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New Zealand natural hazards: Do we really need geotechnical professionals?

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ABSTRACT

New Zealand Geotechnical Professionals sometimes have struggled to convince councils and developers alike of the importance of robust geotechnical ground investigation and design as part and parcel of infrastructure / developments. The recent period of natural hazards activity both within the urban environment and media alike has led to a greater in-depth focus on the statutory requirements considering resource and building consent processing, and indeed the level of scrutiny in which applications are vetted. This paper covers four projects / studies distributed throughout New Zealand that have either influenced thinking and/or practices in relation to natural hazards and planning, consenting, and certifications process. These projects are:

- Christchurch Earthquake Sequence and Geotechnical Land Assessment Team;
- Petone Plan Change Geotechnical Reporting, Wellington;
- Kilmarnock Heights Retirement Home Development, Wellington; and,
- Crestview Residential Development (300+ residential lots), Red Hills, Papakura.

Each of these examples illustrate the varying levels of investigation, review and rigour in regards to consenting and geotechnical design when considering the individual natural hazards to be considered. Without robust and rigorous processes integrated within and reviewed by technical professionals, our resulting private and public sector infrastructure will lack safety in design, resilience and 'whole of life' cost considerations! Therefore, the answer to the questions is 'yes', we definitely need robust and thorough geotechnical investigation and design by completed professionals when progressing projects.

Keywords: natural hazards, planning.

1 INTRODUCTION

The recent period of intensified natural hazards and the potential deadly consequences associated are at the forefront the New Zealand public. However, regulation and sometimes reluctance of officials to see the seriousness of implementing policy and tightening regulation around new and existing building design in relation to natural hazards or geotechnical risks is creating an increasingly short to middle term sustainable communities in an immensely hazardous environment over which we have little control.

The purpose of this paper is to highlight the variance of geotechnical investigation, assessments and reviews in conjunction with geotechnical design for consenting and planning when considering site specific natural hazards, and that we do need geotechnical professionals.

Case Studies

Four case studies are summarised in this paper. They located across New Zealand with varied natural hazard and geotechnical risks in different geological settings.

1) Christchurch Earthquake Sequence and Geotechnical Land Assessment Team;
2) Petone Plan Change Geotechnical Reporting, Wellington;
3) Kilmarnock Heights Retirement Home Development, Wellington; and,
4) Crestview Residential Development (300+ residential lots), Red Hills, Papakura.

2 CANTERBURY EARTHQUAKE SEQUENCE & LAND DAMAGE ASSESSMENT TEAM

2.1 Introduction to case study

The Christchurch area and surrounding region have been subject to ongoing seismic events since the M7.1 earthquake on the 4 September 2010. Since this earthquake the same area was subject to a number of significant earthquakes most notably the M4.7 earthquake on 26 December 2010, M6.2 earthquake (under the Port Hills) on the 22 February 2011, a M6.0 earthquake on the 13 June 2011, and a M5.9 earthquake on the 23 December 2011. Collectively these earthquakes are the aftershocks in between are known as the Canterbury Earthquake Sequence. The highest vertical acceleration recorded for all of the earthquakes was 2.2g (for Feb 2011) with horizontal acceleration of 1.7g (near to the epicentre). The effects of these earthquakes affected a wide area of Canterbury and Christchurch city, in particular the February 2011 earthquake was particularly devastating to the city of Christchurch (Central Business District (CBD) and both flat and hill suburbs) due to its proximity to the city and shallowness.

2.2 Summary of ground condition

Christchurch lies on the coastal edge of the Canterbury Plains and its quaternary geology is a combination of fluvial and marine deposits overlying deep bedrock. The fluvial and marine deposits from glacial and interglacial periods comprise alternating layers of well-graded gravel (mostly greywacke, sourced from the Southern Alps to the west) and fine-grained marine sediments that have accumulated on the continental margin. A combination of swamp and fluvial overbank deposits are common. This low-energy delta environment has resulted in accumulation of relatively soft/loose Holocene soils. The Port Hills are volcanic and plutonic in nature, commonly with a mantle of loess.

