



AGS VICTORIA 2016 SYMPOSIUM
Excavations and slope stability
in Melbourne geology:
experiences and recent developments

Wednesday, 16 November 2016, 12:00pm – 7:00pm
Engineers Australia, 600 Bourke Street, Melbourne



AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIA CHAPTER

WELCOME

The Victorian chapter of the Australian Geomechanics Society (AGS) is pleased to welcome you to this half-day symposium titled "Excavations and slope stability in Melbourne geology: experiences and recent developments".

Since the publication of the "Engineering Geology of Melbourne" in 1992, both the geotechnical profession and Melbourne has undergone significant change. Urban sprawl over the past few decades has seen increasing development in the hillside areas in the Dandenong and Mornington Peninsula regions. This coupled with changes to the regulatory environment and the introduction of the Landslide Risk Management Framework by the AGS in 2007 has changed the way in which local and state government as well as geotechnical practitioners manage and assess slope stability.

In addition to development in hillside areas, significant development in the inner parts of Melbourne has posed many challenges for excavations not just in the soft soils of the Yarra Delta but also the weak rock of the Melbourne Formation.

This symposium seeks to bring together practitioners from consulting, construction and academia to share and discuss their experiences on the separate, but related, topics of excavation and slope stability. Best practices, case histories and innovative solutions for dealing with these challenges will be presented and discussed, with a particular emphasis on local geotechnical issues.

ORGANISING COMMITTEE*

Daniel King (Chair)

Clare Bridgeman (Co-chair)

Mahdi Disfani

Jie Li

Jeremy Barber

Rob Day

Richard Kaser

*a sub-committee of the AGS Victoria committee

TECHNICAL REVIEWERS

Mahdi Disfani (Technical Chair)

Chris Boyd

Stuart Colls

Chris Coulson

David Glover

Richard Kaser

Steven Lankshear

Bing Lee

Ramtin Tajeddin

FIFTEEN YEARS OF SLOPE STABILITY AND RISK ASSESSMENT FOR LOCAL GOVERNMENT PLANNING IN VICTORIA A DISCUSSION OF COMMON MISTAKES AND SHORTCOMINGS

D. R. Paul¹ and A. S. Miner²

¹Golder Associates, Melbourne, P.O. Box 6079, Richmond, Victoria, Australia; PH +61 3 8862 3500; FAX +61 3 8862 3501; email: dpaul@golder.com.au

²A.S. Miner Geotechnical, Geelong 50 Calder Street, Manifold Heights, Vic, 3218; PH 03 5221 9246; email: aminer@pipeline.com.au

ABSTRACT

Over the past 15 years, a number of local governments in Victoria have introduced Erosion Management Overlays (EMOs) to manage slope stability and landslide risk through the town planning process. Local government areas with Erosion Management Overlays include Yarra Ranges, Colac-Otway, Moreland, Frankston and Mornington. Whilst there are some local nuances, the requirements of the EMOs under different Local Government Authorities (LGA) are essentially the same. A key requirement is that a geotechnical assessment or landslide risk assessment is undertaken for development in areas susceptible to landslide or other slope degradation processes. The intent of the geotechnical assessment is to identify whether a proposed development will be at risk from slope instability, if it will create or increase landslide risk and, if required to estimate the magnitude of the risk and evaluate the risk against a criteria.

The authors have in excess of 15 years each of peer review of geotechnical assessments on behalf of local government and combined have reviewed over 1000 geotechnical assessment and landslide risk assessment reports. This paper presents and discusses some shortcomings gleaned from review of geotechnical assessment and landslide risk assessment for residential development within areas subject to EMOs.

Keywords: slope stability, landslide risk assessment, erosion management overlay

1 INTRODUCTION

Over the past 15 years, Erosion Management Overlays (EMOs) have been introduced into most Victorian local government areas with known slope stability hazards, including Yarra Ranges Council, Colac Otway Shire, Moreland City Council and Frankston City Council. A requirement of the EMO's in these areas is that planning applications are supported by a geotechnical assessment or landslide risk assessment (LRA), collectively referred to here as 'geotechnical reports'. Peer review of geotechnical reports has revealed some common shortcomings of LRA reports. The authors' intent here is to summarise what in their opinion are the most common shortcomings they have observed and to suggest means for improvement.

