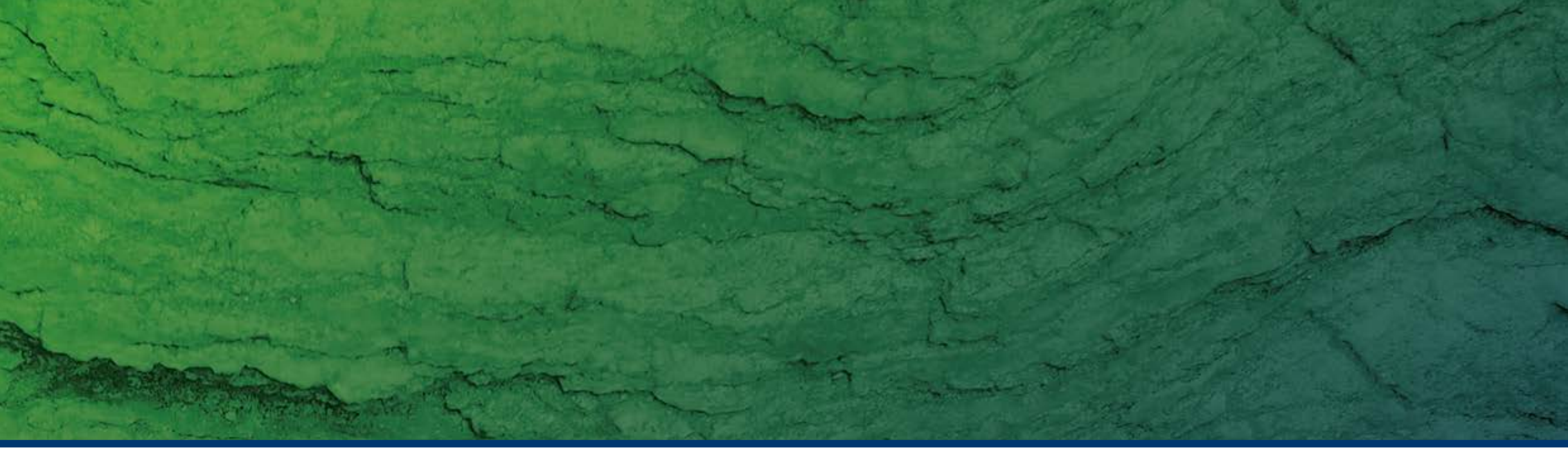
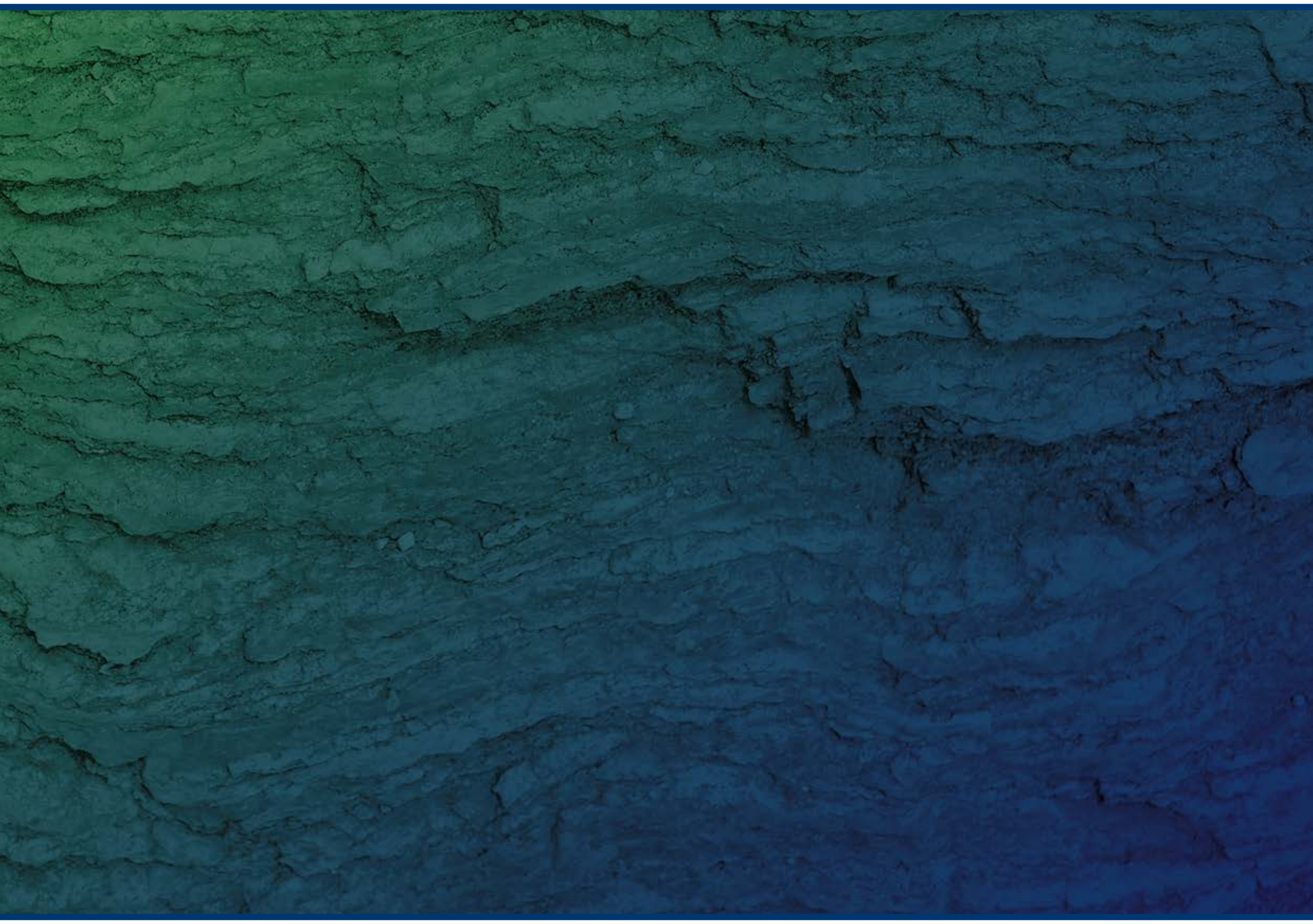


