Assessment of Hazard Potential Caused by Debris Flow of Chui-Sue River

Meei-Ling Lin,
Group Leader, Office for National S&T program for Hazard Mitigation
Professor, Department of Civil Engineering, National Taiwan University
Sin-Hern Lin, and Gee-Jeng Huang
Graduate Students, Department of Civil Engineering, National Taiwan University

Abstract

In this paper the assessment of hazard potential caused by debris flow of Chui-Sue river is developed. The concept of the hazard potential is based on the range of the area affected if debris flow occurred, and the effect debris flow would have considering the social and economic factors. Database needed for the study was established and operated under GIS environment. Area affected by flow and deposit of debris was determined using geomorphic data , and model for assessment was developed based on the effects of debris flow and its impacts on the social and economic aspects.

Introduction

Due to the vast development of economy, usage and development of the land in mountain terrain has grown rapidly for the available land in plane area is limited. However, the mountain terrain in Taiwan is usually very steep and with fragile geological conditions. Heavy rainfall carried by typhoon often caused severe hazard by inducing slope failure and debris flow. In 1996, typhoon Herb struck Taiwan, dumping almost 2000mm of precipitation. Severe debris flow occurred at the Chui-Sue river several times since then. The purpose of this research is to construct an assessment model for hazard potential, which could be provided as a base for decision making of hazard mitigation.

In this paper, the model for hazard potential assessment for debris flow river was developed according to the affected area and impact of debris flow on social and economic aspects. The hazard potential of the Chui-Sue river watershed will be used in verifying the model based on the data from the debris flow caused by typhoon Herb in this research.

Database and determination of area affected by debris flow

In order to perform analysis of debris flow hazard potential, it is necessary to construct database of the related natural environment information of the Chui-Sue river watershed, and to set up the structure of geographic information system. Subsequently, the database for social and economic factors used in the hazard potential analysis is also built into the same GIS system. The ArcView software is used as the spatial data demonstration system.

To perform the hazard potential analysis, it is necessary that the areas and thickness of deposition and erosion caused by the debris flow be determined. The hazard potential of the Chui-Sue river debris flow caused by the typhoon Herb was studied in this research and spatial analysis of the DTM data before and after typhoon Herb was performed. The watershed of the Chui-Sue river was determined using GIS and modified according to the contour and sunshade maps. The Chui-Sue river watershed with the elevation contour and sunshade map is as shown in Fig.1. For the Chui-Sue river watershed, the 10 m by 10 m digital terrain model was built using the aerial photos of the area before (1993) and after (1996) the typhoon Herb. By running a comparison of the elevations for each point with the same coordinates, the changes of the geomorphic condition of the area could be established. The microgeomorphic analysis of the watershed was performed then to identify the triggering area, flow area, and the deposit area in the watershed along the debris flow river. Also through the study, the amount of material eroded away and the amount of material deposited at the downstream area could be determined, and which could be used for the subsequent potential hazard study. Determination of the triggering area, flow area, and deposit areas was based on the variations of erosion and deposit of the terrain along the river and the characteristic of the debris flow mechanism. It was found that riverbed became wider and deeper, and the cross section changed from V shape into U shape after the Typhoon struck. The triggering area was identified as the area where the major action was erosion, the flow area was identified as the area where both erosion and deposit actions occurred, and the deposit area was identified as the area where the major action was deposit. Results of the study are as shown in Fig. 2. The amount of material eroded and deposited could be calculated according to the variation of the elevation. The total amount of material eroded away from the watershed was 8156397 m^3, and the total amount of material deposited in the area was 5123500 m^3. Therefore, there was a total loss of material of 3032897 m^3 from the watershed. With the microgeomorphic model built, the average thickness of deposit and erosion could be computed, and the result is as shown in Fig.3. The significance of the effects of debris flow on each designated area could be determined accordingly. These are the data to be used as input for the hazard potential analysis of the area.

Assessment model for hazard potential

The risk or hazard caused by the debris flow depends on the actual damages to human life and properties. Therefore, a hazard assessment model was developed, which took into account the effects of social and economic factors. The Shen-Mu area at the downstream of Chui-Sue river was selected as the research area, and administration subzones 8, 9,10, and 11 of Shen-Mu village were within this study area as shown in Fig.4.

