CHAPTER 8

DISCUSSION AND CONCLUSIONS

8.1 DISCUSSION

India is a unified country of diverse physiographic and climatologic conditions that faces different natural hazards frequently. In the midst of different disasters our country faces, landslide is one major natural hazard, with which a considerable area of the country has to challenge with, achieving to at least 15 percent of the land area, an area that exceeds 0.49 million km^2 (National Institute of Disaster Management, 2009). The Himalayas and the northeastern hill ranges goes through considerable landslide of varying intensities in the process causing large scale casualties and huge economic losses. (Naithani, 1999) stated that besides causing more than 200 deaths every year, which overall is considered 30% of such type of losses occurring worldwide, it has been predicted that, the damage caused by landslides in the Himalayan ranges alone costs more than US $1 billion.

When an area is to be developed or an infrastructure to be constructed in probable or identified landslide areas, the planned area has to be thoroughly studied and risks appraised to establish whether adequate firmness can be achieved in the course of mitigation or stabilization method. So studies should absorb detailed field investigations for geology, soils, hydrology, topography, rainfall and human factors, which collectively cause slope instability, and geotechnical analyses and monitoring of selected landslides. Studies may wrap up with recommendations for methods and procedures for mitigation of existing landslides.

About 90 percent of Nagaland state is ornamented with hills and for the most part the rocks are highly deformed due to under-thrusting of the Indian plate below the Burmese plate. These deformations are distinct in the form of folding, faulting, shearing and a number of jointing (Plate 8.1.a). Also rapid weathering continues to damage the already weakened rocks as the region receives abundant rainfall. All these factors together add a major role in generating instability in the study area or the region as a whole.