The objective of the EMO as defined in the Victorian Planning Provisions (VPP) is to protect areas prone to erosion, landslip or other land degradation processes. One of the strategies stated to achieve this is the prevention of inappropriate development in unstable areas or areas prone to erosion and to

promote vegetation retention. The EMO also serves to manage risks to life and property associated with development in areas prone to landslide.

The geotechnical reports should inform the LGA whether the proposed development complies with the VPP. The reports are read and relied upon by:

- Planners to assess whether the development can be undertaken with tolerable risk to life and property.
- Peer reviewers on behalf of local government.
- Architects and builders who must implement the recommendations in the geotechnical report.
- The owner.

The undertaking of geotechnical assessments and landslide risk assessments requires skills in a range of areas including geotechnical engineering, geology, geomorphology and hydrogeology. This broad range of skills is held to varying degrees by those who undertake landslide risk assessments and in the experience of the authors, there is a relatively

extreme range in the quality of geotechnical reports provided.

2 EROSION MANAGEMENT OVERLAYS

2.1 Failing to familiarise the EMO requirements

The publically available schedule to the EMO sets out what must be included in a geotechnical report. Peer review of the geotechnical report must consider whether the report meets the requirements of the schedule. Whilst the schedule varies slightly between LGAs, they all require as a minimum:

- Description of site features including slope angle and geomorphology.
- Investigation of the subsurface materials and presentation of a ground model.
- Identification of landslide hazards.
- Assessment of landslide hazards.
- Evaluation of landslide hazards.

It is common for reports to be deficient in one or more of these aspects and often evident that the author is not familiar with the requirements of the EMO schedule or with the purpose for which the report will be used.

A simple way to ensure compliance with the EMO schedule is to use a checklist which sets out observations required and information that must be included in the geotechnical report.

2.2 Geotechnical Assessment versus Landslide Risk Assessment

Most EMO's in Victoria describe a 2 tiered approach to the identification and assessment of slope stability hazards. This approach seeks to make the process less onerous in cases where landslide hazards are of lower significance. All sites which trigger a planning permit under the EMO usually require a geotechnical assessment. The intent of this is to identify landslide hazards and undertake an initial evaluation of the risks associated with the hazards. If there are no significant hazards identified there may be no requirement to proceed to the second and more detailed stage, a landslide risk assessment.

Consultants often appear to use a single report template for geotechnical reports under the EMO. A landslide risk assessment is often provided when a geotechnical assessment is sufficient. Whilst this is not a shortcoming, it may be that clients are paying for unnecessary work.

Conversely, the reverse also occurs, whereby significant landslide hazards are identified in a geotechnical assessment, but no landslide risk assessment is provided.

2.3 Incomplete Information on Geotechnical Declarations

Geotechnical declarations must be provided with geotechnical reports. The declaration form requests specific information. Often they are incomplete or have incorrect information.

The geotechnical practitioner who prepares the declaration should view and list on the declaration the final plans for the proposed development, verify that the development is consistent with the recommendations of the report and can be undertaken to a tolerable level of risk. Common shortcomings on geotechnical declarations include:

- Failure to reference development plans.
- Referencing reports or other documents other than the development plans.
- Referencing plans that show development inconsistent with the recommendations of the geotechnical report.

3 BACKGROUND INFORMATION

3.1 Missing or inadequate desk studies

Most areas covered by an EMO have been the subject of studies commissioned to identify slope hazards and define the extent of the EMO. One of the first and vital steps in undertaking a landslide zoning study is to develop a landslide inventory. This is used to identify the characteristics of land susceptible to landslide. The studies and landslide inventories on which the EMO is based are usually publically available through the LGA who commissioned the study, often online. Colac Otway currently has their landslide inventory available online, Yarra Ranges is in the process of providing an online inventory and Frankston City Council has made the report on which the EMO is based, including inventory available online.

It is apparent in some geotechnical reports that no attempt has been made to research existing information on landslides in the vicinity of the development. For example, reports sometimes state that because the ground at a proposed house location is flat, there is no credible landslide risk. In such cases, the author has failed to recognise that the flat ground is a back tilted scarp or part of a larger landslide feature

hence its inclusion in the EMO. In some cases, the slope angle of areas previously levelled by earthworks are cited. Review of the landslide inventory and available information on past landslides in an essential stage in undertaking a geotechnical or landslide risk assessment.

Whilst an existing landslide inventory or zoning study is the most readily available source of information on past landslides, other sources include air photo review, historical newspaper reports (the NLA's search database TROVE), past geotechnical reports and anecdotal evidence.

