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Designing a Landslide Database; lessons from Australian examples

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ABSTRACT: The Australian Geomechanics Society 2007 Landslide Risk Management Guidelines stress the importance of developing inventories of landslides in order to underpin better land management decisions and facilitate landslide research . In the absence of a definitive (and published) data model for the inventory a number of landslide databases have been created in Australia to serve a range of purposes, all of which pre-date the guidelines.

We outline a project undertaken to develop a website linking four disparate landslide databases together using network service oriented interoperability concepts and technology. From this project we have learned a number of important lessons. Digital landslide databases in our view should combine both spatial and non-spatial data and take advantage of the current information technology available. Unfortunately there is much research and design required before we have a satisfactory model to address a range of required functionality. Conceptual approaches require skill sets and technology that may be foreign to traditional geotechnical practitioners.

We believe that there is merit in establishing an open forum to share, discuss and improve landslide database models. We list data concepts that need to be captured and offer examples of topological representations of various landslide types.

1 INTRODUCTION

The introduction of the Australian Geomechanics Society 2007 Landslide Risk Management Guidelines (especially AGS, 2007a; 2007b) present strong arguments for the development of landslide inventories to assist landslide investigations and research. A brief discussion is provided in the commentary by two of the authors of this paper (A Miner and P Flentje in AGS, 2007b C8.3) that contains an outline of the components of a GIS-based landslide inventory. It also signals the intention to further develop a nationally consistent landslide schema.

The adoption of state-of-the-art information technology tools (e.g. fully relational databases and GIS) is regarded by us as the most appropriate method of handling large landslide inventories. While there are a number of landslide inventories employing this technology around the world, we have found few organisations prepared to freely share their data models. This paper will outline progress to date in the development of a common schema in Australia whereby four organisations have collaborated to develop a common standard, and in the process improved their own inventories though the sharing of expertise. In order to foster broader cooperation nationally and internationally, we wish to share our experiences providing examples of overriding principles, proposed rule-sets and ongoing challenges.

Comment [u1]: Do these changes still portray the right message?

2 THE LANDSLIDE INTEROPERABILITY PROJECT

A small number of landslide inventories exist in Australia built by organisations such as: Geoscience Australia (national extent); University of Wollongong (primarily serving Wollongong City, NSW), Colac-Otway Shire (South-west Victoria) and Mineral Resources Tasmania

(MRT, Tasmania). In a recent project led by Geoscience Australia (GA), representatives of each of the databases listed above met to develop an interoperability schema that would allow each of the databases to be linked together and viewed through a single interface on the GA website. Given that these databases had developed largely independently and for different purposes, it required a considerable amount of effort by the authors to agree on an adopted table structure and terminology to which each database can be mapped and translated via live queries.

While the project achieved its aim (to demonstrate the interoperability concept), it is acknowledged that the facility has limited functionality, unless it is moved into a production ready status. Had the contributing databases been more similar in the first place a greater functionality would have resulted. However, it is our opinion that there are number of fundamental aspects of landslide database design that require further research and development. This work should be undertaken with the involvement of academic institutions that combine the skill-sets of geotechnical engineering, earth science (especially geomorphology), spatial science and computer science.

Comment [u2]: Greater functionality is also possible with a system that moves beyond the pilot demonstrator (regardless of database similarity). However, it is true this functionality is much easier to obtain when databases are the same, and updates etc. are easier to be managed (less effort).

3 OVERRIDING PRINCIPLES

Based on our individual and collective experiences we wish to outline some broad principles we have learned to assist those contemplating building their own landslide inventories.

- The design of a landslide inventory requires a considerable amount of effort to understand and document the business requirements for a given database. This may involve interviews with end-users (e.g. Council Planners) who may have limited understanding of the subject and may require some initial education. The results of this task may allow a prioritisation of the building of functionality where the core is built first and “bedded down” before additional functions are developed. As we have found, building the perfect database that does everything is not achievable in our lifetime.
- Take advantage of the capabilities of modern information technology where possible, as this will serve you well into the future. For example, the use of spreadsheets as surrogate databases, as used by some consultants, offers very limited functionality among a number of disadvantages. The downside of this axiom is that some IT expertise will be required to set up the database in the first place and to maintain it. In our experience it is better to utilise a fully-relational data model that provides all of the functionality benefits and, in conjunction, develop simple “front end” interfaces for data entry and retrieval.
- Build networks with other landslide researchers (such as the authors of this paper) who may be quite happy to share their (complex) data models and adapt them to your own needs. In exchange we ask that you provide critical feedback and the benefit of your wisdom and solutions in return.