PROCEEDINGS

2019 AUSTRALIAN GEOMECHANICS SOCIETY VICTORIAN SYMPOSIUM

Geotechnical characterisation – managing design and construction risk

Wednesday, 30 October 2019, 8:00am – 7:00pm
Rydges Hotel, 186 Exhibition Street, Melbourne



AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIA CHAPTER

reducing geotechnical uncertainty
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PREFACE

The Victorian chapter of the Australian Geomechanics Society invited academics and practitioners in the field of geotechnical and ground engineering to attend the 2019 Australian Geomechanics Society Victorian Symposium held on 30 October 2019.

In recent years Victoria has seen significant growth in the construction industry. Investment in both public infrastructure and commercial real estate is growing, and as our cities and infrastructure grow, so too does the need to develop parcels of land with challenging ground conditions. Economical and safe geotechnical design requires efficient and well thought through ground investigation and characterisation to identify and manage ground risks and opportunities.

The 2019 Australian Geomechanics Society Victorian Symposium presents an overview of current state of-the-art practices, innovation, new research results and case studies relating to geotechnical characterisation with an emphasis on its implications for addressing and managing design and construction risk. The 2019 Symposium brought together professional engineers, researchers, specialist contractors, regulators, educators and students to share and discuss their experiences on the topic of ground characterisation.

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Keynote address

Connecting geotechnical investigations with project risk

R. B. Kelly[1], M. Drechsler[2] and R. Goldsmith[3]

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ABSTRACT

It is often stated by geotechnical engineers that a project pays for a site investigation one way or another as a means of justifying a scope of work aimed at managing a project's risk. This proposition is critically assessed through reviewing three case histories covering site investigations performed for design only, design and construct, public private partnership (PPP) and alliance contract models. An extensive site investigation was performed for the Ballina Bypass Alliance project. Most of the project risks were identified and managed. However, some risks were realised relating to detecting palaeochannels, variable subsurface topography, quantifying material parameters and coping with corestones. An extensive site investigation has been performed for the Snowy 2.0 project, but its scope has been limited by time and access constraints. Risk is managed through adoption of a geotechnical baseline report. Site investigations for Inland Rail for design only, design and construct and PPP contract models have been scoped and partially delivered. In addition, Inland Rail has developed an earthworks materials specification that can be varied to suit site characteristics. Integration of site investigations with the specification and design is shown to be key to controlling the major materials risk. Some thoughts about scoping an investigation to inform geotechnical risk when procuring a PPP are presented. Overall it is concluded that the geotechnical industry generally scopes investigations to adequately manage risk. Quality is shown to be as or more important than quantity. The critical importance of engineering geology for identification of potential risks is demonstrated thus allowing a focussed drilling and geophysics scope to be delivered. Challenges remain when communicating residual risk to stakeholders.

