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PROTOTYPE 1: 50,000 - SCALE MOUNTAIN HAZARDS MAPPING IN NEPAL

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ABSTRACT

Hazards mapping in Nepal is in its infant stages, but holds the potential of playing an important role in efforts to deal with environmental degradation. This paper presents a method for applied 1:50,000-scale geomorphic hazards and risk mapping in the mountains of Nepal. The techniques used take into account the many limitations encountered in terrain mapping here. Hazards maps not only catalogue and document geomorphic problems but also give to decision makers a valuable tool for assessing terrain conditions over large areas and for developing action priorities.

INTRODUCTION

The Himalaya of Nepal is frequently used as an example of a high-energy mountain environment under going rapid denudation. This paper presents a method for applied 1:50,000-scale geomorphic hazards and risk mapping in the mountains of Nepal. The Hazards mapping component of Resource Conservation and Utilization Project (R.C.U.P.) directly addresses Nepal's environmental problems and provides necessary first steps in corrective action, focusing on the districts of Gorkha, Myagdi, and Mustang (Fig. 1). The primary goals of the hazards mapping component of RCUP were to: 1) develop a useful method of rapidly assessing geomorphic terrain within the many restraints inherent in a developing nation such as Nepal; 2) locate major environmental problems areas in the RCUP areas; and 3) provide hazard and risk maps of these areas as a basis for developing priority-area interventions (White, Fort and Shrestha, 1983). Our mapping work is more practical-oriented than previous research-oriented maps such as Kakani area (Ives and Messerli, 1981; Kienholz, et.al., 1983; and Kienholz, et.al., 1983) and Ankhu Khola area (Thouret J-C. 1983).

Collection of Data

About 80% of the study area was visited on the ground, to collect such data as rock types, major rock structures (major cleavages, fracturation, dips), surficial deposits (alluvial, colluvial, lacustrine, glacial), landforms, and any information which local residents could provide on hazard problems and chronology of these events. For the actual mapping of geomorphic hazards, we found the most useful technique to be inspection