4 COMPONENTS OF A LANDSLIDE INVENTORY

A landslide database will include a number of data feature concepts outlined below, the exact number will largely depend on business requirements. In some instances we have not developed a satisfactory schema for depicting these concepts as more R&D is clearly required. The limited format of the conference proceedings prevents us from going into any detail on most of these points and the reader is encouraged to contact the authors directly for further information. However, in order to provide value to the paper we provide specific suggestions for the geometric depiction of landslides that is used to underpin the landslide maps produced in Tasmania.

Table 1 Listing of high level components for a landslide inventory

Component	Description	Comments and Issues

Unique identifier	Unique identifier	May be multiple records of one landslide where multiple interpretations and/or movements exist
Landslide classification	Standard classifiers of material, and movement style (can be derived from rows below)	May be multiple styles involved (rules required)
Inspection details	Includes inspectors, dates of inspection, type of inspection, etc	Will require maintaining as new inspections occur
Land Ownership	Contact details of owners, access, address of site, etc	May require maintaining as details change
Spatial	Geometric depiction of landslide features	Will require maintaining if reactivation, new interpretations or human modification (previous depictions are kept - rules apply)
Landslide Morphometrics	Dimensions of landslide features, volumes, degree of preservation, etc	Will require maintaining if reactivation or human modification occurs (previous depictions are kept-rules apply)
Site descriptions	Vegetation, slope angles, drainage etc	Rules to apply if features change.
Geology and material properties	Description of all relevant units at site (e.g. soils and rock), material tests, ages, weathering, etc	To be updated as necessary
Geomorphology	Description of setting, landscape processes, human influences	Will require maintaining as site is modified
Movement history	Movement amounts, styles, triggers, dates (historic and prehistoric), etc	Will require maintaining if reactivations occur and/or more movements discovered
Damage	Features damaged, casualties, costs, environmental damage, dates and times, etc	Will require maintaining if reactivations occur
Bibliographic references	Reference to related information, records systems, etc	To be updated as necessary
Digital Objects	Digital copies of photos (with metadata), reports, tables	To be updated as necessary
Monitoring	Time series hydrological data, survey measurements of movement including inclinometers, INSAR, etc	To be updated as necessary
Remedial Measures	Details of remedial actions	Requires updating based on inspections and ongoing works

4.1 *Spatial Representation of Landslide Types*

The landslide maps produced by Mineral Resources Tasmania since 2004 are derived from spatial features stored in a corporate spatially-enabled Oracle database. The database has been designed to allow landslide and landslide related features to be stored with point, line and polygon topologies. The symbolisation of these features is a related but substantially separate issue that follows standard approaches such as AGS (2007c Appendix E). In this paper we wish to discuss the depiction of three quite different mass-movement types in a landslide database; slides, flows and falls. However, before these are discussed it is important to realise that in any form of spatial mapping the following concepts should be considered and recorded:

- the scale of capture of the information (e.g. 1:1000)
- the scale at which the feature is designed to be displayed (e.g. 1:5000)

- the purpose of the feature (e.g. which of the published map(s) if any this feature will be portrayed in)
- the spatial accuracy of the information at its best resolution (e.g. +/- 5m)
- the reliability of the mapped feature, often this largely dependant on its preservation in the landscape (e.g. accurate, approximate, inferred)
- whether the feature is concealed or not
- who mapped the feature and when (e.g. the inspector)
- which landslide it belongs to (the landslide identifier)
- which movement it belongs to (important if the feature has significant reactivations)

By storing the attributes in an associated GIS table for each feature, they are used in a query to control outputs for the MRT maps.

4.1.1 *Slides*

The components of a typical "fresh" slide in cross-section are presented in Figure 1 below and in plan in Figure 2. The representations include three geometric forms (point, lines and polygons). As a defined rule, every landslide contains a point feature that is located approximately equidistant with respect to the width of the feature and in the upper half near the headscarp. Landslide component areas are described by the upper labels while linear features are the lower labels.

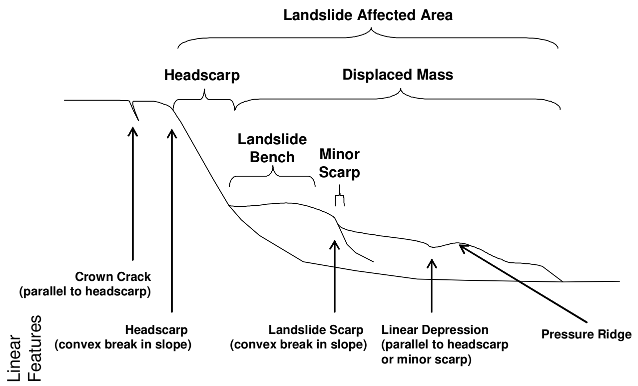

Figure 1 Components of a typical deep-seated rotational landslide database in cross section.