2.3 Earthquake effects

Extensive parts of Christchurch was affected by liquefaction, both sand boils and lateral spreading, affecting both domestic and commercial properties. Liquefaction damage was particularly extensive in the eastern suburbs and along the Avon River. Many buildings in the CBD were severely damaged by shaking (structural) with some building collapses with fatal consequences.

Some sections of the CBD were affected by sand boils and ground settlement causing differential settlement of buildings. Some buildings had different foundations in different sections of the buildings, some had piled foundations, some pad foundations and a variety of structural frame types and constructions. Damage varied according to location, design and construction.

2.4 Land damage and EQC

Extensive parts of Christchurch was affected by liquefaction, both sand boils and lateral spreading.

With reference to domestic residences the damage caused by the earthquakes the Earthquake Commission (EQC) is the primary insurer of residential land and property damage that is a direct result of a natural disaster (provided the resident pays an automatic subsidy to household insurance).

After the first earthquake and a number of the following earthquakes large scale (macro) mapping of ground damage was carried out by geotechnical personnel on behalf of the EQC including GHD. The EQC Land Damage Assessment Team (LDAT) was put together with over 400 geotechnical professionals from 39 difference consultancies across New Zealand (including GHD). The team was coordinated by Tonkin and Taylor. The purpose of the LDAT was to (primarily) assess land damage to residential properties (land) affected by the Canterbury Earthquake Sequence. Between 4th September 2010 and 17 December 2011 79,000 individual detailed property assessments were completed by the EQC LDAT (Wallace and Macdonald, 2012).

2.5 Royal Commission

The deaths attributed to the Canterbury Earthquake Sequence resulted in the establishment of a Royal Commission of Enquiry into Building Failure Caused by the Canterbury Earthquakes (Royal Commission, 2012). The Commission sought information and technical advice on a number of engineering and geotechnical facets including the earthquake sequences and their characteristics in a local and regional setting, geology of Canterbury and Christchurch, liquefaction, foundation performance and seismic design and construction.

Findings of the Royal Commission included that “some local authorities were active in commissioning advice on seismic risk, they were less attentive to applying it in a meaningful way in decision making”, also that the Canterbury Regional Council (CRC) “has seldom used the information in its possession on earthquake risk to either inform decision making or to advocate for earthquake risk management in planning processes" (Royal Commission, 2012). Additional recommendations for geotechnical considerations include:

- A thorough and detailed geotechnical investigation of each building site, leading to development of a full site model, should be recognised as a key requirement for achieving good foundation performance;
- There should be greater focus on geotechnical investigations to reduce the risk of unsatisfactory foundation performance. The Department of Building and Housing should lead the development of guidelines to ensure a more uniform standard for future investigations and as an aid to engineers and owners;
- Geotechnical site reports and foundation design details should be kept on each property file by the territorial authority and made available for neighbouring site assessments by geotechnical engineers;
- The Christchurch City Council should develop and maintain a publicly available database of information about the subsurface conditions in the Christchurch CBD, building on the information provided in the Tonkin and Taylor report. Other territorial authorities should consider developing and maintaining similar databases of their own;
- Greater use should be made of in situ testing of soil properties by the cone penetrometer test (CPT), standard penetration test (SPT) or other appropriate methods;
- The Department of Building and Housing should work with the New Zealand Geotechnical Society to update the existing guidelines for assessing liquefaction hazard to include new information and draw on experience from the Christchurch earthquakes;
- Further research should be conducted into the performance of building foundations in the Christchurch CBD, including subsurface investigations as necessary, to better inform future practice;
- Where liquefaction or significant softening may occur at a site for the SLS earthquake, buildings should be founded on well-engineered deep piles or on shallow foundations after well-engineered ground improvement is carried out;
- Conservative assumptions should be made for soil parameters when assessing settlements for the SLS;
- Ground improvement, where used, should be considered as part of the foundation system of a building and reliability factors included in the design procedures; and,
- Ground-improvement techniques used as part of the foundation system for a multi-storey building should have a proven performance in earthquake case studies.