Keywords: geotechnical, investigation, risk, project, earthworks, specification

1 INTRODUCTION

It is often stated by geotechnical engineers that a project pays for a site investigation on way or another as a means of justifying a scope of work aimed at managing a project's risk. Figure 1 is often used to illustrate the concept that cost over-runs can be associated with the scale of a geotechnical investigation. Figure 1 needs to be interpreted with care because it does not include projects that end up under or on budget. However, there is a relationship between the magnitude of cost over-run and the magnitude of site investigation.

Recent large infrastructure projects in Australia have spent between 0.5% and 1.5% of the estimated project cost on site investigation. According to Figure 1, that suggests there is a risk of significant cost over-run on these projects. Similarly, Manzari (2019) reports a study of 41 legal court cases, where 55% of claims were the result of "changed soil conditions." The study also found that approximately 45% of the claims against consultants were directly related to the geotechnical investigation.

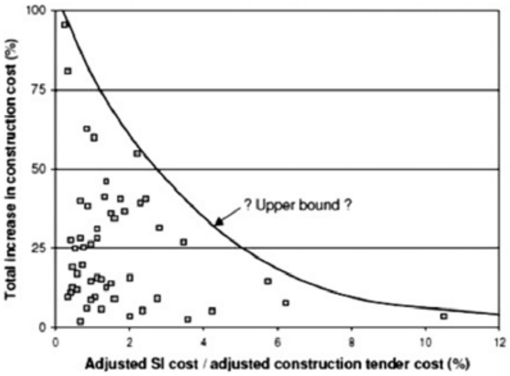

Figure 1. Mott McDonald and Soil Mechanics (1994)

Further inspection of Figure 1 suggests that a site investigation spend in the order of 10% of tender cost would reduce the risk of cost over-runs to less than 5%. In the context of a $1BN project that is $100M, which is unreasonable. Figure 1 also indicates that there are diminishing returns from spending more on site investigations with the greatest benefits arising from a spend less than 3% of tender cost.

Project risk is managed via a contract. Sometimes a risk is shared between asset owners and contractors, sometimes risk is transferred from asset owners to contractors and sometimes risk is taken by the asset owner. The geotechnical profession has a role informing both asset owners and contractors of risks covered by the geotechnical investigation and the extent of residual risk.

Three case histories are presented to discuss how geotechnical investigations can connect with a project's risk controls.

2 CASE HISTORIES

2.1 Ballina Bypass Alliance

The Ballina Bypass traverses a 6km wide floodplain associated with the Richmond River which is underlain by deep deposits of compressible soil. The northern half of the Bypass covers a further 6km largely through hilly terrain. The project took many years to develop due to the challenges related to cost effective construction over the compressible soils. The project was delivered as an

Alliance due to the time and costs risks associated with the compressible soils.

Several geotechnical investigation campaigns were performed, two trial embankments were constructed and two early works construction packages were awarded prior to the Ballina Bypass Alliance (BBA) being formed. An incomplete extent of investigations is summarised in Tables 1 and 2 in order to demonstrate the scale of the site investigation works. A large amount of laboratory testing was also performed. Further investigations were performed during construction.

Table 1: Prior to June 2007

Investigation type	Number
Borehole	295
CPT	142
Hand Auger	41
Test Pit	169
Trial embankment	2

Table 2: BBA TOC phase

Investigation type	Number
Borehole	70
CPT	51
SDMT	2
TBar	2
Shear Vane	2
MASW	2
Electrical Resistivity Imaging	2
Seismic refraction and cross hole	1
Trial embankment	2

The Ballina Bypass was delivered on budget and was opened to traffic 6 months early. Therefore, the extent of site investigation was justified. However, risks were realised during construction relating to site investigations where lessons can be learnt.