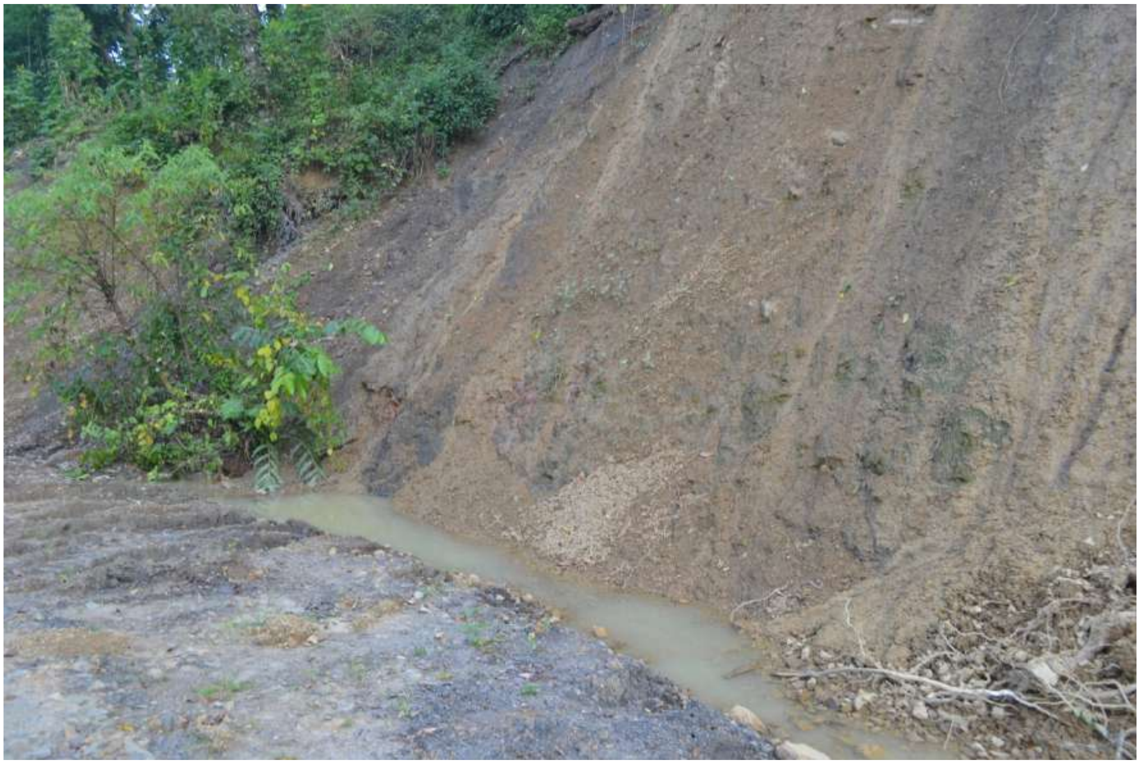

Plate 7.2.2.b Concentration of sub-surface water

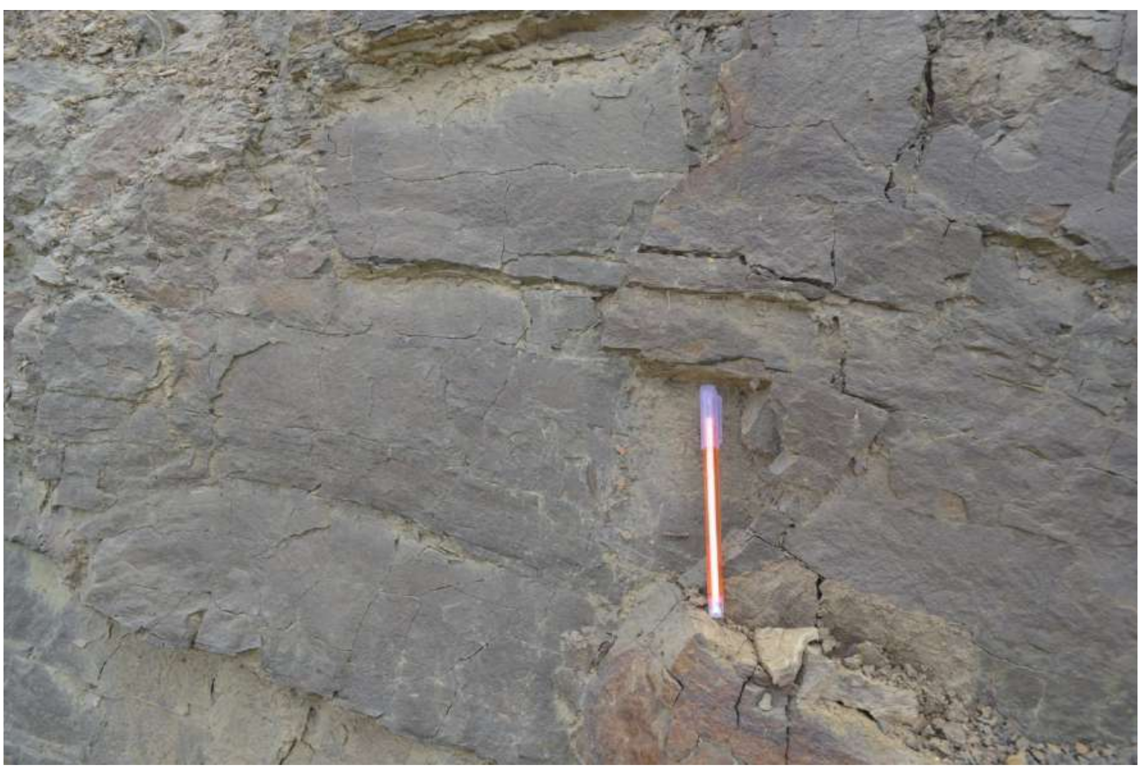

Plate 8.1.a Joints in Sandstone

Landslides are regular and repeated incident with the onset of monsoon in this region, which receives heavy rainfall. It has contributed a huge threat to the people living in this area, particularly during ceaseless rains. Every year landslides create huge hurdles especially in road communications. During this time of the year, traffic along this highway often gets disrupted not only for few hours, a day or two but sometimes more than a week.

The study area is embraced by jagged hills of Upper Cretaceous-Eocene argillaceous sediments of the Disang Group and some younger arenaceous Barail of Oligocene age. They show signs of concretionary structures and box-work weathering. They are also highly jointed, folded, and faulted. The Disang rocks are mostly shales with well bedded siltstones and sandstones. Reddish brown colouration is noted in places due to leaching of iron oxide (Plate 8.1.b). Common characteristic features of rich organic matter which are dark grey and black shales gets weathered to clays. On contact with water these clays turn greasy and perform as a lubricant which increases the pore-water pressure leading to inter grain friction. This exhibits loss in their shearing strength and soil structure finally gives way. The study location is along the area where the shales are highly creased and fissile due to which, on exposure to air, they disintegrate and weather easily. When saturated, they start flowing to cause debris and mud flows. The Barail rocks of the area displays thick beds of sandstones with thin intercalation of shale beds. The failing factors are added by the highly jointed and sheared sandstone beds noted along steep bedding or joint planes (Plate 8.1.c). Also the shales with their weak planes have a trend to cause rockslides.

This study tried to bring about a spatial discrepancy of slope failure probability of the area. Whereby, it becomes obligatory to find out the main cause considering the geomorphology, geological features, human interventions, rainfall, earthquakes, land use / land cover and other associated parameters. While Geo-environmental aspects were derived from different sources through the analysis of topographic maps and satellite imagery (IRS-P6 PAN) including GPS data to deal with the required objective. They are then imputed into the digital format in ArcGIS 9.2 and finally remarkable data bases created for road network, facet, slope angle, land use / land cover, drainage network, lithology, structure, relative relief and landslide incidences engaging visual interpretation and digital modus operandi.