To quantify the hazard induced by debris flow, it was necessary to determine the hazard potential factors that would have direct effects to the severity of damage. The hazard potential factors considered in this research were the distribution of population, values of production, and types of land use. For more population, the hazard potential posed by debris flow is higher, damages are larger with higher production value, and risk is higher for land used by public. When considering the possible effects caused by the debris flow, different thickness of deposit would result in different degree of severity of damage, the thicker the deposit, the more severe the damage is. Therefore, the thickness of the deposit also entered as a hazard potential factor, and the thickness of 2 m, which was a little lower than the height of one floor of building was considered critical for causing severe damage. By inspection of the risk factors and possible damages by the debris flow, it was found that the types of road could have a significant effect to subsequent recover and economic loss, therefore, the type of road was also chosen as a hazard potential factor. As a preliminary study of hazard potential assessment, the weightings of all the factors were all assumed to be 1. By combining all the ratings of hazard potential factors, and assuming normal distribution of the rated results, the total ratings of all subzones could be classified into low hazard potential, medium hazard potential, and high hazard potential. The results of the final hazard potential assessment are as shown in Table 1.

From the results of hazard potential assessment shown below, the hazard potential of the subzone 10 was the highest of all four subzones. This result is fairly consistent with the observation in the field, as the subzone 10 is the area right next to the outburst point of debris flow river..

Table 1 Evaluation of combined hazard potential of debris flow in Shen-Mu area

Subzone	Population rating	Landuse rating	Production rating	Road rating	Deposit thickness rating	Hazard potential	
						total	rating
8	1	3	3	1	3	12	Medi-um
9	3	1	1	1	3	10	Low
10	3	3	2	3	3	14	High
11	3	2	3	2	1	11	Medi-um

Conclusions

Based on the previous discussions, the following conclusions could be reached:

1. The database and geographic information system of the related natural environment information of the Chui-Sue river watershed was constructed in this study. The client-server spatial geographic database is used to demonstrate the natural environment of Chui-Sue river, as well as the social and economic information of the watershed

2. Based on the microgeomorphic analysis performed on the Chui-Sue river watershed, the triggering area, flow area, and the deposit area in the watershed along the debris flow river were identified. The total amount of material eroded away from the watershed was 8156397 m^3, and the total amount of material deposited in the area was 5123500 m^3, resulting in a net loss of material of 3032897 m^3 from the watershed. Average thickness of deposition and erosion of each subarea was computed. Thus, the significance of the debris flow on each subarea could be determined.

3. A hazard potential assessment model was established, which took into account the effects of social and economic factors. The Shen-Mu area at the downstream of Chui-Sue river was selected as the research area with administration subzones 8, 9,10, and11 of Shen-Mu village. From the results of hazard potential assessment, the risk of the subzone 10 was the highest of all four subzones, and which was fairly consistent with the observation in the field.

4. Although using the developed model for hazard potential assessment, the results appeared to be relatively satisfactory, and the method appeared to be feasible. However, there were not enough amount of samples for the rating and statistic analysis. Further study is needed and more data are needed for verification of the hazard potential assessment model.

References

[1] Lin, M. L., et. al., "GIS and Characteristics of debris flow rivers of Chen-You-Lan river watershed", NAPHM Annual Report, 1999.

[2] Williams, G. P. and Guy, H. P., "Debris avalanches-a geomorphic hazard", *Environmental Geomorphology, SUNY, Binghamton, N.Y.*, pp25-27.

[3] Marsal, R. J., " Mechanical properties of rockfill and gravel materials", Proceedings of the 7th International Conference on Soil Mechanics and Foundation Engineering, Vol.3, 1969, pp.499-506.

[4] O'Brien, J. S. and Julien, P. Y., "Physical process of hyperconcentrated sediment flows", Proceedings of the ASCE Specialty Conference on the Delineation of Landslides, Floods, and Debris Flow, 1985, pp.260-279.

