13th Australia New Zealand Conference on Geomechanics – Acosta-Martínez & Lehane (Eds.)

Ground Models - Underappreciated, misunderstood and neglected, a plea for action

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ABSTRACT: With the growing demand for rapid residential development there is a push to develop more challenging terrain, therefore the importance of developing a good ground model to understand the potential geohazards and challenges is also increasing. Price competition and shortened project timescales in the land development market in particular has resulted in a tendency, in some cases, to minimise the preliminary effort required to develop a good ground model. Further, there appears to be confusion amongst our younger practitioners as to what may constitute a ground model and how it should be regarded. In this paper, we seek to promote discussion, remind practitioners of the importance of a good ground model and look at quick economic ways of developing one in what is after all a business environment; and to encourage everyone to impress on clients and our less experienced colleagues what we already know - that early investment saves dividends later.

1 INTRODUCTION

1.1 *Background to this paper*

The authors were prompted to prepare this paper by personal observation and an opinion that in today's fast and hurried business environment the 'ground model' is in danger of relegation to a 'nice to have' tool in site assessment, rather than being seen as the essential and potentially highly beneficial tool we consider it to be.

We consider this to be particularly the case in the residential sub-division and small to medium scale development market where a large number of our younger practitioners 'cut their teeth'. We are concerned that this may lead to poor technical solutions and risk on these projects and that poor habits may then get carried over into more complex and larger scale projects unless sufficient guidance, mentoring and training is provided to these practitioners as they progress in their careers.

Ground model development should commence at the very start of a project, ideally at the proposal/investigation scoping stage. Without robust desk study and development of a conceptual ground model before going to site there is a risk that you may fail to identify fully the potential geohazards and risks associated with your project.

By developing a good ground model from the start of the project potential geo-hazards can be identified, fieldwork can be targeted at key features and the model updated. In this manner, the value of the work is optimised giving our clients improved return for their investment, reducing development and cost risks to the client and technical risk to the engineer.

In this paper we propose to put forward a case for a clearer understanding of ground models, their development and use. Much of what we state below should not be new to the reader however we are concerned that as our title states, and with particular reference to residential sub-divisions and medium size construction projects, ground models are increasingly underappreciated, misunderstood and neglected.

2 WHAT IS A GROUND MODEL?

We believe that there is a common misunderstanding as to what may constitute a 'ground model' and that perhaps the loose or wide use of the term 'model' is confusing the issue.

There are a number of ground model types, such as a geological ground model, a geotechnical ground model and hydrogeological ground model to name but three. Our particular concern is the use and development of geotechnical ground models.

Common factors to them all, is that they start from the geological ground model, are three dimensional, and are living entities ready for constant update and revision as the project develops. All models are an ap-proximation starting from a purely conceptual picture that is then refined, modified and improved with data acquisition as the project advances. Thus, gaining confidence in the model will more accurately reflect what is actually present as the work proceeds and therefore, the level of confidence in the ground model increases and the degree of risk should decrease over time.

A ground model should be at least a three-dimensional representation of the geology and geomorphology, which reflects the initial depositional processes and those factors that have modified them subsequently, such as erosion, weathering and disturbance.

Ideally a geologist should assess likely strata together with their probable vertical and horizontal distribution across the area of the site. The potential depth and effect of weathering alteration should be assessed, and the associated geotechnical properties of the strata identified. Geomorphology interpreted from site inspection and/or air photographs should give a first indication of any modification to the anticipated stratigraphy and resulting geotechnical challenges of the site.

Parry (2016) describes 3 types of model:

1. Geological model: generated at the desk study stage based on published information, commonly in the form of geological maps and/or cross sections.
2. Ground model: generated following a site investigation and laboratory testing.
3. Geotechnical (analytical) model: undertaken during design.

For the smaller project, the ground model can remain entirely conceptual, in the mind of the author, and possibly only expressed in words in the final geological/geotechnical report. However, this can be very difficult and many struggle to get the necessary description and information across. We would argue that every project should have at least some form of ground model sketch on file as a minimum and that as project complexity grows, in scale or situation, the need and level of detail for graphical recording and presentation of the model grows.