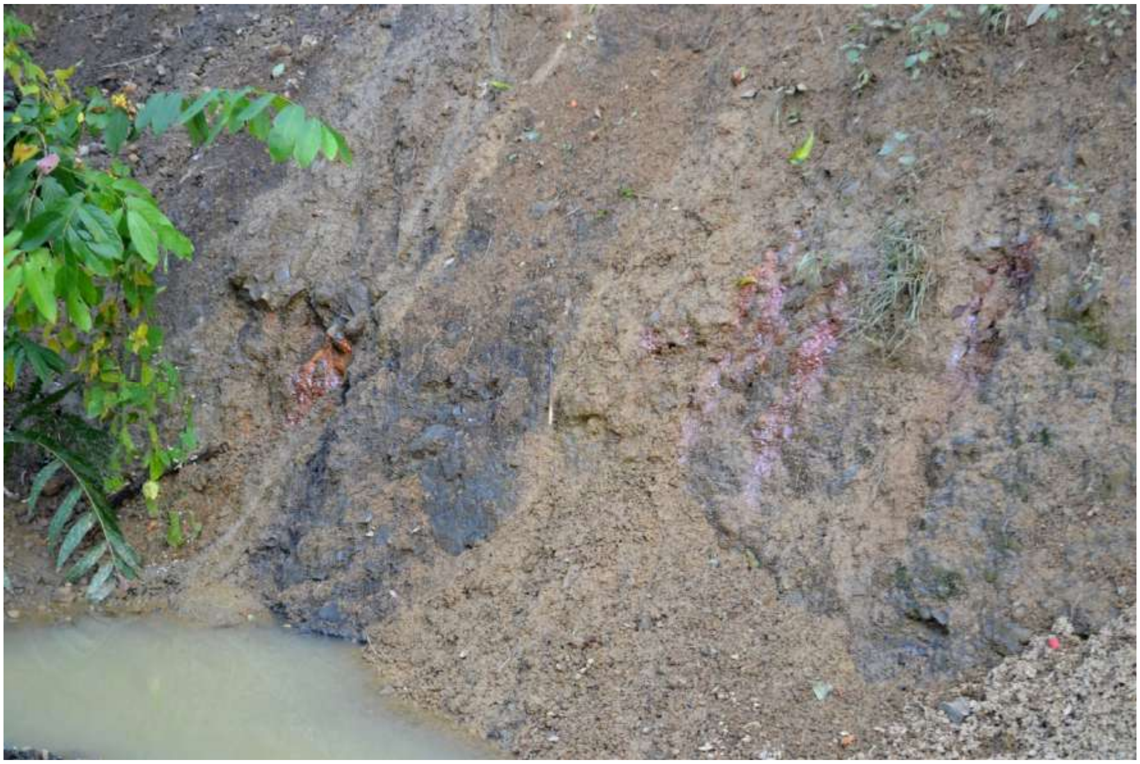

Plate 8.1.b Leaching of Iron oxide

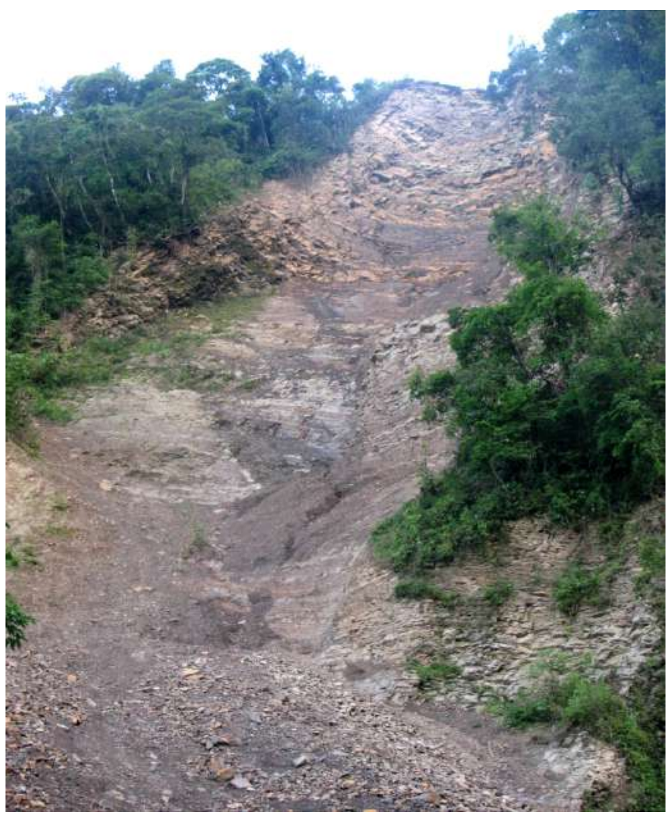

Plate 8.1.c Rock Fall

Basing on their degree of influence special standards has been assigned in causing landslides. The Bureau of Indian Standards (1998) did recommend rating of 2.0 for lithology but in the area instability is observed even in gentle slopes owing to local steepness of the slopes and the weak rocks and soils. For this reason, it was reasonable to upgrade the rating of lithology for this area to 2.5 from the recommended value. Correspondingly, the rating for land use / land cover is reduced to 1.5 from 2.0 as the relative effect of this factor is not as noteworthy as that of lithology. Other rating values for the different classes remain unchanged. The total rating type on these factors is 10, and based on this total value the TEHD is calculated. Therefore, linked to the computed TEHD values susceptible zones were categorized into five categories, viz., very low, low, moderate, high and very high.

