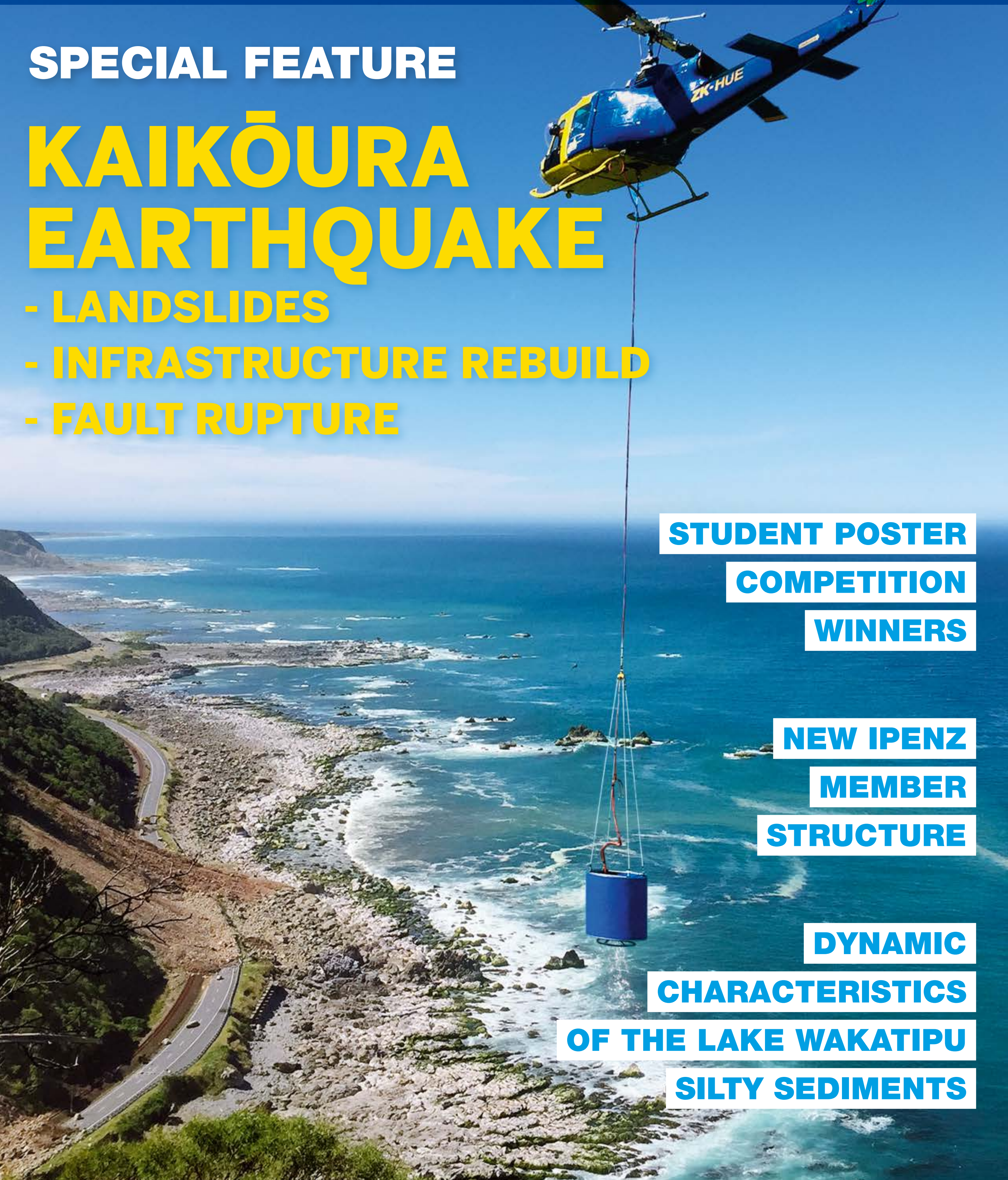
NEW ZEALAND GEOTECHNICAL SOCIETY INC

JUNE 2017 issue 93

NZ GEOMECHANICS NEWS

Bulletin of the New Zealand Geotechnical Society Inc.

ISSN 0111-6851



SPECIAL FEATURE

KAIKŌURA EARTHQUAKE

- LANDSLIDES
- INFRASTRUCTURE REBUILD
- FAULT RUPTURE

STUDENT POSTER COMPETITION WINNERS

NEW IPENZ MEMBER STRUCTURE

DYNAMIC CHARACTERISTICS OF THE LAKE WAKATIPU SILTY SEDIMENTS

NZ Geotechnical Society 2017 PHOTO COMPETITION

The 2017 theme is

Beats being at the office

WIN $250

ENTRIES CLOSE
SEPTEMBER 30

SEND YOUR ENTRY TO

- Email to: editor@nzgs.org (send as jpgs)
- Entries close 30 September 2017
- Clearly mark your entry with your name and provide a caption for your photo

The winning photo and the top runners-up will be printed in the December 2017 issue of *NZ Geomechanics News*

CONDITIONS OF ENTRY

1. Only amateur photographers may enter.
2. Photos must be taken by the entrant.
3. No computer generated pictures.
4. Any photographs received may be published in subsequent NZ Geotechnical Society publications and material.
5. Winning entries will be final and no correspondence will be entered into.
6. NZ Geotechnical Society members only may enter.

RETAINING YOUR BUSINESS IS OUR BUSINESS

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Construct

Perform

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For over more than 40 years, Grouting Services has delivered some of New Zealand's most significant Ground Anchoring, Soil Nailing, Micro-Piling and Post-Tensioning contracts.

With ground anchor technology advancing all the time, our association with Samwoo means our New Zealand clients will continue to have access to world-leading technology including:

- Removable compressive distributive anchors (SW-RCD)
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We have successfully completed some 5000m of removable anchors and the level of enquiry continues to rise as the sustainable benefits of this technology are realised - once a construction project is completed, there is nothing left in the ground that will obstruct future developments on adjoining properties.

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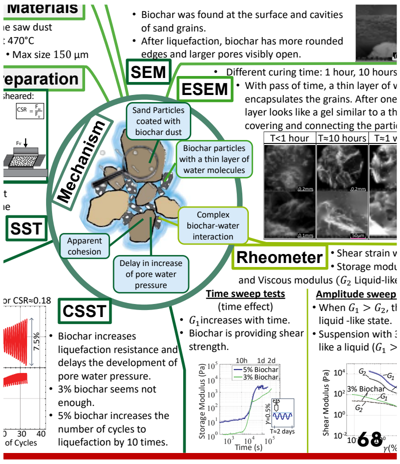

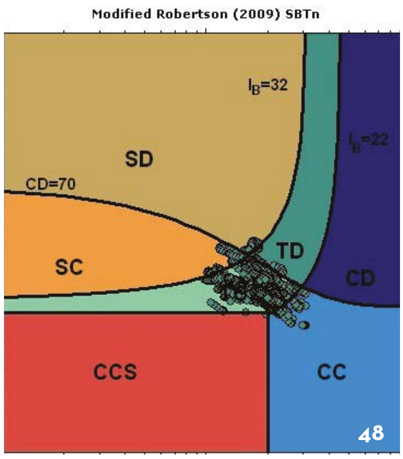

COVER IMAGE: Helicopter sluicing operation, Kaikoura. *Image courtesy NCTIR*

Charlie is the Chief Geotechnical Engineer at MWH in Christchurch. Educated as a civil engineer in Dublin and an Engineering Geologist at Imperial College in London, he has worked on dam and tunnel projects in Africa, oil and gas projects in the North Sea, hydroelectric power stations in Pakistan and the UK. He moved to New Zealand in 2003 to work on Project Aqua, and spent seven years working with URS in their Christchurch office before moving to MWH in 2011.

Charlie Price
Chair, Management Committee

THIS WILL BE the last of my 'Chair's Corner' articles, as my term as Chair will come to an end in September after two and a half years. As they say, it's been a blast - well, pretty full-on anyway. The normal two year term for the Society's Management Committee officers was extended to two and a half by virtue of our decision to move the AGM from March to September each year in order to bring it closer to the end of the financial year on 30th September.

THE EARTHQUAKE GEOTECHNICAL ENGINEERING GUIDELINES SERIES

I gave an update on progress with development of the Earthquake Geotechnical Engineering Guidelines in my last Chair's corner, six months ago, and I'm pleased to be able to report now that two more modules should have been published as drafts for comment by the time you read this: Module 5 'Ground improvement of soils prone to liquefaction' and Module 6 'Seismic design of retaining walls'. This brings to seven the number of modules published in the series so far (Modules 1 to 6 and 5A), and completes the full list which was targeted back in 2015. This is a significant milestone to have reached, for which the society acknowledges the input of all the authors, editors and reviewers of the modules, and in particular that of Mike Stannard for his unwavering support for their development as editor-in-chief, and for MBIE's funding. Without both the funding and the efforts of each of these people the series would not be in the advanced position in which it now finds itself, and I personally wish to thank each of them. One further module, Earthquake Slope Stability, has been added to the series and our expectations are that work will commence with this by the end of the year. In the meantime the editorial panel will examine comments received on these first six modules and revise the existing versions. It is intended to make further revisions in the future, as required.

TRAINING

We are continuing to develop training to accompany each of the module publications, jointly with MBIE and IPENZ. So far we have put on face to face courses on Module 3, Liquefaction, and Module 4, Foundations. Webinars have been produced for Modules 1 (an Overview of the Series), Module 3 (Liquefaction), and Module 5A, the Ground Improvement Specification. These are available from the MBIE website. Training is now being developed for Module 6 (Seismic design of retaining walls), targeting both structural and geotechnical engineers, with a target of October this year, and Module 5 (Ground improvement). Further courses are also being considered for Modules 3 and 4.

MBIE are planning to hold a one day Masterclass on the Series immediately prior to the NZGS Symposium in November. It is hoped that sufficient comments will have been received on the published modules to indicate areas of concern, difficulty or particular interest to members and that these will be targeted for discussion and explanation at the Masterclass.

PROFESSIONAL STATUS

You will no doubt be aware of the changes in store to the pathways to professional membership of IPENZ, which becomes 'Engineering New Zealand' from October. The new membership categories will include a new category of 'Chartered Member', which will be open to engineering geologists as well as geotechnical engineers. The existing PEngGeol status will be included in this membership category, giving engineering geologists the title CMIPENZ (PEngGeol).

The development of 'Bodies of Knowledge and Skills' for both geotechnical engineers and engineering geologists are progressing, with comments on the former being compiled for final publication, and the latter progressing towards a draft in the next Geomechancis News. After further consultation with other stakeholder organisations these will be available on the NZGS website. The BOKS are being developed to define minimum technical capabilities expected of a CPEng (Geotechnical) or CMIPENZ (PEngGeol). They are intended to complement and inform the CPEng and PEngGeol assessment processes and to provide benchmarks for the professions.

SCHOLARSHIP

In recent years the NZGS has funded a scholarship every two years for a member to carry out some research which the society feels will be of benefit to the profession at large. The scholarship was initially valued at $10,000, but in 2016/17 we have increased its value, and this year decided to make awards to two of the applicants that our judges were particularly impressed with. The first of these is Katherine Yates's study *"In trying to better understand the shear strength of Loess"* which she is carrying out at the University of Canterbury, and for which a scholarship of $15,000 has been awarded. A second award has been made to Thomas Robertson for *"Laboratory-scale Trials on the Sensitive Material from Bramley Drive Landslide on the Omokoroa Peninsula"*, for which he is currently carrying out research into highly sensitive pyroclastic-derived halloysitic soils, and has been awarded a scholarship of $7,500.

RANKINE LECTURE

Richard Jardine delivered his 2016 Rankine lecture at two venues in New Zealand in March. It was unfortunate that weather prevented him from landing in Wellington, and so a delivery there had to be cancelled at very short notice. His lectures in Auckland and Christchurch were well received. We are hoping to be able to attract Richard back again in 2018 to deliver a short course for us, possibly in soft ground engineering.

I am pleased to be able to report that we appear to be having a resurgence in support for many of the regional centres. Among others, we now have a set of four fresh faces in Wellington to take over from Ayoub Riman and Dolan Hewitt, two new faces in Hawkes Bay in the form of Tom Bunny and Tom Grace, and a new branch in Northland with Phil Cook. The society is grateful for all the effort that has been put into the planning and running of branch meetings by regional representatives. Without their input the society would not be able to function in the way it does.

