Anticipation of Landslide Hazards

The three types of landslide predictions most useful to planners and the general public are:

1) long-term prediction,
2) medium-term prediction, and
3) short-term prediction.

Long-term Prediction (Geological and Geomorphological Methods)

Long-term prediction is used to identify areas that might have hazards caused by landslides in the future, for the purpose of land-use planning, regional hazard assessment and prevention, urban development, and evaluation of environmental changes after deforestation.

One important principle of long-term prediction is that the past is the key to the future. This means that landslides will probably occur as a result of the same geologic, geomorphic, and hydrologic situations that led to past and current landslides. Based on this assumption, it is possible to estimate the types, frequency of occurrence, extent, and consequences of landslides within a given area.

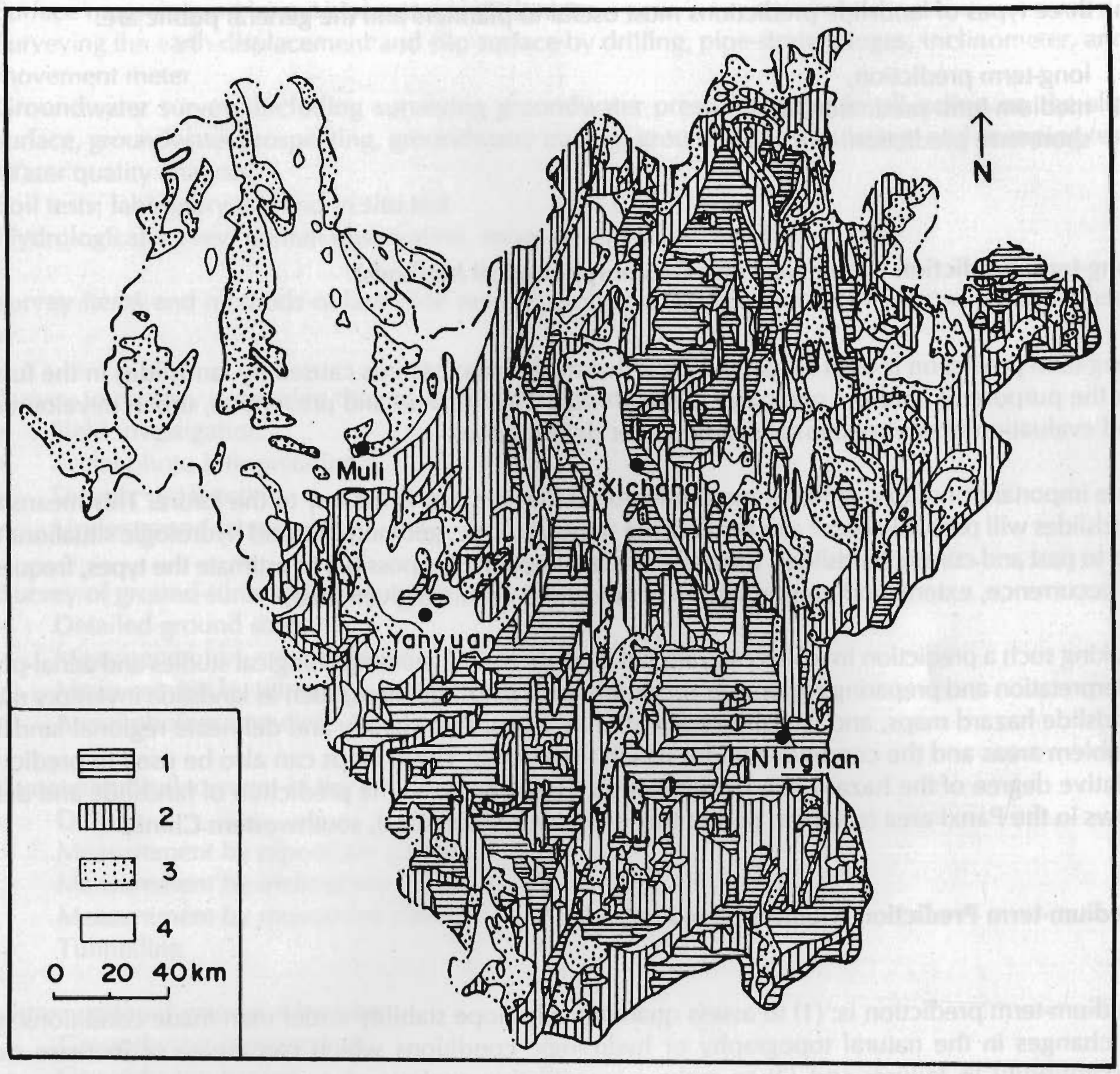
Making such a prediction involves carrying out geological and geomorphological studies and aerial-photo interpretation and preparing regional or reconnaissance landslide maps, such as landslide inventory maps, landslide hazard maps, and landslide susceptibility maps, that identify and delineate regional landslide problem areas and the conditions under which they occur. These maps can also be used to predict the relative degree of the hazard in a landslide area. Figure 8 shows the prediction of landslide and debris flows in the Panxi area (southern part of the Hengduan Mountains), southwestern China.

Medium-term Prediction (Geotechnical Methods)

Medium-term prediction is: (1) to assess quantitatively slope stability under man-made conditions such as changes in the natural topography or hydrologic conditions which can create or increase slope susceptibility to failure; and (2) to make a quantitative analysis of a slope or old landslide under anticipated seismic or meteorologic conditions.