In the study area a good number of slopes are mapped as gentle but to a large point these are locally moderate to steep particularly along stream channels as they are really too small to be classified as individual facets. Hence, by and large the ratings of the general slope of that facet were specified. All the five different groups of slopes were recognized in the study area. With relation to that, 54.54% are under gentle slopes, 40.91% moderately steep slopes and 4.55% as steep slopes. Moderately steep slopes show rationally high values whereas the frequency of landslides on the gentle slopes is also high. Slides normally occur in areas of locally steep slopes but in some areas it occurs in gentle slopes too, mainly because in such areas terrace cultivation were practiced. Water stored in paddy fields induces landslides. The reason is due to greatly increased pore-water pressure generated on the soils due to retention of large amounts of water for the paddy plants. It has also been identified that most of the area under terrace cultivation are actually palaeoslide zones. Though slope triggers landslide, structures and the material making up a slope decides to a great extent whether a slope will fail or remain stable. The allocation above indicates that the structures of the area and the material making up the slope can also be contributory and controlling factors of instability and that slope as thought is also not only a dominant factor.

In the case of relative relief, 31.82% of the slides occur in low relief and 68.18% occur in the moderate relief areas. This is probably because the highway has been cut across areas of low and moderate relief in relation to the steepness of the area.

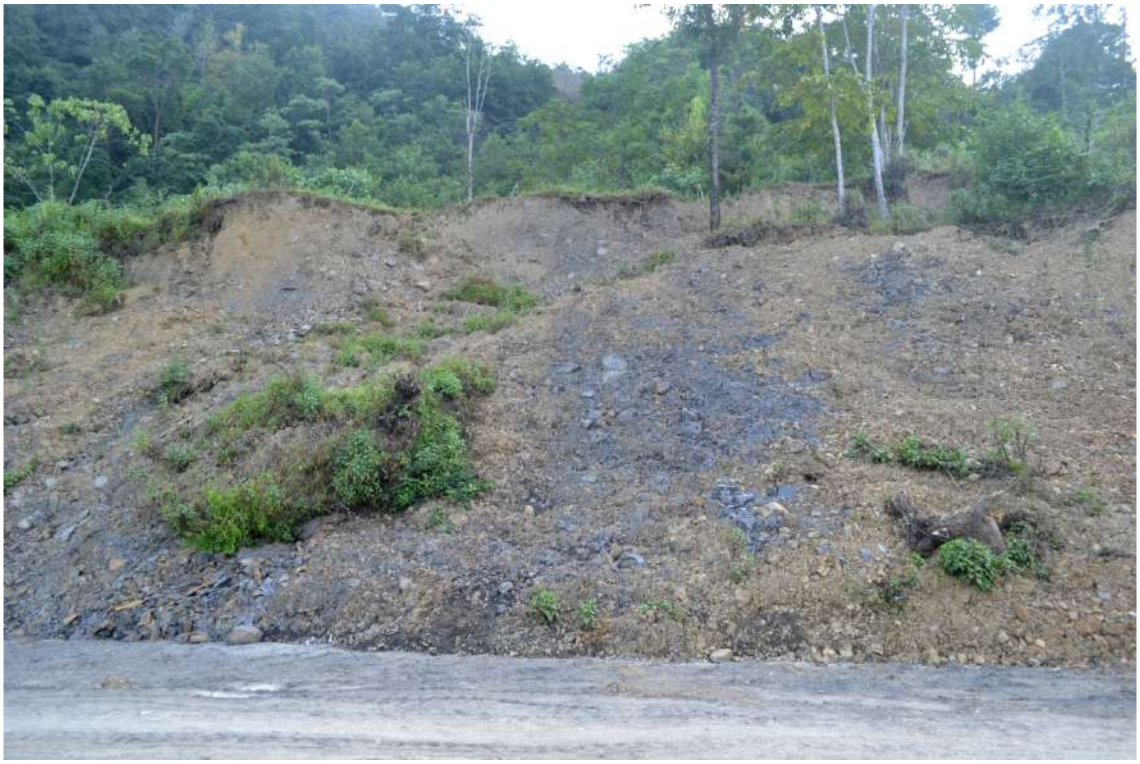

Plate 8.1.d Debris Slide along the Highway

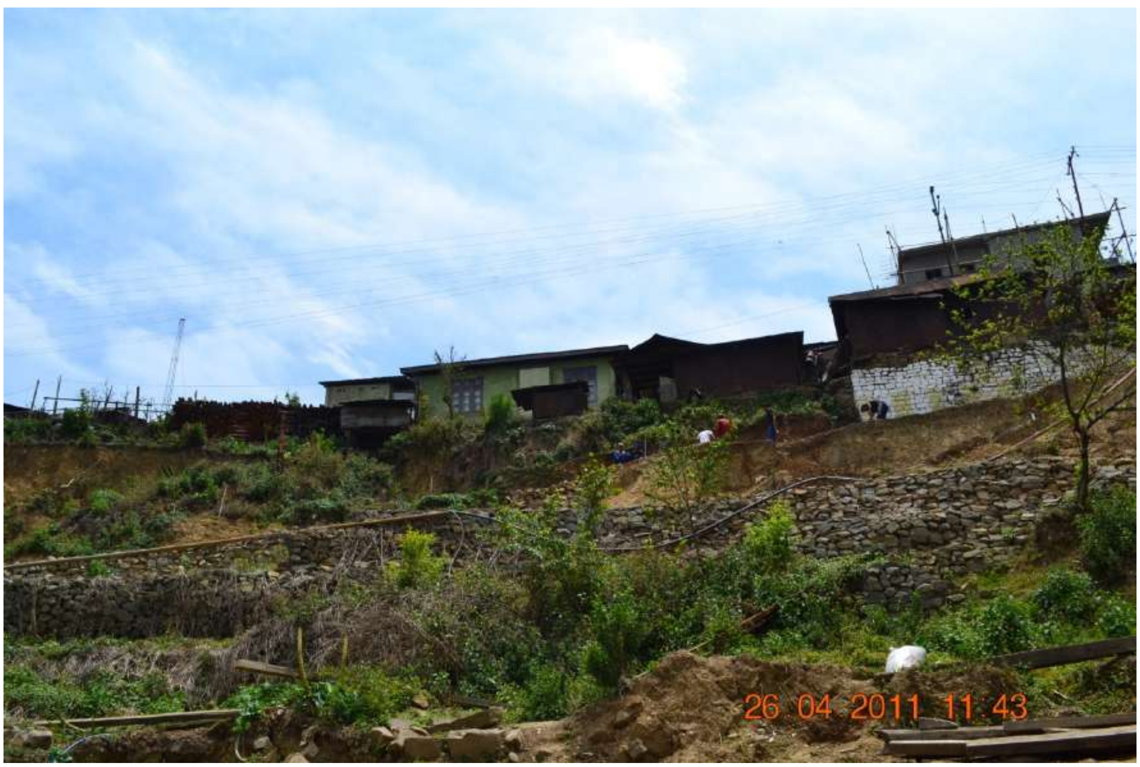

Plate 8.1.e Landslide inside the village

The lithological map of the study area shows varied litho-units. About 36.36% of the slides occur in loose debris and 18.18% in partially loose debris, 27.27% in weathered shale and 4.55% in partially weathered and crumpled shale and 9.09% in shale with minor sandstone. The other litho-units are more stable and not affected by landslides. Incidences of slide are more in loose debris and partially loose debris (Plate 8.1.d). This is because debris slopes are often mixed with clays which have generally low shearing strengths and rumples easily with the presence of water. Weathered horizons and partially weathered horizon show high frequency of slides the reason being continuous rainfall during the monsoon where the shearing strengths of clays are reduced. The frequency of slides in the crumpled shale and shale with minor sandstone also submit to the same grounds rendering to rampant slope cutting.