There is a balance to be struck between effort spent in development of the ground model and the project value, risk and complexity. The law of diminishing returns applies to this process and the point where value added is less than cost or effort can be difficult to judge and takes experience to identify. This is where it is important for the more experienced practi-tioner to give advice and guidance.

3 WHAT IS NOT A GROUND MODEL?

This is where the opinion of the authors may differ from many.

We are aware that some regard a borehole record as a 'ground model'. This is something we do not agree with and consider unhelpful.

Whilst we state above that the conceptual ground model can be simply described in words in a report, it is not simply a listing of strata, depths and ascribed geotechnical properties in a Table as increasingly seen in our experience.

A simple listing of strata depth and presentation of 'average' geotechnical parameters are sometimes being presented as 'the ground model' with no context around the areal distribution of the strata. Whilst this may be adequate for some small-scale developments on simple geology, there are clearly risks if this approach is applied on a larger scale or in areas of complex geology. The three dimensional distribution of strata and the nature of their interfaces needs to be addressed and discussed, as do possible seasonal variation in those properties. This does not always need to be in elaborate detail but should be sufficient to demonstrate the author has considered it.

With the use of computer software and analyses for increasingly complex and challenging work, analytical models are developed, and in the case of limit equilibrium slope stability analyses, they are usually in 2 dimensions.

Whilst this may indeed be considered a 'model', we argue it is not in itself a 'ground model' but a slice through the ground model representing interpreted conditions at a single location. Increasingly, such analytical models/sections are being labeled and presented as "the" ground model.

Whilst this may seem pedantic, we consider that the loose use of the term 'ground model' in these cir-cumstances can lead to blinkered thinking. The fact that ground conditions (and by implication the ground model) may be quite different elsewhere on the same site risks being overlooked.

An increasing tendency with the use of more complex analytical methods appears to be over simplification of the analytical (geotechnical) model. This may be in part to save time and in part though a failure to fully transform the geological model to a geotech-nical one. An example is modeling thickly interbed-ded silt, clay and sand as a single geological unit such as 'alluvium' with a single set of geotechnical parameters whilst a continuous soft clay layer in that sequence may in fact determine the stability of a cut or embankment. It is perhaps this transition from geological to geotechnical analytical models that is not always appreciated and where inexperienced practitioners need most guidance.

4 WHY IS IT IMPORTANT?

As previously stated, it is widely accepted in the industry that developing a well thought out conceptual ground model at the beginning of a project and modifying it as you proceed offers the best prospects for your project and return on your investment to effectively manage project risk.

General thought is that early discussion and agreement with a client as to the level of investment in development of the ground models is desirable, remembering that a poor ground model can mean either an increased risk of unforeseen costs during construction or an over conservative design.

Having a good understanding of the geology, geo-morphology and processes that have occurred and are occurring on your site enables better targeting of subsequent investigation and analyses, with the greatest returns being at the desk study and walkover stages of a project. This was demonstrated by Fookes et al in 2001, (Figure 1).

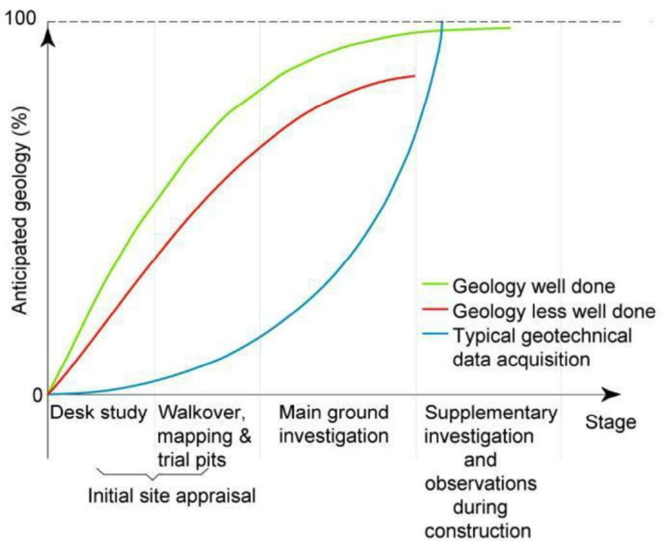

Figure 1. Estimated upper and lower bounds of geological in-formation anticipated during the states of a successful site investigation.(after Fookes 2001).