2.6 Influence

The Canterbury Earthquake Sequence and the subsequent media coverage has brought to the forefront in the general public's (and client's) mind the role of geotechnical professionals in land development and structural design. Royal Commission's outcome and recommendations will have far reaching implications to both regional and local councils, client's developments, and the engineering (including engineering geology) profession.

3 PETONE WEST PLAN CHANGE, WELLINGTON

3.1 Introduction to case study

The Hutt City Council (HCC) proposed to rezone the Petone West Area (PWA) with the intention of increasing the intensity of the development of commercial and retail activity in the area. Due to the PWA being possibly the most vulnerable to natural hazards in the Hutt City the HCC commissioned GHD in conjunction with GNS, to carry out a natural hazards review of the PWA encompassing geotechnical considerations for the purpose of reducing the impact and mitigation of those natural hazards.

3.2 Summary of ground condition

The surface and near surface geology of PWA comprises beach deposits consisting of marine gravels with sand, mud and beach ridges. Development since settlement in Petone has obscured the pre-historic beach ridges. The ridges are above sea level due to the tectonic uplift that has occurred within this area through seismic activity, most recently as a result of the Magnitude-8.2 1855 Wairarapa Earthquake which caused approximately 1.2-1.5m of uplift along the Petone foreshore.

The subsurface geology generally comprises alternating glacial and interglacial alluvial and marine sediments. The depth to bedrock in the PWA varies between ~20m and ~350m in depth below ground level (bgl) (Boon et al, 2010). The variation of the depth to bedrock is due to the presence of the Wellington Fault controlling subsidence to the downthrown side of the fault (east) creating in effect a perpetually increasing basin depth prime for sediment depositions.

3.1 Hazards

The Petone West Area is subject to many potential natural hazards including; fault rupture, ground shaking amplification, tsunami, earthquake induced ground level changes, liquefaction, storm flooding and sea level rise. In their submission to HCC in regards to the proposed plan change GNS Science highlighted that co-seismic slip subsidence of an average of 1.7mm/yr has been detected via GPS records since 2000. GWRC, in their submission to HCC in regards to the proposed plan change, quoted from the Bell and Hannah (2012) report that Wellington has the highest rate of sea level rise of all the main centres in New Zealand at 2.03 mm/yr and Predications are that in the Wellington region sea-level could rise by 0.8 m by the 2090's or 1.0 m by 2115.

All of the above causing concern regarding sea level rise, storm surge inundation, changes to drainage gradients (uplift/subsidence) etc. which could potentially lead onto inundation and erosion of the low lying coastal margin, along with the more classically thought of earthquake induced hazards of ground shaking, ground rupture and amplification of shaking, and the implications of those to life safety and performance of our buildings and infrastructure.

3.2 Recommendations

In light of the natural hazards, geological lithology and geographical settings, the following recommendations were presented to HCC commission.

1) Specialist be engaged to better constrain the Wellington Fault location through the PWA;
2) Increased ground investigation (20-25 m bgl) for all new buildings and those to be retrofitted;
3) Initiations of ground engineering register allowing technical peer review of geotechnical studies;
4) Register of "Geotechnical Gurus" to be qualified to review geotechnical work for the HCC;
5) HCC incorporate recommendation of Canterbury Royal Earthquake Commission with high consideration to Christchurch and Petone West geological similarities;
6) Review of local building consent processing requirements, guidelines and infrastructure;
7) Buildings within the Wellington Fault Section continue to have the whole property subject to restricted discretionary activity status until the Wellington Fault rupture zone is better constrained;
8) All new buildings and structures to have completed geotechnical desk study and a site specific geotechnical intrusive investigation; and,
9) Section 14H Natural Hazards of the district plan be revised to encompass current knowledge levels of the natural hazards associated to the wider Hutt City.