Majority of the study area depicts damp condition owing to the reason that the water table of the area is quite low and any amount of additional water can bring about instability in the area. The largest percentage of slides occurred in dripping areas (63.64%) followed by the damp areas (18.18%).The wet area shows (13.64%) of landslides. However, the frequency of landslides in flowing areas (4.55%) is low as their contributing action in the area is less and they occupy only a small section in the division.

Land use / land cover has been conveniently classified into five categories. Some small villages are positioned in geologically uneven areas and as such these areas suffer constant landslide (Plate 8.1.e). Furthermore, haphazard earth cutting and unscientific land use practices for construction of large and heavy structures results in instability. A large amount of wet cultivation for paddy is interconnected to old landslides as the water retention during the growing season increases the pore-water pressure continuously resulting to subsidence and/or damage to hill slopes and roads. In the lightly vegetated areas, the soils are usually lean and lack cohesiveness and hence do not sustain flourishing plant life. Such areas are normally prone to landsliding and have been involved in about 50% of landslides. It is observed that moderately vegetated areas are also affected by landslides owing their cause to structural disturbances and weak lithology.

The study area has been demarcated into four LHZ classes. The map consists of low, moderate, high and very high hazard zones. The low and moderate hazard zones are free of landslides. About 31.82% are in the high hazard zones whereas 68.18% are in the very high hazard zones. Very high hazard zones have a frequency of 2.57% and high hazard zones 0.76% indicating that very high hazard zones are highly unstable. The high hazard zones are unstable too. Great deal of the area coming under moderate hazard zones is more or less stable as long as outside causes like large earthquakes, cloudbursts, excessive anthropogenic activity, etc., do not disturb the balance.

On studying the satellite imagery of the area, well-defined lineaments were identified. A number of deep channel have dissected the hill slopes. It is identified that steep gullies have formed owing to base erosion by streams cutting along fault planes. This example shows structural control where the lower order streams generally follow major joint patterns. Dendritic drainage pattern is common in the study area.

