI, SHIMLA LANDSLIDE

The Kachighati landslide occurred on 30th September, 2021, along National Highway-5, connecting Shimla with Chandigarh. The Survey of India toposheet 53E/4, scaled at 1:50,000, includes the landslide site. The term "*Kachighati*" in the local language signifies that the area is characterized by weak lithology and geology. The landslide resulted in the collapse of a multi-storey building in the Kachighati area of Shimla. The eight-storey structure collapsed due to the landslide triggered by heavy and prolonged rainfall. Some cracks had appeared in the building, leading to its evacuation. Fortunately, there were no casualties reported as the building had been evacuated two weeks prior to the collapse after authorities issued a notice to vacate. The people residing in the building had been relocated to a safer place. According to locals, the building advanced forward with the landslide mass before toppling and being reduced to rubble **(Fig. 62).** Besides, a smaller structure below was devastated, but most surrounding buildings remained intact. However, it appears that the foundations of buildings uphill have suffered scour and may be prone to future failures.

Fig. 60 depicts the contour map of the Kachighati landslide, with 1-meter intervals indicating a steep to very steep slope susceptibility to failure, critical to the landslip of the site. **Fig. 61** and **Fig. 62** present the panoramic view and a field photograph of the site, respectively. **Fig. 62** also shows the remnants of the affected buildings.

Geologically, this area is part of the Jutogh Group, characterized by rocks such as Phyllites, Carbonaceous Phyllites, Schist and Quartzite. The predominant rock type in the area is schist. The building affected by the landslide was about 30 years old, and the slope is extremely steep, with an angle of 60^0 to 70^0 . The soil type is silty sand with rock fragments. The failure was mainly caused by the steep slope, continuous rainfall and potentially unscientific building foundation design. The steep slope and unconsolidated soil mass likely underwent saturation due to rain, leading to increased pore water pressure and the subsequent failure. During the field visit, it was observed that lots of weeds have grown on the upper slope, indicating that the slope is currently stable and not active.



N 3442015
N 3442010
N 3442005
N 3442000
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E 703890
E 703895
E 703900
E 703905
E 703910
E 703915
E 703920
E 703925
E 703930
E 703935
E 703940
MAIN ROAD
EXISTING NALA
EXISTING wall
TITLE:-
TOPOGRAPHICAL LAND SURVEY/CONTOUR PLAN
PROJECT:-
SITE SITAUTED AT KACHIGHATI,
, TEH-SHIMLA, DISTT.-SHIMLA. (H.P.)
CLIENT:-
AREA DETAILS:-
WITHIN SURVEYED BOUNDARY
TOTAL AREA AS PER SITE 2556.460 SQ.METERS.
LEGEND:-
1. MAIN ROAD
2. BOUNDARY LINE AS PER SITE
3. EXISTING STRUCTURES
4. EXISTING LINK ROAD
5. EXISTING NALA
6. EXISTING wall
7. SIMPLE TREE ,CHEEL
8. EXISTING tempel
9. BHURJI & BOUNDARY POLE
10.
11.
12.
GENERAL NOTES:
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- UTM CORORDINATES MARKED IN TOPO SHEET MTR. ON WATER TANK
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- SURVEY HAS BEEN CARRIED OUT USING ELECTRONIC TOTAL STATION & DGPS.
- GRID LINES 5.00 MTR. INTERVEL SHOW IN DRAWING.
- CONTOUR INTERVAL 1.0 METER.
- MAXIMUM ELEVATION .00 AND MINIMUM IS .00
- TOTAL NUMBERS OF CONTOURS -
- NUMBERES OF MAJOR CONTOURS -
- NUMBERES OF MINOR CONTOURS -
- ALL RETAINING WALLS & R.C.C WALLS MARKED TOP & BOTTOM LINES
DRG. SCALE 1.00 METER.
DATED :- 18/12/2023
PREPARED BY:
ARCHSPACE DESIGN
ER. ABHISHEK KAPIL
Planning, Architecural and Structural designing, survey and contour, construction consultancy, exterior and interior walkthroughs, 2D & 3D Renderings, Valuations.