During the last six months I have been absent for some time due to illness, and I wish to thank my vice-chair, Tony Fairclough, for very ably picking up the reins and keeping things running during my absences. Tony will take over the Chair's role following the next AGM, in September, and members can be assured of getting a very capable and dedicated new Chair. Good luck Tony. I am also grateful to the remainder of the Management Committee who are so dedicated and committed, and who between them manage to keep the wheels of the society oiled.

I look forward to seeing many of you during the NZGS Symposium in November in Hawkes Bay.

Charlie Price
Chair, Management Committee

Marlène is Senior Lecturer at the University of Canterbury in Engineering Geology. She previously worked in tunnel design in Switzerland, the USA and Australia, having obtained her PhD in tunnelling at Queen's University in Canada. She currently works in rock mechanics applied to tunnelling, geothermal, petroleum, landslides and seismic amplification with a particular focus on lab testing and numerical modelling.

NZ Geomechanics News co-editor

Don Macfarlane has worked as an applied engineering geologist for nearly 40 years and has accumulated some knowledge, a fair bit of wisdom and a few brickbats along the way.
His real interest is dams and associated issues (seismic hazard, slope instability) but any good geohazard affecting an engineering structure will do. These days he is a Technical Director with AECOM in Christchurch.

NZ Geomechanics News co-editor

Tell us about your project, news, opinions, or submit a technical article. We welcome all submissions, including:

- technical papers
- technical notes of any length
- feedback on papers and articles
- news or technical descriptions of geotechnical projects
- letters to the NZ Geotechnical Society or the Editor
- reports of events and personalities
- industry news
- opinion pieces

Please contact the editors (editor@nzgs.org) if you need any advice about the format or suitability of your material.

IT HAS BEEN a whirlwind getting this issue together with many changes and updates at government and professional level that affect our profession. Keep your eye out for these items in the Chair's report and in notices in this issue.

As I indicated last issue, this issue contains a special feature focussing on the early geotechnical response to the Kaikōura earthquake. Given the time frame for this special feature, we focussed mostly on short technical items with plenty of photos providing an update of what has been happening. In reading these contributions it is interesting for us to reflect on how the natural, engineered and built environment performed and what kind of field work have we done. We should be asking ourselves questions about how resilient we are, how the response is proceeding and what we have learned so far. We are keen to receive your thoughts and feedback that are generated by these earthquake updates.

We are also publicising the 20th NZGS Symposium in Napier on 23-26 November 2017. Pierre Malan and the organisation committee have put a tremendous amount of work into organising key note speakers and trialling a new, single stream format aimed at generating discussion amongst the attendees and experts. Keep your eye out for the MBIE Masterclass on the 23rd November and the field trip on 26th November.

For the first time the NZGS has organised a 2-day short course in engineering geology in late August – early September in Auckland, Wellington and Christchurch. This course is aimed at early career practitioners with 3-5 years' experience. NZGS have worked closely with senior engineering geologists from New Zealand and Australia to develop a curriculum that addresses the practical application of engineering geology. This is a great opportunity to upskill and we hope to see many of you there!

Finally, we have several Society announcements in this issue, including announcements for student awards, professional awards and the AGM later this year. Take a close look at these so you know how and when to participate in the activities of the society.

Marlène Villeneuve

shaping the future

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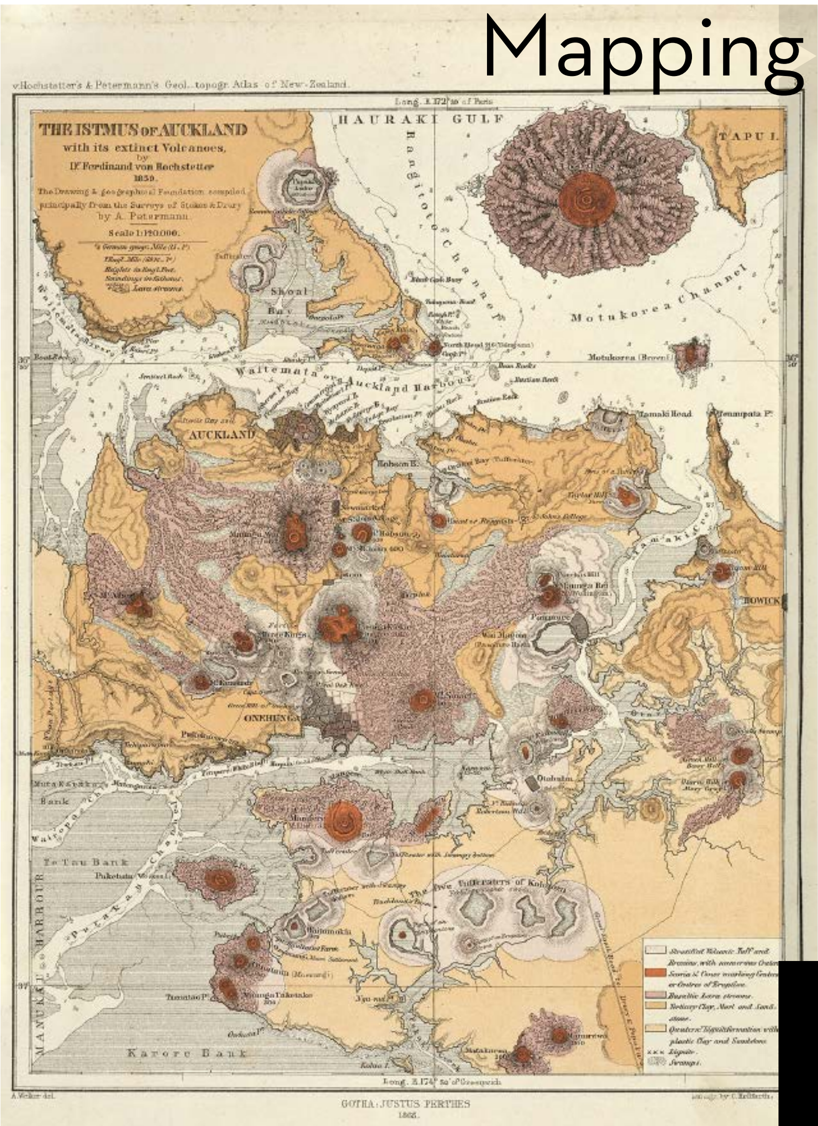
News – In Brief

Mapping AUCKLAND



Interpreting the geology of New Zealand cities is a critical part of understanding and planning to mitigate geological hazards such as landslides and earthquake-vulnerable ground conditions, to locate and manage geological resources such as aggregate and groundwater, and to plan the future growth of our urban areas. GNS is beginning to compile new geological maps of urban areas using a mix of conventional 2D surface mapping and its integration with subsurface information obtained from existing borehole data to create 3D geological models.

Auckland Council is keen that any new maps are undertaken in a way that will meet the needs of the geotechnical industry and maximise the use of existing data. We will be facilitating communications between GNS and the local industry and welcome your involvement.

Please send suggestions for your mapping requirements, or proposals for how you may like to be involved in the mapping project, to ross.roberts@aucklandcouncil.govt.nz.

NEW FIELD GUIDE FOR RAPID POST DISASTER BUILDING USABILITY ASSESSMENT – GEOTECHNICAL

MBIE has published a field guide to accompany two existing field guides for post disaster building assessments for earthquakes and for flooding.

This Field Guide: Rapid Post Disaster – Geotechnical assessment toward building usability has been produced to assist geotechnical professionals in the assessment and categorisation of land instability in conjunction with a rapid building assessment process during a State of Emergency or during a lesser event in special circumstances.

The geotechnical component of a rapid building assessment process involves the rapid assessment of the impacts of land instability on commercial, industrial and residential buildings that could affect the safety of people. This is the third in a series of field guides that target a uniform approach to rapid building assessment.

Rapid post disaster building usability assessment – **geotechnical**

Rapid post disaster building usability assessment – **earthquake**

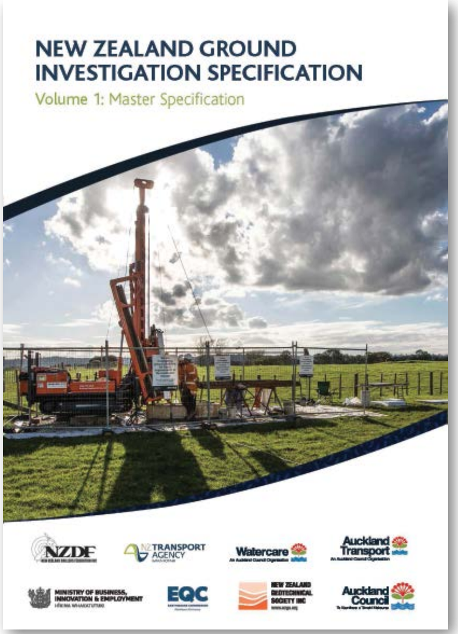
Rapid post disaster building usability assessment – **flooding**

Earlier this year our geotechnical crew installed rock bolts and shotcrete to unstable areas behind the Latter Day Saints Church in Dunedin. Using long reach EWP's and cranes the work was completed in record time.

In March an Abseil Access team of five drilled and blasted over 300m^3 of rock using two cliff face drill rigs and sequentially timed explosives in Northern Coromandel. Check out the shocking video on our facebook page.

A steep boulder bank threatened the hydro pipes and new valves at Cobb Powerstation in Takaka. In April the geoteam set to work with three weeks of boulder destruction with explosives followed by building twin rockfall catch fences.

NZ GROUND INVESTIGATION SPECIFICATION



THE EDITORIAL PANEL are delighted to announce that the feedback on the draft New Zealand Ground Investigation Specification has now been taken into account and incorporated into the Specification. All four volumes are now available online in the NZGS website library. We would particularly like to thank all those who gave such comprehensive and useful feedback, including:

Shane Strode-Penny – *WorkSafe New Zealand*
Kevin Hind – *Tonkin & Taylor*
Eleni Gkeli, Darrel Oosterberg, Christine Parkes, Dave Dennison, Steve Cooke, Doug Mason, Ella Boam, Jon English, Helen Davies, Robert Bond, Ken Read, Roger High, Lisa Bond and **Reagan Knapp** – *Opus*
Brian Tracey – *DataTran*
Ross Paterson – *Beca*
Phillip Falconer – *Perry Drilling*
Paul Carter – *ENGEO*
Greg Haldane, Ann Neill, Martin Gribble, John Donbavand, Illya Kautai *and* **Andrew Spittal** – *NZ Transport Agency*

Further improvements are likely as lessons are learned using the specification in practice. Advice on how to provide feedback is also available on the NZGS website.

NZGS/MBIE GEOTECHNICAL MODULES WORKSHOP THURSDAY 27 NOVEMBER, 2017

A one day Workshop covering the Earthquake Geotechnical Engineering Modules prepared by NZGS and MBIE will be held immediately before the NZGS Symposium in Napier, in November.

The day will include presentations by the authors, and discussions based on the comments received back from members on each of the Modules. Comments on the documents are requested in advance from members In order to facilitate these discussions and to address the most challenging issues pertinent to practitioners. The expectation is that sufficient comments will have been received on the published modules to highlight the most significant areas of concern to members, which can then be targeted in the Workshop.

Please send comments to Modulefeedback@nzgs.org, and you can register for the Workshop at the Symposium Website www.nzgs2017.co.nz.

GEOTECHNICS

Smarter and Safer - The Reliable Service Clearance Solution

Avoiding a service strike is a high priority for all of us in the field. The delays, expensive repairs, personal injuries - let alone potential loss of life - are simply not worth the risk.

Utility plans are often out of date – or indicative rather than definite, making Geophysical scans the only way to accurately locate unseen services.

With different geotechnical applications requiring varying levels of clearance, it can be hard to work out which type your site needs. Thsi is where our specialist team can help.

Because this comes second nature to us, Geotechnics can take all of the hassle out of determining what needs to be done to comprehensively locate utilities on your site.

Our tiered approach reduces the risk of service strike and includes:

- Utility Records Search
- Site Reconnaissance
- Geophysical Scanning
- Physical Verification and Vacuum Excavation

For more information, or a demonstration ofhow this could be applied to your next project, contact our friendly team on **0508 223 444** or visit **www.geotechnics.co.nz**

SOIL AND ROCK CELEBRATES 30 YEARS!

This year Soil & Rock Consultants is celebrating its 30th anniversary of service to New Zealand businesses and developers. Soil & Rock was founded in 1987 and started with only a couple of staff.

Soil & Rock Consultants currently has 51 technical staff operating from 3 offices throughout New Zealand. They operate an integrated management system with full administrative support provided centrally from the Auckland head office. The Christchurch office was initially established to provide services following the 2010/11 Christchurch earthquakes and continues to provide services in that region following effective completion of earthquake related work. The Whangarei office was recently established to provide better support to Northland roading-related work which they have carried out since 2003.