The tectonic disturbances in the area are reflected by numerous faults, folds riddled by a number of joints and fractures (Plate 8.1.f). Joint data which has been plotted in a rose diagram show majority of the lineaments in a NE-SW direction, which is essentially parallel to the regional trend. An additional set of joint trends NW-SE which owes its origin to tensile or shear stresses similar to antithetic and synthetic shear faults that are concentrated around the regional NW-SE compression. Due to contact of these stresses it generated hybrid fractures in the territory causing widespread deformation of the rocks. Rock falls are also dominant in vertical rock faces related to relief of the area coupled with road cutting. The shales are extremely fissile due to presence of anoxic waters (Curtis, 1980). The fissility coupled with the joint planes, have made this regions highly susceptible to mass wasting. These zones encompass varied materials that are thoroughly mixed with clayey, silty and sandy soils.

Bringing to a close in this study the chief reason following the factors of instability in the area is excessive rainfall received during the monsoon and anthropogenic activity. Meusburger and Alewell (2008) proved that there was an accelerating increase of 92% in landslide activity due to anthropogenic and environmental factors during a 45-year period (1959-2004) in the Central Swiss Alps.The study area too experiences prolong monsoon that continues for several months.Cloudbursts a very common phenomena in this region is a heavy downpour that usually last for few minutes or sometimes they last to continue for two to three hours. It is eminent that in case of cloudburst extending for long periods large magnitude of devastation occurs. It proves that this damage is worse than the combined effect of rainfall of the whole year. Relentless and continuous lesser intensity rainfall also activates landslides at numerous places. Thus the combine affect of continuous rainfall and the sporadic cloudbursts results to numerous and devastating landslides.

Another heartening reason behind slope instability is human interference. Removing of slope support for widening of roads also triggers landslide in areas where topographic slopes and dips of beds are consistent, with beds dipping at equal or lesser amounts than hill slopes. Overcapacity of slopes or removal of lateral support by human hindrance is one most important concern for slope failure in these areas. Soil cover in the area enhances plentiful vegetation but urbanisation and other human actions have distressed the natural processes exposing the soil to water action, which ultimately results in extensive surface erosion and slope instability. Improper drainage system in the area has added more problems in causing instability. Cultural practice like terrace cultivation for paddy in old landslide areas where the soils are rich in silt and clay, traps water for about 60 days during the planting season, whereby complete saturation and extreme pore pressure is generated leading to slope failure. Such terraces are familiar in patches along the highway leading to continuous subsidence and damage of the road particularly during monsoon.

8.2 CONCLUSIONS

Landslide investigations ought to promote disaster preparedness and to establish a network of efficient operation for all disaster related activities during pre-disaster period, at an actual disaster and afterwards. Therefore the current study made an effort to create a landslide record based on field studies using topographical maps and satellite records in a GIS background, as there is lack of information on landslides. The landslide hazard map produced can serve as a mechanism that can serve as an effective channel for proper planning, formulation of policy and decision making through data integration and modeling. The 3-D models can be suitably used to