Fig. 60

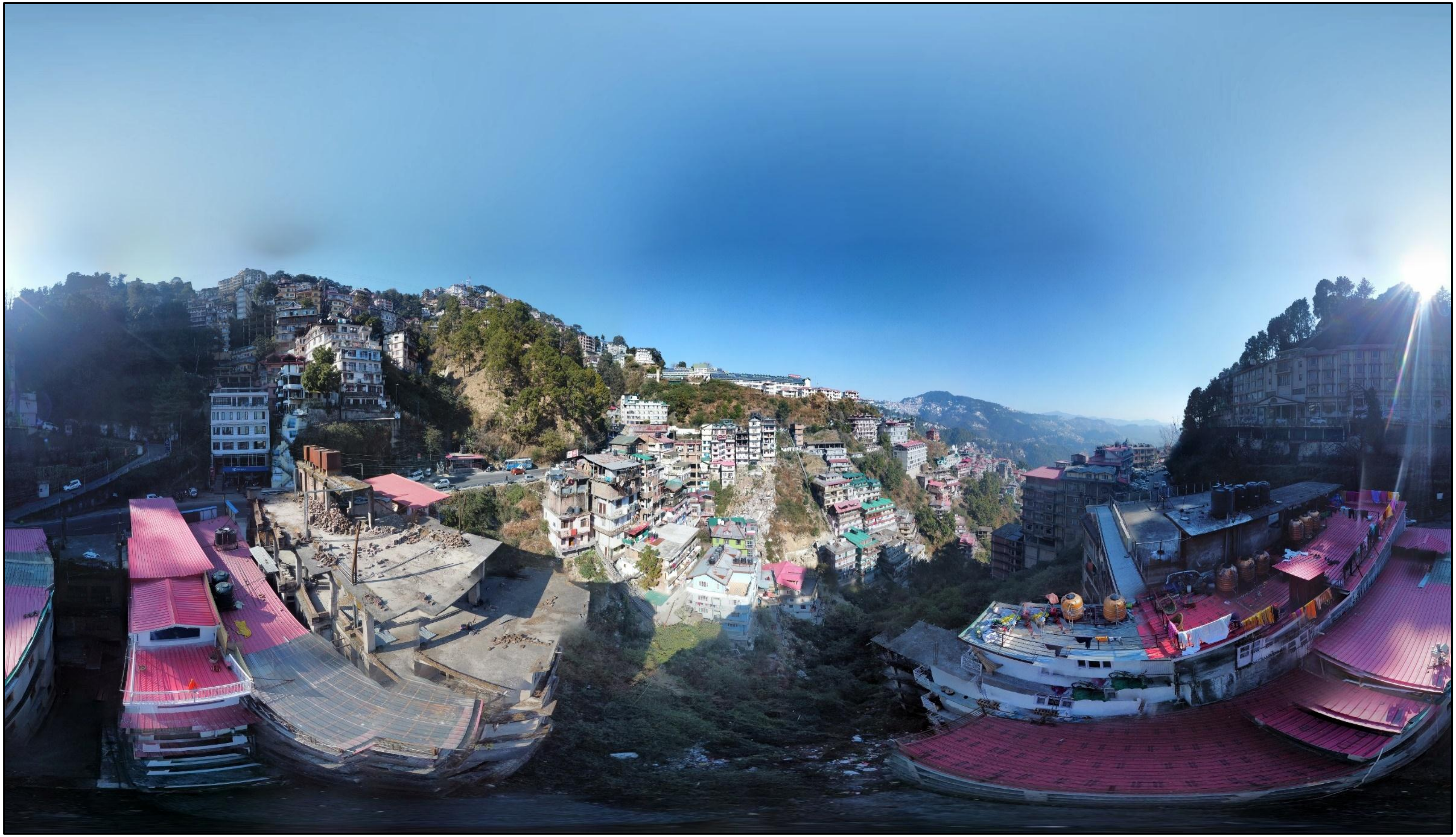


Fig. 61. A panoramic view of Kachighati, Shimla landslide site, Shimla district

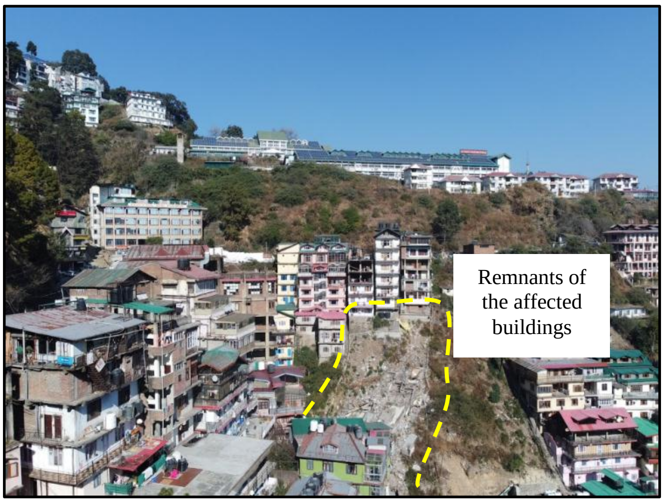


Fig. 62. Field photograph of collapsing building (Left) and remnants of the affected buildings (Right), Kachighati, Shimla

Causative Factors

- The landslide was primarily triggered by the steep slope, continuous rainfall and possibly the unscientific design of the high-rise building's foundation.
- The combination of the steep slope and the unconsolidated soil mass likely led to saturation from rainwater, increasing pore water pressure and resulting in the landslide.

Short-Term Remedial Measures

- The local authorities evacuated the building and made necessary arrangements in anticipation of its collapse.
- Affected residents were provided with financial support by officials.

Long- Term Solutions

- Given the seismic sensitivity of the zone, construction should not exceed a slope angle of 45^0.
- Given the fragile lithological setup and steep slope, buildings in the area should be limited to two-and-a-half stories.
- Municipal Council Authorities and the Town and Country Planning Department should enforce building bylaws to prevent future violations in the vicinity of the city.
- Due to the fragile lithology, thorough geotechnical investigations are necessary before any construction in the Kachighati area.

6.12 UCHI, RAMPUR LANDSLIDE

Uchi village, with a population of about 200 persons and 44 households falling under Dofda Gram Panchayat, has been grappling with a subsidence issue. The land subsidence site falls in the Survey of India toposheets 53E/15 at 1:50,000 scale. Initially observed in 2005, the problem resurfaced on July 11, 2023, following heavy rainfall in the village. The entire village is affected, with 10 houses experiencing subsidence, 4 of which are completely lost and 6 declared unsafe. About 7-8 natural springs have disappeared, while about 3-4 have become active and are now oozing.

Approximately 1000 apple trees have been damaged, exhibiting a drunken appearance. The village earns about 1.5 crore annually from apple sales. Besides, the village has apricot, pears, walnut, deodar, mulberry and silver oak trees, with the latter two having deep roots and being local species. The spreading out of tree roots is causing issues among village residents. Drainage problem is widespread in the village and growing highly water-intensive local tree species is necessary to counteract the damp and wet underground conditions. The damp to flowing water conditions on the slope are contributing to triggering land subsidence. Locals have noted that the existing drainage is partially cracked, enlarged, and squeezed at certain locations due to the sinking phenomenon of the village landmass. They have also expressed the opinion that the village appears to be situated on the water surface.

