PART 5

SYNOPSIS

26

Landslide Hazard and Risk – Concluding Comment and Perspectives

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26.1 Introduction

There is no doubt that the prerequisite for establishing a rational programme for managing risk is an objective assessment of risk and its careful evaluation in terms of community perceptions and aspirations. The research challenges required to achieve these objectives are manifest. First, there is still a poorly developed ability to comprehensively estimate landslide hazard. It is useful but not sufficient to represent the threat by identifying areas that show a range of susceptibility to landslide occurrence. Research needs to employ a range of modern earth science techniques in order to reveal the type of landslide that is likely to occur and the frequency of its occurrence. Furthermore, the expected landslide impact characteristics and intensity need to be clearly stated. How fast, how deep, how disrupted and how far will the material move?

There is a demand for risk assessments over a broad range of scales. The scale of investigation warranted is determined by a number of factors. One of these is the value and vulnerability of what is at risk. For example, a threatened school or hospital would demand a much more detailed assessment than a nature reserve or a parking lot. What is more, if there is a specific locational advantage for a particular site (in terms of economic or other values) compared to other sites, this may be sufficient to initiate detailed site investigation. However, the cost of investigation or the anticipated risk may outweigh the original site advantage and lead to the investigation of alternative sites.

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If an area under investigation shows an unacceptable benefit/risk assessment and there are no obvious alternatives, then potential risk treatment measures need to be addressed and assessed from a feasibility and cost–benefit perspective. In some instances, there may be no ‘site elasticity’. In other words, an established element under threat may gain its sole value by association with the site. In this case, the cost of remedial measures must be weighed against the uniqueness of the site values. For example, if it is unacceptable to shift the ‘Leaning Tower of Pisa’, the cost of risk reduction measures becomes less important in the ultimate decision. In reality, many elements at risk are essentially locationally fixed and have very little site elasticity. Main road and rail links in mountainous country are examples of where there are few options to relocate and engineering solutions rather than avoidance measures are required.

Broader-scale investigations are generally driven by longer-term planning horizons. With regional assessments, for example, the immediacy of the threat is less of a concern than the characterization and anticipation of future problems. Planning authorities want to know where problems might arise within their jurisdiction and what they can do to prevent them. These demands may be satisfied by the characterization of the region in terms of relative susceptibility to landslides. But ultimately, few rational planning decisions can be made without a clear statement of the hazard and risk. The challenge for scientists is to provide land managers with a statement not only of the frequency of landsliding expected at a site but also of the nature or the failure and its intensity.

Whereas certain economic units (for example, buildings and lifelines) can be readily identified as elements at risk, their vulnerability in the face of different types of landslide is currently poorly understood. A standardized and acceptable categorization of vulnerabilities with respect to landslide activity is a task yet to be achieved. An understanding of vulnerability requires a concerted effort of post-event record keeping using standardized protocols of damage assessment. There are, however, many other values (e.g. environmental quality) and activities in society that are also threatened or affected by landslides but which are much more difficult to represent in economic terms or are not readily assessed in terms of vulnerabilities. This aspect of risk estimation remains a challenge to economists, accountants, valuers, sociologists and psychologists. Despite their elusive quality, the representation of these elements at risk and their vulnerabilities are critical in characterizing loss and risk.

The derivation of a carefully crafted statement of risk is only the starting point for management. Essentially, it is an expert's representation of the problem. Communities or individuals are then faced with judging this statement before any decision to respond is considered.

The response to a calculated level of risk represents a value judgement. It is a balance of the risk and benefits of being exposed to this particular risk. Furthermore, risk reduction needs to be judged in terms of the costs involved compared with the benefits accrued. All these aspects are culturally, ethnically and value based. No one solution will ‘fit all’. There is a timely warning here for the imported experts who deliver judgements for a foreign community. Decisions on risk acceptance or the acceptability of risk reduction measures must remain with the affected communities.