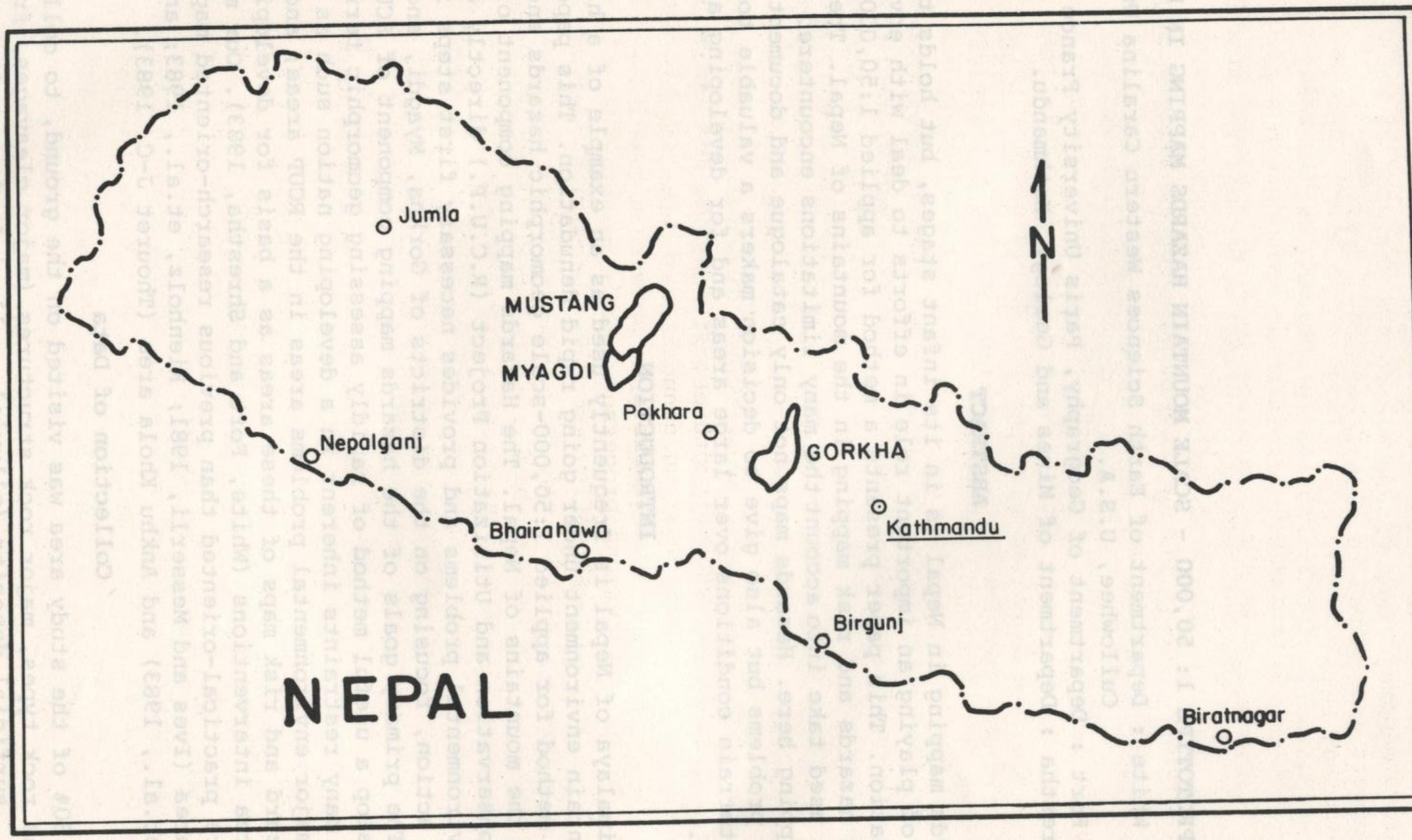

FIGURE I. Locations of Areas Mapped in this Study of slopes from opposite divides, often using binoculars, and supplemented by site visits and surface photographic documentation. 1:20,000 (nominal) black and white vertical aerial photos facilitated completion of the geomorphic - mapping. They provided more consistency and accouracy in the final products and helped in transferring from field-work scale to 1: 50,000 mapping scale.

In the later stages of our work all information gathered from the ground and aerial photography was placed on 1:50,000 topo-maps (as base maps).

Under optimal conditions hazards mappers should have at their disposal or have the capability of producing a set of detailed resource maps which show such information as soils, vegetation, geology, hydrology, slope, precipitation patterns, and land use. With each of these maps in transparent overlay form, and by sandwiching these with geomorphic information, hazards analysis is greatly facilitated. Since we could, in the time available, produce only the maps of geology and geomorphic information, the other resource data had to be integrated and studied in one step from stereo aerial photographs supplemented by field-gathered information.

Maps of Geomorphic Features

Since our final aim was to produce geomorphic hazards and risk maps, a major step toward this goal was the compilation of a complete set of 1:50,000-scale maps of geomorphic features for the RCUP district areas.

The legend of geomorphic features which resulted (Fig. 2) has five principal categories: 1) rock structures, 2) deposits, 3) erosional denudational forms, 4) mass-wasting denudational forms, and 5) alpine forms. At this scale it is not feasible to show such important, but small-scale, geomorphic features and processes such as weathering, rainsplash erosion, rilling, piping, sheetflow erosion, and vey small landslides that were obseved in the field. In addition, we opted to lump together certain features and processes which produce similar hazard consequences. Special care was given to mapping for former, in active mass-wasting landforms, since they are associated with displaced material which nowadays is the most prone to new mass-wasting features. Figure 3 shows a sample of a geomorphic features map.

Maps of Geomorphic Hazards and Degrees of Risk

Geomorphic hazards here refer to those landform processes which create surface instability and result in substantial surface change over a relatively short time period (e.g., ten years). Our study areas are, with the exception of the highest alpine zone, subject to human activities, and due to the difficulty of identifying all human activities in all areas, we chose to assume that any sighificant geomorphic process in mountain Nepal is either a direct or indirect threat to humans and is, as such, a hazard. However, as in the case of geomorphic features mapping, we had to limit our consideration to those hazards which we judged significant at a scale of 1:50,000. Although this is a limitation for decision-makers and analysts at the panchayat or lower levels, it is the sort of generalization necessary for processing complex information from large areas.