Fig. 63 shows the contour map of Uchi, a village experiencing land subsidence, with 1-meter interval contours indicating a moderate to steep slope liable to slope failure, which is critical to the village's land subsidence issue. **Fig. 64** and **Fig. 65** depict the panoramic view and a field photograph of the site, respectively. **Fig. 66** depicts the development of tension cracks on the floor of a house affected by land subsidence in the village. **Fig. 67** shows evident tension cracks on the floor and walls of residential structures, indicating sinking of the structure and land subsidence in the area. Besides, cracks are visible in a village temple, serving as a mark of ongoing sinking landmass **(Fig. 68).** Locals also noted that some tree roots are spreading out in the village. A surprising phenomenon of trunk hollowing and widening of a mighty oak tree due to root spread caused by land subsidence was observed during the field visit **(Fig. 69).** The field investigation reveals the impact of the landslide subsidence on buildings and horticultural land. Without intervention, the situation is expected to deteriorate during future monsoons. Poor drainage, leading to damp to wet conditions, combined with heavy rainfall, is contributing to the land subsidence and slope instability in Uchi village, as observed during discussions with locals and the field visit.

Geologically, the area is part of the Jutogh Group of rocks within the Lesser Himalayan Crystalline, bounded by the Munsiari thrust (MT) or Main Central Thrust-I (MCT-I) to the south at Jhakri and the Kullu thrust (KT) to the north at Karcham. The Jutogh Group mainly consists of gneisses and schists. Although the area is relatively close to the MT, its impact on the rocks and terrain cannot be ignored. The rocks are not exposed at the site. There are tension cracks on the crown, ranging from 8 to 10 meters in length, with openings of 15-30 cm and depths up to 29 cm. The slope is predominantly wet, with flowing and dripping water present. The slope ranges from less steep to steep, with angles varying from 25° to 60°. Water entering the slope through the tension cracks during precipitation increases its susceptibility to failure. The current landslide at this site is a debris slide triggered by heavy precipitation and existing groundwater conditions.

Based on laboratory observations, the grain size analysis of the Uchi soil indicates that this site contains 40% silt content, while sand accounts for approximately one-third of the total. Clay content is reported at only 3% of the total. The site has a higher moisture content of about 26%, indicating a greater susceptibility to soil detachment **(Table 1)**. It falls into the non-plastic class with small dry density values. In terms of shear parameters, the site exhibits low cohesion.