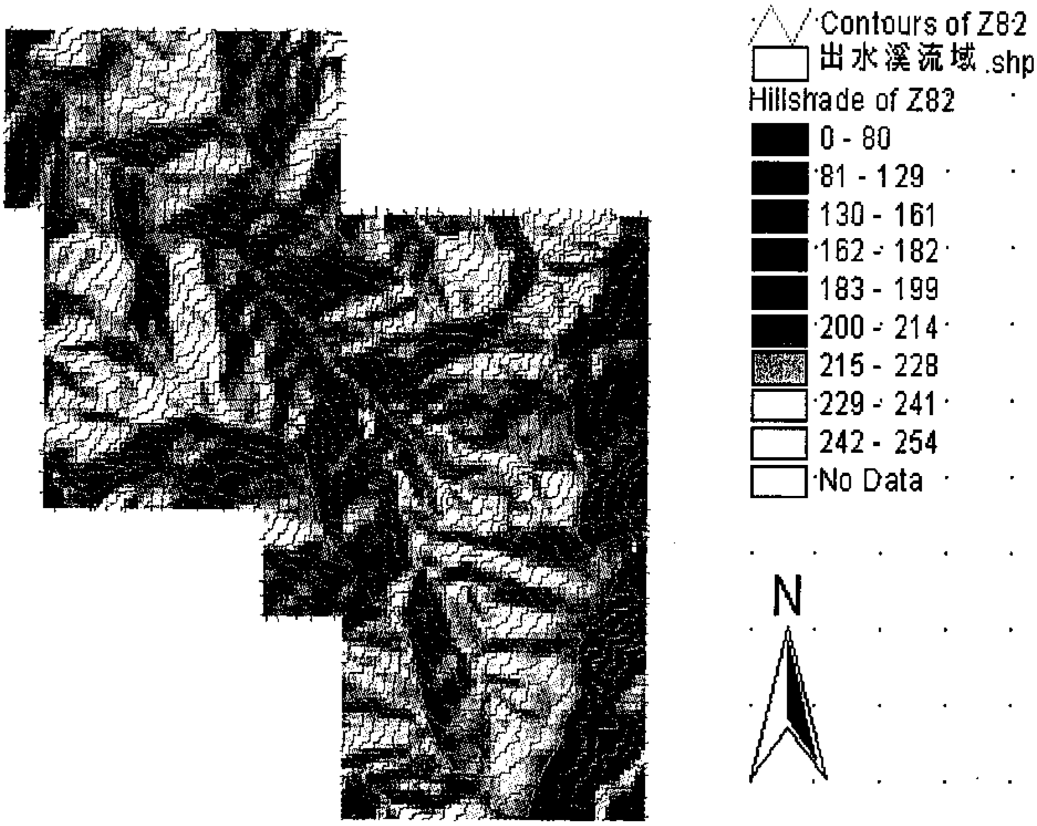

Figure 1 Chui-Sue river watershed

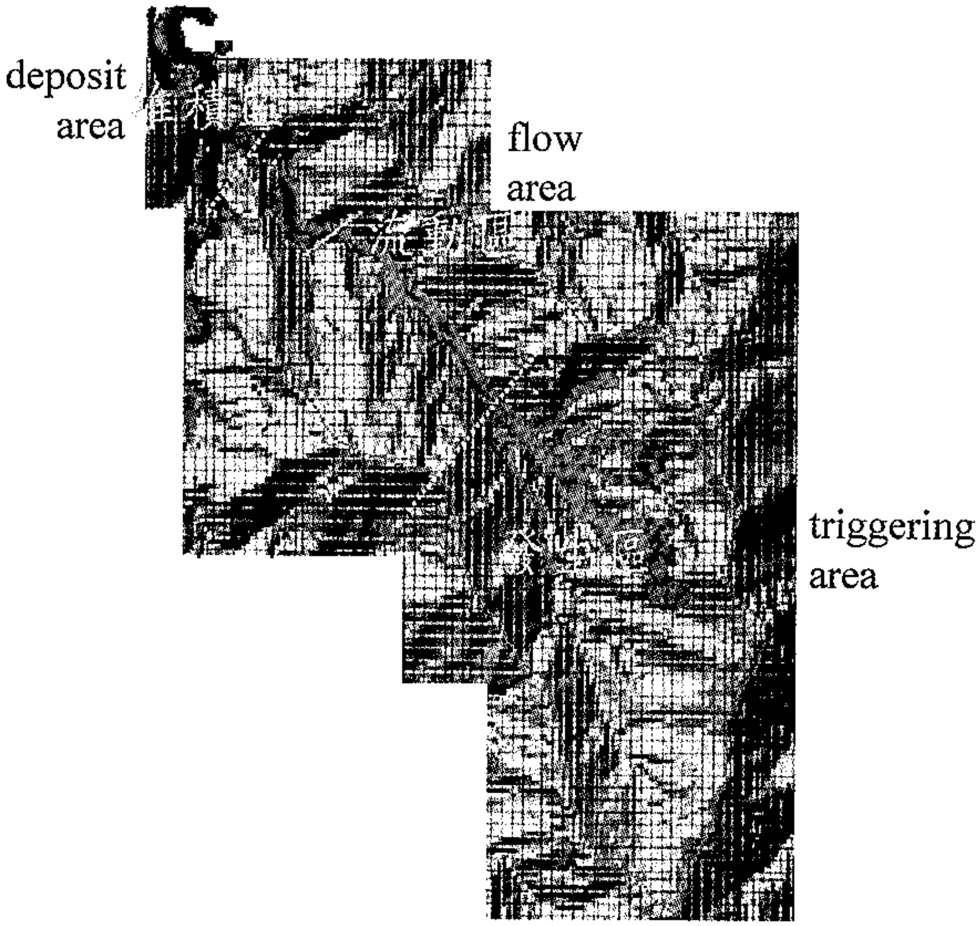