In general, embankments constructed on the soft soil settled as expected or more than expected. This trend first presented itself during the early works vacuum consolidation treated embankment (Kelly and Wong, 2009). The embankment is shown in the lower half of Figure 2 and one of the trial embankments is shown in the upper half of the figure. The vacuum platform was constructed, a vacuum of -65kPa was applied and then fill up to 8.5m high was placed. The embankment was left to consolidate for a period of about 6 months after filling. The embankment had settled 3.5m at that time. A back analysis was performed that matched the settlement plate data but did not match the excess pore pressure data. At that time the pore pressure data was considered to be less reliable, the settlement plate data was assessed to meet design requirements and the vacuum system was dismantled. Further monitoring in the following months showed that settlement had not been completed and projected long term settlement would vastly exceed design requirements. The vacuum system was converted to a vertical drain system and a further 5.5m of fill was placed. A second back analysis was performed after 6.4m of settlement had occurred which matched both settlement and excess pore pressure data and this developed sufficient confidence that long term performance would be achieved.

Figure 2. Vacuum embankment

The differences between the first and second back-analyses were that the compression ratio of the clay had to be increased from 0.35 to 0.45 and the preconsolidation pressure reduced. The original material parameters had been obtained from cone penetrometer and oedometer tests. Some examples of the oedometer tests are shown in Figure 3. This data showed that extensive sample disturbance had occurred which had the effect of reducing the measured compression ratio. Some examples of cone penetrometer tests are shown in Figure 4. These were obtained in 2006 with equipment utilising 8 bit data loggers. These loggers were not sensitive enough to accurately measure soft clay, as shown by the blocky nature of the trace. Interpreting pre-consolidation pressures from these data was difficult. Other indirect methods of interpreting pre-consolidation pressure were also used but again were affected by soil disturbance or accuracy of CPT measurements.

A few years later, the National soft soil field testing facility was established less than a kilometre from the vacuum site and a research level site investigation performed (Pineda et al, 2016, Kelly et al, 2017). These investigations demonstrated that compression ratios could be in the order of 0.7 when high quality samples were collected.

This case history demonstrates that the quality of site investigation data has a direct impact on actual performance versus predicted performance and hence on cost and time. In retrospect it would have been better to drill fewer boreholes and in-situ tests but perform

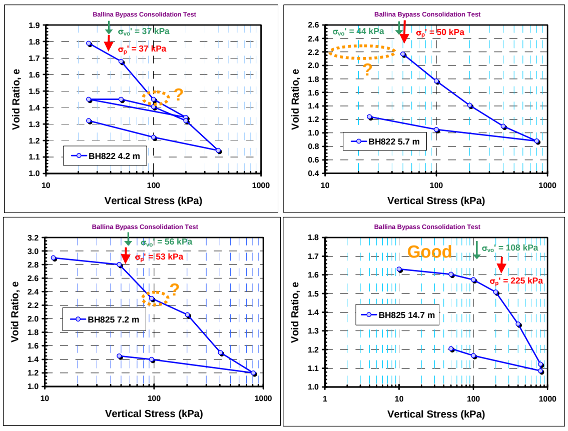

Figure 3. Oedometer test data

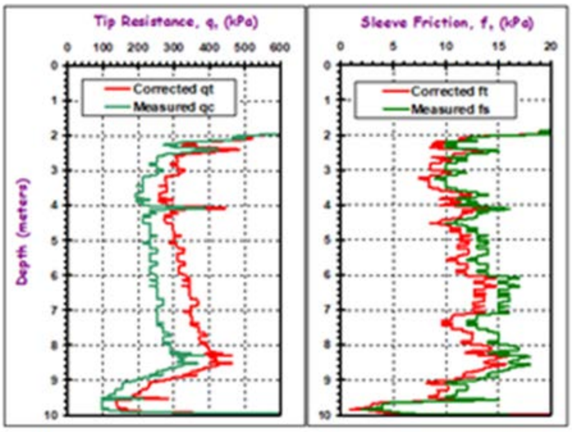

Figure 4. CPT data circa 2006

these works to a much higher quality. These risks were controlled by an extensive instrumentation and monitoring program coupled with the Observational Method. Overall the soft soil component of the project came in on budget as savings were realised in the ground improvement component of the works.

Despite the extensive investigation other residual risks were also realised. One major residual risk was piles having the same pre-cast length were driven to refusal at different levels, as shown in Figure 5. There were major differences in the stick up of the piles caused by a highly irregular underground basalt flow. The variability of this flow was not detected by the site investigation even though a borehole was drilled at each pier. Several piles were broken during driving. The second major residual risk turned out to be excavation of a cutting which comprised of about 30% basalt corestones (Figure 6). Large excavator pits were performed during the site investigation and it was estimated that about 30% corestones would be found. What was not appreciated was the presence of weathered clay between corestones, and the size of the corestones, such that they could not be easily excavated or blasted (explosives just removed the clay and left the rock in place). The corestones were removed by rock breaking and digging out resulting in an approximate $15M cost over-run on this element of the works.

