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Abstract
Assessing the hazard and risk of slope instability and landsliding requires a consideration of basic geological and geotechnical factors which control stability as well as external agents or events which decrease stability and which may trigger landsliding. Prediction of slope performance is difficult and it is, therefore, considered appropriate to develop approaches for hazard and risk assessment. This paper is concerned primarily with one important aspect or element of such an approach. The essential and desirable features of a landslide database are outlined with particular reference to an urban area in New South Wales, Australia. The procedures and processes for developing such a database are introduced and attention is given to uncertainties which are associated with the processes of identification, mapping and describing landslide sites. Several features of a database which was recently developed are described and discussed.

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A LANDSLIDE DATABASE FOR LANDSLIDE HAZARD ASSESSMENT

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ABSTRACT

Assessing the hazard and risk of slope instability and landsliding requires a consideration of basic geological and geotechnical factors which control stability as well as external agents or events which decrease stability and which may trigger landsliding. Prediction of slope performance is difficult and it is, therefore, considered appropriate to develop approaches for hazard and risk assessment. This paper is concerned primarily with one important aspect or element of such an approach. The essential and desirable features of a landslide database are outlined with particular reference to an urban area in New South Wales, Australia. The procedures and processes for developing such a database are introduced and attention is given to uncertainties which are associated with the processes of identification, mapping and describing landslide sites. Several features of a database which was recently developed are described and discussed.

KEYWORDS

Landslip, Database, Shear Movement, Monitoring, Hazard, Probability, Risk, Shear Strength Parameters.

INTRODUCTION

Slope instability and landsliding processes have significant economic, social and environmental impacts in many regions of the world. Over the last 50 years or so, considerable research has been carried out on the geological and geotechnical aspects of landsliding. The need for continued research concerning fundamental and applied aspects of slope instability is being highlighted.

Strategies for hazard and risk assessment are necessary in order to manage existing landslide areas and to prevent the development of new landslides. Such strategies are also needed for planning of new urban areas or the expansion of areas already urbanised. An important role of local government bodies is to make decisions concerning the suitability for development of small or large areas of hilly land. A reliable approach for hazard assessment is also necessary in order to provide advice to citizens and developers.

ESSENTIAL REQUIREMENTS FOR LANDSLIDE HAZARD ASSESSMENT

The role of geological, geomorphological, geotechnical and hydrologic factors has been highlighted over the last 50 years or more. There is also recognition and growing awareness of the impact of human activities such as deforestation, urbanisation and development of transportation routes. Many landslides are triggered by external events such as rainstorms and earthquakes. Therefore, the frequency or return period of events of particular magnitude or intensity has immense importance in assessing the probability of landsliding. Accurate prediction of ground conditions and of external events is difficult if not impossible. Consequently, it is considered appropriate to develop strategies for assessment of hazard which recognise and deal with uncertainties in a systematic or logical manner.

The first essential consideration in hazard assessment is to recognise that both spatial and temporal aspects must be considered. While these can be analysed or assessed separately, possible relationships between the two aspects should not be ignored.

Having recognised this important fact, a number of important elements can be listed as follows:

1. Reliable and accurate maps of geology in addition to reliable topographic maps.

2. Reliable and accurate maps of existing landslide areas.

3. A geological database. For example, this would contain information from borehole logs and information concerning geological discontinuities.

4. A landslide database which may include only essential information or which may be comprehensive.

5. A database on the external disturbing agent which is most relevant to the particular area or region. For example, historical rainfall data are most relevant to landsliding in Australia.

6. Observational data concerning the occurrence of landslides or the performance of slopes. This will include observations of the ground surface as well as subsurface observations such as those from inclinometers and piezometers. Much of this information can be included in a comprehensive landslide database.

7. Methods of modelling, analysis and synthesis which enable the use of relevant data as part of a complete approach to hazard assessment.

In order to progress from hazard assessment to risk assessment it is also necessary to have data concerning elements at risk from landsliding and on the vulnerability of those elements.

In recent papers, the writers have highlighted several of the above elements with particular reference to research concerning slope instability in the Greater Wollongong area of New South Wales. The use of a Geographical Information System (GIS) package for mapping of geology and landslip and the relevance of such mapping have been discussed by Chowdhury and Flentje (1996). The validation of digital maps of geology and slope instability has been discussed by Flentje and Chowdhury (1996). The analysis of spatial relationships concerning stratigraphic features using the GIS package and the use of observational data from specific sites is also part of the same project.

In the remaining part of this paper attention is given to the development of a landslide database.

REQUIREMENTS OF A LANDSLIDE DATABASE

Essential Requirements

The main requirements of a landslide database should include the following which should, however, not be considered, as a complete list.

1. The inclusion of existing landslides or sites of slope instability including size and location.

2. A reliable site reference code.

3. Nature and history of instability and, in particular, if it is a first time slide or a renewal of previous instability.

4. Attention to uncertainties concerning boundaries as well as history of instability.

Desirable Requirements

In order to develop the landslide database into an effective tool for hazard assessment as part of an integrated approach, comprehensive information on each site should be incorporated in it. This would include the following (again, this should not be taken as a complete list):-

1. Information from previous site investigation including aerial photo interpretation and field laboratory testing; for example, local geological details, values of shear strength parameters, depth of landsliding, location of critical slip surface.

2. Results from back-analyses of landslides; e.g. back-calculated values of shear strength parameters, values of factors of safety with and without remedial works.