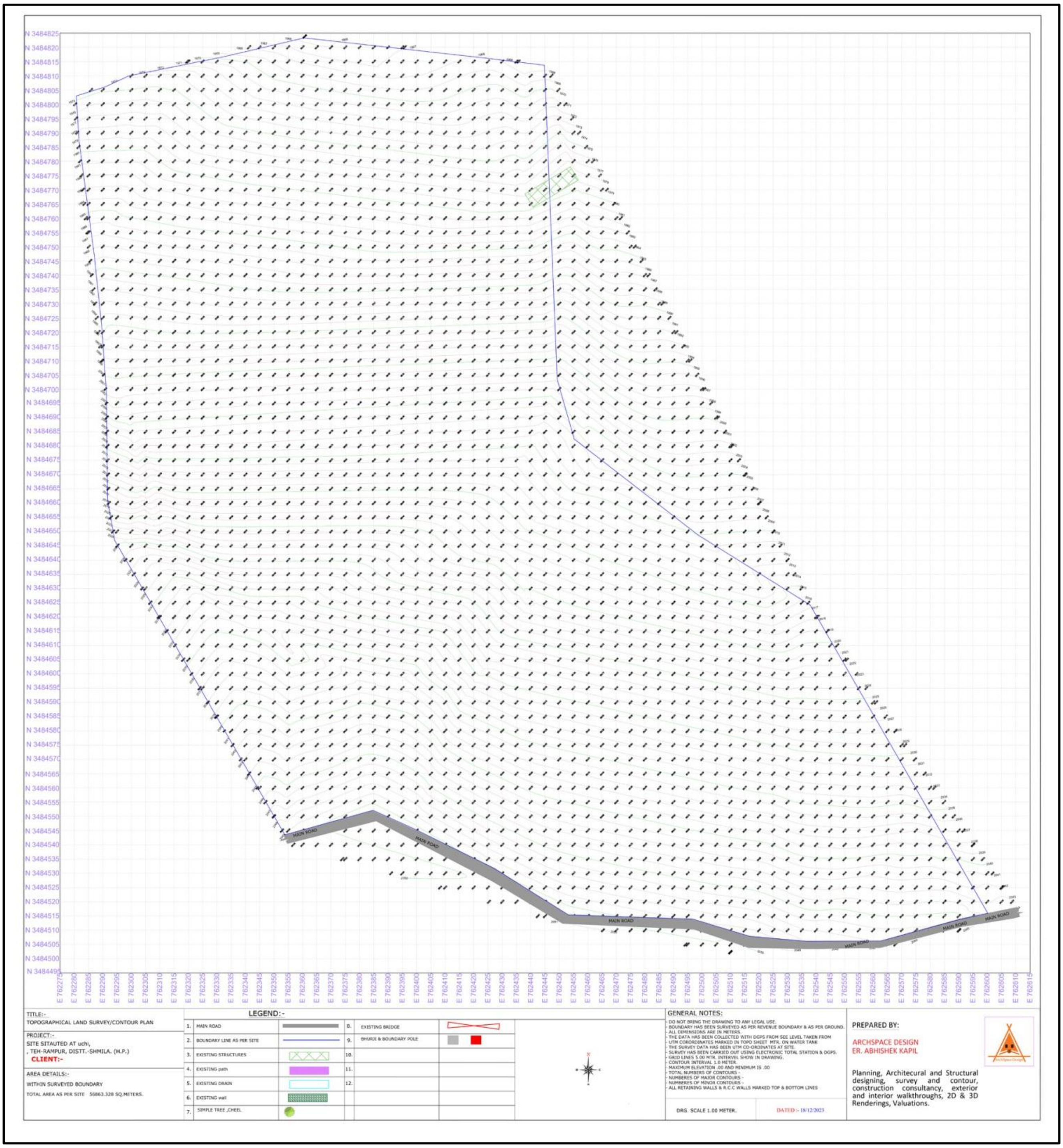

TITLE:-
TOPOGRAPHICAL LAND SURVEY/CONTOUR PLAN
PROJECT:-
SITE SITAUTED AT uchi,
, TEH-RAMPUR, DISTT.-SHMILA. (H.P.)
CLIENT:-
AREA DETAILS:-
WITHIN SURVEYED BOUNDARY
TOTAL AREA AS PER SITE 56863.328 SQ.METERS.
LEGEND:-
1. MAIN ROAD
2. BOUNDARY LINE AS PER SITE
3. EXISTING STRUCTURES
4. EXISTING path
5. EXISTING DRAIN
6. EXISTING wall
7. SIMPLE TREE ,CHEEL
8. EXISTING BRIDGE
9. BHURJI & BOUNDARY POLE
10.
11.
12.
GENERAL NOTES:
- DO NOT BRING THE DRAWING TO ANY LEGAL USE.
- BOUNDARY HAS BEEN SURVEYED AS PER REVENUE BOUNDARY & AS PER GROUND.
- ALL DIMENSIONS ARE IN METERS.
- THE DATA HAS BEEN COLLECTED WITH DGPS FROM SEE LEVEL TAKEN FROM
- UTM CORORDINATES MARKED IN TOPO SHEET MTR. ON WATER TANK
- THE SURVEY DATA HAS BEEN UTM CO-ORDINATES AT SITE.
- SURVEY HAS BEEN CARRIED OUT USING ELECTRONIC TOTAL STATION & DGPS.
- GRID LINES 5.00 MTR. INTERVEL SHOW IN DRAWING.
- CONTOUR INTERVAL 1.0 METER.
- MAXIMUM ELEVATION .00 AND MINIMUM IS .00
- TOTAL NUMBERS OF CONTOURS -
- NUMBERES OF MAJOR CONTOURS -
- NUMBERES OF MINOR CONTOURS -
- ALL RETAINING WALLS & R.C.C WALLS MARKED TOP & BOTTOM LINES
DRG. SCALE 1.00 METER.
DATED :- 18/12/2023
PREPARED BY:
ARCHSPACE DESIGN
ER. ABHISHEK KAPIL
Planning, Architecural and Structural designing, survey and contour, construction consultancy, exterior and interior walkthroughs, 2D & 3D Renderings, Valuations.
MAIN ROAD

Fig. 63

Fig. 64. A panoramic view of Uchi, Rampur landslide site, Shimla district

Fig. 65. Field photograph

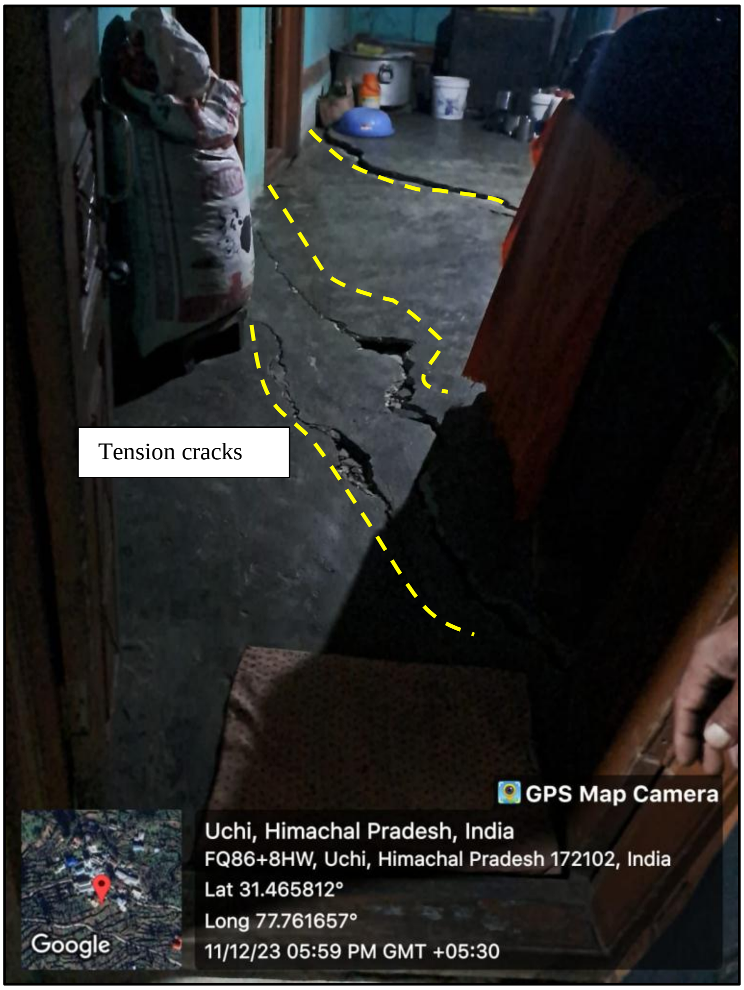


Fig. 66. Land subsidence affected house

Fig. 67. Evident tension cracks in residential structures indicating subsidence

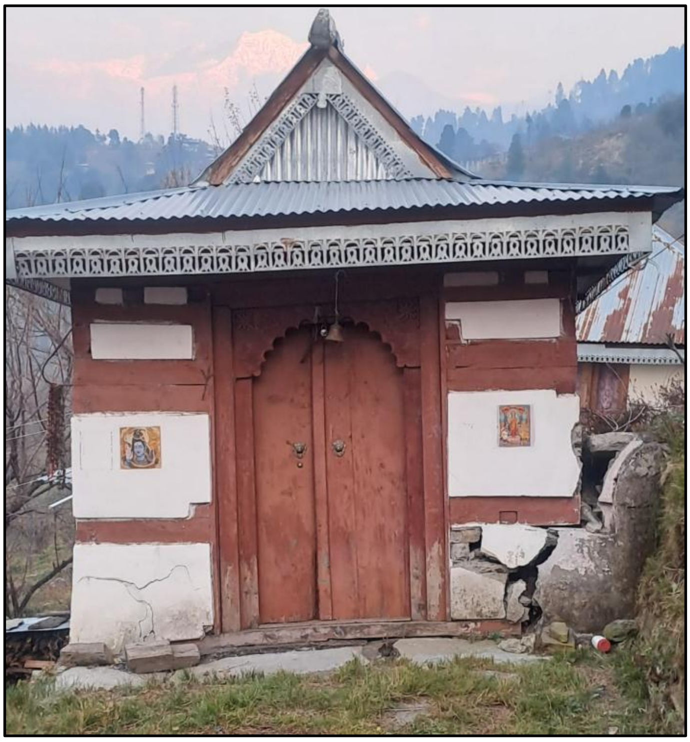


Fig. 68. Temple affected due to subsidence

Fig. 69. Trunk hollowing and widening due to root spread caused by land subsidence