2.2 Snowy 2.0

Snowy 2.0 hydro pumped storage project has been awarded as a design and construction contract with a Geotechnical Baseline Report (GBR) which acts as a risk sharing mechanism between asset owner and the contractor. One of the key aims of the geotechnical investigations was to identify baseline conditions and potential hazards for inclusion in the GBR.

Figure 5. Piles driven onto basalt flow

Figure 6. Corestones in cutting

Working in a national park provided severe constraints on all aspects of geotechnical investigations, including planned drilling programs. New tracks could not be cut and works needed to occur from existing tracks. The deep (up to 1km deep) boreholes at very remote sites meant that drilling was a slow and expensive process and needed to be carefully scoped. Therefore, development of a geological model in advance of drilling was more important than usual because the drilling works needed to be targeted at key risks for the project.

Initially a geological model was developed based on a sequenced geotechnical investigation program (GIP). Methods included a desk-study of old archives from the original Snowy Mountains Scheme, performing geological mapping, geophysical traversing, drilling of boreholes, in-situ testing and laboratory testing. Following this site work the data was evaluated by statistical analysis of the test results, review of the geological stratigraphy and structure by preparing sections along tunnel alignments and describing Ground Types (GT). The GT formed the basis for classifying the anticipated conditions for tunnelling and other underground openings.

This case history concentrates on the evaluation of the subsurface data to develop the model of the geological stratigraphy and structure. This has significant impact on the distribution of GT and the anticipated ground conditions for the critical facilities such as the power station complex, shafts and pressure tunnels.

The project risks considered in the GBR that are dependent on the distribution of various rock types and structures includes;

- Fault intersections
- Contrasting rock quality
- Naturally occurring asbestos
- Acid mine drainage
- High silica content
- High flow of pressure ground water occurrences
- Potential ground water draw down in sensitive environmental areas
- Variable in situ stress conditions
- TBM boreability

The desk study indicated a complex geology mainly comprising a sequence of sedimentary, metamorphic and volcanic rocks spanning the period from the Ordovician (485 Million years, Ma) to Devonian (359 Ma) that have developed during multiple orogenic events

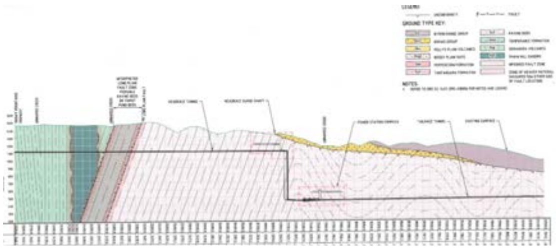

Figure 7. Feasibility stage geological model

associated with extensive faulting and folding; forming major geotectonic structures throughout the area. This knowledge indicated there would be major changes to tunnelling conditions along the 27 km alignment. A snapshot of the feasibility stage geological model in the vicinity of the power station complex is shown in Figure 7. The model shows the geological units, major structures and inferred folding.

Based on the feasibility model, the initial site work was scoped as a number of geological traverses targeting key risks for tunnelling and cavern construction over significant parts of the project area, including:

- Across the Long Plain Fault; a 1.2 – 2.0 km wide major thrust fault, which separates the highland country, or plateau terrain, on the east side from the deeply dissected ravine terrain to the west;
- Across several faults that intersect the plateau terrain, separating complex geological formations with a variety of lithologies
    - Through the higher parts of the ravine terrain where the folded Devonian strata have a complex relationship with the older Ravine Beds.
    - Surface geophysical investigations to investigate faulting, deep intrusive rocks and fracture zones.

The scope of drilling was developed over several campaigns as more information became available. Drilling of 53 boreholes, for a total of over 23 km of core, attempted to cover much of the 27 km tunnel alignment, shaft locations and power station complex, located up to 850 m below ground level. Restricted access above the power station complex lead to a borehole being drilled with 3 branches to cover more of the cavern area. A range of downhole testing was performed including geophysics, stress testing, televiewers and permeability testing. At least 3000 laboratory tests were performed. Significant findings from the drilling included the nature of the Long Plain Fault. There was poor rock outcrop exposure at the surface, but it appears at depth there were several discrete faults and fracture zones separated by competent rock zones.