The inverse of the plot in Figure 1 is that risk is reduced as the knowledge of anticipated geology increases.

Without good ground model development at the start of a project, the following stages are at risk of, at worst, not determining key geotechnical hazards on a site or, at best, underestimating them. Furthermore, our clients may end up spending more and potentially getting less reliable, higher risk designs than may otherwise have been the case. Conversely, the design may become overly conservative.

5 WHAT IS THE PROBLEM?

Accepted good practice is to carry out a desk study and visit the site prior to scoping any intrusive investigation work. However, with increasing price competition and shortened timescales for development, there is pressure to take shortcuts and an increasing tendency to minimise the preliminary effort required to develop a good ground model. Engineers are increasingly asked to price and scope ground investigations without time (or budget) to do so.

We work in a business environment with commercial pressures, tight budgets and equally tight programs. With this and the increasingly rapid pace of projects we fear that basic ground models are being developed after projects have been awarded and are not being sufficiently updated and modified as projects develop.

In some cases, ground model development is being initiated after site investigation fieldwork starts. Not having a conceptual geological ground model to inform the pre-tender/proposal stage of a project may result in a poorly informed or inappropriate geotechnical investigation. This can then lead to design changes, delays, increased and unknown technical, safety and commercial risks to the project.

6 WHAT IS THE SOLUTION?

6.1 *Rapid, free and easy access to quality data*

Today with so much previously unheard of levels of data literally available at our finger tips the authors consider that there is little excuse for failing to commence ground model development at the pre-tender/proposal stage for even the smallest of projects.

There are a number of quick and economic ways of developing a conceptual ground model at tender/proposal stage whilst remaining competitive in what is after all a business environment.

Many countries now have the following information online and freely available:

1. geological maps and memoirs
2. geotechnical databases
3. historic and current aerial imagery
4. contaminated sites
5. roadside imagery
6. historic maps and plans
7. topographic data, and
8. water well information

- to name but a few.

These can be accessed quickly and easily giving in the space of an hour (or two) information that would take considerably longer to obtain and interpret using paper and library sources.

In New Zealand, 1:250,000 scale national geological maps are available to download and the government, together with the NZ Geotechnical society, has built on the success of the Canterbury Geotechnical Database to roll out the scheme nationally.

Practitioners can freely access PDF's of exploratory hole records and digital borehole and CPT data in AGS Format on a user beware basis. The only pro-viso is that you upload new data to the database in return – on a quid pro quo basis. As this database grows it will be uncompetitive not to use it.

Further Regional and District Councils increasingly have publicly accessible GIS based information on potential geo-hazards and geotechnical risks within their areas.

We understand that the situation in Australia is broadly similar with the availability of digital and web-based information varying between states and government agencies. Examples being the CSIRO Atlas of Australian Acid Sulfate Soils, or the Western Australia Department of Water and Environmental Regulation publication on Acid Sulfate Soil Risk maps, and also the Perth Groundwater atlas.

It is therefore now a simple, cheap and quick process to access a suite of websites and information sources useful in developing an initial conceptual geological or geotechnical ground model, prior to pre-paring and scoping any ground investigation.

On Table 1 below we present an example checklist developed for preliminary desk study and ground model development using solely publicly available digital data in New Zealand. For each row all relevant information should be recorded for the subject site as a part of the project scoping and proposal presentation phase.

Table 1. Example checklist for preliminary desk study/ ground model development.