4 THE GROUND MODEL

4.1 Failure to identify geological processes

In the context of landslide risk assessment, the ground model is a representation of the surface and subsurface conditions at a site used to inform the landslide risk assessment.

One of the key intents of a ground model is to assist in identifying what geological processes might be present and affecting an area. Rarely do reports include ground models which highlight the geological processes and link those processes to landslide hazards.

For example, a ground model might show a bedded sedimentary material and highlight that groundwater infiltration into the bedding planes can elevate pore pressures on the plane and lead to sliding along the bedding plane. This should guide hazard identification and analysis. In this example, a circular slip surface/deep seated failure would not be relevant. However, it is common to see a default hazard with circular slip surface, inconsistent with the ground model.

4.2 Reporting the Ground Model

A common misconception in geotechnical reports is that the ground model describes the geological origins of the area and includes things like descriptions of mineralogy and regional geological history. Whilst this information can be useful, it is not the primary information required in the ground model. The ground model should be specific to the site and its surrounds and describe, preferably visually through cross sections or diagrams the subsurface conditions, geomorphological and hydrogeological process acting at the site. There should be a clear link between the

ground model and the landslide hazards identified.

4.3 Inappropriate Scale

A very common shortcoming is selection of an inappropriate scale at which to develop the ground model and undertake the landslide assessment. Often the study area assessed is limited to a house location or to property boundaries. However, there is generally no correlation between the extent of a landslide hazard and land defined by an allotment boundary or house location. The scale selected or area in which hazards are identified must consider from where landslide hazards could originate, where they could affect and whether the development is between the two, irrespective of property boundaries. Common failings include:

- Failure to identify debris flows or landslides with large runout distances that could originate upslope from the property. In extreme cases, for example, in Montrose, debris flows could originate hundreds of metres upslope of the property being assessed.
- Failure to identify that the 'flat' area on which the development is proposed is the back tilted block of a much larger landslide feature. Common in the Older Volcanics in areas such as Chirnside Park, Silvan and Wandin.
- Failure to identify that the proposed development through, for example, changes in earthworks or drainage could create a hazard that affects another property downslope.
- Reporting the natural slope angle based on measurement at a specific, small scale location, usually the proposed house location rather than the overall, more relevant slope angle.

5 SLOPE STABILITY ANALYSIS

5.1 Undertaking inappropriate limit equilibrium analysis

Limit equilibrium slope stability analysis is commonly used to support landslide risk assessments. The analysis is typically undertaken using a computer program such as Slope/W, Slide, Galena, etc. Commonly, a grid of points representing the centre of potential slip circles is placed into the limit equilibrium model and hundreds of slip circles analysed to identify the 'critical' slip surface. The critical slip surface or critical mode of failure can often bear little resemblance to landslides known to occur

in the area or to the ground model. Slip circle analysis is only useful if it is used to analyse a realistic scenario. For example, where instability is controlled by bedding planes, analysis using a circular surface is unlikely to be relevant, yet this is commonly seen in geotechnical reports.

Slope stability analysis should only consider feasible slip surfaces.

5.2 Failure to consider other, non-analytical indicators of slope stability

Observation of landforms and geomorphology are often not included or poorly considered in geotechnical reports. However, these observations can reveal more about slope stability than a limit equilibrium analysis.

The processes that have led to the formation of the slope should be identified. Most slopes form through some form of landslide or erosion process. If the slope forming process is understood, it allows back analysis to be undertaken which can inform an appropriate slope stability analysis. A simple indicator is to consider the steepest natural slope maintained in a particular geology as an indicator of a slope angle likely to be close to the point of limit equilibrium under long term or drained conditions. For example, within the residual rhyodacites of the Yarra Ranges, the steepest natural slope angle is about 27° or 2H:1V. Analyses that indicate long term stable angles similar to or greater than the steepest natural slope angle should be carefully considered.

5.3 Poor parameter selection

A limit equilibrium analysis requires input parameters. The reports reviewed by the authors cover a very broad range of parameters and methods of parameters selection.

The appropriate type of parameter can be confused or poorly selected. For example at a basic level, the choice of whether to adopt undrained, drained (effective) or residual parameters is not well made. Any of these might be relevant depending on the problem under consideration, in particular whether long term or short term stability is under assessment and whether the failure plane under consideration has previously had movement on it. A common shortcoming is to use unrealistically high cohesion values which have a significant impact on stability in a limit equilibrium analysis. A report benefits from

having justification for the type of parameters selected.