Drilling over the initial target area for the power station complex was expected to pass through a thin sequence of the Devonian Boraig Group sedimentary and volcanic rocks and pass into fine grained folded rocks of the Ravine Beds. However, several holes encountered thick sequences of interbedded conglomerate, sandstone and felsic volcanics that indicated the Boraig group extended to about 800-900 m depth, before reaching the fine banded siltstone, characteristic of the Ravine Beds. It was appreciated that this unit had deep synclinal folds further to the north as reported from the early Snowy Mountains Scheme mapping in the 1950s. Such large structures were also assessed to occur in the power station complex area.

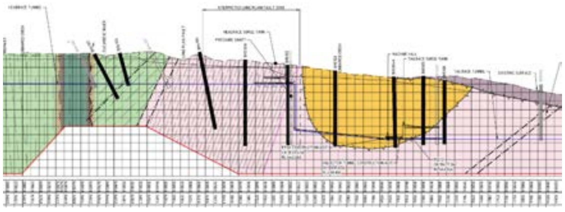

Figure 8. Geological model for initial version of GBR

An initial geological section was prepared by combining data from the geological mapping, aerial photo interpretations, LiDAR terrain models and drilling (Figure 8). This was further revised when core orientation data indicated local faulting and possibly at least two separated phases of folding.

This modelling provided a better confidence in the geological structures such that the power station complex was initially set in the reference design within the interbedded conglomerate and siltstone. However, the Contractor was concerned about the contrasting rock types with varying quality that could affect the cavern construction, so they decided to shift the cavern site west to lie wholly within the Ravine Beds. The geological modelling had anticipated a folded metasiltstone and sandstone strata dipping consistently to the north east and subsequent drilling into the vicinity of the revised cavern site has confirmed this.

The geological information was used by the client and the tenderers to develop versions of a GBR. A final version of the GBR was agreed with the preferred tenderer.

2.3 Inland Rail

The Inland Rail program is constructing a 1,700km freight rail line which will form the backbone of the national freight network between Melbourne and Brisbane via regional Victoria, New South Wales and Queensland.

An initial geological assessment was performed for the entire route (Coffey, 2015) which identified key geological constraints relating to material utilisation, subgrade conditions, tunnelling and slope stability.

Earthworks form a significant component of the program's scope of work and has a major impact on the capital cost, whole of life cost, and in-service performance and associated maintenance for the railway.

Inland Rail recognised that due to the complexity and diversity of the geological conditions the program will encounter that it needed to upgrade its earthworks specifications (Drechsler et al, 2019). Inland Rail developed two new performance based specifications, ETC-08-03 for Earthworks Materials and ETC-08-04 for Earthworks Construction to assist the delivery of Inland Rail earthworks design and construction (ARTC, 2017a and 2017b). The specifications: 1) facilitate the maximum use of site won materials by replacing prescriptive with performance-based design criteria, 2) provide consistent test methods and conditions in accordance with the latest Australian standards; 3) integrate with quality plans; and 4) encourage industry best practice earthworks designs to be constructed on the Inland Rail project.

One of the major aspects of the early geotechnical investigations was to identify the subgrade conditions for track formation design and the potential sources of earthworks materials within or adjacent to the corridor. The early identification of earthworks material characteristics and their limitations/deficiencies in respect to the specifications allows the designers to implement a wide range of risk mitigation strategies in their earthworks designs that provide engineering value to each project. For example, the compliance criteria for general fill could be amended, based on extensive investigation data, to allow local materials to be used instead of importing from distant quarry sources, with the track formation designed according to the local material performance behaviour within rail embankments. This approach reduces the risk of designing and constructing track formations and earthworks with 'theoretical' materials that can only be sourced, at great cost to the project, from distant widely distributed existing sources. In many instances, local materials can be improved by selective winning, mixing or stabilisation to improve any identified deficiencies, thereby reducing the risk of lower design life performance due to generally avoided materials with high fines content, high plasticity, high shrink/swell behaviour, or high susceptibility to erosion and dispersion.

identifying the risks associated with the earthworks in the geotechnical investigation program allows those risks to be mitigated and potentially turned into opportunities to provide significant earthworks cost and schedule savings to Inland Rail.

The Inland Rail program will be brought to market using a range of contract methods including construct only, design and construct and a public private partnership. These projects are implemented in three phases, concept design, reference design (for environmental approvals) and detailed design (for construction).