Data Type	Where to Look	Looking For
Received from Client	Correspondence records	Development plans, foundation loads? Previous work / existing information?
Geological Map	QMaps / Google Earth Layer http://data.gns.cri.nz/	Units, Age, Rock/Soil, liquefiable?
In-house Records	See our Google Earth Layer, Ask around office	What investigations were done, what did they find?
NZ Geotechnical Data-base, Borehole & CPT Records	https://www.nzgd.org.nz/	Any investigations by others near the site?
Lidar/Survey Plans	From client or for example: https://waikatomaps.waikatore-gion.govt.nz/Viewer/?map=2fb1b81851ca43bcb21295daccca3b75	Topography /geomorphology, steep slopes, gul-lies, flat land, river terraces?
Historical Photos	https://data.linz.govt.nz/set/2-nz-aerial-im-agery/ http://retrolens.nz/	Historic Environmental Effects? Historic landslides or movement? Changes in landform, land use, river course / drain-age patterns, roads, areas of fill, development his-tory
Google Earth	Google earth pro can be downloaded from https://www.google.com/earth/down-load/gep/agree.html	Past slips, instability, flooding? Recent changes. Geomorphology
GNS Databases	http://data.gns.cri.nz/landslides/wms.html https://data.gns.cri.nz/af/	Any mapped /known natural hazards including ac-tive faults, landslides, tsunami, flooding etc?
Archaeology/Heritage/ Contaminated land	Check local and regional council web sites and databases	Is the site on Council SLUR or HAIL? Are there known archaeological or heritage sites?

6.2 *Improved understanding and communication with clients*

We should always be encouraging our clients to in-vest in good thorough desk studies and to allow time and budget for site inspections, geological and geo-morphic mapping and phased data gathering.

We need to discuss and agree with our clients an agreed level of desk study for initial ground model development. We should stress the potential benefit of a greater return for their dollar and be exposed to reduced levels of risk with early development of a good ground model due to better targeted intrusive investigation and laboratory testing.

6.3 *Ensuring on-going training and mentoring of inexperienced practitioners*

We should also be reminding ourselves that ground models are never fully developed and that they should be constantly revised and challenged as new data becomes available throughout the desk study, investigation and construction phases of a project.

We should encourage our site staff to consider if what they are logging and observing during investigations fits the model, if not why not and what are the implications? If further investigation is required, should test locations be changed, do we have enough laboratory test data and have the correct tests been scheduled to fully understand the geotechnical properties of the various strata, their distribution and their variability?

We need to encourage our young professionals to prepare, question and challenge ground models, to think in 3 dimensions and to recognise that simply listing strata in a column is not a ground model unless some context is placed around that.

We need to ensure all staff are aware of and understand the differences between model types, the stages of ground model development and the limitations of analytical models. In particular, an understanding that the quality of the geotechnical and analytical model is dependent both on the quality of the original geological ground model and the quality of the data ascribed to the various strata. We also need to encourage them to consider how their models may change with time and through changes effected by the project and increasingly possible changes imposed by climate change.

7 CONCLUSION

The early development of a geological ground model, its evolutionary transformation from a conceptual model to a geotechnical model and its use in better targeting intrusive investigation and understanding of the ground is well known and acknowledged within the industry.

With modern information technology allowing easy, fast and cheap access to geological, geomorphic and geotechnical data it is relatively simple to quickly develop ground models enabling investigations to be scoped and planed with some confidence without visiting the site.

However, the business environment, commercial pressures, tight budgets and programs can lead to shortcuts being taken with little or no ground model development being undertaken at project conception or throughout the project.

If we are to exploit the value locked up in the information freely available to us, then we must use it well and encourage our clients to see the benefits to them of our doing so.

With remote assessment and formation of ground models, there is a greater need for them to be revised, challenged and updated to incorporate fresh information and data as it becomes available. This can be achieved through ongoing training and encouragement of practitioners to recognise this. For them to be aware of the differences in ground model types and their limitations and the need to look at the 'bigger picture'; to consider the ground in 3 dimensions, to consider the level of detail needed to effectively manage the geotechnical risks for their project and to challenge models in the way described above.

Finally, it is the responsibility of our more experienced practitioners to ensure that our younger colleagues and future leaders receive the guidance and encouragement they need and deserve to deliver quality work and uphold and improve standards in our industry.

REFERENCES

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