26.2 Hazard Assessment

An estimation of hazard is the fundamental starting point for any risk analysis. Landslide management decisions are strongly dependent on information on frequency, impact characteristics and magnitude of failures. Currently, the assessment of the probability of occurrence of a damaging event is being achieved by careful scientific appraisals of:

- monitored and modelled kinematics of active landslides;
- recorded past occurrences;
- spatial attributes of the terrain, including factors known to promote instability; identified by, for example, field surveys, remote sensing or GIS;
- the use of new dating techniques and the establishment of protocols for recording in a systematic fashion past landslide behaviour.
- computer simulation models of landslide occurrence under triggering conditions of rainfall and earthquakes (e.g. some using physical process-based estimations of unsaturated and saturated flow condition within the soil);
- runout models.

Depending on investigation scales, this information can be portrayed at specified levels of accuracy. For example, to determine frequency and magnitude of single landslides, detailed site investigations are crucial, but are commonly costly and time-intensive. On the other hand, spatial landslide hazard analysis, using different methods (e.g. qualitative or quantitative/mathematical approaches) depends very much on the availability of existing spatial information (e.g. geology, soil, vegetation, topographic information). In particular, spatial landslide inventories contain data indispensable for identifying critical stability factors or for verifying results of prior modelling.

26.3 Elements at Risk

Numerous approaches are available to assess different elements at risks. If the objective is to represent economic or human elements, the options are to use either existing databases, or, in their absence, to carry out specific surveys. In many jurisdictions most of the economic and human information is already available from government or private (e.g. insurance companies') databases. In the absence or lack of availability of specific data on the value of the elements at risk, reasonable assumptions can be made. However, it is a complex task, requiring considerable expertise, to assign average monetary damage values to classes of elements at risk (e.g. industrial district, residential area, agricultural regions, lifelines such as roads, railways, water supply, sewage, etc.). In addition, economic concerns are only one aspect of the problem; social and psychological consequences of landslide occurrences should also be taken into account when assessing elements at risk. Thus elements at risk can be determined by:

- establishing post event damage recording protocols;
- detailed field surveys including extensive questionnaires to assess object-based information; and
- deriving regional information from other sources such as official statistics.

The choice of assessment techniques is strongly dependent on the study's framework; however, it might also be influenced by administrative and legislative constraints.

Future efforts for establishing what is at risk need to be directed to the chains of consequences instigated by landslide occurrence. These chains of events may be extremely complex and attenuated. One salutary example illustrates the ramifications of government policy direction on land management. In the 1980s, the New Zealand government decided to address its negative balance of payments situation by attempting to increase its sheep and beef exports. Incentives were provided to farmers to clear scrub and forest from the steep land in order to provide more pasture for stock grazing. This process destabilized the slopes and landslides soon followed, destroying farm infrastructure and releasing sediment to the drainage system. Landslide erosion resulted in both enhanced runoff and downstream channel aggradation. The net effect was loss of primary productivity on the steep slopes, burial of high productive soils on the lower slopes, destruction of farm infrastructure and enhanced flooding downstream. Clearly this example shows that elements of risk from landsliding can be recognized well beyond the immediate on-site damage. Risk management procedures need to recognize all the possible consequential physical impacts.

Elements that are immediately and directly affected by landslide activity are easily recognized. However, there is yet a greater challenge to recognize and account for the less easily identifiable consequences of landslide impact, such as community viability, cultural values, and physical and mental well-being.