3. Name of person or organisation who carried out site investigation and/or analyses or both.

4. Performance of remedial or preventive measures.

5. Post-failure performance including subsurface data from inclinometers and piezometers.

6. Classification of speed of movement and the basis on which it was made.

7. Qualitative hazard classification and the basis on which it was made.

LANDSLIDE DATABASE DEVELOPED FOR THE MAJOR CASE STUDY

As part of a major research project, a comprehensive database has been developed for the Northern Suburbs of the City of Greater Wollongong, New South Wales, Australia. This includes 328 sites of instability of which -40 sites have been identified for the first time. The database has 60 primary fields.

This microsoft access database has many useful features and these include (a) secondary fields which are options for user to complete or to modify existing entries (b) queries designed to obtain statistical information and other relationships concerning the whole of the study area. These are discussed below.

Secondary Fields

In order to facilitate entries to be made in the database, the user is given several choices under some of the primary fields of the database. For example, under the primary field "Varnes (1978) - Classification of Movement", the complete and well known list of movements proposed by Varnes (1978) is included. Similarly, under the primary field of the database "Velocity (WP/WLI 1993)", the full proposed range is available to choose from. Again under the primary field "Primary and Secondary instability types", a number of choices are given. Similarly there are several options to choose under each of the primary fields (a) "How the Landslide was discovered", (b) "Potential damage to structures and services" (c) "Potential damage to land" (d) "Potential damage to economic activity" and (e) "Potential for loss of human life".

Queries to Obtain Statistical and other Relationships

An important feature of the landslide database is that appropriate queries can be programmed to obtain relevant, organised sets of data or information. For example, all the landslides associated with any particular geological unit can be listed. One may wish to list all the landslides within a particular map amongst the series of accurate geology and land stability maps produced using a GIS based-approach. One may wish to tabulate all shear strength data relating to colluvium or colluvium-rock interfaces related to a particular basal rock unit.

Typical queries which have been designed and have proved useful are shown below as Table 1.

TABLE 1:
List of queries designed to obtain organised information or data from the land instability database

- Costs of remedial works
- Damage to houses, number destroyed or damaged
- Damage, all sites
- Geotechnical Parameters Listing
- Inclinometer Velocity
- Landslide Classification
- Landslide Recurrence Dates
- Relationship to Rainfall, Velocity listed
- Rnw Geotechnical Parameters Listing
- Search within an ISG square
- Seek RSA sites
- Seek RTA sites
- Sites mapped/referenced by Flentje
- Subcrop geology Rnw
- Summary of remedial works applied
- Volume Rank of all sites sorted ascending
- WP/WL1 velocity classification
- All slips in (you select suburb)

EXAMPLES OF DATABASE APPLICATION

The history of landslide occurrence is only known for the period since the colonial settlement of the subject area. As far as possible, recorded instances of landsliding have been compiled from various sources and included in the database with the respective dates of occurrence. From the database, the variation with time of the number of landslides per year has been plotted as shown in Figure 1. Several periods of increase in the number of landslides per year are evident since 1950 and a much sharper period of increase since 1988 is also evident. In general, of course, increased landsliding is associated with periods of heavy rainfall. However, progressive development of the urbanisation of the hilly areas of the region is a very important factor.

There are significant gaps in the graph which could be attributed to long periods of low rainfall, lack of housing development in the hilly areas during those periods and lack of reporting.

An important aspect of the Landslide Database is that dates of landsliding at individual sites (first occurrence and recurrence) are recorded where known. In some cases, there may be doubt about the precise dates and in other cases, it may be difficult to conclude whether a particular event was a first-time landslide or a reactivation of an existing landslide. These uncertainties are also included in the database as far as possible.

Based on the history of recurrence, a historical frequency or probability of landsliding can, therefore, be calculated for each site. These probabilities would be useful for assessments of landslide recurrence in the future. The database also enables the tabulating of landslides by rank of volume, by rank of probability of recurrence as well as by rank of hazard where hazard is defined as the product of volume and probability. Table.2(a) shows 20 landslides with the largest volume (log of volume in cubic metres is tabulated). Table.

2(b) shows the 20 landslides with the highest probability of occurrence. Hazard rank and probability rank are compared for the 20 most hazardous landslides in Table.2(c).

The shear strength parameters of colluvium and/or residual soil/weathered bedrock associated with a particular basal rock unit (Wombarra claystone) have been tabulated from the Landslide Database and are shown in Table 3. The table distinguishes between parameters from laboratory testing and those from back analysis of failures and this is extremely useful information for understanding of site performance and for analysis.

CONCLUSIONS

The desirable features of a landslide database have been outlined in this paper. Important features of the Landslide Database developed for the Northern Illawarra (Northern Suburbs of Greater Wollongong Area), State of New South Wales, Australia, have then been outlined. Several important applications of the database have been presented. These include total annual landslide frequency per year over the historical period and the frequency of individual landslide sites. The ranking of landslides by frequency of occurrence or probability, and by hazard (product of probability and volume) is demonstrated.

The comparison of hazard and probability ranks can be very useful. The database also enables the tabulation of all landslides related to rainfall. Shear strength parameters related to a particular basal rock unit can also be tabulated and include data from laboratory testing as well as the results of back analysis. The importance of all such organised information for landslide hazard assessment and management can hardly be overemphasised. In practice, the Landslide Database will be one of the major components of a quantitative hazard and risk assessment system; the other major components include (a) the Geotechnical Landscape Map Series (maps of geology and of existing landslides) and (b) the researched relationships between rainfall and subsurface shear displacement.

Discussion of these important aspects of landslide hazard assessment is, of course, outside the scope of this paper.

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