When making such assessments, it is important in all aspects of the study, including geologic definition, stability evaluation, and monitoring evaluation, to understand the relationship between the landslide subsurface geometry and strength parameters of the slide plane with changes in natural conditions. Due to the high cost, this method can only be applied to those slopes on which large risks are anticipated according to the long-term prediction, or on which economically important engineering operations are being carried out. For instance, such a landslide prediction has been made in the reservoir area of the Longyang Gorge Hydroelectric Power Station, located on the upper reaches of the Huanghe River on the boundary of Gonghe and Gude counties, eastern Qinghai. The locations, volumes, and sliding velocities of potential landslides were made on the basis of quantitative analyses of the slopes, characteristics of rocks and soil, changes in reservoir water level, and physical and mathematical model studies. This medium-term prediction suggested raising the water level to 10m and ensuring the safe operation of the Hydroelectric Power Station (Qing 1987 and Wang 1989).

Figure 8: A Map Showing the Prediction of Regional Landslide Activities in the Panxi Area in Southwest Sichuan



Source: Tan et al. 1994

NOTES

1. Extraordinarily active area

2. Most active area

3. Active area

4. Less active area

Short-term Prediction

Generally, short-term prediction is used for evacuation before an imminent large-scale landslide, so it is also called 'time prediction of landslide occurrence'. Such predictions are usually based on (1) field measurements of displacements and rainfall and porewater pressures and (2) forerunning indications of landslides. At present, only the method based on the observation of displacement by extensometers and distance measurement equipment can be applied to predict the time of landslide occurrence.

Landslides are monitored or instrumented to provide timely warning of incipient hazards and to minimise property losses. Instruments used for monitoring include inclinometers, extensometers, tiltmeters, and pipe-strain gauges.

Successful predictions of large-scale landslides, based on measurements of surface displacement and displacement rates, have been presented by Luo (1988), Cheng (1988), and Cheng and Sun (1988). For instance, a measurement system for the Xintan landslides, composed of eight monitoring survey points and a triangulation network, were added in July 1984. Based on the measurement data and other indications of forerunning slope failure, a landslide of 20 million cubic metres on the upper slopes of Xintan Town, which occurred on June 12, 1985, was accurately predicted. The warning was given before the event so that all of the 1,371 inhabitants of the town were safely evacuated. This kind of success in landslide prediction is rare (Chen 1989 and Luo 1988).

Another successful example was the Jimingshi landslide predicted in 1991 on the basis of more than a year's observation and surface deformation measurement. The warning was given one day before large-scale sliding and more than 2,000 inhabitants from the town of Guojiaba were safely evacuated.

In predicting the time of landslide occurrence, the biggest difficulty is in determining the critical rate of displacement; the problems of providing such data are due to (1) the variation in characteristics and type of movement of each landslide and (2) insufficient available data on which to base the criteria for warning. To solve this problem, the criteria for the rate of displacement can be established on the basis of previous displacement records and the records of the sliding velocity of some landslides. The initial criteria can be checked and re-established during the monitoring period.

Prediction of the Extent of Major Rapid Landslide Disasters

When we make a time prediction of landslide occurrence, we should estimate the extent of area affected by the landslide. The pattern of deposits of a minor rockfall or landslide generally consists of an irregular halfcone of debris at the foot of the parent cliff. The geometry of deposits of a major landslide, on the other hand, is similar to that of a glacier or lava flow. The extent of most major landslides of high velocity is well beyond the base of the steep slopes where the landslide originated. Field observations show that the distance travelled and morphologies of deposits of a major landslide are mainly influenced by the volume, vertical drop, and relief of the deposit area. In recent years, many methods have been developed in China to estimate the sliding velocity, travel distance, and area covered by sliding deposits.

Empirical Model

In 1983, Li discovered a relationship between landslide volume and the spreading area of the landslide mass, by using a statistical method for predicting the hazard area as well as the travel distance. The correlation of the volume (V in m^3) of landslide to the ratio of the maximum vertical drop (H) to the maximum horizontal distance travelled (L in m) was given as:

$$\lg(H/L) = A + B\lg V$$

with:

$A = 0.6640$ and $B = -0.1529$.

The correlation of the covered area (S in m^2) to the volume (V in m^3) of a landslide possesses the form:

$$\lg S = A + B \lg V$$

with:

A = 1.8807 and B = 0.5667.

Analytical Model

According to the energy balance and contributing factors of rapid landslides caused by liquefaction, and the effect of the rate of peak value strength on the residual value strength, Wu and Li (1986) demonstrated the mechanism of rapid landslides with examples of vast landslides of poorly consolidated rocks; they proposed a formula to calculate the maximum velocity of a rapid landslide as follows.

$$V_{max} = \sqrt{2K1.K2.g.H}$$

where:

K1 = (1 - R),
K2 = F1/(F1 + F2),
R = Residual strength/peak strength,
g = Acceleration of gravity (m/s),
H = Height of the gravity centre of the sliding mass (m),
F1 = Area of driving section (m^3), and
F2 = Area of resisting section (m^3).

In 1989, Wang and Wang discussed the synthetic mechanism of high-speed and far-reaching landslides through energy analysis of the high speed of large-scale landslides in the processes of pregnancy, sliding, development, and stillness. They found that the velocity of high-speed landslides was related to the presence of forces of deformation and the positions of landslides. The formulas suggested for calculating the speed and travel distance of a large-scale landslide are as follow.

$$V = \sqrt{2U/M + 2g(H-fL)}$$

$$L_{max} = (1/gf) \times U/M + H/f$$

where:

V = velocity,
Lmax = maximum travel distance,
M = mass,
g = acceleration of gravity,
f = friction factor,
L = horizontal travel distance,
U = deformation energy of assisting sliding, and
H = height of sliding position.

The methods mentioned above are applicable for the approximate prediction of the sliding velocity and travel distance of an anticipated major landslide. However, it is difficult for these methods to take account of the influences of the ground conditions, the degree of saturation of the landslide mass, and the micro-topography.