For the hazards maps, the emphasis was placed on defining hazards mosaics or combinations rather than locating individual geomorphic features. The basic unit area of these maps is the <u>hazard unit</u>, any delineated area of the surface in which operate one or more hazardous geomorphic processes in a combination or of a magnitude unique to that area relative to adjoining surface areas having different hazard characteristics. In many cases the boundary of a hazard unit is indefinite and transitional rather than abrupt. Implied in the concept of a hazard unit is that the defined

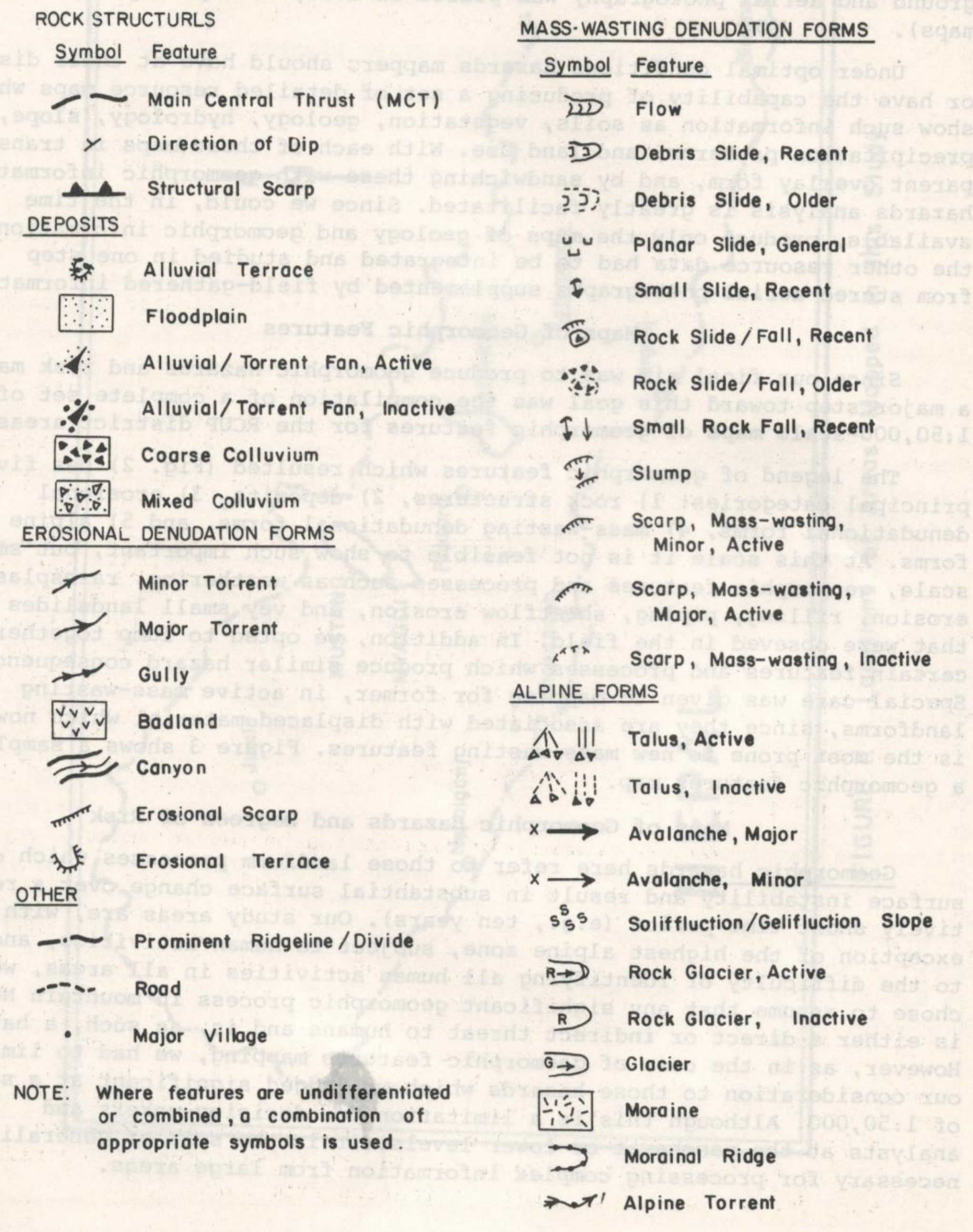

FIGURE 2. Legend for Maps of Geomorphic Features.