For the construct only and D&C projects (the majority of the alignment) geotechnical investigations are scoped to target bridge, viaduct and culvert structures, cuttings, embankments, subgrade conditions, groundwater and earthworks materials. Some of these projects involved reconstruction of existing rail formations and some were greenfield. Foundation and earthworks design parameters and identification of constructability issues were assessed by excavating test pits at fixed chainage intervals and taking samples for conventional laboratory earthworks materials testing. Scopes of these investigations were prescribed to allow tender pricing. Typically the investigations were delivered in parallel with the design.

Geotechnical investigations within the concept and feasibility stages were generally limited in size and complexity due to alignments were being developed and therefore land access/tenure was limited. High risk areas of the alignment were investigated as a high priority, these included expansive black soils and erosive/dispersive subgrades in flood prone areas. Bridge structures were investigated with widely spaced test locations to identify the types of foundation conditions (shallow or deep), anticipated settlement/consolidation behaviour and potential constructability issues. Most cuttings had at least one test location, supplemented by geological mapping and some seismic profiling.

Geotechnical investigations during the detailed design stages targeted features with more extensive and complex investigation methods to meet Australian Standard or other design requirement at each feature. Boreholes at bridges were located to meet AS5100 bridge and AS2159 piling compliance requirements to reduce previously identified project risks.

These scopes of investigation have provided an understanding of the geotechnical conditions and their variability along each project. This covers the majority of the geotechnical risks. However, the process of prescribing investigations at set intervals and performing investigations in parallel with design prevented more targeted investigations that could further refine the design, reduce risk and convert opportunity.

For the Inland Rail PPP, covering Gowrie to Kagaru (G2K), an Extended Geotechnical Program (EGP) was scoped to inform the PPP proponents such that they can price risk effectively in their tender. The EGP was based on the reference design. The EGP field and reporting program was constrained by time, with 9 months to deliver from contract award the scale of works summarised in Table 3.

Table 3: Inland Rail EGP

Investigation type	Locations	Quantity
Boreholes	413	12,800m
Downhole Imagery	74	4,000
In situ tests	84	504
Test Pits	580	
Standpipes	36	1,960
Geological Mapping	112	
Seismic Profiling	48	14,200m
Laboratory Tests		+2,500

The PPP EGP targeted tunnels, portals, cuttings, embankments, bridges, viaducts and major culverts at a sufficient spacing, frequency, method and depth according to their risk profile. High risk areas have high capital cost and high risk of adverse cost outcomes due to ground conditions. These include the tunnels, portals, converting tunnels to deep cuts, large viaducts (>20m high), potential embankment failures on colluvial slopes, excavatability of large cuts, material utilisation, impacts on groundwater and bridge abutment locations. Medium risk targets included defining structural geology of cuts (slope stability) and bridge foundations. Defining formation subgrade conditions, drainage, black soils and culverts were assessed as low risk targets.

Termination criteria were developed during the EGP implementation phase for bridges, major roads over rail crossing (as per QLD Department of Transport and Main Roads requirements), small roads and pedestrian crossings, viaducts over 20m height, tunnels, cuts, embankments and culverts. The termination criteria were adopted to provide sufficient geotechnical data to the PPP Contractor to make reasonable assumptions during the tender process. The termination criteria ensured efforts and costs involved to undertake the PPP EGP were minimised, and vital geotechnical information was not lost, and the investigation achieved the desired outcome of de-risking the PPP tendering.

The EGP did not target potential locations for construction materials, such as borrow pits, quarries or other external sources outside of the corridor as this was considered a known consistent risk for all PPP proponents.

The EGP was developed on the basis that additional geotechnical investigations will be required by the PPP during detailed design work at locations where the EGP were not completed (access or time constraints), where the detailed design changed from the feasibility design (ie culvert to bridge, bridge to viaduct etc) or at specific locations to comply with Australian Standard requirements (AS2159 piling and AS5100 bridge code) for each foundation structure.

3 DISCUSSION

There is little incentive for designers to push the boundaries in reference design and construct only models, particularly when time is limited. Risk in the form of higher construction costs is therefore held by the client. Risk can be transferred to a contractor in a D&C model. Risk can be shared via GBR or PPP or Alliance type models. Risk is shared when it is too high to be taken by either the client or the contractor. Typically, the scope of geotechnical investigation is greater when risk is shared than when the risk is held by the client or transferred to the contractor.