Soil & Rock Consultants have carried out geotechnical engineering work for clients throughout New Zealand, including central government organisations, regional and territorial authorities, industrial and commercial property owners and developers, infrastructure providers and residential property owners and developers. The geotechnical team undertakes a full range of geotechnical investigation, interpretation of information obtained from field testing, formulation of design and development recommendations, design of geotechnical related structures, construction monitoring and testing and formal documentation related to geotechnical construction aspects.

The holding company, Geotechnical Engineering Ltd, which owns Soil & Rock Consultants, is 100% owned by senior employees. This ensures progressive and planned renewal at ownership and management level and has, in part, been a reason for the longevity and success of Soil & Rock Consultants.

They are very proud of their 30-year heritage and growth and continue to add substantial experience to the technical team. The most recent additions include:

Andrew Irvine – *Principal Geotechnical Engineer* with over 25 Years of experience in New Zealand and Overseas

Ilai Waqa – *Senior Engineering Geologist*, joined Soil & Rock late last year with more than 20 years experience in New Zealand and Overseas

Raymond Lo – CPEng – *Senior Geotechical Engineer*, highly experienced geotechnical engineer with expertise in computer modelling using Plaxis, Wallup etc.

Sharon Tenger (Vujnovich) – *Senior Environmental Scientist* with more than 20 years of experience in soil contaminated land, hydrogeology and engineering geology.

Mark Sinclair - CPEng – Principal Geotechnical Engineer, the most recent addition to our geotechnical team. Mark is highly experienced with over 20 years on major projects across New Zealand.

WHY SHOULD YOU ATTEND THIS SYMPOSIUM?

This symposium is New Zealand's prime forum for sharing geotechnical knowledge. A huge volume of technical content is distilled into a few days by leading professionals in your industry, providing a high quality, condensed learning experience. With the planned emphasis on the practical and pragmatic side of geotechnical engineering you will be using your learnings in your every-day practice.

The symposium will be attended by industry icons, consultants, contractors, suppliers, academics, researchers and students. You will make lasting contacts who can help you with technical and career advice. This symposium will be held in sunny Napier, one of the best destinations in the country. You'll get to stay in accommodation with sea views, eat fine fresh local produce while drinking locally made wine or beer with your colleagues. You're bound to enjoy the experience while you're learning and networking. You could arrive early, stay late and enjoy all the offerings of the Hawke's Bay.

MBIE MASTERCLASS

In addition to the symposium main stream, there will be an MBIE Masterclass on Thursday 23rd November. The masterclass will cover the MBIE/NZGS co-authored modules that provide guidance to the geotechnical profession in New Zealand. Four modules are currently available, covering site investigations, liquefaction hazards, foundation design for earthquakes and a specification for ground improvement. An additional two modules are likely to be released before the symposium and will be covered in the Masterclass.

MBIE representatives and authors of the guidelines will introduce, discuss and summarise content, provide guidance and commentary on the use of the modules, why there were developed and the intended outcomes. They will be able to answer questions on the implementation, with queries and requests welcomed prior to the masterclass. This is a unique opportunity to interact with authors and regulators and offers high value CPD.

The symposium theme is **What In Earth Is Going On:** ***balancing risk, reward, regulation and reality***. International keynote speakers will lead a single streamed event over two full days, complemented by top quality presenters from around New Zealand. You can look forward to engaging presentations, technical papers and rigorous discussions that consider the inherent risks of dealing with variable subsurface conditions, and the regulatory, ethical and practical challenges associated with this. With an emphasis on practical and pragmatic geotechnics, we expect this to be an extremely valuable event for all our members. This will be an interesting and exciting symposium.

Further information will continue be posted on the symposium website **www.nzgs2017.co.nz**

KEYNOTE SPEAKERS

The 2017 NZGS Symposium is delighted to announce four high profile keynote speakers. **Emeritus Professor John Atkinson is a Rankine Lecturer**, the Emeritus Professor at City University, London and a Senior Principal at Coffey Geotechnics. **Ruth Allington is an Engineering Geologist, expert witness and qualified mediator**. She is the Joint Senior Partner and Chief Engineering Geologist with GWP Consultants based in the United Kingdom.

Professor Dave Petley is the Pro-Vice-Chancellor (Research and Innovation) at the University of Sheffield in the United Kingdom. He has a particular interest in seismically induced landslips, and runs the popular Landslide Blog. **Professor Michael Pender is one of New Zealand's most prominent geotechnical experts**, and has worked at Auckland University since 1977, becoming a Professor of Geotechnical Engineering in 1985.

SYMPOSIUM SUB-THEMES ARE:

- **Communicating and managing risk**
- **Innovative tools and techniques**
- **Standards, guidelines and regulation**
- **Putting theory into practice**
- **Best practice in design and construction**
- **Driving efficiency from investigation to construction**
- **Natural hazards and resilience (sponsored by EQC)**

2017 NZGS SYMPOSIUM ANNOUNCES KEYNOTE SPEAKERS

23-26 NOVEMBER 2017 NAPIER

EARLYBIRD REGISTRATIONS OPEN 1 JUNE 2017

OUR SPEAKERS

Professor John Atkinson

Ruth Allington

Professor Dave Petley

Professor Michael Pender

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Understanding Lateral Spreading

Dr. Gregory De Pascale
Dr Gregory De Pascale is an Assistant Professor in the Department of Geology at the University of Chile. He is fortunate to have worked on all 8 continents (including Zealandia) between the private sector and academia and is interested in fault rupture, seismic hazard, and coseismic geohazards.

ALTHOUGH MUCH OF the recent focus is on the 2016 Kaikoura event, we want to provide a brief update for the NZ geotechnical and geological community about our project: "Improving our Understanding of Liquefaction-Induced Displacements: Integration of Remote Sensing Data and Field Data from the 2010/2011 New Zealand Earthquakes", which is funded by the US National Science Foundation (NSF). This project focuses on lateral spread hazard in Christchurch from the Canterbury Earthquake sequence. The majority of the homes in the "red zone" were impacted by lateral spreading so understanding lateral spread is of critical importance for future events not only in NZ but globally.

During 2016 we undertook two field investigations in and around the "red zone" in Christchurch which including trenching, boreholes, CPT, geophysics, field mapping, lab work, and dating, combined with remote sensing. We are currently compiling this information and developing site models that we feel will change the way we look at lateral spread globally and can be used for enhanced predictive mapping and hazard avoidance. Here is a photo from one of the trenching campaigns of a trench floor showing liquefaction sand dikes that verge on "Geo-Art".

We will present the results of our work in NZ and globally.

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SEPTEMBER 30

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The winning photo and the top runners-up will be printed in the December 2017 issue of *NZ Geomechanics News*

Opus Materials Testing Laboratories

Opus laboratories have a proud history dating back more than 65 years. Opus have a network of thirteen IANZ (International Accreditation New Zealand) accredited laboratories, consisting of eleven in New Zealand and two in Fiji. We provide specialist independent testing and analysis of engineering construction materials.

Through collaboration, our multi-disciplinary team of highly trained and motivated technicians have the capability to deliver large projects in a short timeframe.

Opus laboratories provide a wide range of site investigation and laboratory services, including:

- Specialised geomechanics testing (eg triaxial)
- Instrumentation installation and monitoring
- CPT (Cone Penetration Testing) services CPTu, seismic including SCPTu and temperature cones for geothermal areas
- Field investigations and soils classification

Contact us for more information:

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e. Daniel.Grebenar@opus.co.nz

NZ CPT Testing:
Jared Kavanaugh
t. 0274744423
e Jared.kavanaugh@opus.co.nz

AS WE WERE once again reminded in November 2016, New Zealand is a very dynamic country. Being a country with a relatively small area, such a large earthquake will inevitably affect our infrastructure and a wide variety of intensive and non-intensive land use. This provides our industry with a large number of geotechnical challenges, usually at very short notice.

I experienced the hectic organisation of the expert response to the earthquake in the first few days following the event. A full day in a helicopter chasing landslide dams in every catchment between Lewis Pass and Kaikoura was enough for me and I have since focussed on landslide mapping. Despite the strain on our stomachs, those helicopter flights provided us with some fascinating images of the shaken and ruptured ground, and allowed us to identify the areas at greatest risk of sudden flooding. I particularly like the photo above with the debris and vegetated raft entering the braided river.

The following contributions are short descriptions of the work done so far both to characterise the nature and effects of the earthquakes, and to recover from those effects. We have asked the contributors to provide short, clear descriptions of their work with a large focus on photos.

It is clear from these contributions that this was a very complex earthquake, with complex impacts. What we see in the following pages is just a hint of the magnitude of the different challenges that both industry and researchers face. I am grateful to all of the contributors who took time from their very busy schedules to give us some insight into their work. It is certainly a fascinating read.

Marlène Villeneuve

Marlène is a Senior Lecturer at the University of Canterbury and the coordinator of the Engineering Geology Programme. She previously worked in tunnel design and construction in Switzerland, the USA and Australia, having obtained her PhD in tunnelling at Queen's University in Canada. She currently works in rock mechanics applied to tunnelling, geothermal, landslides and seismic amplification with a particular focus on lab testing and numerical modelling.

Kaikoura Earthquake – Landslide dams: identifying the hazard and managing the risks

Prepared by sally Dellow and Chris Massey on behalf of the GeoNet Landslide Team and the USGS and GEER reconnaissance teams[1]

The November 14, 2016, M_w 7.8 Kaikoura earthquake triggered thousands of landslides over a total area of about 10,000 km², with the majority concentrated in a smaller area of about 3,500 km² on the north-eastern side of the South Island in the North Canterbury and Marlborough regions. Given the sparsely populated area affected by landslides, only a few homes were impacted and there were no recorded deaths due to landslides. However, a large number of landslides occurred on the steep coastal cliffs south of Ward in Marlborough and extending to the south of Oaro in North Canterbury, leading to the closure of state highway routes, including State Highway 1 and the Main Trunk Rail line.

Sally Dellow
Sally is an Engineering Geologist with 29 years of experience. Sally has been involved in collecting and collating landslide data for over twenty years. She has led the effort to produce high-quality landslide and landslide related datasets that allow for the development of landslide hazard models that underpin landslide risk assessment.

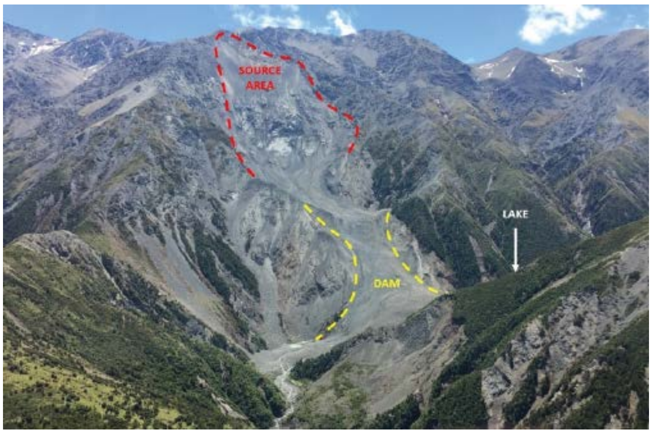
Chris Massey
Chris is an Engineering Geologist with wide experience in engineering geology in many countries. Chris leads engineering geology research team at GNS Science and has a strong publication record. He led the effort to produce landslide and rockfall risk maps for the Port Hills after the Christchurch earthquake and is putting the knowledge gained from this to understanding the landslide impacts of the Kaikoura Earthquake.

THE DAY AFTER the earthquake it was quickly established that there were many landslides and that in some instances these had blocked river and stream courses creating a potential hazard should they fail rapidly, as a large landslide on the Clarence River had done about 16 hours after the earthquake. Rapid failure of landslide dams sends a flood wave down the river, which although expected to attenuate relatively quickly, presents a potential threat to people and assets in their path.

A plan to systematically find and assess landslide dams was developed and instigated. Over the following weeks through to mid-December over 200 landslide dams were found, characterised, the potential hazard assessed, and if found to be significant, the potential risks identified.