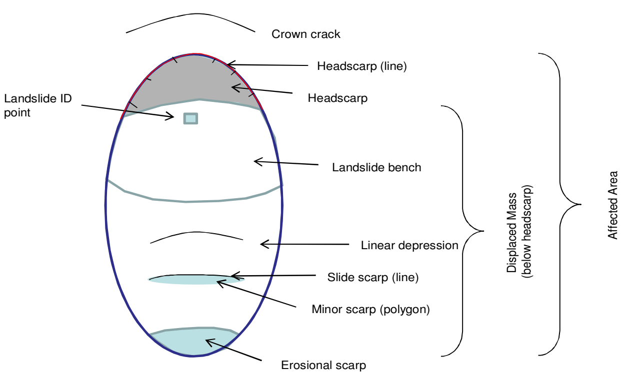

Figure 2 Spatial representation of slide-type landslides stored in the landslide database (plan view).

While these depictions work well with fresh landslides, degraded features present additional problems as parts may be eroded, such as at the toe, where we have introduced an additional feature type (the erosional scarp). The development of standardised descriptors of degradation is issue that has yet to be satisfactorily resolved by MRT.

4.1.2 *Flows*

Flows require a generally simpler representation than slides. Like slides, a point is required for all flows, the position of which is shown on Figure 3, and is placed on the source area in such a location that it will generally be indicative of the pre-failure slope and aspect of the feature. A headscarp can be shown where scale allows and the classification of the large polygon will change accordingly.

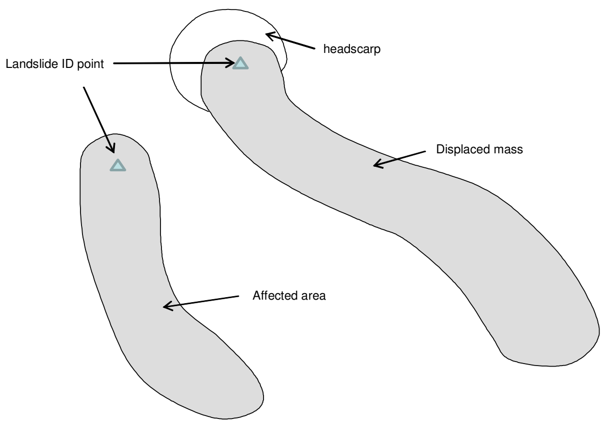

Figure 3 Spatial representation of earth and debris flows stored in the landslide database

4.1.3 *Falls*

Falls have surprisingly complex topology (Figure 4). Point features can represent source location(s) (where known) and/or the resting places of boulder(s) (where known). Therefore, there may be more than one point, for a given rock fall, in contrast to slides and flows. The path of a rockfall is depicted as straight line segments to indicate where each boulder has left some indication of its journey downhill. This can be augmented by a damage point (stored in a separate table) if necessary. A polygon is used to define a rockfall deposit (e.g. talus). Conceptually, a source polygon could also be depicted but so far we have yet to find a case where this has been required.

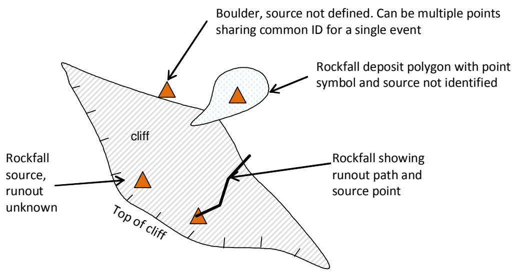

Figure 4 Spatial representation of rockfalls stored in the landslide database. The cliff is shown for illustration only.

5 CONCLUSION

The development of a landslide database may appear to be a straight-forward task to underpin landslide risk management practice as outlined in AGS (2007b). However, we demonstrate that it is challenging and that a considerable amount of further research and development is required to build robust data models. We encourage interested parties to build a formal or informal network, who are prepared to freely share their data models and knowledge. In this discussion we have presented some of the data-concepts that should be stored in a landslide database and offer examples of topological rules for the mapping of different types of landslides.

6 REFERENCES

AGS 2007a. Guideline for landslide susceptibility, hazard and risk zoning for land use planning. Australian Geomechanics 42: 13-36. [available online: www.australiangeomechanics.org].

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AGS 2007c. Practice note guidelines for landslide risk management. Australian Geomechanics 42: 63-114. [available online: www.australiangeomechanics.org].