The Ballina Bypass is an example of a project which was developed over many years and risks controlled via an Alliance model. Current trends are that projects such as Snowy 2.0 and Inland Rail are being developed in much shorter timeframes where investigations are performed in parallel with design. While the geotechnical profession can have some input into client decisions regarding what contract model they wish to adopt, such influence is generally limited. Therefore, the geotechnical profession needs to be agile and to develop geotechnical investigations within contract, risk and delivery constraints that maximises project outcomes.

Ideally geotechnical investigations are developed in multiple stages with periods of interpretation in between stages. Key issues can be progressively identified and mitigated using this process. However, current trends in project development limit opportunities for multiple stages of investigations.

Geological assessments have always been a key component of a quality site investigation. When time is short the geological model becomes even more valuable because understanding the geomorphology and current conditions provides the majority of geotechnical inputs into a risk assessment (eg Fookes et al, 2000). Geological assessments occur early in the process allowing information to be fed into design and appropriate decisions on risk management and contractual arrangements to be made.

Time constraints also limit the scope of investigation programs. Geophysics, drilling, in-situ testing, sampling and laboratory testing need to be carefully specified to provide detail and confirm features indicated by a geological assessment. Snowy 2.0 is a good example of an investigation strategically targeted to inform the GBR risk control tool. The Inland Rail geotechnical investigations provide sufficient data to understand the variability of natural materials and their conventional earthworks parameters. These investigations have typically confirmed geological assessments of ground conditions; specifically the presence of low quality earthworks materials and the absence of high quality materials. To date, the investigations have not been specifically crafted to maximise the use of site won fill, which is one of the major project risks. An alternative to test pits excavated at set chainage intervals could be a site walkover followed by test pit location in key geological units and a laboratory testing program targeted at solutions as well as material characterisation.

One of the key lessons from the Ballina Bypass Alliance was that quality is more important than quantity. Multiple stages of investigation were performed and a very large amount of work done. However, much of the soft soil compression data was affected by sample disturbance which contributed to embankments performing differently during construction than anticipated during design. With the benefit of hindsight, an investigation comprising geophysical traverses aimed at finding palaeochannels in the floodplain coupled with a smaller number of in-situ tests, boreholes and laboratory tests but performed at a higher quality would have identified and controlled risks at similar or lesser cost of investigation.

No matter how large or small the geotechnical investigation there will always be residual risk because not every element of soil and rock can be tested. Residual risk needs to be understood and communicated to the client to inform subsequent phases of the project. Higgins (2017) provides a perspective from an asset owner in Figure 9. Actual risks diminish through the various stages of a project as additional information becomes available. However, perception of risk increases over time as a result of some risks being realised. Standard practice for consultants is to list limitations of the geotechnical investigation and interpretation in reports to control their commercial risks. It is becoming more common for interpretive and design reports to identify and communicate residual risks to the asset owner, but this communication can be overlooked in subsequent years when the risks eventuate.

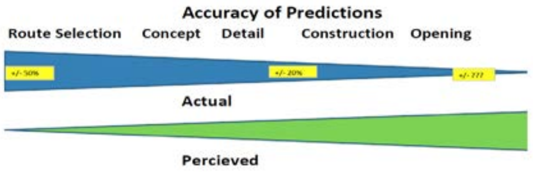

Figure 9. Actual versus perceived risk (Higgins, 2017)

4 CONCLUSIONS

Infrastructure projects are increasing in scale and are being delivered in shorter timeframes. The proportion of project cost being spent on geotechnical investigations is relatively small. According to Mott McDonald and Soil Mechanics (1994) that should mean project risks related to the quantum of geotechnical investigations are high.

The case studies for the Ballina Bypass, Snowy 2.0 and Inland Rail suggest that the geotechnical industry generally scopes investigations to adequately manage the majority of project risks. Where residual risk is considered high by the client additional contract controls in the form of a construct only contracts, GBR's or an Alliance are implemented. Arguably, risks associated with the quantum of geotechnical investigations are generally appreciated by asset owners and appropriate controls are usually implemented.

The effectiveness of a geotechnical investigation can be compromised by poor quality, scope that does not address key risks and work that occurs in parallel with design. These elements are considered more critical by the authors than the quantum of the investigation.

A geotechnical investigation that effectively manages risk is likely to include:

- A high quality geological assessment to identify key risks for the project;
- A scope designed to answer key questions as much as obtain material parameters; and
- Fewer tests at fewer locations but performed with higher quality than is normal industry practice.

Every investigation will include residual risk which needs to be communicated effectively to people throughout subsequent phase of a project.

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