CHAPTER 7

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 SUMMARY

Landslides and mass movements in Kohima region occur as a result of interplay of adverse geological features, heavy and prolonged rainfall, indiscriminate cutting of slopes and seismicity. The study area situated in Kohima and its adjoining areas comprises of young geologic terrain with pervious and unstable rocks and soils. Landslides hamper the economic activities in the study area. Due to increasing population and urbanization, human activities have added to landslide occurrences, leading to loss of life and property. Landslide and related phenomena occur independently or due to human activity, therefore, it is necessary to determine the causative factors by analyzing the geomorphology, human activities, land features and their associated parameters. Large numbers of integrated studies have been done in India on the impact of urban growth, population density and land use/land cover changes on landslide using remote sensing and GIS but such integrated studies are not carried out in Nagaland, including Kohima, which are crucial for the evaluation of the overall environment of Kohima.

Keeping this in view, the present study is carried out to evaluate the factors responsible for land-sliding and other mass movements using remote sensing and GIS and subsequently to generate the landslide hazard zonation. Besides, an attempt is also made to assess the vulnerability and risk.

In order to achieve the present objective, the various geo-environmental parameters such as geohydrology, topography, geological structures, lithology, demography, meteorology and landslide events data are derived from different databases through the analysis of satellite IRS ID LISS III and PAN data, Survey of India toposheets, GPS data and other collateral data collected from various sources. These databases are
converted into digital database compatible to Arc/Info GIS. Two databases viz., spatial and attribute database are created. The spatial digital database is consist of base map, road network, facet, slope angle and aspect, hydrogeomorphology, land use/land cover, drainage network, lithology, structure, relief, drainage density and frequency and landslide maps. All the above maps are generated employing visual interpretation and digital techniques. Attribute digital database constitute rainfall, population and landslide events data. Rainfall data has been collected from different stations and compiled. This data is used to correlate landslide events in the present area of investigation.

The susceptibility of the terrain to land-sliding is evaluated taking into consideration a number of factors such as slope angles, relative relief, lithology, structure, drainage density and frequency, and land use and land cover. Each factor is assigned a Landslide Hazard Evaluation Factor (LHEF) rating depending upon the susceptibility to land-sliding due to that factor. A total rating of 100 is given to all the factors combined. This is the Total Estimated Hazard (TEHD) rating. In this scheme slope morphometry is assigned 20 points, lithology 20, structure 20, relative relief 10, drainage density 10, drainage frequency 10, and land use and land cover 10. These values are assigned using ArcView attribute table. This rating scheme is based on the relative importance of various causative factors derived from this study. The Total Estimated Hazard values are then computed to delineate the study area into various landslide hazard zones, namely, very low, low, moderate and high. Field data on landslides are employed to evaluate and validate the Landslide Hazard Zonation map.

Spatial distribution maps are generated showing all the existing landslides area, rainfall and population distributions. All the landslides are mapped using Global Positioning System (GPS) and information about the events and damages are recorded during the field work. These maps are generated by building its topology in Arc/Info GIS platform and also by using three-dimension analyst.

Using GIS as a management tool, vulnerability and risk maps are also generated to assess the area that are likely to be damaged and are under threat. Therefore, the risk
areas are those, which fall under high hazard and vulnerability category. Given the emphasis on population density and human economic activities in assessing vulnerability and risk, the areas with major roads and highly populated settlements are identified as high risk.

During field investigation it is found that the rock types mainly consist of argillaceous sediments (Disang Group) and arenaceous sediments (Barail Group) and form NNE-SSW to NE-SW trending elongated hill ranges. The strike of the rocks is nearly parallel to the orientation of the hill-ranges.

The study area is located in a terrain that is lithologically very diverse. The oldest rocks in this area are the Disang Group of sediments. The lithology of Disangs is dominant of shales alternate with minor siltstones and fine grained sandstones. At a number of places the shales are weathered to clays. The shale and clays are usually dark grey to black in colour, turning to reddish brown in colour at places due to leaching of iron oxide. The dark grey and black shales are rich in organic matter and the clays are very slimy when saturated with water and hence act as lubricants. High saturation of these clays leads to building up of high pore water pressure thereby causing the loss of shearing strength and collapse of the soil structure. Landslides of this area are found where abundant water percolates through the permeable units. The crumpled state of shale (Plate 7.1) and excessive saturation generate conditions favourable for shear failure of slopes due to increase of pore pressure and consequent decrease in shear resistance of the slope material. Most of the landslides are confined here. The lithology of the terrain and its slope play an important role in the slide prone areas. Surface runoff is responsible for removing the top soil.