Causative Factors

- The causes of landslide and subsidence in the Uchi village include heavy rainfall, drainage problem and a slope angle ranging from 25° to 60°.
- Water entering the slope through tension cracks during precipitation increases its instability. The current & ongoing land subsidence is triggered by heavy precipitation and existing damp ground conditions.
- The proximity of the village to the Main Thrust and its impact on the rocks and terrain cannot be ignored. The site's high moisture content of about 26% indicates a greater susceptibility to soil detachment.

Short-Term Remedial Measures

- Considering the poor sewerage and drainage system in the village, effective drainage management needs to be implemented as a priority.
- The structures and families impacted by the landslide/ subsidence require immediate attention and care to mitigate the effects of the disaster

Long- Term Solutions

Note: ***Given the scale of sinking and its impact on the inhabitants, their houses and local assets & resources, it is essential to prepare a detailed project report (DPR) to address the issue of land subsidence in Uchi village.***

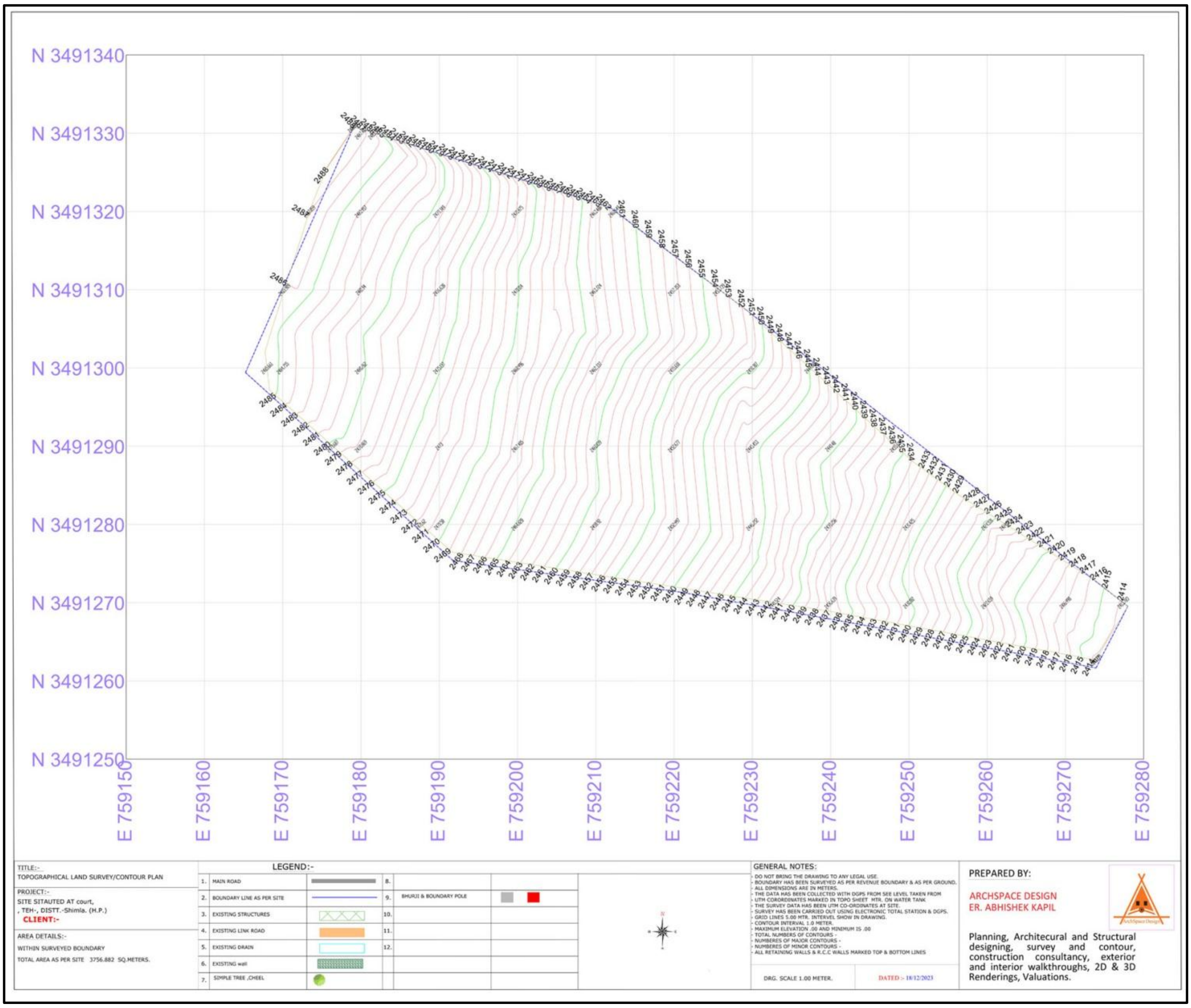
6.13 KOT, RAMPUR LANDSLIDE

The Kot landslide occurred on 8th July, 2023, triggered by heavy rainfall and slope instability. The Survey of India toposheet 53E/10, scaled at 1:50,000, includes the landslide site. Ram Chand, an 81-year-old village resident, remarked that such unprecedented rainfall had not been experienced in many years. The landslide damaged a 5-bigha land belonging to Prem Singh, which had fruit-bearing apple trees. Above the crown, there are pine, jamun, and deodar trees. Field investigations and discussions with locals revealed that the locals had encroached upon a nallah, which has now disappeared and been converted into horticultural land. Four residential structures were lost during the subsidence and landslide. There is also a problem of underground seepage from the river, which has now disappeared, resulting in completely damp soil conditions.