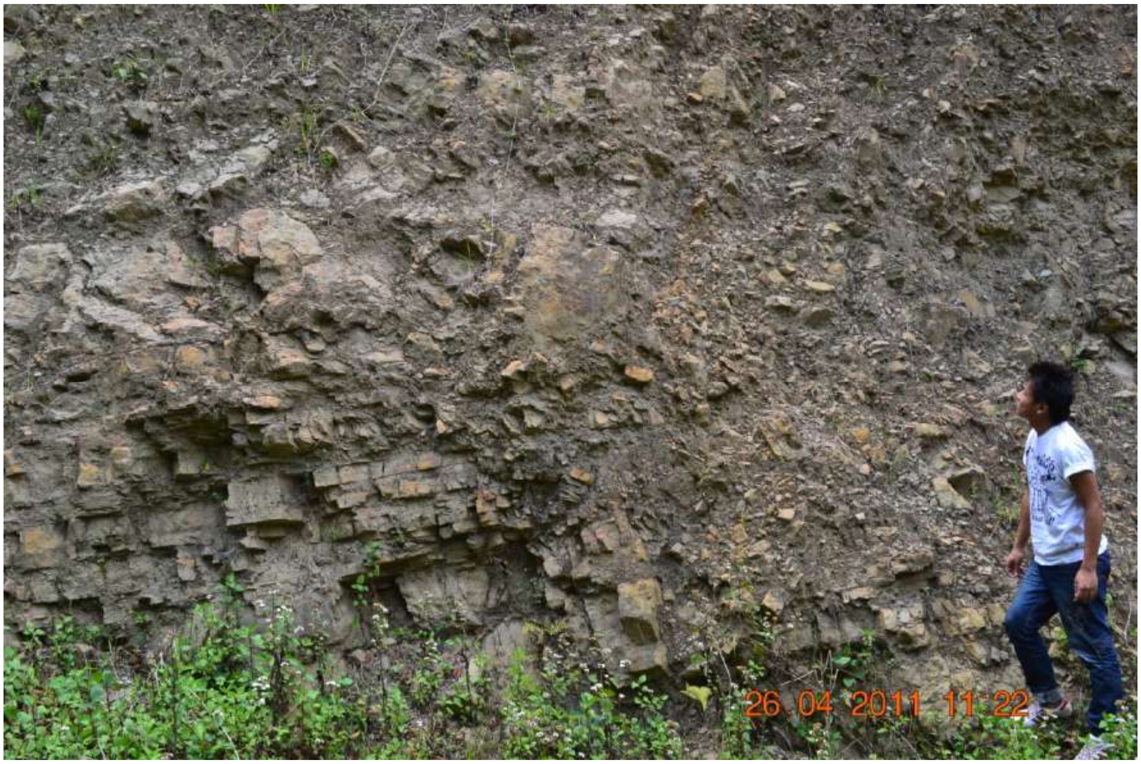

Plate 8.1.f Local fault

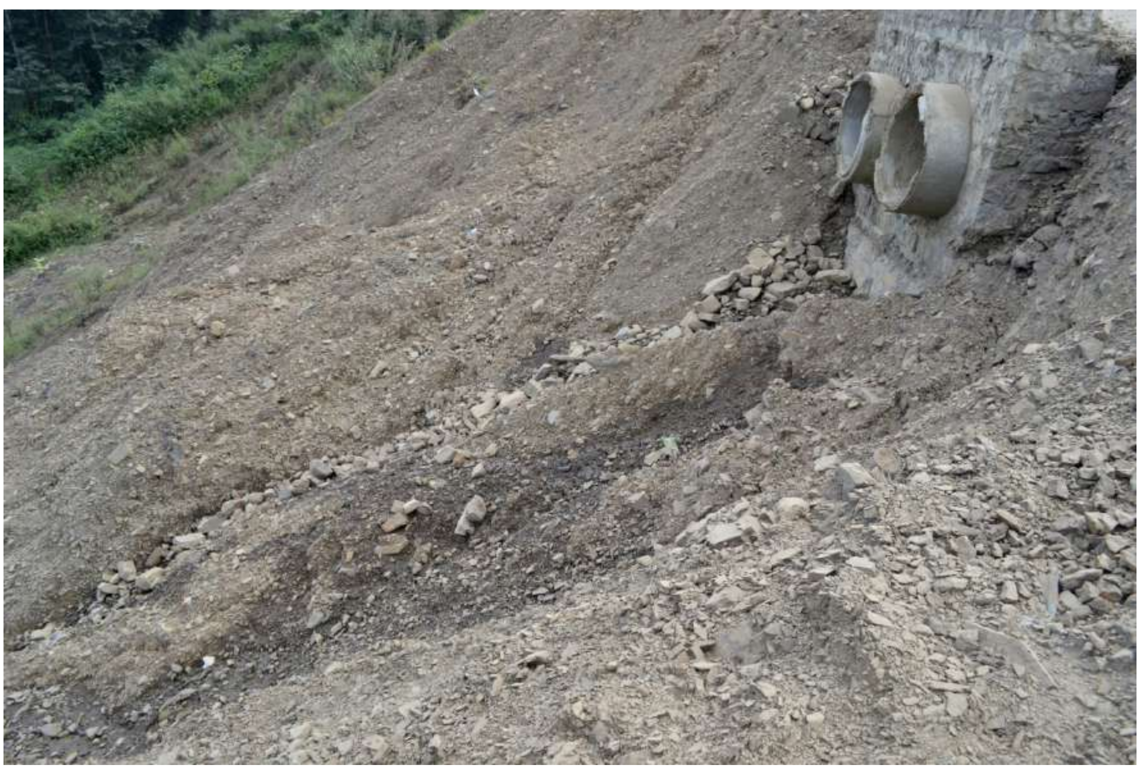

Plate 8.2 Water draining in an unstable area

evaluate and view the rugged terrain and plan accordingly. Such data can be simulated for use elsewhere under similar condition. Geotechnical investigations have proved to be significant for the prediction of future landslides so investigations have been cautiously undertaken to help device fitting control and preventive measures.

Drainage system in the studied area is improper and very poorly constructed. This has led to surface run-off along the whole unstable area and also leading to huge percolation of water into the subsurface making the soil lose its shearing strength and causing failure. Therefore, drainage enhancement should include surface and subsurface clearance. To enhance surface drainage it has to take care of lined catch-water draw off above the crown of a slide, lined contour drains at different levels of the slide mass and lined cascading chutes to intercept and divert rainwater from the upslope so that water will not enter present and old landslide zones (Plate 8.2). Splashing of impermeable material like tar mulch or mortar at the crown and head regions can also be opted to shut any tension cracks and other permeable zones that provide avenues for excessive water infiltration.Such technique can help check infiltration and ease pore water pressure appreciably. Subsurface drainage development works can minimize and remove groundwater from within the landslide mass and it can lower the groundwater table. It can be of any type like the low or deep subsurface drainage control mechanism which again depends upon the nature of the slide. Some systems that can be interpolated are intercepting under drains, interceptor trench drains, horizontal gravity drains and drainage wells.