Barail Group of rocks lie conformably over the Disang. The Barail, as a whole, are made up of sandstones with alternations of siltstones and occasionally, papery shale. These are very tough and competent rocks. The Barail group of the study area is represented by the Laisong formation, which is the oldest (Plate 7.2). The Laisong comprise of well bedded greywacke. Landslides are not frequent in the area represented by these sandstones.
The study area pertains in a tectonically deformed zone. The Disang and Barail formations between Kohima and Kiruphema are part of the Kohima Synclinorium. For the most part the study area falls in the Disang. The Disang formations have not been structurally mapped, the reason being the monotonous nature of the shale. However it is believed that some thrusts slice through the Disang. This is because of repeated thrusting. The repetition and disappearance of rock formations or beds are attributed to the different phases of deformation suffered by the rocks of the area in the form of thrusts, faults, and different types of folds. Beyond Kiruphema, the Disang thrust is encountered. This is a very persistent thrust that is the extension of the Dauki-Tear Fault in Meghalaya. This thrust is the easternmost thrust that limits the Belt of Schuppen in Nagaland. The fault zones are marked by the presence of crushed material, discontinuities, and displacement of beds. Due to continued push of the continental plates, tectonic movements are still continuing. This is seen in the active fault zones in the area of investigation. Active faulting is responsible for the crumpling and weathering of the rocks.

In the study area, it is found that the tectonic disturbances are manifested in the form of numerous folds, joints, shear zones, and fault planes. Hence, erosion in this region is very high. Small-scale folds and faults are common. The rocks in the major portion of this area are rendered weak because of the presence of three to four sets of joints. Many of the slides in this area were initiated as deep seated, multiple rotational slumps of old surfaces of weathered and jointed rocks. The joints are responsible for imparting splintery nature to Disang shales. The shales being highly fissile coupled with the joint planes, has made this terrain highly susceptible to mass wasting. In this area intense shearing of the rocks and number of crushed zones has also been noted. These crushed zones comprise colluvial debris comprising rocks of various sizes mixed with clayey and sandy soils. Several crushed zones have also been identified conforming to palaeoslide sites. Landslides commonly occur in areas where the rocks are intensely fractured and sheared. Since most thrusts, faults, and shear zones are associated with the presence of breccia and other crushed material, their shearing strength is reduced in the presence of water.
A number of well defined lineaments are noted from satellite imageries, some of which have been identified as faults. Investigations have revealed numerous faults within the Disang formations particularly between Kohima and Zubza. Most of these faults occur in parallel groups. Numerous streams have cut deep channels along some fault and other planes (Plate 7.3). It is observed that fracturing caused by the intersection of folds and faults are often responsible for steeply cut gullies. During the monsoon these youthful streams vigorously erode the highly jointed Disang and Barail sediments and deposit their debris on the road. Streams running through shear zones in the Disang are responsible for some of the slides. It is noted that most of these stream channels are in fact fault planes, some of which are still active.

The hill slopes are dissected by a number of deep gullies that meet at lower levels. Most of the small channels follow available ground slopes. However, some of the higher order streams follow major joint patterns and fault traces. Rising groundwater pressure, particularly during the rainy season is one of the causes for slide movements. The unlined gullies in the area coupled with the naked slopes allow rainwater to percolate into the subsurface through the overburden. This has resulted in the development of undesirable pore pressure that has reduced the shear strength of the slope material.

The drainage system in the study area is poorly developed. The area experiences heavy rainfall which causes abundant percolation of rain water through the soils and highly jointed shale. Soil creep is a very common phenomenon in Disang terrain. The soil creep is manifested in the curved trunks of trees and slowly collapsing retaining walls (7.4). Poor drainage also affected some of the slopes, particularly those having unconsolidated overburden, thus offering easy access to percolating waters and leading to slope instability. The drainage patterns found in this area are mostly trellis, parallel, angulate and some dendritic. Most of the stream channels in the area of investigation are controlled by geological structures.
Toe erosion at lower levels by streams has also led to the loss of shearing strength by removal of the support at the lower levels. The terrain exhibits moderate to high relief which also renders it susceptible to slides.