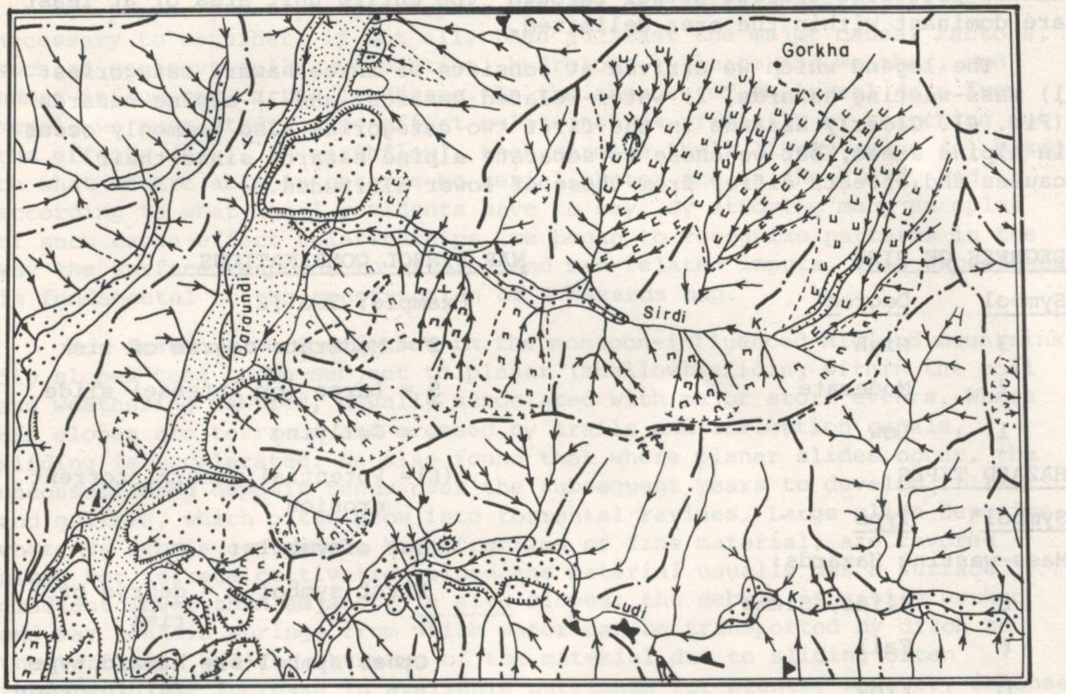

FIGURE 3a Geomorphic Features of a Portion of the Gorkha District, Nepal

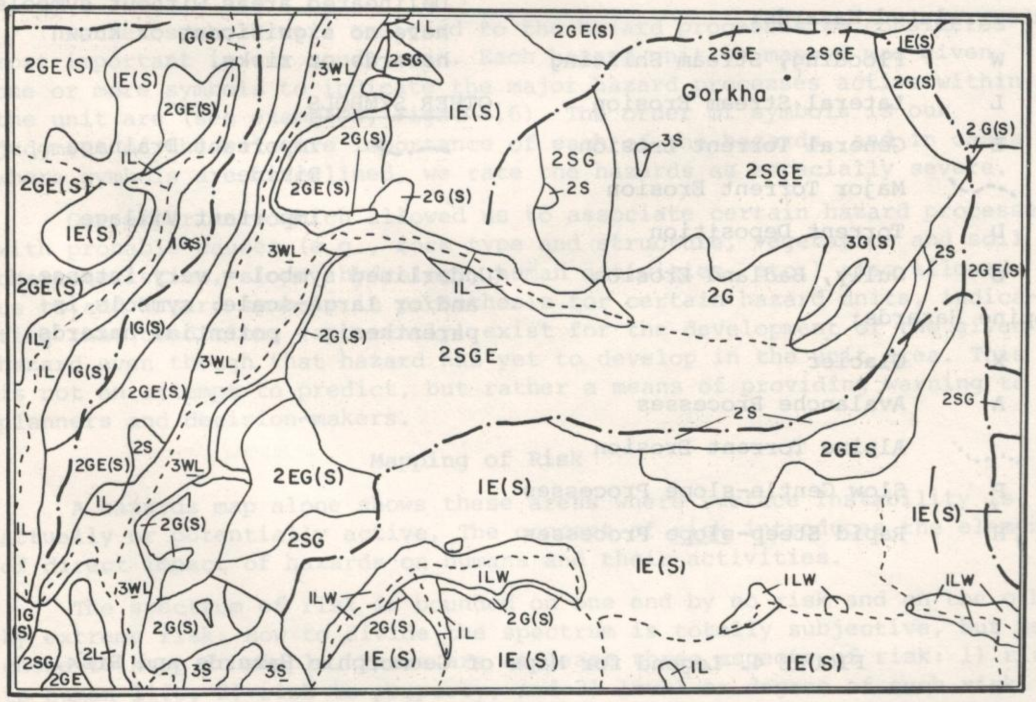

FIGURE 3b Geomorphic Hazards and Risk Map of a Portion of the Gorkha District, Nepal

nazard processes operate either through the entire unit area or at least are dominant within the area delimited.