Fig. 70 shows the contour map of Kot, a village experiencing land slide and subsidence issue, with 1-meter interval contours indicating a steep slope susceptibility to slope failure. **Fig. 71** and **Fig. 72** depict the panoramic view and a field photograph of the site, respectively. **Fig. 72** shows the sinking area and houses at risk. **Fig. 73** illustrates the extent of the landslide's impact with debris runout material. **Fig. 74** provides a closer look at the debris runout material. **Fig. 75** depicts cracks in apple orchards caused by subsidence.

Geologically, the area is formed by the rocks of J-WGC forming part of Lesser Himalayan Crystalline bounded by Munsiari thrust (MT) or Main Central Thrust- I (MCT-I) in the south at Jhakri and Kullu thrust (KT) in the North at Karcham. J-WGC is comprises chiefly of a variety of gneisses and schists. Though the area is not very far from MT the effect on rocks and terrain cannot be neglected. This site is formed by the debris and rock blocks of gneiss and augen gneiss. As per the local people, this site was used to be natural water drainage got buried by approximately 30 years old rock fall event and water flows below the debris in the rainy season. This landslide is rainfall induced triggered in monsoon season due to heavy precipitation. Water between the rocky surface and debris provides the ramp to the overlying debris. Groundwater condition on failed slope at crown is damp while at toe it is flowing.

The soil analysis reveals that this site contains 35% silt content, while sand comprises 28% of the total **(Table 1)**. Clay content is reported at only 4% of the total. Due to the higher percentage of sand and gravel, the soil's moisture holding capacity is restricted to low levels. The site falls into the non-plastic class with small dry density values. In terms of shear parameters, the site exhibits low cohesion and a high coefficient of permeability, indicating susceptibility of landslip.



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E 759270
E 759280
TITLE:-
TOPOGRAPHICAL LAND SURVEY/CONTOUR PLAN
PROJECT:-
SITE SITAUTED AT court,
, TEH-, DISTT.-Shimla. (H.P.)
CLIENT:-
AREA DETAILS:-
WITHIN SURVEYED BOUNDARY
TOTAL AREA AS PER SITE 3756.882 SQ.METERS.
LEGEND:-
1. MAIN ROAD
2. BOUNDARY LINE AS PER SITE
3. EXISTING STRUCTURES
4. EXISTING LINK ROAD
5. EXISTING DRAIN
6. EXISTING wall
7. SIMPLE TREE ,CHEEL
8.
9. BHURJI & BOUNDARY POLE
10.
11.
12.
GENERAL NOTES:
- DO NOT BRING THE DRAWING TO ANY LEGAL USE.
- BOUNDARY HAS BEEN SURVEYED AS PER REVENUE BOUNDARY & AS PER GROUND.
- ALL DIMENSIONS ARE IN METERS.
- THE DATA HAS BEEN COLLECTED WITH DGPS FROM SEE LEVEL TAKEN FROM
- UTM CORORDINATES MARKED IN TOPO SHEET MTR. ON WATER TANK
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Fig. 70

Fig. 71. A panoramic view of Kot, Rampur landslide site, Shimla district

Fig. 72. Field photograph showing sinking area and houses at risk

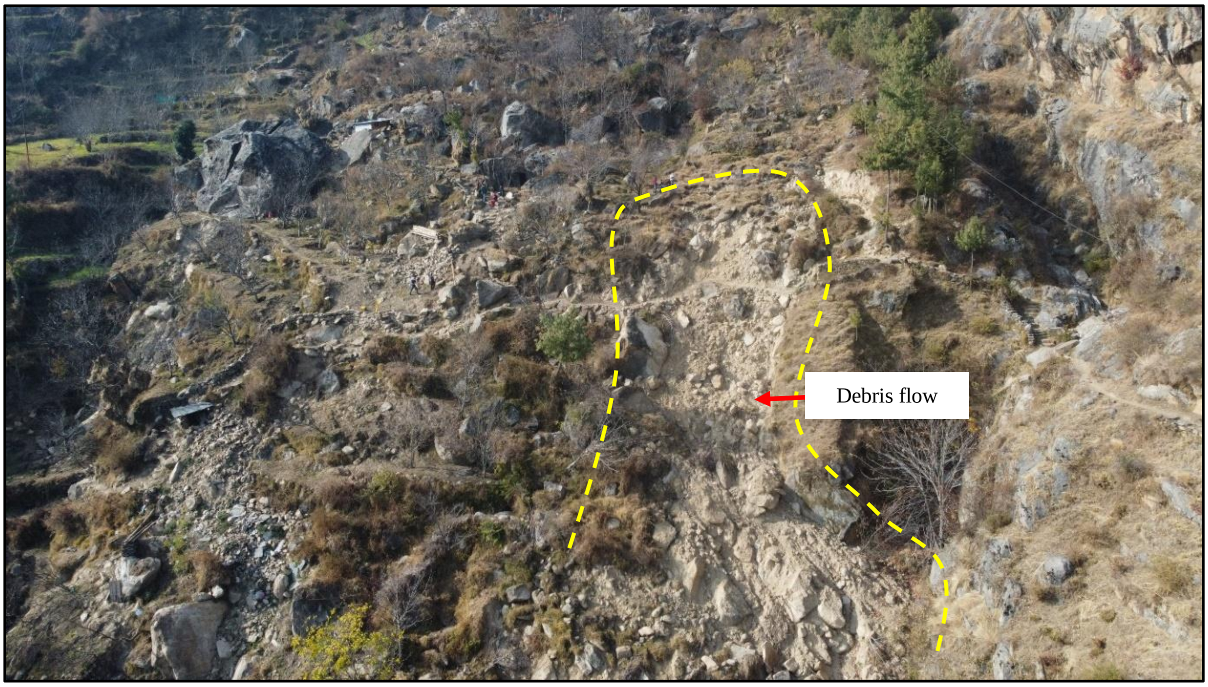

Fig. 73. Debris runout material illustrates the extent of the landslide's impact

Fig. 74. Debris run out material

Fig. 75. Cracks in apple orchards due to subsidence

Causative Factors

- Local encroachments on a vanished stream, now converted into horticultural land, have disrupted natural drainage pattern, leading to increased soil dampness.
- Underground seepage from a disappeared river has further contributed to the saturated soil conditions.
- The in-situ geological formations, combined with heavy rainfall, altered drainage pattern and increased soil saturation might have led to the current landslide/ subsidence.