The two triggering factors of landslides in the study area are human activity and excessive rainfall. Landslides in the area are caused due to over-steepening of hill slopes and increase in pore-water pressure. Anthropogenic activity has helped the natural processes to bare the slopes. The agricultural practices of any given area determine the degree of mass wasting, soil erosion, siltation, and other ecological imbalances. Faulty land use practices such as jhum cultivation, water storage in paddy fields and lower areas, constructional activities on steep slopes, etc. have caused irreparable loss to the environment and aggravated the problems of landslides (Plate 7.5). In Nagaland, jhum/shifting cultivation has been practised for centuries. Throughout the region population and economic pressures have shortened the rotation period of this land thus decreasing the stabilizing influence of vegetation in the study area. In many areas shifting cultivation is rampantly being practiced. The existing vegetation cover too has been disrupted by landslides and gullying in areas where erosion is initiated or accelerated by activities including road constructions and depletion of natural vegetation by clearing, grazing, and burning (Plate 7.6). Most of the road construction is substandard and has greatly increased the landslides incidence along the National Highway 39. The combined effect of erosion of the slope, weight and vibrations caused by the vehicular traffic on the semi-consolidated mass, and build-up of pore pressure are the main factors that contribute to slope failure.

Thus, any activity that increases hillside gradients, under cuts earth materials, adds weight to the slopes, or produces more water can lead to instability and set the stage for land-sliding. Highway or road constructions have directly or indirectly caused landslides. In the study area, most landslides occur along hillsides that are cut and the design and slope stabilization structure is inadequate. The soil cover in the area can support a luxuriant growth of vegetation, but the practice of shifting cultivation has exposed soil to water action resulting in extensive erosion and slope instability (Plate 7.7). Terrace cultivation along the slopes where shale is predominant have a disastrous
effect upon soil stability. Water stored in paddy fields also induces landslides. This would be because of the greatly increased pore-water pressure generated on the soils due to retention of large amounts of water for the paddy plants. It is also noted that most of the area under terrace cultivation are actually palaeoslide zones (Plate 7.8).

Most of the landslides in study area have been initiated during intense monsoon precipitation. Cloudbursts are very common phenomena in this region. It is noted that in cases of cloudburst extending for long durations large scale devastation occurs. Investigations of the phenomena have revealed that this damage is worse than that inflicted by the combined effect of rainfall of the whole year. In the study area, continued rainfall of lesser intensities has triggered off landslides at numerous places. Because of the high amounts of rainfall and the occasional cloudbursts, surface run-off is very high as also the case with waters percolating into the surface.

Landslides and other related mass movements cannot be totally prevented, however, their frequency and severity can certainly be minimized through appropriate and timely biological, geological, and engineering measures. Minimizing rock excavation and predicting the safety and behaviour of rock slopes, whether for highways, townships, mines, etc, should be the common objectives of geologists and civil and mining engineers. It is important in landslide investigations to determine whether the driving forces that seek to change hillside equilibrium exceed the resisting forces that operate to maintain slope stability. The rational design of rock slopes is particularly important where slopes are steep and cost of slope design is optimum. The resultant long-term savings should justify the greater initial investments in time and money, in as much as maintenance and repair costs for land-sliding and landslide-caused damage.
Plate 7.1: Crumpled Disang shales

Plate 7.2: Fault scarp in Bazail
Plate 7.3: Streams channel along fault plane

Plate 7.4: Soil Creep in Disang
Plate 7.5: Anthropogenic activity and landslide

Plate 7.6: Burning of forest cover
Plate 7.7: Shifting cultivation

Plate 7.8: Paleoslide zone
Some of Landslide Photos taken During Field Work

Plate 7. 9: 160 km slide along NH 39

Plate 7.10: 170 km slide

Plate 7.11: Džūza slide
Plate 7.12: Zuboa slide

Plate 7.13: Crown and Scarp of Keviisa slide

Plate 7.14: Below Merima slide
Plate 7.15: Adj. Keziekie slide

Plate 7.16: PWD slide

Plate 7.17: A.G slide
Plate 7.18: BKTF slide

Plate 7.19: Naga Bazar slide with Keziekar slide (back view)

Plate 7.20: Below Assam rifle slide
7.2 CONCLUSIONS

- On the basis of landslide hazard zonation and risk maps, landslide risk management programmes can be planned in order to check possible risk to land, property, and human lives. Further, the areas identified in the zonation map as highly susceptible to landslide may be considered for short or long term remedial or control measures.