The legend which we arrived at consists of three hazard categories: 1) mass-wasting hazards, 2) water-related hazards, and 3) alpine hazards (Fig. 4). Clearly hazards in the first two categories also commonly occur in alpine areas, but we chose to separate alpine hazards since their causes and effects differ from those of lower altitudes.

DEGREES OF RISK

Symbol	Degree
3	High
2	Moderate
1	Low

HAZARD TYPES

Symbol*	Type
Mass-wasting Hazards:	
S	Slide, Slump
F	Fall
O	Flow
T	Talus Deposition
Water-related Hazards:	
W	Flooding, Stream Shifting
L	Lateral Stream Erosion
E	General Torrent Erosion
	Major Torrent Erosion
D	Torrent Deposition
G	Gully, Badland Erosion
Aopine Hazards:	
X	Glacier
A	Avalanche Processes
	Alpine Torrent Erosion
P	Slow Gentle-slope Processes
H	Rapid Steep-slope Processes

MAP SYMBOL COMBINATIONS

Example: 2SG (E)

2 = Moderate degree of risk

S = Large (or intense) slide

G = Gullying

(E)= Potential general torrent erosion

Order ofsymbols:

First symbol = degree of risk

Other symbol(s)= hazard type (s) in order of importance

Delineated areas without symbols have no significant or known hazards or risks.

OTHER SYMBOLS

Important Drainage Divide

Important Village

*Underlined symbol = very intense and/or large-scale; symbols in parenthesis = potential hazards.

FIGURE 4. Legend for Maps of Geomorphic Hazards and Risk.

To properly analyze geomorphic hazards and their dynamics, it is necessary to consider, if not all, then at least the major causal factors, such as geology, soils, vegetation, hydrology, climate and weather, and human influences on the landscape. In the absence of empirical data from Nepal, we must study cause-effect relationships primarily by searching out the effects (e.g., an earthflow), then surmise their likely cause (s) based on what we are able to observe on aerial photos and in the field, and according to what local residents have to say. By studying many examples of such cause-effect relationships, we began to recognize patterns in the way the surface responds to natural and man-related inputs. This experience is fundamental to the construction of a hazards map.

For instance we found that in the monsoon-influenced Midland mountains, dip slopes tend to be subject to planar (shallow) sliding within the soil and weathering mantles, usually associated with major storm events. Where dip slopes are terraced and crossed by trails and irrigation canals, sliding is accelerated. We also found that where planar slides occur, the unconsolidated deposit tends over the subsequent years to develop rills and gullies, which often grow into torrental ravines. Large slide deposits, where the debris contains a high fraction of fine material, are favored sites for terrace cultivation since the material usually has a surface gradient lower than adjacent in situ slopes; the debris is easily worked and may contain springs from which water can be transported by ditch to the terraces; and the churning of the material due to sliding often results in the increase in available nutrients for plants. However, intense landmanagement frequently results in continued small-and/or large - scale recurrence of sliding on these deposits.

Latter symbols were assigned to the hazard processes we considered most important in our study area. Each hazard unit we mapped was given one or more symbols to indicate the major hazard processes active within the unit are (see examples, Figs. 5,6). The order of symbols is our judgment of the relative importance of each of the hazards, and in cases where symbols are underlined, we rate the hazards as especially severe.

Our experience which allowed us to associate certain hazard processes with probable causes (e.g., rock type and structure, vegetation and soil characteristics, slope, hydrology, human activities, etc.) also allowed us to add hazard symbols in parenthesis for certain hazard units, indicating that conditions (apparently) exist for the development of the given hazard even though that hazard has yet to develop in the unit area. This is not an attempt to predict, but rather a means of providing warning to planners and decision-makers.

Mapping of Risk

A hazards map alone shows these areas where surface instability is actually or potentially active. The concept of risk introduces the element of direct impact of hazards on humans and their activities.