The basis for the parameters selected is often lacking or poorly justified. Laboratory testing is expensive. For example consolidated triaxial tests, and a sufficient number of them to provide confidence in the parameters is cost prohibitive for most residential scale assessments. Because of this, parameters might be selected as 'typical' for a particular material type, or using approximate empirical correlations (eg. correlation with plasticity index). Often overlooked, but perhaps a more cost effective and accurate method of assessing slope stability is to undertake back analysis based on observations of existing slopes, landforms and past landslides. User manuals for slope stability programs can provide useful insight to parameter selection.

5.4 Failure to appropriately consider groundwater

In Victoria, groundwater or surface water infiltration is the most common landslide trigger. In some terrain, usually impermeable ground such as Older Volcanics, groundwater levels rise due to prolonged or sustained rainfall (multiple years above average in Figure 1) and trigger landslide. In other terrains storm events are the main trigger landslide. With reference to Figure 1 as an example, periods of high or prolonged rainfall correspond to greater landslide activity.

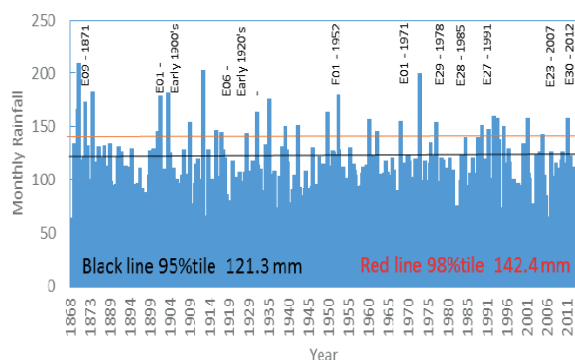


Figure 1. Annual Rainfall record for Mornington. 'E' labels are known landslides in the Frankston area. (Golder and A.S. Miner Geotechnical 2015)

The rainfall record in Victoria shows that rainfall over the past 20 years is relatively low (Figure 1). A common line of evidence cited for slope stability is that a slope has been stable for 20 years, therefore it is inherently stable. However, over a time frame of 20 years, the slope may

not have experienced 'peak' moisture conditions with stability derived from its being in an unsaturated condition. The moisture condition the slope might be subject to in the future is uncertain.

Slope analysis should consider the feasible groundwater conditions that could prevail over the life of the proposed development under worst case conditions. Whilst these are difficult to predict with certainty, they are probably higher than has occurred in the past 20 to 30 years.

5.5 Failure to review outcomes of analysis against observations.

In some cases, unrealistic outcomes of risk assessments are presented. For example, Factors of Safety of 20 have been cited, totally inconsistent with the slope forming processes. The outcomes of the analysis should be reviewed against the ground model and hazards. If not consistent, it might indicate that limit equilibrium analysis is not a suitable means of assessing slope stability.

The link between Factor of Safety and likelihood of failure is not well understood and is dependent on the level of confidence in the ground model and input parameters. The link is often made with no discussion or justification. Discussion on the confidence of input parameters and sensitivity analysis around the parameters should be undertaken where possible to support this link.

6 LANDSLIDE RISK ASSESSMENT

6.1 Poor hazard identification

Hazard identification is fundamental to the geotechnical assessment or landslide risk assessment and is perhaps the aspect of landslide risk assessment reports that is the most poorly applied. Common shortcomings in hazard identification include:

- Nominating hazards that are not consistent with the ground model or not feasible. For example deep seated circular failure in areas with shallow rock.
- Nominating the same hazards irrespective of the site or location. It is common to see repetition across reports by the same consultant: 'deep seated failure', 'shallow failure', 'failure of batter'.
- Providing insufficient detail to explain the hazard. The hazard description should describe what the hazard is, its magnitude,

intensity, likelihood of occurrence and area that could be affected.

- Failure to link the hazard to the ground model and geomorphic processes.
- Failure to identify hazards that might originate off the site or failure to identify landslide issues on the site that could present a hazard off the site.

The hazards identified must be site specific, their description supported by observation and be consistent with the ground model.

6.2 Poor understanding and interpretation of AGS 2007 and risk assessment process

The AGS 2007 Landslide Risk Management Guidelines are referenced in most Victorian EMO's and must be complied with for landslide risk assessments provided in support of a planning application. It is evident based on common errors in reports that the AGS 2007 guidelines are often poorly understood, the author of the report. It is acknowledged that the guidelines have a level of complexity and some aspects are challenging. However, that need not preclude the production of a useful geotechnical report.