- It is also noted that slides often occur at the sites of earlier slides. Failure is due to loss of shearing strength of the debris in the palaeoslide zone. Hence, the palaeoslide zones should be identified and thoroughly mapped which are the potential zones. It has been observed that the occurrences of past landslide events (as evident from Kiezekie slide) (Fig.6.4) overlap with the most hazardous zone obtained in the present study. Many slopes in this zone have already reached the geologic threshold of equilibrium and in equilibrium state as is evident from soil creeps, shifting of springs, tilting of trees at some places etc.

- To evaluate hazard, a complete record of past landslides from which to derive their frequency of occurrence is required. In the present study area, there is no landslides database. However, due to lack of information on the temporal occurrence of landslides for most of the investigated sites, in the present study, the landslide frequency analysis is based on the field work and satellite imagery. Hence it is suggested that landslide database should be prepare and keep it available to the planners concern.

- In the present attempt to correlate the landslide and rainfall, the exact temporal relation could not be derived due to unavailability of data and more over the rainfall data available might have been just an approximation. It is found that in Kohima area, the annual average rainfall is less when compared to Sechu area, though the number of landslides are more in Kohima area. Hence in Kohima area, long duration of rainfall without dry intervals with lesser intensity influence the
initiation of landslide. From the analysis, it can be said that structure and lithology are the main factors contributing the landslides in Kohima town. For detailed investigation, it is necessary to install more rain gauges at various places to obtain more accurate and detailed data.

- Since surface waters is one of the factor causing slides, appropriate drainage facilities should be provided where the slope materials are susceptible to erosion, particularly under unfavourable groundwater conditions. As far as possible, the water should not be allowed to enter the landslide zones. This includes both the present landslides and the palaeoslide zones. Surface channels must also be constructed around the crown of slides to prevent sheet-wash from entering the landslide areas. It is necessary to remove excess water from the subsurface too so as to reduce the pore-water pressure below that which can cause slope failure.

- Anthropogenic induced construction of the road has added further to the instability of the area. Human activity along the road is to be regulated. The method of construction of roads including realignment in the identified high hazard zone is to be improved.

- The slopes ranging from 15°-35° may be utilized for terrace cultivation and horticulture and efforts may be made toward afforestation. Precipitous slopes, i.e. those slopes greater than 35° should not be disturbed for any developmental activities.

- With adequate weather forecasting abilities and careful analyses of cumulative rainfall patterns it may be possible to predict to some degree the landslide hazards during a particular rainy season. If it appears that an oncoming storm will bring rainfall exceeding the threshold, then the public may be warned of the potential landslide hazards, and those homes situated in areas where sliding has occurred in the past may be safely evacuated or closely observed so that lives and property might be saved in the event if land-sliding is renewed.
• GIS provides a tool for effective in the planning, policy and decision-making process through the data integration and modeling. An attempt is made to apply the various GIS models for the present study. The use of these models in this rugged terrain is found to be quite suitable where the whole terrain can analyze and view in 3-D perspective.

• The landslide hazard maps generated using GIS for this area can serve as management tools, which can be replicated elsewhere under similar environs.

• From the present study, it can be concluded that there exists a linear and positive correlation between, the impacts of human activities and landslide in most part of the study area coupled with rainfall and unstable landform.

• Based on the identified risk areas, appropriate long-term and short-term strategies are recommended for landslide management.

Suggestion of further study for a comprehensive and in-depth analysis comprising of the following steps may be adopted

• Detailed geotechnical investigations are very important for the prediction of landslide risk. Such investigations should aim at analyzing the shearing strengths of the various clays and deposits of soils. The safety factor should be calculated for all types of soils before any developmental works are executed. The evaluation should also include an analysis of the slope stability characteristics of the terrain, incorporating factors such as the size and shape of unstable masses, the nature and composition of rock types, detailed attitude of joint and bedding planes, water conditions of the area, seismic triggering of landslides and other factors. Thus, a combination of geologic, geomorphic, and hydrologic studies with soil and rock mechanics is necessary. The data should be evaluated in terms of a total benefit-cost ratio.
7.3 RECOMMENDATIONS

Landslides in the high relief, high rainfall, geologically young and incompetent, tectonically disturbed and high seismic zone of study area can not be avoided totally. However, their frequency and adverse effects can be minimized to a fair extent by adopting certain remedial measures. Based on the analysis of the result, experience acquired during field survey and interaction with the local people and local governments, all the possible recommendations are categorized into

i) Legal and regulatory approach
ii) Environmental and land use approach
iii) Engineering approach
iv) Economic approach
v) Social approach

These five approaches of remedy are explained below and this list will be useful to the planners, administrators and engineers.