The spectrum of risk is bounded on one end by no risk and on the other by extreme risk. How to divide the spectrum is totally subjective, but we chose to keep it simple. There are at least three aspects of risk: 1) risk to human life, 2) risk to property, and 3) level or degree of such risk. We consolidated these aspects into the following classification of risk (see Figs. 4 and 5):

FIGURE 5a. Geomorphic Features of a Portion of the Mustang District, Nepal

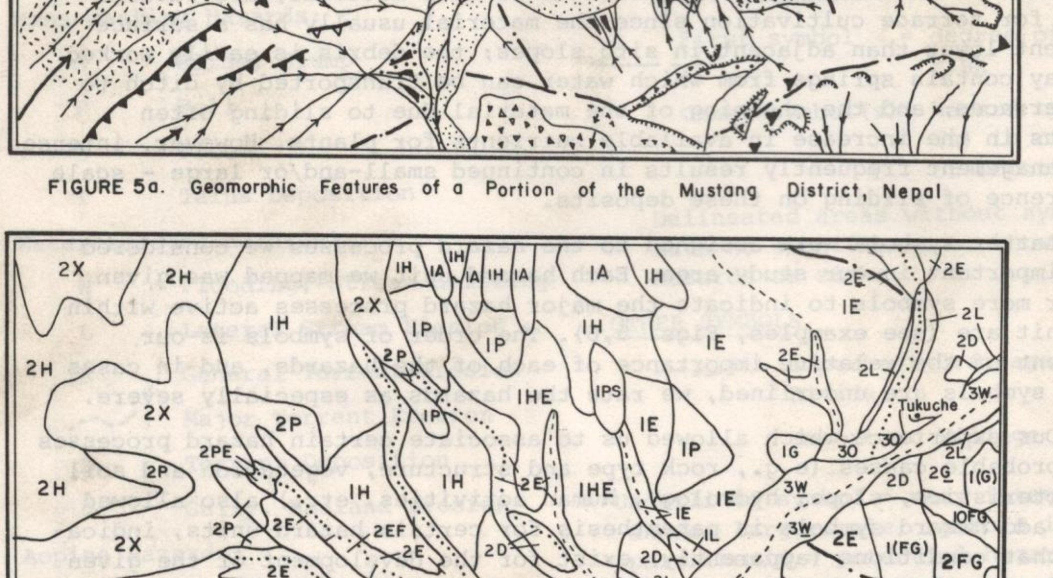

FIGURE 5b. Geomorphic Hazards and Risk Map of a Portion of the Mustang District, Nepal