Initially all catchments were searched systematically by helicopter reconnaissance flights and any constrictions located by GPS, photographed and recorded in a GIS with a unique identifier relating to the catchment name and altitude (in m) above sea level. Landslides were triaged daily, with their hazard classified into high, medium, low, unlikely and yet to develop. Where the hazard or risk was assessed as high, either because of a large volume of impounded water, or people or critical assets (e.g. road bridges) in the path of a flood caused by rapid failure of the landslide dam, further work was undertaken. Other dams, assessed as a low or moderate hazard, were dealt with by the generic warnings issued by Environment Canterbury and Marlborough District for all rivers in the

1. The GeoNet landslide team includes scientists and engineers from GNS Science, Massey University, the University of Canterbury and NIWA. Our colleagues from the US Geological Survey landslide team and the international Geotechnical Extreme Event Response (GEER) landslide team also helped out in the initial landslide response.

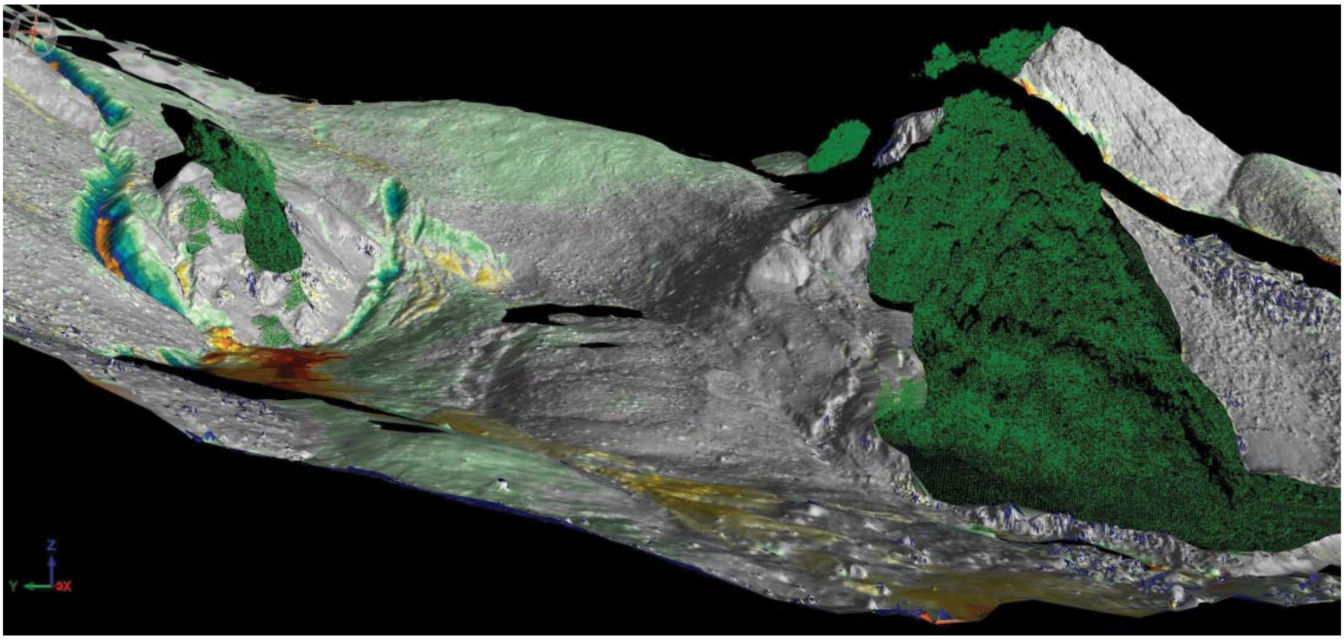


Above: The Hapuku River Landslide dam (Hapuku 740) is the largest landslide dam caused by the 14 November 2014 Kaikoura earthquake. The initial estimates of dam volume are in the range of 12 to 18 million cubic metres of debris. The landslide is a rock avalanche (Hungr et al, 2014) and the distance from the top of the head-scarp to the toe of the debris is 2.7 km. (Photo: GNS Science).

affected area but in some cases more specific warnings were issued, for example, for the rising lake levels in the Gelt and Lower Conway – which people were crossing in vehicles below the dams.

Initially twelve landslide dams were identified as having the highest hazard. Five of these had identified risks to people or property that required attention. These dams were on the Hapuku (road and rail bridges and some homes in low-lying areas), Linton (bridge over the inland Kaikoura road and a school), Conway (inland Kaikoura road), Goose Bay (up to 20 homes on the alluvial fan at the coast) and the Waima (homes close to river level). These dams were prioritised for more detailed investigation. This included measuring the key parameters of the landslide dams using a terrestrial laser scanner and RTK GPS unit (height, width, cross-section shape, area, and volume) and using this data to model potential rapid failure scenarios using RAMMS© software.

A challenge with this work was balancing the demand from authorities managing the earthquake response for rapid provision of information to help them identify and mitigate hazards versus the need to collect accurate, measurable data which takes time. This was highlighted by substantial changes in the modelling outputs in one case where the key parameters estimated by experienced geotechnical professionals were found to have been over-estimated by 50% when subsequently measured using survey equipment. The initial modelling results using the estimated parameters were highly conservative and in hindsight overstated the potential hazard (and risks). There is a trade-off between accuracy (when the dam failed the modelling results based on the measured data were shown



Above: A change model derived from terrestrial laser scans taken on 15 December 2016 and 28 March 2017. The image shows areas of settlement and erosion (cool colours) and sites of deposition (warm colours) as measured normal to the slope. The settlement near the dam crest is in the order of one metre. The other feature of note is the seepage outlets in the face of the dam. (Image: G Archibald, GNS Science; 9-04-2017).

to have been accurate) and urgency (basing model outputs on estimated parameters carries risks of over-estimating the hazard and risks).

Another aspect to consider is the source material of the dam. The majority of landslides occurred in two geological and geotechnically distinct materials: Paleogene-Neogene sedimentary rocks (sandstones, limestones and siltstones) where first-time and reactivated rock-slides were the dominant landslide type, and the Paleozoic-Mesozoic basement rocks (greywacke sandstones and argillite) where first-time rock and debris avalanches dominated. The weaker rocks tended to be finer-grained and produced less permeable dams relative to the stronger rocks (greywacke) which essentially produced large piles of highly permeable angular gravels. The 'gravel' dams did not overtop under dry conditions but in all cases piping through the dam could be observed.

Several of the landslide dams breached in early April 2017 when rainfall associated with ex-tropical Cyclone Debbie hit the Kaikoura region, leading to overtopping and breaching of the dams under flood conditions.

The process of finding and assessing landslide dams developed as part of the Kaikoura earthquake response provides an opportunity to further develop and refine

Above: The Hapuku River landslide dam taken 5 December 2016. Seepage is beginning to develop from the face of the dam and side streams are forming ponds on the debris. This photo predates the initial scan in the change image above by 10 days. (Photo: B Lyndsell, GNS Science; 5-12-2016).

the process and methodologies for future earthquakes, particularly an Alpine Fault event where there will be many landslide dams. A particularly useful step to avoid miscommunication of hazards was the adoption of unique identifiers for each dam, using catchment name and approximate altitude, and not changing these 'standards' between organisations.

REFERENCES

Hungr, O., Leroueil, S., Picarelli, L., 2014. The Varnes classification of landslide types, an update. Review article. Landslides. April 2014. Volume 11. Issue 2, pp 167-194.

Above: The Hapuku River landslide dam taken 7 April 2017, two days after rainfall from ex-Tropical Cyclone Debbie dumped heavy rainfall on the Kaikouras. Lake level monitoring installed by NZTA showed the dam was overtopped for the first time and the shallow breach channel (1.5 to 2 metres deep) is visible. This photo postdates the second scan image in the change model above by 10 days. A further scan is being taken to capture the change shown in this photo. (Photo: D. Townsend, GNS Science; 7-04-2017).

Left: There were several landslide dams on the Conway River. This landslide dam was the largest and posed the greatest risk being only five kilometres upstream of the Conway River bridge on the inland Kaikoura Road. This photo shows the largely unmodified landslide dam and growing lake two days after the earthquake. (Photo: D. Townsend, GNS Science; 16-11-2016).

Above: On 5 April 2017 ex-Tropical Cyclone Debbie delivered heavy rainfall over the Kaikoura District. As a result, several dams overtopped/ appear to have overtopped (we only have unequivocal data for one dam overtopping, the rest are based on circumstantial evidence) and in most cases breached sending a flood wave down the river. We know this happened to landslide dams on the Conway River (photo) Linton Creek and Ote Makura Stream. (Photo: D. Townsend, GNS Science; 7-04-2017).

Right: A small landslide on the Dog Stream (Dog 200) impounding a small volume of water. The relatively small volume of impounded water meant this landslide dam received a low hazard rating because a breach event was going to be confined to the active flood channel. (Photo: S. Cox, GNS Science; 18-11-2016).

Opposite: By the 22 November 2016 piping through the coarse gravels forming the dam had seen headward erosion from the downstream toe. Although it developed quickly and looked spectacular it stabilised in this state for several months. (Photo: Jon Mitchell, Joint Centre for Disaster research; 22-11-2016).

Left: A landslide on the Leader River (Leader Left Tributary 260) impounding a small volume of water. The relatively large size of the landslide compared to the small volume of impounded water meant this landslide dam received a low hazard rating. Again, a breach event was assessed as likely to be confined to the existing flood channel. **(Photo: B. Lyndsell, GNS Science; 28-11-2016).**

Geotechnical Engineering in the Road/Rail Corridor on the Kaikoura Coast – NCTIR Geotechnical Team

NCTIR GEOTECHNICAL TEAM.

The North Canterbury Transport Infrastructure Recovery (NCTIR) has been set-up by the government under the Hurunui/Kaikoura Earthquakes Recovery Act 2016. Its purpose is to repair and re-open the earthquake-damaged road and rail networks between Christchurch and Picton by the end of 2017. NCTIR is an alliance partnership between the NZ Transport Agency, KiwiRail, Fulton Hogan, Downer, HEB Construction and Higgins. A large number of engineering geologists, geotechnical engineers and (some) geomorphologists drawn from many different organisations are working on the recovery project. This short summary outlines our role(s) and the key understandings that have developed from our work, so far.

The 2016 Kaikoura earthquake caused significant damage over a very large area, with large debris slides on the coastal slopes closing both State Highway 1 (SH1) and the Main North Rail Line between Picton and Christchurch. This has disrupted the lives of those who live along the highway and who rely on the road and rail networks to access their homes, farms and businesses and the movement of goods to market.

State Highway 1 remains closed between Clarence and Mangamaunu (North of Kaikoura). South of Kaikoura to Oaro is open during daylight hours, weather permitting.

Significant geotechnical input and a huge effort from contractors enabled road access to be restored to Kaikoura before Christmas 2016. This access is via the Inland Route 70 and on State Highway 1 south of the seaside town, with restrictions. The work by NCTIR includes repairing and rebuilding the networks to be more resilient and safer, helping keep everyone better connected in the future. NCTIR also manages the upgrade of the alternate highway route between Picton and Christchurch along State Highways 63, 6, 65 and 7 (Lewis Pass), and the Inland Road between Kaikoura and Culverden.

WHAT DO WE DO?

The geotechnical teams on the project provide a range of inputs to the project. Initially the geotechnical staff undertook site inspections to help assess the damage to the slopes and the road/rail corridor assets below. Site-based personnel subsequently undertook daily inspections before work commenced on unstable sites. They also supervised initial 'make safe' works on the major slips. This involved supervising and directing helicopter operations sluicing loose debris from the slopes (Figure 1) and abseilers removing or stabilising remaining unstable rock, observing rock behaviour for modelling inputs (Figure 2), and installing (and reading) simple monitoring systems.

Concurrently, the site teams provided input to field mapping to define the nature and extent of instability, landslide characterisation reports, and observations of rockfall and rock roll behaviours from the sluicing and abseiling. A separate team was established to undertake engineering geological and geomorphological mapping of the transportation corridor between the Clarence and Mangamaunu, north from Kaikoura, and between Peketa and Oaro to the south. A specialist rockfall modelling team has assisted with the design of temporary protection for construction crews clearing the major landslides north of Kaikoura, and are now providing input to the design of remedial works at critical sites (Figure 3). Experienced geotechnical engineers manage the work, and the team includes a 'geotechnical challenge' group to provide high level review.

A separate geotechnical team provides input to the teams repairing and/or designing new structures (bridges, tunnels, seawalls, culverts).

WHAT HAVE WE LEARNED?

Once the LiDAR information was available it did not take long to realise that many old landslides and creeping slopes are concealed in the bush and scrub-covered slopes above the transportation corridor (Figure 4).