3.3 Influence

The plan change came into effect on 5th September 2014. The recommendations of the natural hazards technical review brought about the following actions; Recommendation 1 for a qualified specialist to better locate the Wellington Fault Section and for part of recommendation 9 that the District Plan 14H Natural Hazards section is reviewed within the next council triennium.

4 KILMARNOCK HEIGHTS RETIREMENT HOME DEVELOPMENT, WELLINGTON

4.1 Introduction to case study

Kilmarnock Heights Retirement Home is owned and run by Presbyterian Support Central (PSC) in Berhampore, Wellington. PSC are looking to redevelop the site to maximising the site and provide improve services for the elderly. The current Home sits atop a steep embankment slope that dips moderately steeply to steeply southeast to the east of the home and is approximately 20 m high. As part of the geotechnical assessment of the site for the redevelopment purposes an intrusive ground investigation for machine boreholes, window sampler boreholes, hand auger boreholes and scala penetrometers were undertaken.

4.2 Summary of ground conditions

The site is indicated to be underlain by greywacke sandstone-mudstone sequences and poorly bedded sandstone of the Triassic Rakaia Terrane (Beggs, 1996). The ground investigation encountered material investigation range from clayey silt or silty clay to gravel with various amounts of silt and sand. The material varies in consistency from soft and loose to stiff and dense. Colluvium on site consists of silty clay, while residual soil is a less cohesive, sandier soil. The greywacke was generally highly fractured, extremely weak to weak and completely to moderately weathered. Bedrock (Greywacke) was encountered at depths from 1.3m to 15 m bgl. Bedrock depth increased to the southeast of the site, although bedrock was shallowest at the western margin of the site and outcrops were visible in the slope.

4.1 Hazards

During the assessment historical aerial photographs of the site revealed that the site and the land upslope to the west and northwest had undergone extensive earthworks with large cuts and fills. The photographs indicated that approximately the eastern half of the Home was located on fill material from this period of large scale development between 1938 and 1962 (the dates of the photographs available). It is assumed that only very basic engineering standards would have been adhered to at the time, as was common practice during this period.

This type of practice is often associated with land movements (landslides and settlement), and may have been a contributing factor to the recent large landslide from Priscilla Crescent on to the PSC property (to the northwest of the Home). The slip directly undermined two dwellings which are now unsafe for residing in, and inundated an area up to approximately 100 m long and a maximum of 50 m wide, blocking the exit road from the Home (reducing access to a signal lane bi-direction road).

Evidence of settlement is visible in the Home structure (and internal decorations) and in the paved and surfaced areas outside the home (along the eastern half of the site).

4.2 Recommendations

Redevelopment of the site requires the design of any earthworks (and associated structures) account for the future stability at the site and the poor quality of fill / placement of the fill. The future instability could include shallow or deep seated failures resulting from a number of drivers including increase groundwater levels, steep batter angles, unsuitable (more) fill material, earthquake loading and loading from new structures.

Slope stability improvement works could include a toe buttress with reduced slope angle, an MSE wall (Mechanically Stabilised Earth) or large diameter piles. As an alternative the slope could be benched (either reducing the useable area or as part of the new Home design). A further alternative would be to zone the section of fill as “green space” and having no development further than garden, pathways or car parking (and accepting the risk of further settlement and ground cracking).

4.3 Influence

Projects such as Kilmarnock Heights Retirement Home demonstrate the importance of a sound geotechnical assessment. Without a desk study examining historical aerial photographs and intrusive investigations to ground truth the data, the design and redevelopment of the site may have either been put at risk of increased cost if the geotechnical work was done post development architectural design, or in jeopardy if only examined during construction or only shallow investigations were done, or if not completed at all and damage to the property and infrastructure should occur.

5 CRESTVIEW - AUCKLAND

5.1 Introduction to case study

The development consists of 300 plus residential lots and involved significant bulk earthworks and land drainage (including dual shear keys) as depicted in Figure 1. The site is an irregular shaped block of land located at the western edge of the Papakura Hills and accessed by Kerry Vista Rise, Papakura. The block is bound to the north by farmland, to the east by rural residential lots accessed from Kaipara Road, and to the north-west by older developed residential properties.