7.3.1 Legal / Regulatory Approach

i) Setting up landslide management and regulatory board (Apex committee) must be the top priority for the following functions. This Apex committee should be supported by regional committees and sub-committees under online networking system.

a) Landslide digital database should be established.

b) Establish protocols and research program for landslide assessment, landslide hazard delineation, mapping, collection and dissemination of information using modern technologies such as Geoinformatics.

c) Regularisation and monitoring for construction and allied activities in and around the high risk zone.

d) Through land-use planning, any type of construction or development activities in the identified high hazard areas should be cleared only after appropriate remedial measures. The different hazard prone zones must be
clearly identified and defining the type of activities to be carried out in each zones and preventing the activities that could be hazardous. This approach should aims to assemble land uses or activities with compatible environmental requirements in the area.

c) Real-time monitoring of active landslides by GPS networking methodology.

f) Installation of warning system for the events like earthquake, unusual rainfall.

7.3.2 Environmental and Land Use Planning Approach

a) Environmental Approach

i) There should be a proper land use planning and adopt effective land use regulations.

ii) In the high hazard area management plans, attention is to be paid to both on environment and human aspects, which are to be managed with the ultimate goal of achieving an ecological balance with the land use activities.

iii) For any management plan, Environmental Impact Assessment must carried out before execution.

iv) Creation of buffer around the landslide sensitive zone for prevention of any activity within the buffer zone. This will help land use and EIA planning activities simultaneously.

b) Land Use Planning Approach

i) Areas covered by degraded natural vegetation in upper slopes are to be afforested with suitable species.

ii) Plantation of fast growing deep rooted trees such as eucalyptus, alder, and willows like Salix tetrasperma and Salix ichtnostachya Lindl in the lower reaches of slide zones will help control slides (174 km slide).

iii) Intensive afforestation covering the slide areas and their surroundings, preferably grass so as to prevent water from seeping through. The reason for
choosing grass is that it is light and its root system forms matted structures that do not allow too much of water to penetrate the surface. This will prevent the soil erosion and will also arrest further lateral progression of slides.

iv) Perennial shrubs and trees need to be planted on landslide prone slopes. The roots of which will act as anchors to prevent mass movement. This is done at Zubza slide with good results.

v) Biotechnical slope stabilization is generally cost effective as compared to the use of structural elements alone. This will increases environmental compatibility, and allows the use of local natural materials.

7.3.3 Engineering Approach

i) This should include the feasibility in analysis of geologic, slope and hydrologic conditions at the site to ensure the physical effectiveness of the remedial measure.

ii) Removal of loose debris to reduce the dead load (180 km slide). Terrace/benching structure may be constructed for slope reduction.

iii) Improvement of the drainage system by providing catch water drains at the crown, toe, and sides of the slide area for channelising the rainwater (174 km slide). The drainage system should be so planned that surface runoff should be led to such site where the running water will not affect the area. Subsurface waters should be properly drained so that the soil is not allowed to saturate. Water from above the slide channelised along drains on the sides of the road as in case of Peducha slide (Fig. 6.5).

iv) Toe and surface erosion must be controlled by constructing grip walls at the lower reaches of slide zones (Lower Chandmari slide).

v) The drainage at the foot of fault scarps, and at heads of slide zones, should be carefully diverted (Lalmati slide). Water should be prevented from seeping through. Surface and subsurface drainage are important to divert undesirable surface flows.
vi) It is recommended that impermeable material such as mortar or asphalt be sprayed at the crown and head regions to seal or plug tension cracks and other permeable areas that provide avenues for excessive water infiltration (170 km slide). Polythene sheets may also be used temporarily.

vii) As the affected slopes have unconsolidated overburden material, which offer easy access to the percolating water, the surface run-off easily saturates the slope forming material leading to instability. The grass/bushes on slopes should not be removed as far as practicable to keep the area covered with natural vegetation.

viii) Some measures that should be taken up to prevent further sliding in the slide zones include construction of catch water and deep trench drains for certain slide zones. These will prevent erosion of the debris. They should be interconnected to intercept and divert surface waters along hill slopes. Such drains should be properly lined. Waters flowing along such drains should be led into properly lined culverts at road level from where the same can be led into surface stream channels.