The AGS guidelines for quantitative risk assessment define specific inputs. A common shortcoming is to see inputs defined with no explanation of how they have been derived. For example inputs for likelihood, spatial and temporal probability that simply appear in the report as a number. The inputs to the risk assessment must be linked to the ground model and hazard definition and supported by observation.

Even if the AGS risk assessment process is not well understood by the author, if the thought process that has led to the risk assessment inputs is well set out and transparent, it can allow the author's logic to be followed and a reasonable review to be undertaken.

6.3 Risk Assessment Outcomes

In the author's experience of reviewing hundreds of geotechnical assessments and landslide risk assessments, it is estimated that less than 5% evaluate an unacceptable risk. This seems an unlikely statistic the reason for which can only be speculated. This observation however reinforces the aforementioned point that the logic behind the risk assessment must be transparent and clearly articulated.

6.4 Separation of assessment of risk to life from risk to property

Consistent with AGS 2007, most EMO schedules in Victoria require risk to life to be assessed quantitatively and risk to property to be assessed qualitatively. However, it is common to see the two methods mixed. For example, risk to property assessed a qualitative assessment, then 'converted' to a quantitative outcome and compared to a quantitative criteria.

Risk to property is sometimes assessed quantitatively using remedial costs/dollars, a method which is described in AGS 2007, however, no EMO schedules in Victoria provide criteria against which such an assessment can be evaluated.

The logic behind the risk assessment is generally much clearer when risk to property is assessed in a fully qualitative manner and risk to life in a fully quantitative manner.

6.5 Assigning inappropriate level for risk evaluation

All assessed risks must be evaluated against a criteria to determine whether they are acceptable. AGS 2007 nominates that the criteria is usually set by the regulator, and this is the case in Victoria. The practitioner must review the relevant EMO schedule and be familiar with the applicable criteria. Some LGA's, for example Yarra Ranges nominate a criteria in the EMO schedule, whereas others, for example Colac Otway refer to criteria included within AGS 2007. It is common to see the criteria in AGS 2007 used without reference to the EMO schedule.

7 RISK MITIGATION

7.1 Risk mitigation inconsistent with hazards

A common method of presenting the outcomes of a risk assessment, is to present an assessed risk which assumes engineered mitigation has been put in place. It is rare to see an assessment based on the pre-mitigation condition. This is not necessarily a shortcoming in itself, but can be if the mitigation measures are unrealistic or if no evidence is provided through the geotechnical declaration that the measures will be implemented.

Mitigation measures can be unrealistic for a number of reasons, for example:

- Their construction would likely be cost prohibitive.
- For access or other reasons their construction would be impractical.
- The measures are unlikely to be effective, and no supporting analysis or calculations are provided to demonstrate that they could work.
- The measures proposed are not consistent with the identified hazards and no design event is specified for which the design is undertaken.

A common example is where measures are proposed to mechanically stabilise deep seated landslides such as piles or ground anchors. Such mitigation is rarely feasible at residential scale and often cannot be shown to be effective through analytical methods. For example, soldier piles are sometimes proposed as means of mechanically stabilising deep seated landslides and their effectiveness assessed using limit equilibrium methods such as Slope/W. However, checks of the bending moments and structural capacities of the piles show them not to be structurally adequate. Finite element modelling typically indicates that much greater embedment into stable ground is required than a limit equilibrium analysis would suggest.

8 CONCLUSION

The standard of geotechnical and landslide risk assessments provided in support of planning applications in Victoria is highly variable and in many cases inadequate. The intent of this paper is to provide feedback on where in the author's opinion the key shortcomings lie. In particular, shortcomings are associated with the development of a realistic ground model, identification of feasible hazards and the use inappropriate methods to analyse the hazards highlighted but the ground model.

REFERENCES

- Australian Geomechanics Society (2007). "Landslide Risk Management." Australian Geomechanics, Vol. 42, No. 1, March 2007.
- Golder Associates and A.S. Miner Geotechnical (2015). "Landslide Susceptibility Study, Cliff Road Area." Report to Frankston City Council.

AGS VICTORIA 2016 SYMPOSIUM
**Excavations and slope stability
in Melbourne geology:
experiences and recent developments**



**AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIA CHAPTER**