Short-Term Remedial Measures

- There is a need to restore the natural drainage pattern by removing encroachments and rehabilitating the vanished stream. This will help reduce soil dampness and prevent water accumulation.
- Constructing drainage channels or installing drainage pipes can help manage underground seepage by redirecting water flow.

Long- Term Solutions

- There is need to evelop and implement land use planning strategies that consider the area's geological characteristics and natural drainage pattern. This will help in preventing future encroachment and land use practices that could contribute to landslide and subsidence in the village.

- Considering the social backwardness in the area, there is a need to raise community awareness and focus on preparedness regarding the causes and risks of landslides and sinking issues in the village.

6.14 SARYARLA-BARSHOL, RAMPUR LANDSLIDE

The Saryarla-Barshol landslide initially occurred in 2005 and was reactivated in July 2023 due to heavy rainfall. The landslide site falls in the Survey of India toposheets 53E/11 at 1:50,000 scale. It is a small translational landslide. During this event, the old road subsided and the waist wall collapsed. This landslide disrupted the road connectivity of Taklech village, which has a population of about 1000 persons in approximately 200 families located above the crown of the site. The entire village of Taklech is at risk of future damage, with about 7 bigha of land susceptible to damage if proper mitigation measures are not taken. During the monsoon, 8-10 houses were vacated. The PWD rest house located above the road is also at risk of being impacted in the future. **Fig. 76** shows a contour map of Saryarla-Barshol, a village prone to landslide, shows a moderate to steep slope, crucial for understanding the landslide disaster. **Fig. 77** and **Fig. 78** offer a panoramic view and a field photograph, with the latter revealing debris flow and deposition zones.

Geologically, the area comprises rocks of the Rampur Group, which is divided into three formations: Bhallan Formation, Banjar Formation and Manikaran Formation. The Bhallan Formation forms the base, overlain by the Banjar Formation, and then the Manikaran Formation. The Rampur Group consists of shale, greenish phyllite, schists with interbeds of white flaggy quartzite, and metabasalts. Meta sedimentary rocks or schists are exposed. The rocks are foliated, fractured and sheared, with three sets of discontinuous planes (J_0, J_1 and J_2). Shear seams and quartz lenses are also present. The J_1 (265°/79-80°) and slope face (253°/34°-40°) are nearly parallel, but there seems to be no discontinuity that daylight the slope kinematically.

Groundwater conditions on the slope are damp. The main reason for this landslide is heavy rainfall and poor drainage management. Road subsidence also occurred downhill, and the slope at the lower end is very steep, positively correlating with J_1. This lower slope is kinematically unstable. The burst wall on the slope was damaged during the last landslide. Rainfall on the lower slope acted as a crucial factor in the slope's disruption.

Based on laboratory observations, it has been found that the soil at the site contains 60% gravel content **(Table 1).** The high percentage of gravel and sand limits the soil's moisture holding capacity to about 8%, while the absence of clay accelerates soil detachment. Silt and finer grains make up less than 15% of the total soil mass. The site falls into the non-plastic class with small dry density values. In terms of shear parameters, the site exhibits low cohesion and a high coefficient of permeability, indicating probability of landslides.