26.4 Vulnerabilities

The determination of vulnerability in landslide risk analysis focuses in particular on two aspects of vulnerability: economic loss and vulnerability with respect to life ‘restrictions’ (e.g. inquiry, death). When calculating risk, vulnerability needs to be registered against some aspect of the hazard (e.g. landslide volume) and qualified with respect to the element at risk (e.g. type of building). In terms of earthquake hazard, for example, this aspect of risk assessment is well established. In this instance, records are kept for the purpose of establishing the damage ratio (vulnerabilities) of different types of structures in particular isoseismal (earthquake shaking) bands. For example, the records might establish that within a zone where shaking intensities are registered as MM VII, brick houses may suffer destruction equivalent to 30% of their value, that is, a vulnerability of 0.3. Although in this book we have provided some examples of vulnerability with respect to landslide activity and elements at risk, they are largely educated guesses. There needs to be a much more concerted effort of recording and research to establish reliable vulnerability factors for combinations of elements at risk and types of landslides. There are even greater challenges to characterize vulnerabilities for the less tangible elements at risk. These less easily identifiable elements include the political, social, psychological and community vulnerabilities, to name only a few (see Winchester, 1992 or Blaikie *et al.*, 1994 for more details).

26.5 Conclusions and Perspectives

As population grows, there is inevitable pressure on the land resource. Initial settlement generally takes the best and safest places and subsequent settlement the more marginal sites. At the same time, increased urbanization, with its inevitable reliance of lifelines for survival, introduces a new set of risks. Inevitability, more of the population becomes at risk. As marginal sites are occupied there is a need to both inform those affected of the risk and to devise means for reducing the level of risk. It is increasingly important that the land occupier and the consent authorities are aware of the implications of increasing exposure to hazard.

Within this book the contributors have highlighted certain aspects of the landslide risk system that are still poorly understood or that require a better base of information before reliable risk assessments can be made. This does not detract from the importance of conventional field investigation, laboratory testing and stability analysis. Landslides will always need to be mapped, their subsurface and subsurface structure will need to be examined in the field, and their behaviour will need to be modelled. Some of those areas where future effort could usefully be directed to enhance our understanding of hazard include:

- The prediction of geometry and behavioural characteristic of first-time landslides.
- The further refinement of models capable of linking climate, slope hydrology and stability.
- Determination of sensitivity of different landslide types to changing boundary conditions such as climate and hydrology.
- Forecasting landslide movement: initial occurrence, reactivation, including the identification of precursors of failure.
- Determining the factors that control the mode of movement of existing landslides, especially the transition from creeping to catastrophic rates.
- The refinement of the relationship between geomorphic and geotechnical site models.
- Further refinement of landslide-triggering models based on rainfall and seismic shaking by taking into account preconditions such as availability of material, antecedent hydrology and exhaustion of available sites through previous landslide activity (event resistance).
- Application of developments in dating techniques including luminescence and cosmogenic techniques to refine frequency of movement.
- Ground truthing of airborne remote sensing techniques for stability assessment.

It is also evident from the contributions to this book that carefully kept records of past failures are indispensable to hazard analysis, particularly at the regional scale. Such inventories can be used as input data for the direct calculation of landslide susceptibility. In addition, if there is temporal and magnitude information available in the inventory, the probability of landslide occurrence of a given magnitude, in a specific time period and within a predefined location can be estimated. Thus the landslide hazard can be estimated. Another application of landslide inventories is their use for verification and validation of calculated susceptibility or hazard. If inventories need to be used for both analysis and validation of results, the data sets can be split in two groups, one for model development and one for validation (e.g. Chung and Fabbri, 1999). Major issues for comprehensive spatial analysis include:

- The implementation and maintenance of spatial data sets, including the use of information supplied by other disciplines (e.g. historical geography, archaeology, etc.).
- Whenever possible, the differentiation of these inventories by landslide type and magnitude.
- The increased usage of remote sensing techniques (both airborne and satellite imagery) for landslide detection and observation.

- Further improvements in spatial modelling techniques, including physically based modelling and numerical modelling approaches.
- The development of methodological concepts and definition of accuracy limits for landslide hazard and risk analysis for different scales, ranging from <1:10 000 to >1:750 000.
- The comparison of the current results from scientific hazard and risk analysis with 'user' needs and demands.

A fundamental issue in the representation of landslide hazard and risk involves the linking of methods, concepts and investigations that have been developed at different scales in order to provide an answer at a specified scale. A challenge to landslide hazard and risk research, however, is to not only upscale information, but also to downscale boundary condition information (Figure 26.1) (e.g. Dehn and Buma, 1999; Schmidt and Glade, 2003). Although information extrapolation across different scales occurs in other disciplines (e.g. climatology), the complexities of the geosystem and human system that make up the hazard–risk system ensure that this is a particularly difficult task.