Figure 2 Microgeomorphology of the Chui-Sue river watershed

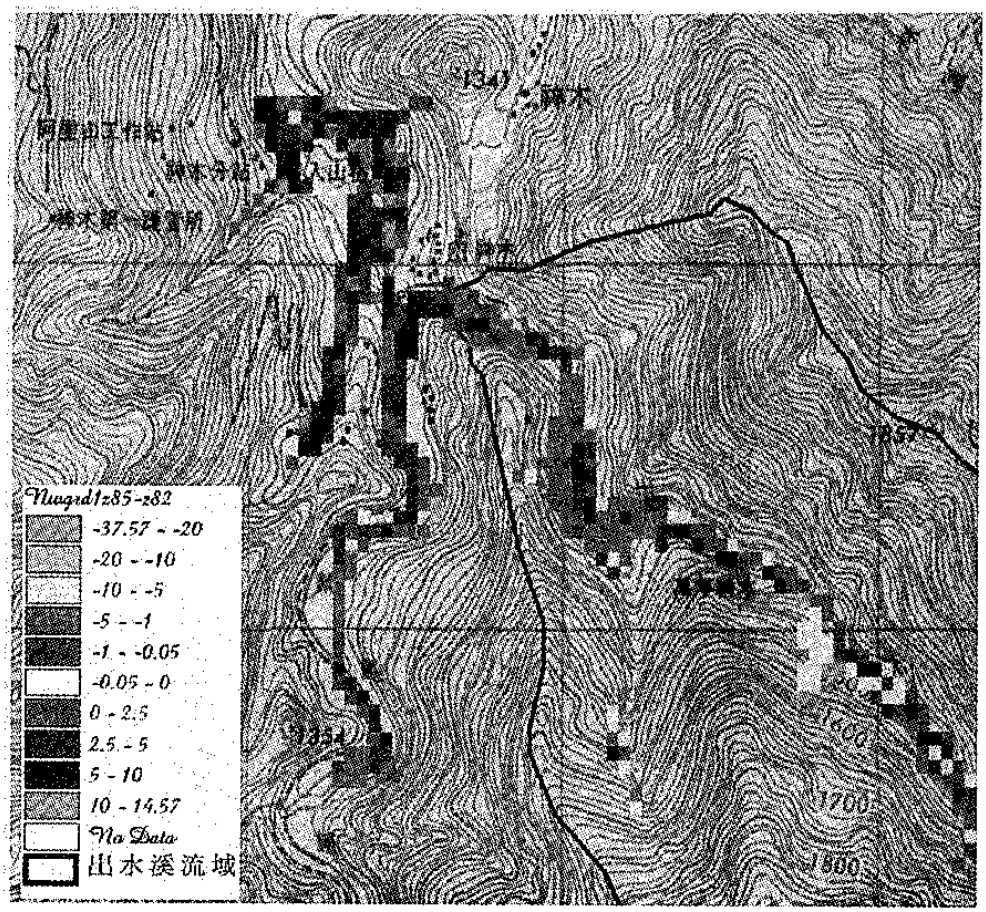

Figure 3 Change of Deposition of Chui-Sue