ix) The stability of slopes can be improved by installation of bamboo or wooden stakes. Such measures are purely temporary and are to be used for short term benefits only. Such nails or stakes help in stabilizing slopes by preventing surface erosion of slide areas. Bamboo check dams should be constructed so as to check the downhill slide of material (174 km slide).

x) Retaining walls are used to increase the resistance to slide movements and are generally installed at or near the toe of unstable areas. Such structures should have deep foundations with weep holes for smooth passage of water. To increase their efficiency they must be anchored with tie rods to adjacent stable terrain. The backside of retaining walls must contain adequate drainage to divert water build up. Retaining walls of appropriate design should be constructed to protect slopes.

xi) Retaining walls should be constructed along the roads to prevent debris from further flowing down. It should penetrate beyond the surface of sliding and the wall located must not give additional loading. Provisions should also be made to allow excess groundwater to flow out thereby lowering the water
table during the monsoon (Keziekie slide). This may be achieved by siphoning out the water. This will considerably increase the shear resistance of the soil.

xii) The landslides along the highways are directly related to flowing water, both surface flows and underground seepage. Construction of watertight drains along the road to collect the surface and seepage water and their release either below the road surface through culverts or diversion into nearby streams can be undertaken. This has produced good result at the Zubza area.

xiii) Construction of heavy buildings should be avoided in order to avoid excessive loading on slopes. Care should be taken while excavating for road, it should be in such a way that the road cuttings are gently sloping towards the road. The overburden hanging towards the road are to be removed. In landslide areas like those at Zubza and Peducha, the process may have to be carried out for long period of time. It took more than 15 years of slope management to partially stabilize the slope at Zubza. Efforts for the last 4 years did not produce any tangle results at Peducha.

7.3.4 Economic Approach

i) The planning of mitigation measures and maintenances should be in terms of cost benefits ratio.

ii) Economic feasibility should take into account the cost of the remedial action to the benefits.

7.3.5 Social Approach

i) Awareness should be created among the people about the hazards.

ii) Post warnings of potentially hazardous areas and educate the public about areas to avoid, such as; (a) existing old landslides, (b) on or at the base of a slope, (d) at the base or top of an old fill or steep cut slope.
iii) Educate the public about tell-tale signs that a landslide is imminent so that personal safety measures may be taken.

iv) People’s participation.

7.3.4 Main Causes of Landslides and Remedial Measures

A summary of the landslide causes and remedial measures based on the present analysis, which can be adopted for the study area, Kohima and its surroundings is given in Tables 7.1.