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Figure 1: Helicopter sluicing operations

Figure 2: Observation of rock roll from scaling operations

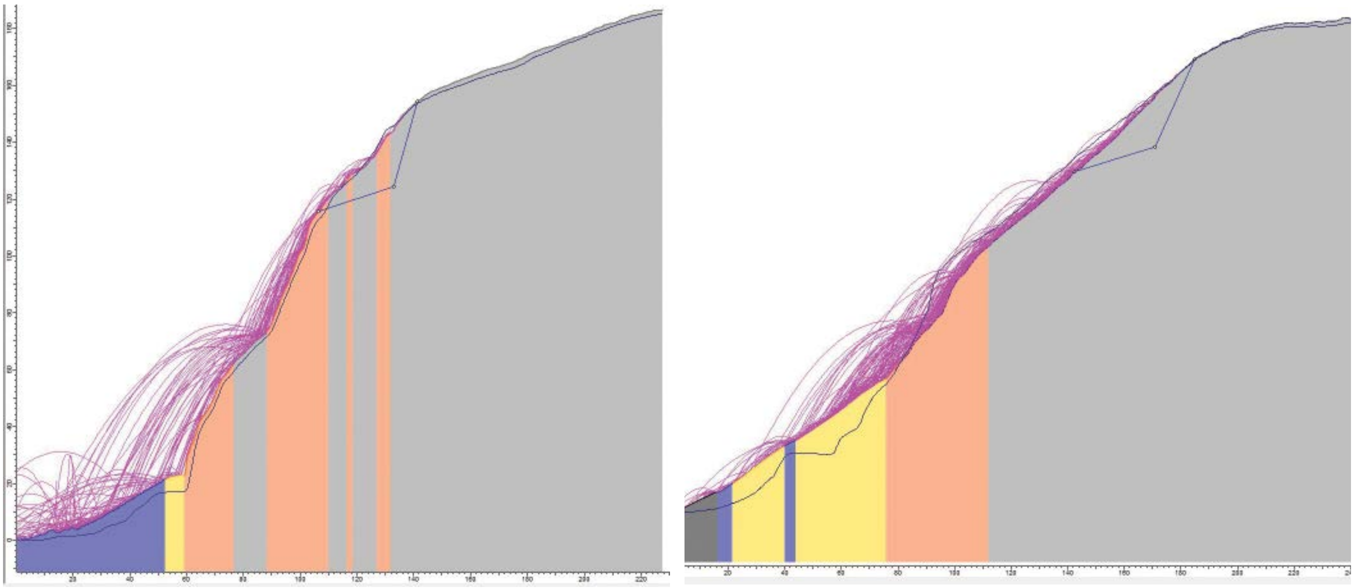

Figure 3: Example rockfall models.

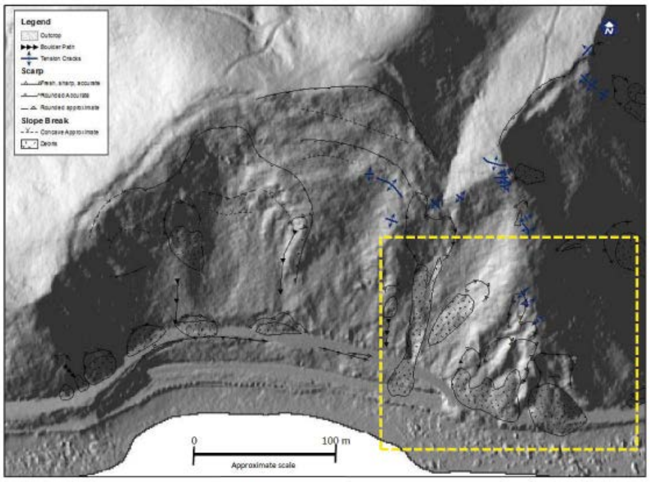

Figure 4: DEM showing large pre-existing landslide with localised failures onto the road. Box outlines approximate area shown in Figure 5.

Figure 5: Slope failures onto SH1 north from Kaikoura. The rail is in a tunnel at this location.

The LiDAR enabled preliminary mapping of slips directly affecting the road/rail corridor and secondary features that did not impact on the corridor (Figures 4 and 5). The subsequent field mapping revealed extensive ground cracking, tension cracks and scarps within, around and in some cases well beyond these features (Figure 6). The mapping also highlighted that despite extensive damage, only a very small proportion of the slopes had actually failed.

Helicopter inspections immediately after the earthquake had shown many of the ridge crests to be intensely shattered and dilated. Many of the landslides had originated in these areas (Figure 7).

The more detailed field mapping and observations by the personnel supervising sluicing and abseil works showed that many of the earthquake-induced slope failures were relatively shallow rock and debris slides. They were caused by the very broken rock sliding off better quality rock below, capturing additional material (and vegetation) as it slid downslope. This ultimately accumulated as talus cones covering the road and rail links (Figure 8). Some slips left a displaced 'tree island' in the head area (Figure 9).

Terrain analysis and the mapping also showed that in many cases valleys and streams behind the coastal slopes acted to drain the slopes so that groundwater springs and seeps were rare. This indicates that groundwater pressures within many of the slopes are not a major control on stability.

Conversely, quite small rainfall events have initiated debris flows from the secondary failures and erosion on the primary landslide slopes. The debris flows have deposited new debris on the road and rail links and discharged via culverts onto the foreshore. The rainfall associated with Cyclone Debbie (April 2017) emphasised that debris flows will continue to be a problem until source

Figure 6: Tension crack upslope from well-defined slide feature

Figure 7: Earthquake-shattered, dilated rock in ridge crest above Ohau Stream

Figure 8: Shallow failure at head of slip P2 with debris cones burying SH1

Figure 9: 'Tree island' left at head of slip P1A, north Kaikoura Coast

Figure 10: Debris flow onto SH1 and foreshore following heavy rain in April 2017.

Figure 11: Slip P1A, North Kaikoura coast – before, during and after debris removal from SH1. Note progressive failure of the 'tree island'

areas revegetate and that under-sized culverts will be blocked by debris (Figure 10).

A key outcome from our work to date has been an assessment of hazard and risk along the transportation corridor to identify the ongoing hazards and high risk locations. This information is based on the work described above. It is being used in the development of engineering solutions to manage both construction risks and long term risk to the road and rail users to a level that is as low as reasonably practicable (ALARP).

Following sluicing and rock removal works, slip clearing work to date has involved top down removal of talus cones to recover the road and rail, or to make it safe to realign road and/or rail at some locations (Figure 11). The details of alignment changes and risk mitigation measures are still being finalised at the time of writing, but are likely to involve rockfall and debris catch ditches, bunds and barriers.

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Rock mass classification for NCTIR slopes – Don Macfarlane & Richard Justice, NCTIR

THE NORTH CANTERBURY Transport Infrastructure Recovery (NCTIR) has been set-up by the government under the Hurunui/Kaikoura Earthquakes Recovery Act 2016. Its purpose is to repair and re-open the earthquake-damaged road and rail networks between Christchurch and Picton by the end of 2017. This includes the Kaikoura Coast and the inland road (SH70). NCTIR is an alliance partnership between the NZ Transport Agency, KiwiRail, Fulton Hogan, Downer, HEB Construction and Higgins.

In this contribution we present the rock mass classification system adopted for use by the NCTIR geotechnical team when selecting design and construction solutions for slope failures caused by the Kaikoura earthquake.

Many rock mass classification systems have been developed in the past 100 years, initially for tunnel design. The two most widely accepted systems are the Geomechanics classification scheme, RMR (Bieniawski, 1973) and the rock quality index, Q (Barton et al. 1974). Terzaghi (1946), Wickham et al. (1972) and Palmstrom (1996), among others, have also proposed classification systems for underground works. Most of these systems have significant shortcomings when applied to rock slope stability. In particular, they do not specifically consider triggering factors (such as earthquakes or rainfall), and groundwater is not taken into account as a trigger for failure.

Many researchers have attempted to address these shortcomings. A geomechanical classification for slopes, Slope Mass Rating (SMR), was introduced by Romano in 1985. The SMR system provides adjustment factors, field guidelines and recommendations on support methods for slopes. However, this system also proved to have limitations in closely jointed rock masses and large-scale rock slopes.

More recently, the Slope Stability Rating (SSR), based on the widely used Geological Strength Index (GSI; Hoek et al, 2002), has been developed for assessing the stability of non-structurally controlled failures in fractured rock slopes (Taheri & Tani, 2010) and for the design of cut slopes in rock (Taheri 2012). SSR considers five additional parameters: uniaxial compressive strength of the intact rock, rock type (lithology), slope excavation method, groundwater condition and earthquake force.

The fundamental problem with all of these systems is that they do not readily apply to the Upper Paleozoic to Mesozoic-age greywacke that is widespread throughout New Zealand. Comprising strong sandstones, interbedded sandstones and weak mudstones, and mudstones, these rocks are typically closely-jointed and commonly tectonically disturbed, and have an unusual combination of joints with low persistence but very high intact rock strength (unweathered, intact greywacke sandstones commonly have unconfined compressive strengths above 100 MPa).

The classification system shown below is only intended for use by NCTIR. It is based on the descriptive elements of GSI (rock mass structures) but recognises the unique characteristics of the greywacke and the ways in which the slopes along the Kaikoura coast have failed so that in addition to true rock slopes there are many slopes mantled with colluvium and/or landslide debris. These are equally important in identifying and addressing potential slope hazards and remedial options for the road and rail links along the coast.

Richard Justice
Richard is the geotechnical principal in NCTIR for 'Kaikoura South', being responsible for slope hazard mitigation works for the transport corridor between Oaro and Peketa. At his 'home organisation' of ENGEO, Richard is a Principal Engineering Geologist in the Christchurch office. Areas of special interest include landslide and slope stability assessment, geotechnical risk assessment, geomorphological and geological interpretation for corridor projects.

Don Macfarlane
Technical Director AECOM, Christchurch. Don is an applied engineering geologist with 40 years of experience as consultant, manager and reviewer in investigation, construction and monitoring for a range of projects in a range of geological environments. His current (part time) role at NCTIR is as a member of the Geotechnical Challenge team.

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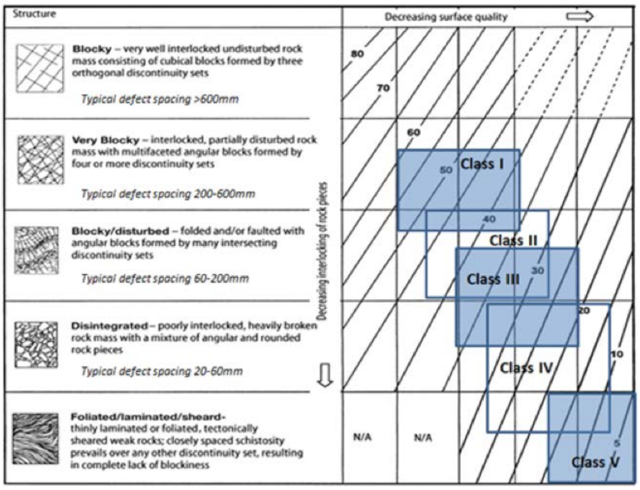


Figure 1: Rock mass classification for selection of design options for Kaikoura Coast slopes

The proposed rock classes are outlined below. Figure 1 relates them to the GSI chart and table given in Read et al (2000, their Figure 2 and Table 2):

Class I. Blocky rockmass. Stability controlled by persistent defects (wedges, plane failures, topple). Sluice/scale if necessary. Further treat at source (bolts, anchors, mesh)

Class II. Blocky/disturbed mass. Failure may be governed by defects (broken/dilated rock slides off underlying less disturbed/less relaxed rock) or may be governed by rock mass strength. Sluice/scale affected parts of the slope. Install additional protection on slope (mesh, drape) or at base of slope (bund, fence, catch ditch) as appropriate

Class III. Disturbed to disintegrated rockmass. Failure governed by rock mass strength. Sluice/scale affected parts of the slope. Install additional protection on slope (mesh, drape) or at base of slope (bund, fence, catch ditch) as appropriate

Class IV. Colluvium/landslide debris/talus. Inherently unstable if oversteepened (undercut); erodible under moderate to high precipitation. Remove where practicable; protect assets at base of slope (bunds, catch ditches).

Class V. NOT USED. Rock class only occurs in small area(s). Behaviour can be covered by other classes.

Class I. Defect controlled wedge failure

Class II. Defect controlled outcrop in blocky rock, roadcut, south Kaikoura coast

Class III. Rock mass failure in closely fractured, disturbed rock, head of Slip P6, Ohau Point

Class IV.* Old landslide debris, Slip P5, North coast south of Ohau Point

Figure 2: Sample photographs of rock mass classes for Kaikoura Coast slopes. *Class IV is the failed version of Classes I to III

CONCLUSION

While very simplistic, this classification scheme has proved itself useful for its intended purpose.