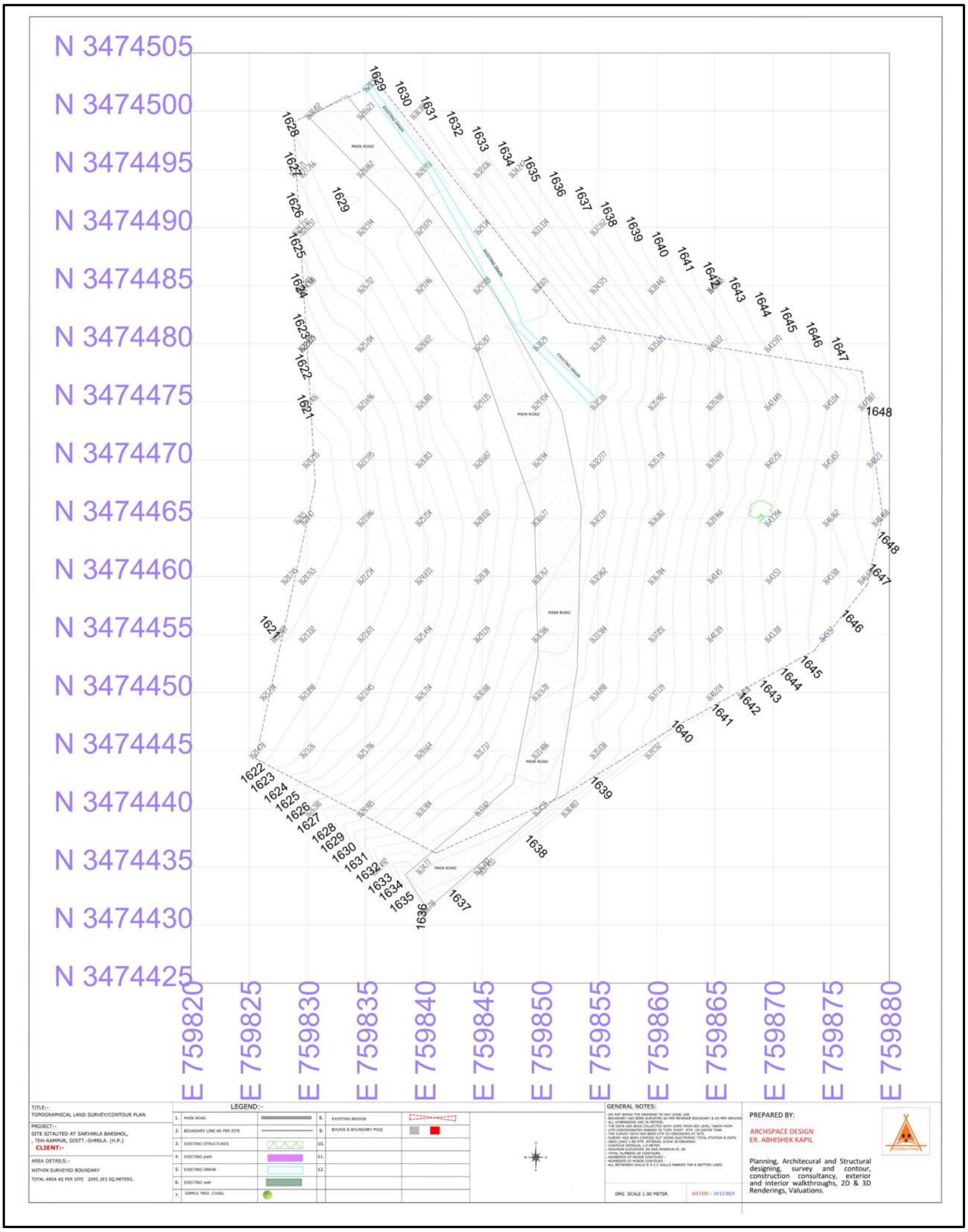

Fig. 76

Fig. 77. A panoramic view of Saryarla-Barshol, Rampur landslide site, Shimla district

Fig. 78. Field photograph showing debris flow and deposition zones

Causative Factors

- Heavy rainfall, coupled with poor drainage and damp groundwater conditions, collectively triggered the current landslide.
- The rocks exhibit foliation, fractures and shearing with three sets of discontinuous planes, but there are no discontinuities that kinematically daylight the slope.

Short-Term Remedial Measures

- The road has already been restored by the Public Works Department, as a crucial step in mitigating the effects of the landslide.
- Another short-term measure could be constructing a retaining wall with weep holes to stabilize the slope.

Long- Term Solutions

- Implementing an effective drainage management system is necessary to prevent water accumulation and further slope instability.
- Bioengineering measures suiting local conditions in consultation with PWD and Forest departments of the state.

Table 1: Geotechnical Properties of Soils at Various Landslide Sites

Location	Description of Sample	Grain Size Analysis				Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Moisture Content (%)	Bulk Density (GM/CC)	Dry Density (GM/CC)	Specific Gravity	D_{60}	D_{30}	D_{10}	Shear parameters			Coeff of permeability (CM/S)	Hydraulic Conductivity (CM/S)
		Gravel (%)	Sand (%)	Silt (%)	Clay (%)											Type of Test	Cohesion C (t/sqm)	Angle of riction (Degree)		
Nerwa	Silty Sand (SM)	25.5	57	17.5	0	35.09	23.4	11.69	12.21	2.196	1.95	2.64	0.043	0.009	0.003	DST	0.57	35.05	0.5×10^{-3}	3.75×10^{-3}
Labrot	Sandy Silt (SM)	10	48	39	3	Non-Plastic			13.67	2.07	1.84	2.65	0.061	0.008	0.002	DST	0.33	25.09	1.05×10^{-5}	7.89×10^{-5}
Tangnu	Silty Sand(SM)	18	49	33	0	Non-Plastic			9.55	1.873	1.7	2.64	0.043	0.009	0.003	DST	0.286	27.03	1.25×10^{-3}	9.39×10^{-3}
Kupvi	Silty Sand with Clay of low Plasticity (SM-CL)	20	10	56	14	35.4	23.4	12	14.83	2.134	1.85	2.7	0.061	0.008	0.002	DST	0.5	11.31	0.95×10^{-5}	7.14×10^{-5}
Fedizpul	Silty Sand (SM)	14	76	10	0	Non-Plastic			9.51	1.84	1.68	2.63	0.043	0.009	0.003	DST	0.167	32.32	1.15×10^{-3}	8.26×10^{-3}
Titrikyar	Silt with Gravel (GM)	50	29	21	0	Non-Plastic			11.63	2.135	2.134	2.64	0.043	0.009	0.003	DST	0.31	34.23	1.14×10^{-2}	10.67×10^{-2}
Plouthi dhar	Silty Sand (SM)	10	52	38	0	Non-Plastic			16.97	2.033	2.029	2.63	_	_	_	DST	0.32	26.17	1.01×10^{-3}	7.59×10^{-3}
Lamba khatal	Sandy Silt (ML)	46	23	29	2	Non-Plastic			8.85	2.246	2.06	2.65	0.061	0.008	0.002	DST	0.72	35.77	0.15×10^{-2}	1.12×10^{-2}
Uchi	Silty Sand (SM)	24.5	32.5	40	3	Non-Plastic			25.53	1.699	1.35	2.65	0.061	0.008	0.002	DST	0.52	9.65	_	_
Saryala Barshol	Silt with Gravel (GM)	60	24	16	0	Non-Plastic			8.3	2.118	1.95	2.62	0.041	0.008	0.002	DST	0.02	30.12	_	_
Rahighati	Silt with Gravel (GM)	38.6	34	25.4	2	Non-Plastic			8.83	2.08	1.91	2.63	0.061	0.008	0.002	DST	0.45	37.25	0.16×10^{-6}	1.2×10^{-6}
Kot	Silt with gravel (GM)	33	28	35	4	Non-Plastic			15.47	2.14	1.91	2.64	0.061	0.008	0.002	DST	0.37	29.69	_	_
Marni Kanhar	Silt with Gravel(GM)	45.5	27.5	27	0	Non-Plastic			12.86	2.17	1.92	2.66	_	_	_	DST	0.27	30.126	_	_

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