Though some fresh cut slopes along the roads actually remains stable, a number of places generate devastation as the debris from the slopes tears down the bitumen on the road. The techniques used for construction of road in this part of the region are very poor. Thus the technique and material used for road construction in high hazard zones should really improve. A wiser alternative in badly deformed areas would be realignment of roads, innovating as far as possible to reduce cost, improve speed of construction, and encourage utilization of slope waste to the amount viable.Other weak parts of the highway away from the study area should also be considered though mitigation plans in all the landslide prone area may not be achievable due to unaffordable expenses, engineering and economic feasibility and social acceptability. However improvement methods should be adopted to reduce cost.

Random cutting of slope for road construction and altering the nature of slope in bringing about development should be stopped. With urbanization and development, slope instability problem along NH 39 has been drastically disturbed by human activities in the form of unsystematic agricultural practices, construction of RCC buildings and other land use practices. Ultimately it has increased the load on hill slopes. People should be highlighted and made conscious of these specifics that such constructions make the slope more vulnerable and should be encouraged to use light construction materials. An example that can be cited in this circumstance is the Landslide Mitigation Programme of Japan (NAP, 1987) where the Japanese Government set up land use management controls for agricultural practice and building construction. Since it got implemented it helped a lot, as it noticeably reduced the loss of lives and property in the country. As pointed out, age old practise of jhum or shifting cultivation and terrace cultivation should be discouraged as it compounds the problem due to retention of water for longer period of time, increased degree of mass wasting, siltation, and other ecological imbalances. So, instead of these practices, an alternative is plantation of cash crops, etc. which can minimize the problem of slope failure to a great extent. Inspection of vehicles beyond the allotted weight and minimizing vibrations from vehicular movement can all contribute in some ways to stabilize the area.

Afforestation can be encouraged so that it will minimize excessive infiltration and surface runoff. To help control the slides planting of different species of grass such as Ginni Grass, Napier Grass, Java Grass, Lemon Grass, Palma Rosa Grass, Golda Grass, etc will ensure more stable slope. Planting fast growing, deep rooted trees such as eucalyptus, alder, cedar, willows like *Salix tetrasperma*, *Salix ichnostachya Lindl* and *Salix sitchensis* and fir like *Pseudo tsugamenziessii* in the lower reaches of slide zones also help in stabilizing the slope. However, planting of large and heavy trees on highly susceptible slopes should be avoided, as these plants may compound the problem as they grow larger and taller and infact unstabilize the slope because of its weight.

After thorough study, engineering mitigation procedures such as pilling, tie bars, soil nailing and designing special types of retaining walls or other slope stabilizing structures may be taken up to stabilize the slopes to some extent. Rock slope engineering therefore is necessary and important as slope forming materials are quite fragile and thick.

Precise and accurate weather forecasting of cumulative rainfall patterns can warn people of an approaching storm and prevent devastation to a considerable degree hence this information have become an important tool. Therefore, for better planning and proficient investigations it is necessary to install more rain gauges at various places to obtain more accurate and detailed data.

Bhandari (1984) has given importance to instrumentation and field monitoring of landslides and other mass movements as such gadgets in unstable, site specific, prone areas and habitated areas can help in untimely warning and evade from major disasters.

From geotechnical studies of soils along the hilly routes of NH 39 it has also been found that the soils contain clay sediments of organic matter mainly because of terrace cultivation, or it may be because of other anthropogenic activities. Studies have indicated that during the rainy season, natural water content is high, going beyond the plastic limit and possibly during certain seasons the water content exceeds the liquid limit. From index properties of these soils it is observed that when the natural water content is high, the liquidity, consistency indices approach the critical limit, implying the possibility of slope masses going into the liquid state, leading to slides and flows of the slope materials. Studies of the two slides have established that the soils are in a state of near failure. The soils are highly saturated though they have been collected during the lean period, indicating that during the monsoon period the saturation of the soil will be even higher making the soil even more unstable leading to slope failure. Consistency properties of the soil show near zero and negative values, which indicates near failure in the future. Hence, slopes cut greater than the internal friction angle will be unstable. That is to say that, landslides will be common if the slope cuts are more than 16° and 13° in these two particular studied areas. Probably this is the reason why slides are common during rainy season.

Forming active and proper Landslide Management and Regulatory Board by the Government to check and examine instability is thus recommended. Programs for educating people should be taken up to make them aware of proper land use practice on the slopes as well as construction designs for hill roads, buildings, etc. Governing establishments should check that no plans are cleared unless satisfactory provisions are made for fullest investigation and protective measures are guaranteed. Alcedo (1998) cited that well-implemented disaster mitigation programs will professionally contribute to reduce the physical, social, and economic vulnerability of disaster prone areas.

It can be seen that the Bureau of Indian Standards (BIS) and the Indian Roads Congress (IRC) have no proper specification and recommendation for construction of roads in hilly areas. Hence, further research in engineering and construction techniques for slope stability for hill roads will help improve safety measures and loss of lives.

From the LHZ map generated, the high hazard and very high hazard areas are clearly distinguished. Thus these areas must be considered in terms of probable risk to property and human lives. Disaster preparedness and remedial management programs in whatever achievable way for these areas must be worked out immediately. Thus it is necessary to have implementable plans in place and for which resources should be available.