REFERENCES

Bieniawski, Z.T. 1973. Engineering classification of jointed rock masses. *Trans S. Afr. Inst. Civ. Engrs 15, pp335-344.*

Barton, N.R.; Lien, R.; Lunde, J. (1974). Engineering classification of rock masses for the design of tunnel support. *Rock Mechanics and Rock Engineering 6 (4)*: 189–236

Hoek E, Caranza-Torres CT, Corcum B (2002) Hoek–Brown failure criterion- 2002 edition. In: Bawden HRW, Curran J, Telsenicki M (eds) Proceedings of the North American Rock Mechanics Society (NARMS-TAC 2002). Mining Innovation and Technology, Toronto, pp 267–273

Palmstrom, A. (1996). Characterizing rock masses by the Rmi for use in practical rock engineering, part 1. *Tunnelling and Underground Space Technology 11(2)* 175-188

Read, S.A.L.; Richards, L.; Perrin, N.D. (2000). Assessment of New Zealand greywacke rock masses with the Hoek-Brown failure criterion. GeoEng 2000, Melbourne, Paper 0868

Romana, M. (1985). New adjustment ratings for the application of Bieniawski classification to slopes. In *Proc. Int. Symposium on the Role of Rock Mech*, pp49-53

Taheri, A. & Tani, K. (2010). Assessment of the Stability of Rock Slopes by the Slope Stability Rating Classification System. Rock Mech Rock Eng 43: pp321-333. doi:10.1007/s00603-009-0050-4

Taheri, A. (2012). Design of rock slopes using SSR classification system. *International Conference on Ground Improvement and Ground Control, Wollongong, Australia.*

Terzaghi, K. (1946). Rock defects and loads on tunnel supports. *In Proctor, R.V.; White, T. Rock Tunnelling with Steel Supports*. Youngstown, Ohio: pp. 15–99

Wickham, G.E., Tiedemann, H.R. and Skinner, E.H. 1972. Support determination based on geologic predictions. *In Proc. North American rapid excav. tunneling conf., Chicago, (eds K.S. Lane and L.A. Garfield), 43-64. New York: Soc. Min. Engrs, Am. Inst. Min. Metall. Petrolm Engrs.*

UC Geologists key contributors to fault rupture mapping following the M7.8 Kaikoura Earthquake

– Jarg Pettinga, Clark Fenton and Andy Nicol, Department of Geological Sciences, University of Canterbury

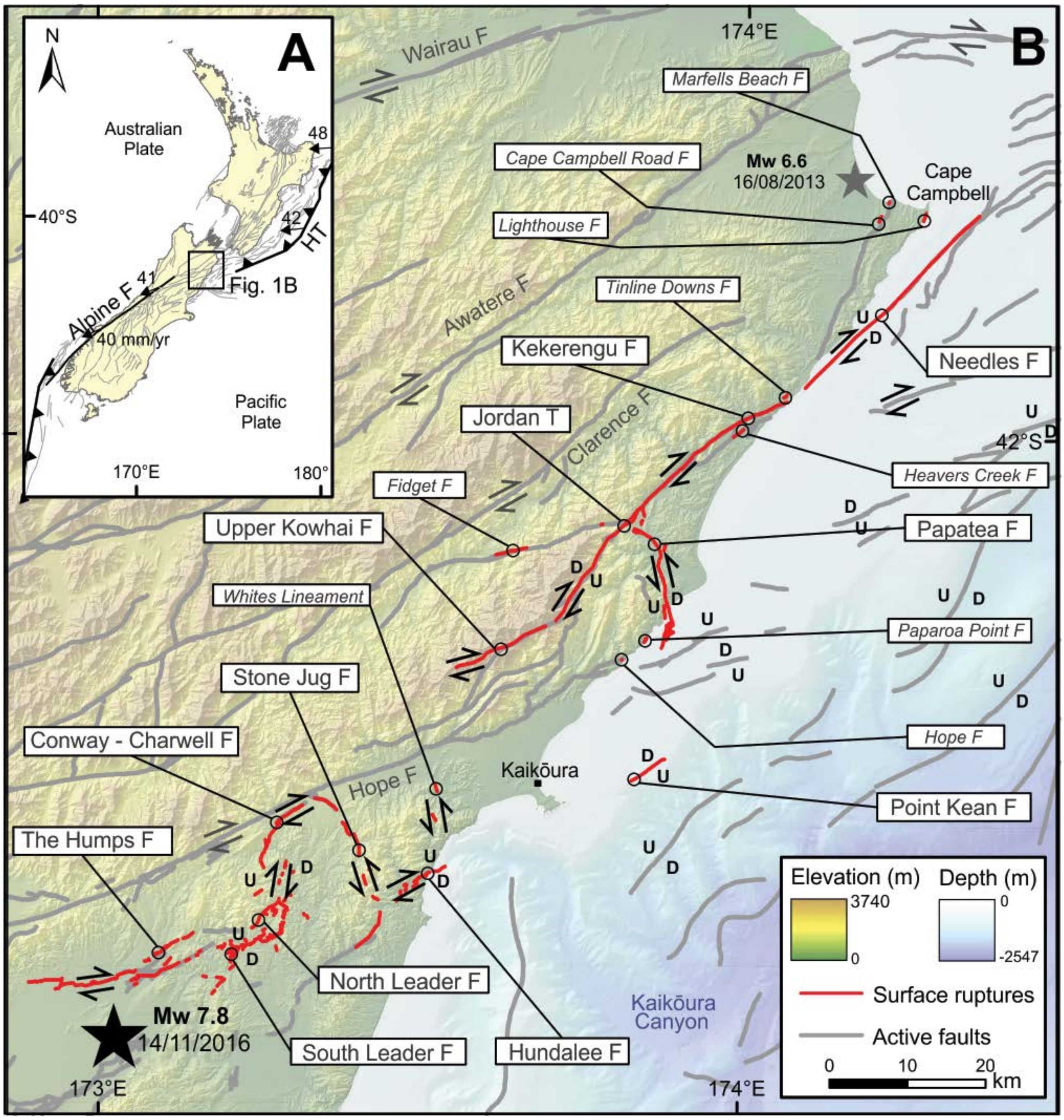
Above: The "Woodchester Wall" South Leader fault rupture scarp (Photo - Kate Pedley).

SINCE 14 NOVEMBER 2016 a large team of staff and postgraduate students from the Department of Geological Sciences have been working long hours to support the science response to the massive Kaikoura Earthquake. Our team has focussed on capturing fault ground rupture data from the epicentral region in north Culverden basin, near Waiau Township and from there to the NE toward Kaikoura. The complex array of ground ruptures extends into the more remote and rugged topography of the upper Leader River catchment and to the NE along the eastern range front of Mt Stewart to the Charwell area along the Inland Kaikoura Road.

While in the first few days after the earthquake we were undertaking field reconnaissance, that quickly moved on to detailed mapping using RTK, GeoXH and total station surveys to document fault zone ground ruptures location and offsets. We have also deployed our drone to capture video and photo imagery to developed detailed fault zone ground rupture maps. Even now some six months after the earthquake we continue to locate new fault ruptures in the more remote parts of the region as the LiDAR survey coverage has just been made available. To date our team has documented more than 100 km of fault ground ruptures.

Jarg Pettinga

Jarg is Professor of Geology at the University of Canterbury. His research interests include theactive tectonics and structure along the NZ plate boundary zone as well as earthquake hazard assessment with particular emphasis on the Canterbury region. He is a current member of the Royal Society of NZ Marsden Fund Council and chairs the Earth Science and Astronomy panel.



Above: Mapped fault ruptures as of press time (courtesy GNS Science).

OVERVIEW OF GROUND RUPTURES:

In the area we have covered a number of faults have ruptured in a complex relay extending from the NW margin of Culverden basin to the NE, toward Kaikoura. The SW tip of the coseismic ground ruptures is located in the Amuri Range west of the central Emu Plain. Detailed mapping has documented a series of sub-parallel NE to ENE trending fault rupture splays of the Humps Fault Zone with predominantly dextral strike-slip offsets cutting across the extensive low angle alluvial fans sourced from the various catchments on the adjoining Amuri Range. The

Above: Oblique transtensional fault cutting SH70 - Inland Kaikoura Road, dextral shear ~2.2m graben ~1 to 1.5m vertical offset (photo – Jarg Pettinga))

Above: Oblique slip dextral fault scarp – Glenbourne Woolshed (photo – Jarg Pettinga)

ground rupture zone is characterized by a Reidel shear pattern indicative of rupture through near-surface granular alluvial deposits. There are also a number of antithetic oblique sinistral Reidel shears, some with decimetre scale displacements extending up to 100's metres from the principal shear zone. We have noted these are most prominent at splay step-overs.

In the Lower reaches of the Lottery and Mason Rivers, north of Waiau Township, we have identified two main fault rupture zones within the Humps Fault Zone. These are provisionally named the *Willow Bank Strand* (west of Lyndon Rd) and the Glenbourne Strand (east of Lyndon Rd). Both are characterized by oblique dextral strike-slip. The most prominent Glenbourne splay extends to the NE into the upper Leader catchment area near Woodchester Station. Here the Humps Fault Zone links with the more northerly trending South Leader and North Leader Faults.

A spectacular ground rupture has been documented from the South Leader Fault with an oblique sinistral slip of up to ~3.5m south of the Leader River. To the north, the North Leader Fault is accompanied by a ~2km wide zone of complex deformation and multiple ground rupture splays. Fault traces are often co-mingling with landslide scarps in the hillslope topography making fault zone delineation an interesting and challenging process. The main ground surface displacement zone coincides with the eastern range front of Mt Stewart; here we have documented up to ~4.5m of vertical offset of along the oblique thrust defining the principal fault zone.

Ground ruptures extend to the North and northeast from Mt Stewart range front to immediately west of the area where the Inland Kaikoura Road crosses the Conway River. The fault ruptures relay into a NE trending dextral oblique-slip fault located 1-2 km south of and trending parallel to the Hope Fault. In turn from east of the nearby Charwell River the coseismic fault rupture relays to the SE on the sinistral Stone Jug Fault, connecting in turn onto the Hundalee fault.

Rare class fieldwork opportunity for Geology students following the November 2016 Mw7.8 Kaikoura Earthquake:

Students enrolled in the Geology and Engineering Geology programmes have taken advantage of a most unusual opportunity – gaining new field mapping skills documenting some of the fault ground ruptures and large landslides that were formed during the November 14th earthquake.

Both undergraduate and postgraduate geology classes were out in the field in March mapping fault ruptures east of Waiau township and near Woodchester Station in North Canterbury. The fault scarps mapped by students are part of a very complex zone of faults that extend more than 180 km across North Canterbury to East Marlborough and then offshore. Seeing and learning how to record and interpret the complexity of the ground surface ruptures and associated zones of deformation, as well as linking the structural detail of fault zone geometries with the landforms and geomorphology represent a rare opportunity.

The Professional Masters in Engineering Geology class has also taken advantage of the unique opportunity for gaining fieldwork experience mapping the active fault ground ruptures as well as documenting and interpreting the hazards and risk scenarios associated with a huge landslide dam blocking the Leader River.