River Before and After Typhoon Herb

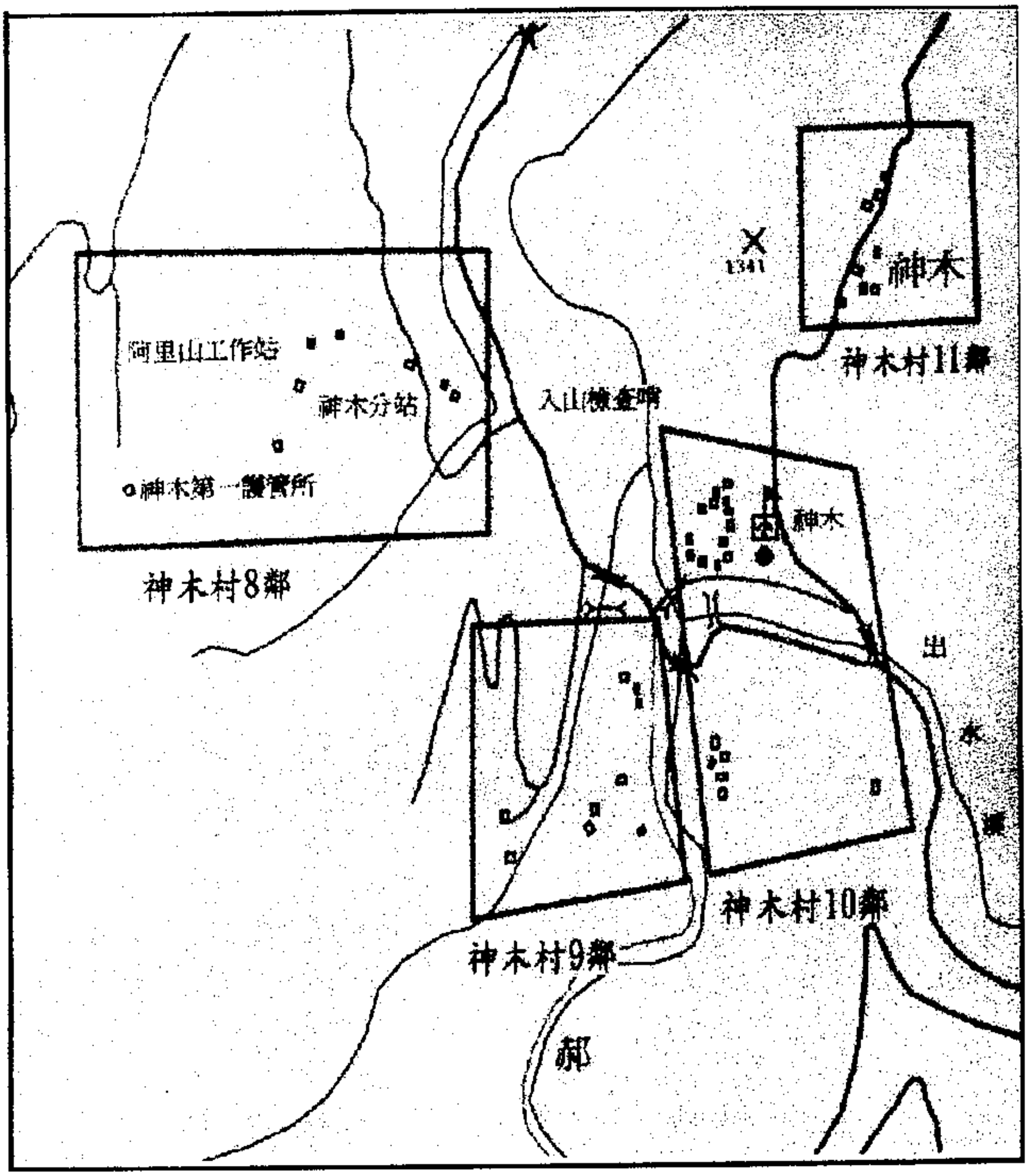

Figure 4　Distribution of Residents of Shen-Mu Village