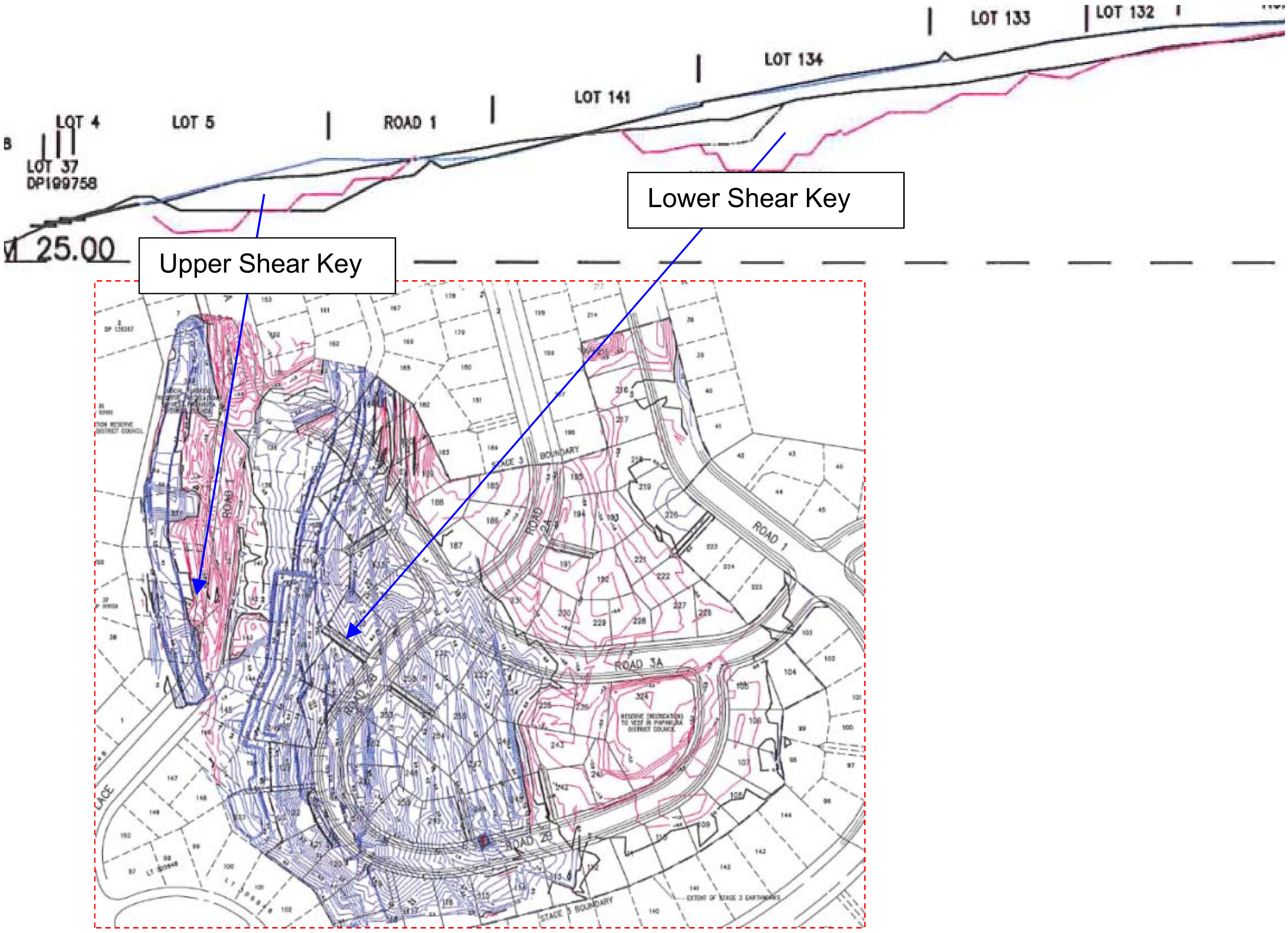

Figure 1. Upper and Lower Shear Key and Earthwork / Subsoil Drainage Plan

The developed block is divided by a central predominant ridge which trends in a north to north-west direction. On the western side of the ridge are two tributary spurs. The eastern margin of the Manukau Lowlands forms low-lying land on the western margin of the block. The eastern portion of the block is marked by a deep valley that drains northward and runs parallel to the ridge. The site is predominantly in long grass, however, the northern portion of the western sidling slope and large areas of the eastern gully contain a dense cover of gorse.