SUMMARY

While the impact of the main M7.8 Kaikoura Earthquake and subsequent many moderate to large magnitude aftershocks has had a devastating effect on communities

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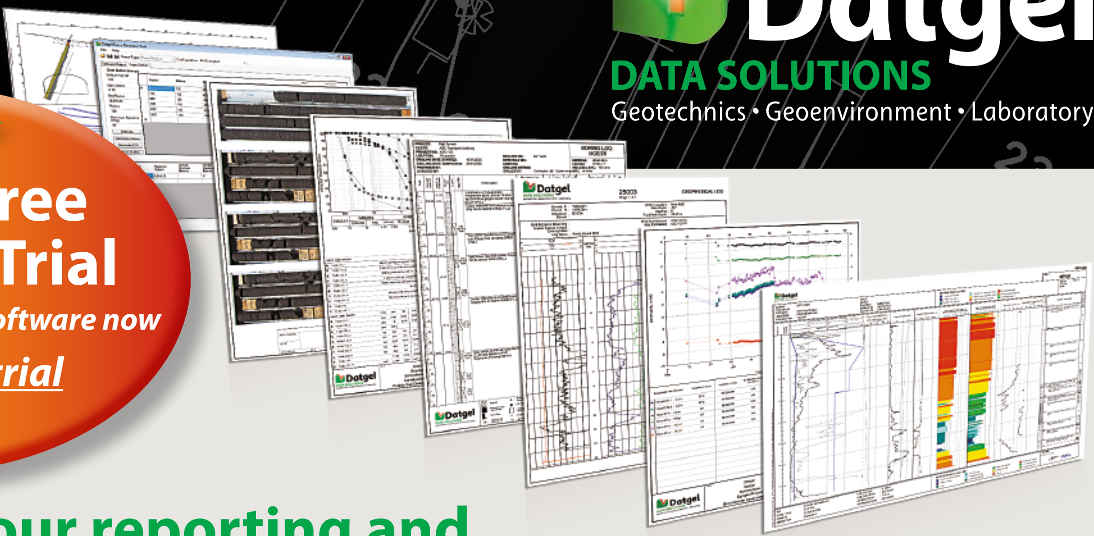

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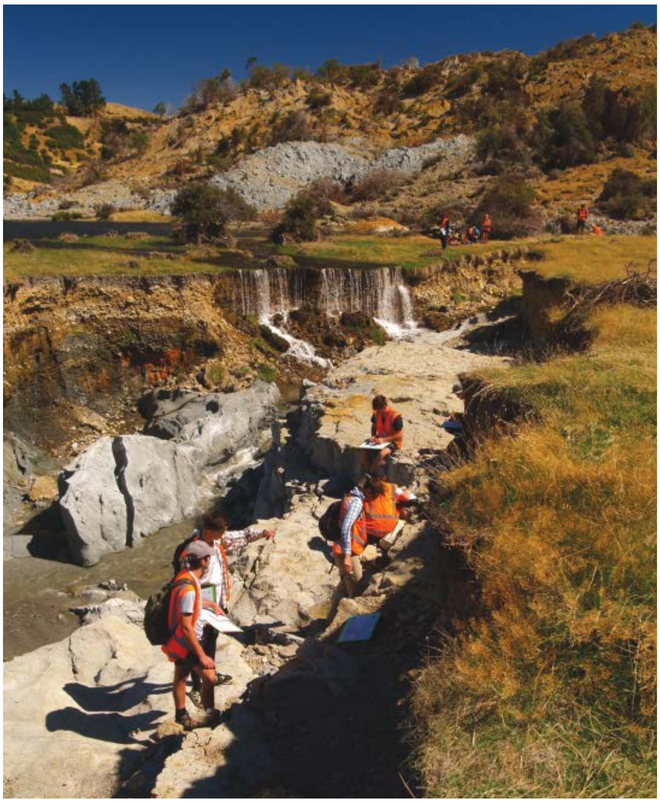
Above: Oblique reverse left lateral ground rupture of the South Leader Fault Zone. (Photo - Kate Pedley)

such as Waiau and Kaikoura as well as the regional lifeline infrastructure, we are also seeing the severity of impact on the farmers in the region. On-farm facilities such as stockyards, woolsheds, feed supply silos, farm access tracks and water supply pipe network are posing ongoing challenges for farmers. Our field mapping data will be an important part of the recovery strategy and decision-making over the coming months.

Scientifically we are generating a vast new database which will underpin future research both in terms of earthquake hazard assessment as well as a better understanding of the geologically driven landscape evolution of the NE South Island plate boundary zone. Already it is clear that this event is of global significance, the sheer scale and complexity of fault rupture, the impacts on our natural environment and the crustal dynamics involved will mean a lasting legacy of new insights into the geological and seismological processes in active tectonic regions straddling obliquely collisional plate boundaries.



Above: Postgraduate Engineering Geology class mapping a fault rupture in a new bedrock exposure created by flood erosion as Lake Rebekah overtopped the toe of the Leader River Landslide dam (background) (Photo – Clark Fenton)

Dynamic characteristics of the Lake Wakatipu Silty sediments

– Andreas Giannakogiorgos, Miyamoto International NZ Ltd, Christchurch, New Zealand

SUMMARY

Queenstown, New Zealand, is a known seismically-active area. A major soil type overlying the flat lands in and around the city is the varved micaceous clayey silt / sandy silt laminated lake sediment overlying the schist bedrock. In-situ (boreholes, CPTu, sCPTu, DMT, V_s and V_p downhole testing) and laboratory investigations (including X-Ray Diffraction mineralogy tests) were carried out on these soils to evaluate the liquefaction potential in the area of interest. However, despite the comprehensive list of assessment methods used, the factual data are not converging at one definitive conclusion and engineering judgement was needed to better interpret the body of data. To clarify the matter, further samples have been collected and monotonic and cyclic triaxial tests were performed to explore and determine the liquefaction resistance that will enable a comparison to the empirical correlations based on case-history data.

1. INTRODUCTION

Queenstown is a known seismically-active area in New Zealand. The nearby mapped active faults – the Alpine, the Nevis and the Cardrona faults – are all capable of producing earthquakes greater than M_w 7. As per the recent seismic hazard study undertaken by the Otago Regional Council for the Queenstown Lakes District (Otago Regional Council, 2015), the primary seismic hazard facing the region is an Alpine Fault earthquake; which is predicted to have a 30% probability of rupturing in the next 50 years.

Given the seismological setting, we sought to evaluate the liquefaction potential of the horizontally interbedded clayey silt / sandy silt laminated Wakatipu Lake sediment soils (lake sediments). To provide a tangible benchmark, an initial liquefaction susceptibility and triggering assessment was carried out following the simplified procedures set out in Modules 1 and 3 of the New Zealand Geotechnical Society (NZGS) "Modules for Earthquake Geotechnical Engineering Practice (2016)". Additional methods to assess liquefaction triggering were also utilized (eg. dynamic-cyclic triaxial laboratory tests, as well as shear and compressional seismic wave velocity profiling).

Despite the numerous methods used, the data obtained from conventional empirical liquefaction analyses did not converge towards a definitive conclusion and engineering judgement was needed to better interpret the body of evidence.

In this technical note, the results of the cyclic triaxial testing (CTX) on selected specimens from the Frankton area near the existing Kawarau Falls Bridge are presented in continuation of the previous presented work (Awad & Searle, 2016).

2. GEOTECHNICAL PROPERTIES OF WAKATIPU LAKE SEDIMENT SOILS

The X-Ray Diffraction (XRD) method was used in order to test mineralogy of selected samples from the Wakatipu lake sediments. It was found that the laminated lake sediments are rich in mica and chlorite (~ 84% by weight; mica and chlorite are approximately in equal amounts). Quartz makes up only 10% of the mineralogical composition and feldspars make up the remainder.

Several geotechnical investigations have been carried out throughout the Queenstown area, but this paper is dealing mostly with those in the Frankton area where the samples were retrieved from.

Seismic piezocone penetration testing (sCPTu), with down-hole shear-wave velocity (V_s) profiling and boreholes were performed above the sampling location. The lake sediments had a minimum thickness of 25 m in the area of interest and the site was classified as Class D – deep or soft soil sites – in accordance with NZS1170.5:2004.

Andreas Giannakogiorgos

Andreas is Miyamoto International New Zealand's Geotechnical Engineering Manager. With an MSc DIC degree in Soil Mechanics and Engineering Seismology from Imperial College, he has worked for 18 years on large scale geotechnical design and investigation projects on numerous infrastructure, commercial and residential projects in Greece, and New Zealand. He moved to New Zealand in 2013 to work on the Christchurch rebuild, and spent three and a half years working with Coffey in their Christchurch office before moving to Miyamoto in August 2016.

Parameters	Values
USCS type	ML
Unit weight γ_{sat} (kN/m^3)	18.5
Void ratio	0.900 – 1.140
Water content (%)	24 – 40
Fines Content (%<75·m)	>90
Liquid limit (%)	37.5-46.0
Plastic limit (%)	27.0-35.0
Plasticity Index (PI)	2.5-19.0
OCR	≥1 (4 to 5 from the CPT)

Table 1: Lake sediment index properties (laboratory testing)

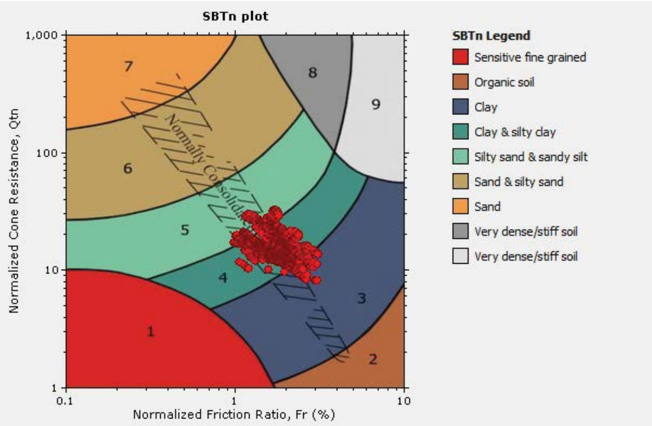
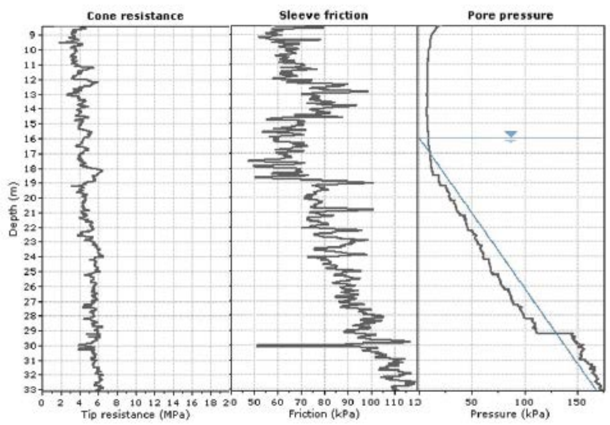


Figure 1: Normalised soil behavior type plot



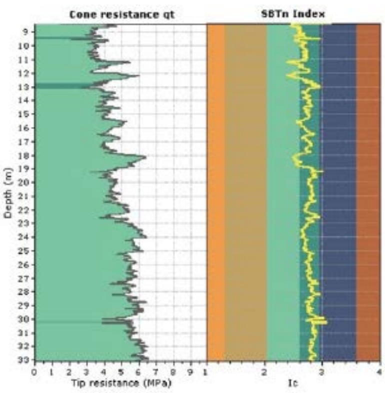


Figure 2: Cone resistances (q_c, q_t), sleeve friction, pore pressure and Soil Behavior Type Index (I_c) records below 8.4m within the lake sediments (from the site-specific sCPT)

Apart from the samples obtained for the cyclic triaxial testing, several other soil samples were retrieved from nearby boreholes at depths ranging from approximately 2m to 27m below ground level and tested in the laboratory to determine the soil composition and material properties. The measured lake sediments index properties are presented in Table 1 and the normalized Soil Behavior Type (SBTn, Robertson 1990, 2009) derived from the piezocone penetration testing (CPT) is presented in Figure 1.

Figure 2 illustrates the sCPT profile from 8.4m down to 33.0 m below ground level (lake sediments) and Figure 3 illustrates the shear wave velocity and shear modulus (V_s and G_o) profile from the seismic CPT downhole measurements as well as the estimated V_s and G_o values (Robertson and Cabal 2014) from the cone resistance.

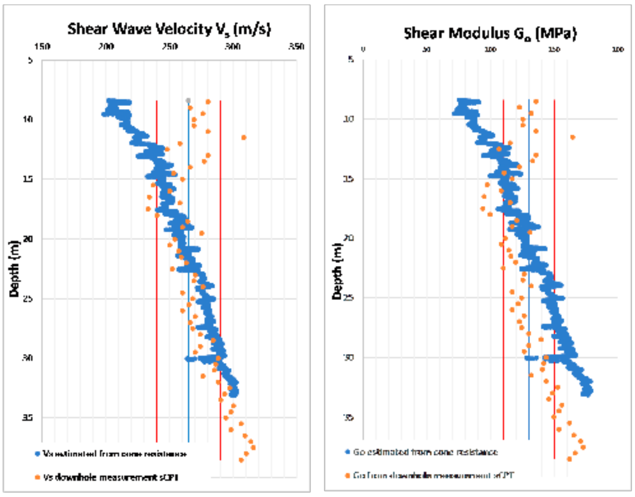


Figure 3: Shear wave velocity (V_s) and shear modulus (G_o) profile with average ± standard deviation values for the lake sediments

The sCPT data indicates that the lake sediments are transitional in behavior (i.e. transitional between sand-like and clay-like soils) as presented in Figure 4, and the transitional nature is confirmed by the index laboratory testing (medium plasticity silts – ML).