Table 7.1: Landslide Main Causes and Remedial Measures

<table>
<thead>
<tr>
<th>Name</th>
<th>Main Causes</th>
<th>Remedial Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH 39, Peducha slide (160 km)</td>
<td>Toe erosion, weight due to building, vibrations of traffic on semi-consolidated mass, and build-up of pore water pressure</td>
<td>Diversion of water, construction of grip wall, plantation of fast growing and deep rooted plants, reinforcement of bamboo/wooden stakes</td>
</tr>
<tr>
<td>NH 39, Sinking zone (162 km)</td>
<td>Paleoslide, water, shear zone</td>
<td>Diversion of water, retaining wall, reduction of water seepage.</td>
</tr>
<tr>
<td>NH 39, Lalmati slide (Between 162-163 km)</td>
<td>Tectonic contact zone, faults, weathered shale, poor drainage, &amp; severe topography</td>
<td>Relieved of banana plants at the site, removal of excess water, plantation of grass cover, diversion of drainage at to foot of fault scarp, construction of surface and sub-surface drainage.</td>
</tr>
<tr>
<td>NH 39, Zubza slide (170 km)</td>
<td>Soil creep, rainfall, loss of shearing strength of debris, palaeoslide zone</td>
<td>Construction of surface drain to divert surface flow, removal of debris, sealing of tension cracks, plantation, retaining wall, removal of excess groundwater.</td>
</tr>
<tr>
<td>NH 39 Kevuza slide (174 km)</td>
<td>Active fault, loose debris, soil creep, heavy and prolonged rainfall</td>
<td>Construction of catch water and deep trench drains, Bamboo check dams.</td>
</tr>
<tr>
<td>Dzaza ru slide (below Zubza)</td>
<td>Paleoslide, water, soil creep, loss of shearing strength</td>
<td>Construction of surface drain to divert surface flow, sealing of tension cracks, removal of excess water.</td>
</tr>
<tr>
<td>Sinking zone (south of Sitsie Ru - between 179-180 km)</td>
<td>Shear zone</td>
<td>Diversion of drainage, plantation, reduction of water seepage.</td>
</tr>
<tr>
<td>180 km slide (north of Sitsie Ru, NH 39)</td>
<td>Faults, joints, lithology</td>
<td>Benching, plantation of grass</td>
</tr>
<tr>
<td>181 slide km (along NH 39)</td>
<td>Weathered shale, shear zone, sub-surface water</td>
<td>Removal of sub-surface water, construction of retaining wall.</td>
</tr>
<tr>
<td>Location</td>
<td>Shear Zone, Lithology, Water, High Density Settlement</td>
<td>Removal of Sub-Surface Water, Avoidance of Constructions</td>
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<tr>
<td>---------------------------</td>
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<tr>
<td>Naga Bazar slide</td>
<td>Palaeoslide, Lithology, Water, Topography, High Density Settlement</td>
<td>Removal of Sub-Surface Water, Avoidance of Constructions</td>
</tr>
<tr>
<td>Keziekie slide</td>
<td>Shear Zone, Water, Lithology, Anthropogenic Activity</td>
<td>Retaining Walls, Grass Cover, Proper Drainage, Avoidance of Constructions</td>
</tr>
<tr>
<td>BRTF Camp slide (High School Area)</td>
<td>Subsurface Water, Rainfall, High Density Settlement</td>
<td>Construction of Subsurface Drains, Retaining Walls</td>
</tr>
<tr>
<td>Forest Colony Sinking Zone</td>
<td>Palaeoslide Zone, Water, Settlement</td>
<td>Improvement of Drainage System, Avoidance of Constructions, Minimize Water Seepage</td>
</tr>
<tr>
<td>PR Hill Sinking Zone</td>
<td>Shear Zone, Water, Heavy Structures</td>
<td>Subsurface Drains, Avoidance of Constructions</td>
</tr>
<tr>
<td>Merhulietta Sinking Zone</td>
<td>Heavy Structures, Water</td>
<td>Reduction of Load, Minimizing of Water Seepage, Construction Retaining Walls</td>
</tr>
<tr>
<td>Officers' Hill Slide (below Indoor Stadium)</td>
<td>Shear Zone, Toe Erosion, Subsurface Water, Topography</td>
<td>Retaining Wall on Side of Stream, Water Seepage to be Prevented, Vegetative Cover</td>
</tr>
<tr>
<td>Officers' Hill Slide (below AR Rest House)</td>
<td>Exposed Surface, Topography</td>
<td>Vegetation Cover, Retaining Wall</td>
</tr>
<tr>
<td>Phezhu Sinking Zone</td>
<td>Shear Zone, Slope, Water, Human Activity</td>
<td>Retaining Walls, Water Seepage to be Prevented</td>
</tr>
<tr>
<td>Potter Lane Slide</td>
<td>Slope, Lithology, Structure</td>
<td>Slope Reduction, Water Seepage to be Prevented</td>
</tr>
<tr>
<td>Lower AG slide, Kohima</td>
<td>Neotectonism, Toe Erosion, Reduction of Shearing Strength of Debris due to Subsurface Water</td>
<td>Diversion of Stream, Retaining Wall to Stop Toe Erosion, Minimizing Seepage of Water in the Area</td>
</tr>
<tr>
<td>Assam Rifles Slide</td>
<td>Slope, Lithology, Structure</td>
<td>Retaining Walls, Water Seepage to be Prevented</td>
</tr>
<tr>
<td>Lerrie Sinking Zone (along NH 39)</td>
<td>Fault, Shear Zone, High Water Table, Topography</td>
<td>Retaining Walls, Water Seepage to be Prevented, Avoidance of Constructions</td>
</tr>
<tr>
<td>Lower Chandmari Slide</td>
<td>Shear Zone, Toe Erosion</td>
<td>Retaining Walls, Check Dams, Water Seepage to be Prevented</td>
</tr>
<tr>
<td>AG Road Sinking Zone</td>
<td>Shear Zone</td>
<td>Water Seepage to be Prevented, Construction of Culvert</td>
</tr>
<tr>
<td>Midland Sinking Zone</td>
<td>Shear Zone, High Water Table, Toe Erosion</td>
<td>Water Seepage to be Prevented, Check Dams, Retaining Walls</td>
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