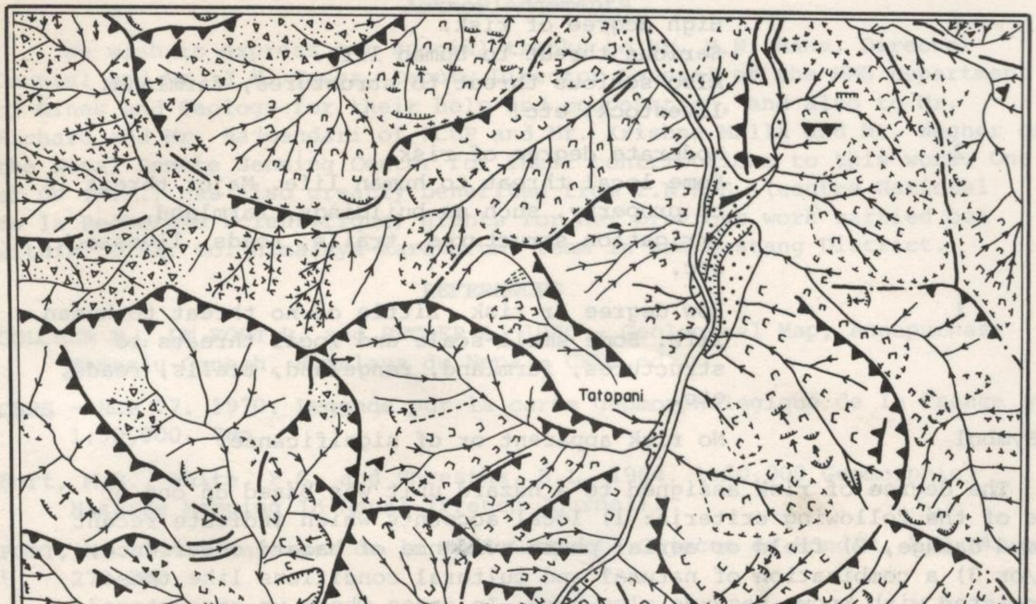

FIGURE 6a. Geomorphic Features of a Portion of the Myagdi District, Nepal

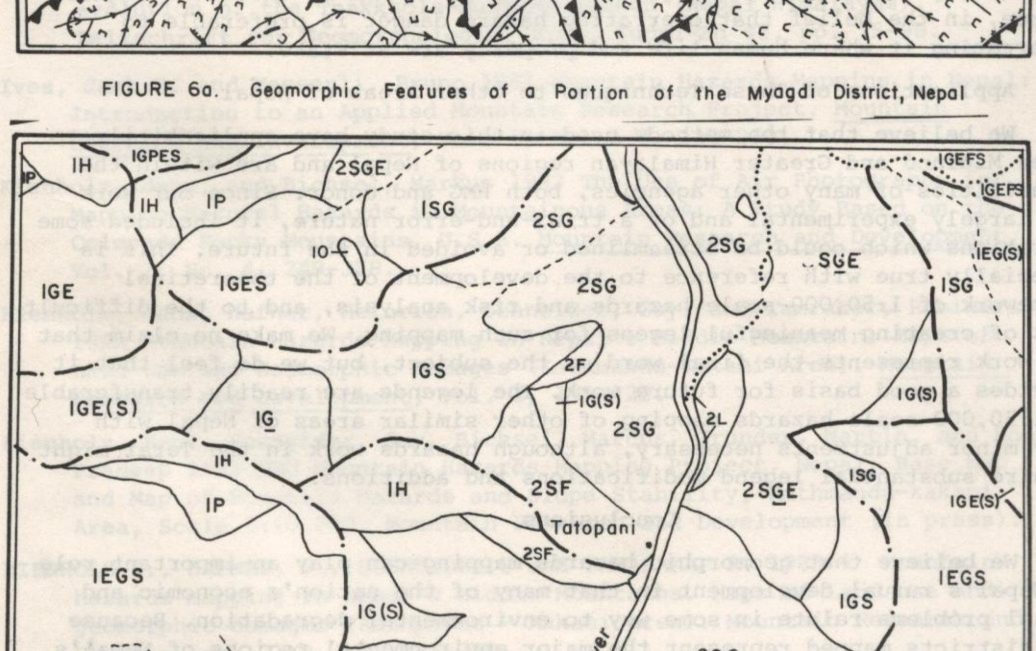

FIGURE 6b. Geomorphic Hazards and Risk Map of a Portion of the Myagdi District, Nepal

Degree of Risk	Definition
3	High degree of risk. Serious threat to human life. Also serious threat to structures, farmland, livestock, etc.
2	Moderate degree of risk. Some local threat to human life. Major threat is to property, such as buildings, farmland, irrigation structures, trails, roads, livestock, etc.
1	Low degree or risk. Little or no threat to human life. Some small-scale and local threats to structures, farmland, rangeland, trails, roads, etc.
No Symbol	No risk apparent or of significance.

The degree of risk assigned to a hazard unit was based on one or more of the following criteria: 1) local accounts which indicate recent hazard damage, 2) field or aerial photo evidence of hazard occurrence, and/or 3) a combination of natural and cultural conditions like those associated with known hazards elsewhere. In cases where we encountered uncertainty in assigning a degree of risk, we tended to chose the higher degree, in the belief that overrating hazard danger is preferable to underrating it where human life and property are at stake.

Applications of These Techniques to Other Areas of Nepal

We believe that the methods used in this study have applicabitily to other Midland and Greater Himalayan regions of Nepal and are within the capabilities of many other agencies, both HMG and donor. Since our work was largely experimental and of a trial-and-error nature, it included some operations which could be streamlined or avoided in the future. This is especially true with reference to the development of the theoretical framework of 1:50,000-scale hazards and risk analysis, and to the difficult task of creating meaningful legens for such mapping. We make no claim that our work represents the final word on the subject, but we do feel that it provides a good basis for future work. The legends are readily transferable to 1:50,000-scale hazards mapping of other similar areas of Nepal with only minor adjustments necessary, although hazards work in the Terai might require substantial legend modifications and additions.

Conclusions

We believe that geomorphic hazards mapping can play an important role in Nepal's rurual development in that many of the nation's economic and social problems relate in some way to environmental degradation. Because the districts mapped represent the major environmental regions of Nepal's Himalayas, the methods of hazards mapping presented in this paper provide a should basis for wide-ranging terrain analysis in Nepal and hopefully will stimulate new interest in this form of mapping.

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