5.1 Summary of ground condition

Published geological records indicated that the block is underlain by two main lithologies, namely Pleistocene alluvial terrace deposits to the west on the lowlands and by Waitemata Group sedimentary siltstones and sandstones to the east (i.e. the ridge and adjoining slopes). The north-trending Drury Fault marks the boundary between the two units and is the principal reason for the topographical boundary between the lowlands and the Papakura Hills. The fault is not considered active although it is linked too much of the instability observed on the western slope.

Further, exposures of Waipapa Group (Jurassic Epoch) were present within the lower (north-western) corner of the site. The Waipapa Group sedimentary lithology (Greywacke) comprises of massive to thinly bedded, lithic volcaniclastic sandstone and argillite which form an overburden of clays and silts when exposed to weathering.

5.2 Hazards

A significant landslide was identified within the western side of the subdivision. Dual shear keys (upper and lower – see Figure X) were required to be constructed to provide code compliant land for development. Investigation encountered / defined two main failure types:

1. Deep Seated Failures (transitional / planar – slope movement oblique to bedding dip); and,
2. Residual Soil Failures (shallow seated circular).

Following the deep seated slope movement, recent residual shallow seated circular failures in the form of soil slumping / creep have occurred along the southern and eastern slopes of the site.
Shear key excavations revealed that these features are controlled by fine sand or silty fine sand layers (rock soil interface) and to bedding plane.

5.3 Recommendations

In light of the ground investigation phase of several machine and hand anger boreholes along with trial pits, the natural hazards identified, geological lithology and geographical settings, the following recommendations were presented to the client and local authority:

- Upper and Lower Shear Key's (6-10 plus metres deep, 150 plus metres long and 10 to 20 metres wide at base) with underfill drainage;
- 30+ Counterfort Drains (up to 6 metres deep); and,
- In ground Timber and Steel Tied-Back Retaining Walls.

5.4 Influence

Appropriate ground investigation, geotechnical analysis and reporting along with construction monitoring has enabled the development of land that may have otherwise not have been suitable for the residential land use.

The project required a significant amount of bulk earthworks within an elevated visually exposed landscape. This development along with others completed at the same time (within Auckland in particular) as driven a philosophy shift to a clustered development approach that lessens the overall impact of environmental effects. This is achieved by isolating unstable areas within developments for useable green space with clusters of higher density buildings located on naturally stable areas.

6 CONCLUSIONS

This paper only starts to highlight the loopholes of responsibility at different levels to adhere to the recommendations and best practice in regards to natural hazards. Cost and reluctance for hazard recognition in terms of one's own property is considerably easy to write off if natural hazards are not considered likely to have an effect in the short term (i.e. in the time the property is relevant to "you").

New Zealand tectonic setting and young geology make for a country ripe with natural hazards, and their effects are felt every day. The recent devastation felt by the Christchurch region only further demonstrates this point.

Review of standards and technical guidelines should hopefully intensify the rigours around geotechnical investigations, assessments and geotechnical design and geotechnical input into the nation's infrastructure. Hopefully changes to the process and assessment of consents takes place and more robust training for the assessors will be provided to ensure consistency in the decision making / consent assessment process.

The authors hope that these improvements to the system and councils and other regulatory bodies will enable Christchurch to recover and rebuild, along with providing the people of New Zealand with more resilient communities through improve geotechnical practice and consenting and planning processes.

Finally in answer to our question: Yes we do need geotechnical professional!

7 ACKNOWLEDGEMENTS

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