Irrespective of scale, the concepts and approaches to landslide hazard and risk analysis outlined in this book allow a reproducible and, in most cases, objective assessment of the potential consequences of a landslide event. As well as comprehending the ultimate statement of a level of risk, decision makers and planners should also be aware of the concepts, assumptions, methods and limitations involved in its computation. As with any modelling procedure, the limitations of the approach have to be appreciated when using the information for subsequent decision making in the areas of policy and management:

- With any spatial landslide information uncertainties are inherent, which are difficult to evaluate (e.g. Ardizzone *et al.*, 2002; Carrara *et al.*, 1992).
- The resolution and quality of the socio-economic data influence the accuracy of the resulting risk estimate.

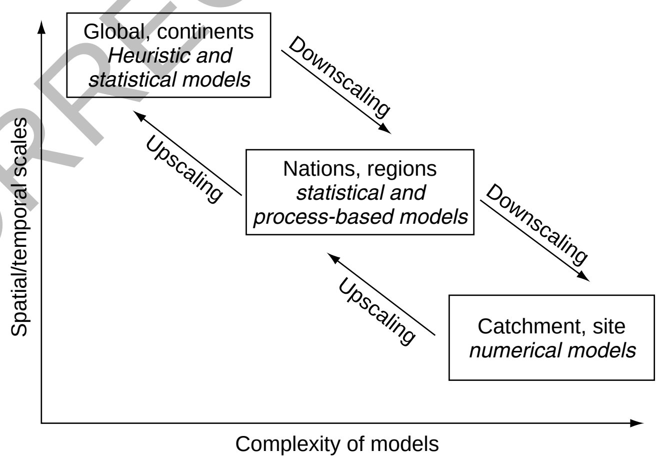

Figure 26.1 *Bridging the gaps between scale-dependent analysis and the complexity of models*

- In most cases, the vulnerability of structures and of societies can only be roughly estimated or approximated (e.g. Glade, 2003).
- The risk model is always a generalization of reality, and the model performance is strongly dependent on data constraints.
- The calculated landslide risk is a static expression of reality at the time of analysis.

On the other hand, there are many advantages of landslide risk assessments (e.g. Petrascheck and Kienholz, 2003). These are, in particular:

- Risk values and information are transparent and comprehensible.
- Scenarios allow assessment of the consequences of future developments.
- If the reliability of the model performance is strongly dependent on data quantity and quality, then with increasing data availability and quality, the reliability of the risk estimate increases.
- Most models of landslide risk can be adapted to allow for significant changes in the environment, such as vegetation changes or changes in land use (e.g. suburban developments). Therefore the potential exists to regularly update the static risk information.
- The conceptual approach and established methods allow a comparison not only of risk from different landslide types, but also from other natural hazards.

The wide range of perspectives presented in this book show that there are several solutions and approaches to analysing, understanding, managing and reducing landslide risk. At present, the level of understanding of the landslide risk system appears to be more advanced than society's ability to translate this information into risk reduction sytems. There are, however, notable exceptions where the hazard–risk management system is treated in a holistic manner, and the human element is adequately acknowledged. Many developed societies have built into their hazard and resource management legislation requirements to publicly notify and consult with affected parties and in some cases have regard to cultural values. The 'buy-in' of the affected parties and their participation in decisions on the acceptability of risk and risk reduction measures is essential for sustainable management of risk. The understanding of risk perceptions and the evaluation of risk, however, are critical components of risk management that still remain largely within the research arena.

As populations expand and urbanization increases, infrastructure, assets and human behaviour continue to change and thus affect the level of risk Probably one of the most important research challenges is to understand how risk evolves through time. It is only when this is appreciated that rational land planning and development adjustments can be made to reduce it.

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