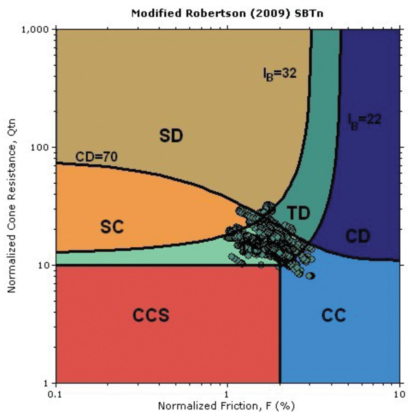


Figure 4: Modified Robertson Soil Behavior Type (SBTn)

As shown in Figure 5 (analysis of the sCPT data done with CPeT-IT software by Geologismiki Ltd.), the lake sediments have little microstructure with K*(G) values less than 330 but above 200. The normalized sCPT measurements also suggest that these soils are contractive at large strains.

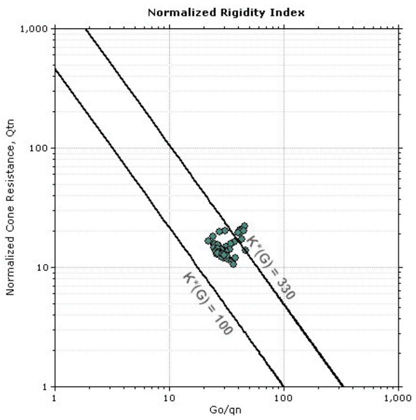


Figure 5: Normalized rigidity index; soils with K*(G) > 330 can be considered to be with significant microstructure (e.g. age and cementation)

3. LIQUEFACTION ASSESSMENT-cyclic triaxial testing (ctx)

3.1 Previous Work

Bowen et al. (2015) carried out 13 cyclic triaxial tests on low plasticity micaceous lake sediments in Central Otago which have similar properties to the soils we assessed in Queenstown, but with a lower plasticity range (PI = 0 to 7%). The laboratory testing revealed a cyclic mobility behavior (progressive accumulation of limited strains after r_u = 100% has temporarily occurred) but no liquefaction flow-type behavior (rapid increase in pore pressure leading to complete loss of shear strength).

3.2 Soil sampling and laboratory testing procedure

Twelve (12) undrained cyclic triaxial tests were performed on undisturbed samples by the Soil Mechanics, Foundation and Geotechnical Earthquake Engineering Laboratory of the Aristotle University of Thessaloniki (AUTh-SMFGEE) on behalf of Miyamoto International NZ Ltd., and the lead author. The objective was to estimate the liquefaction resistance (cyclic triaxial tests) of the Wakatipu varved lake sediments and the post-liquefaction undrained shear strength (monotonic triaxial tests).

The physical properties of the tested soils are given in Table 2, with the grading curves of two representative samples, after they were loaded cyclically, to be illustrated in Figure 6.

The samples were block samples retrieved by constant pressure via plastic tubes with sharp cutting edges and typical steel samplers above the river level (GWT – saturation level), within the unsaturated zone to avoid disturbance while travelling for New Zealand to Greece. The samples were then carefully extruded, and saturated to represent the site conditions. It should be noted that the comparison between the void ratio, plasticity indices, unit weights etc. with those from the New Zealand tested laboratory samples are similar without providing clear evidence of significant sample disturbance during sampling, travelling, and handling.

Property	Sample	
	1-B-300	4-A-50 & 4-A-150
Fines Content f_c (%)	92	96
Clay Fraction CF (%<5μm)	2	5.5
Specific gravity G_s	2.70	2.70
Liquid limit W_L (%)		46.3
Plastic limit W_P (%)		35.8
Plasticity Index P_I (%)		10.5
Uniformity coefficient, C_u	3.6	3.6
Particle size d_{10} (mm)	0.0094	0.0073
Particle size d_{50} (mm)	0.0284	0.0217
Particle size d_{60} (mm)	0.0338	0.0259

Table 2: Summary of physical properties of tested soils

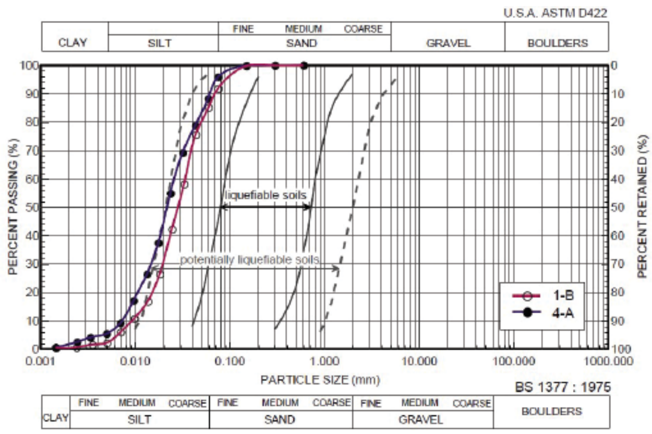


Figure 6: Grain size distribution of tested soils which lie within the suggested bound gradation curves for potentially liquefiable soils (after Tsuchida 1971)

All triaxial tests were performed using a closed-loop automatic cyclic triaxial apparatus (M.T.S. Systems Corporation).

Saturation of samples was achieved by applying a series of consecutive cell and back pressure increments, while maintaining an effective confining stress of 10kPa, until a Skempton B = $\Delta u/\Delta\sigma$ value equal or greater than 95% was

	Saturation		Con-solid-ation	After consolidation				Cyclic Loading							Monotonic loading		
Test	u_b (kPa)	B (%)	P'_o (kPa)	H (mm)	D (mm)	e	γ_d (kN/m^3)	CSR	N total[2]	N 1%	N 2.5%	N 5%	N $\Delta u/p'_o \geq 95\%$	max ε_{DA} (%)	e_v[3] (%)	S_{umax}[4] (kPa)	ε_a(%) @ S_{umax}
1-A-50[1]	495	95	50	97.37	48.80	1.035	13.02	0.36	9.1	1.3	3.8	6.8	7.2	6.8	6.4	71.9	12.6
2-A-50	493	95	50	96.77	48.86	1.110	12.56	0.25	26.0	9.8	15.3	22.3	19.2	6.1	10.3	71.7	14.0
3-B-50[5]	452	95	50	96.36	48.86	0.954	13.55	0.20	127.2	73.3	93.8	112.8	90.2	6.0	9.7	73.7	10.1
4-A-50	394	95	50	95.89	50.31	1.050	12.92	0.16	502	-	-	-	-	0.1	-	-	-
1-A-150	473	95	150	89.18	47.60	0.834	14.44	0.42	2	0.2	0.3	0.7	1.2	20	-	-	-
2-A-150	473	95	150	100.76	48.05	0.989	13.32	0.31	8.1	0.3	1.3	2.7	6.2	17.8	13.8	176.5	15.3
3-A-150	474	96	150	89.77	48.96	0.931	13.72	0.18	27.2	9.4	16.8	20.3	26.1	11.2	8.9	165.9	15.3
4-A-150	476	95	150	96.71	47.19	0.978	13.39	0.15	472	-	-	-	-	0.2	-	105.6	18.1
1-B-300	393	95	300	95.63	47.88	0.924	13.77	0.26	5.2	0.6	1.8	2.7	4.2	17.1	11.7	193.1	10.8
2-B-300	400	95	300	95.76	48.20	0.944	13.63	0.20	18.1	4.8	11.3	13.7	16.3	16.0	14.1	231.2	16.1
3-B-300	401	95	300	94.41	47.86	0.916	13.82	0.19	54.1	36.8	47.8	50.7	52.2	10.4	10.5	-	-
4-B-300	400	95	300	96.43	48.53	0.966	13.47	0.15	207	-	-	-	-	0.3	-	-	-

1 **I-X-Y**: **I** (distinctive number), **X** (A=short PVC tube / B=long steel tube), **Y** (mean effective stress, p'o)
2 Total number of loading cycles
3 Volumetric deformation during consolidation after liquefaction
4 Post-cyclic undrained monotonic strength during loading performed after liquefaction and consolidation
5 Contained plant roots

Table 3: Summary of cyclic triaxial test (CTX) conditions, cyclic loading and post-cyclic monotonic strength

obtained. Following saturation, samples were isotropically consolidated under an effective isotropic stress, p'_o, of 50kPa, 150kPa, and 300kPa. During consolidation, the volume change and the axial displacement deformation of samples were recorded to calculate the post-consolidation void ratio. A period of time equal to double the consolidation time (approximately 50 minutes) was allowed before cyclic loading. The change of void ratio of the tested samples with consolidation stress is shown in Figure 7.

Cyclic loading was performed by applying a sinusoidally varying deviatoric axial stress (σ_d) at a frequency of f = 0.1Hz, under undrained conditions. In this work, the occurrence of double amplitude axial strain, ε_{DA} = 5%, was used as a reference point for the onset of liquefaction of the tested samples. For this reason, a series of cyclic triaxial tests with different cyclic stress ratios, CSR = $\sigma_d / 2p'_o$, were carried out in order to determine the number of loading cycles (N) required for the development ε_{DA} of 5%. It is noted that the development of Δu practically equal to p'_o according to the relationship: $\Delta u/p'_o \geq 95\%$, was also examined as a reference point for the onset of liquefaction and compared to the aforementioned criterion of ε_{DA} = 5%.

In view of the equivalent number of loading cycles of actual earthquakes (10 to 20 for an earthquake of M_w = 7.5), in this work the onset of liquefaction and thus the cyclic resistance ratio, CRR_{15}, was considered as the CSR, required to produce ε_{DA} = 5% in 15 load cycles.

After cyclic loading, which resulted in liquefaction, samples were consolidated once more at the mean effective stress level prior to loading, in order to determine the volumetric deformation, ε_v, after liquefaction.

Following the second consolidation stage, samples were loaded monotonically under undrained conditions to determine their post-cyclic undrained shear strength (S_{umax}). Samples were subjected to undrained compression at a constant rate of axial displacement of 0.1 $^{mm}/_{min}$. The undrained shear strength, S_{umax}, is equal to half the maximum deviatoric stress, q_{max}, during compression.

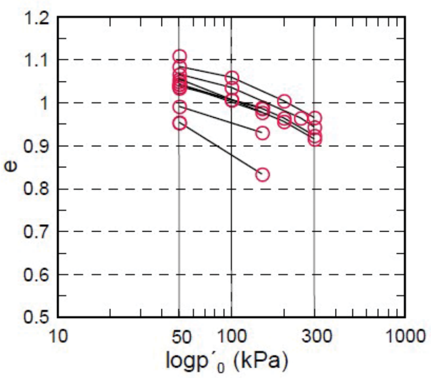


Figure 7: Variation of void ratio, e, with mean effective stress, p'_o, for the tested samples

3.3 CTX results and discussion

Table 3: presents the cyclic test conditions and results for tests on undisturbed samples.

Figure 8 presents the cyclic triaxial test of sample 2-A-50 (as per Table 3) showing:

- the variation of (a) single amplitude cyclic deviatoric axial stress,σ_d, (b) double amplitude axial deformation, ε_{DA} and (c) excess pore water pressure, ·u with versus time, t;
- the variation of (d) deviatoric stress, q, and (e) Δu versus ε_{DA};
- (f) their stress paths, in terms of q and p', and
- (g) the stress – strain behavior during cyclic loading.

The plots demonstrate a characteristic cyclic mobility bahavior with limited strain potential and the typical inverted s-shaped loops on the CSR vs shear strain plots. Due to change of soil stiffness the deviator stress is decreasing with cycles for the specific testing conditions of sample 2-A-50 and low confining pressure.

Similarly, Figure 9 illustrates the cyclic test results for sample 4-A-150 demonstrating an 'elastic' response during cyclic loading.

Figure 11 presents the variation of CSR with the number of cycles, N, required to reach ε_{DA} = 1, 2.5 and 5%, as well as $\Delta u/p'_o \geq 95\%$ for tested samples at p'_o = 50kPa, 150kPa and 300kPa. It is shown that regardless of the p'_o level, at relatively low levels of CSR the required N to reach the aforementioned characteristic deformations practically coincides, whereas at higher CSR the N value at each ε_{DA} is distinctive from another.

Furthermore, it is shown that at the smallest p'_o level the two criteria for the onset of liquefaction practically coincide. With increasing p'_o, however, liquefaction is triggered first based on the ε_{DA} = 5% criterion and afterwards according to the Δu criterion.

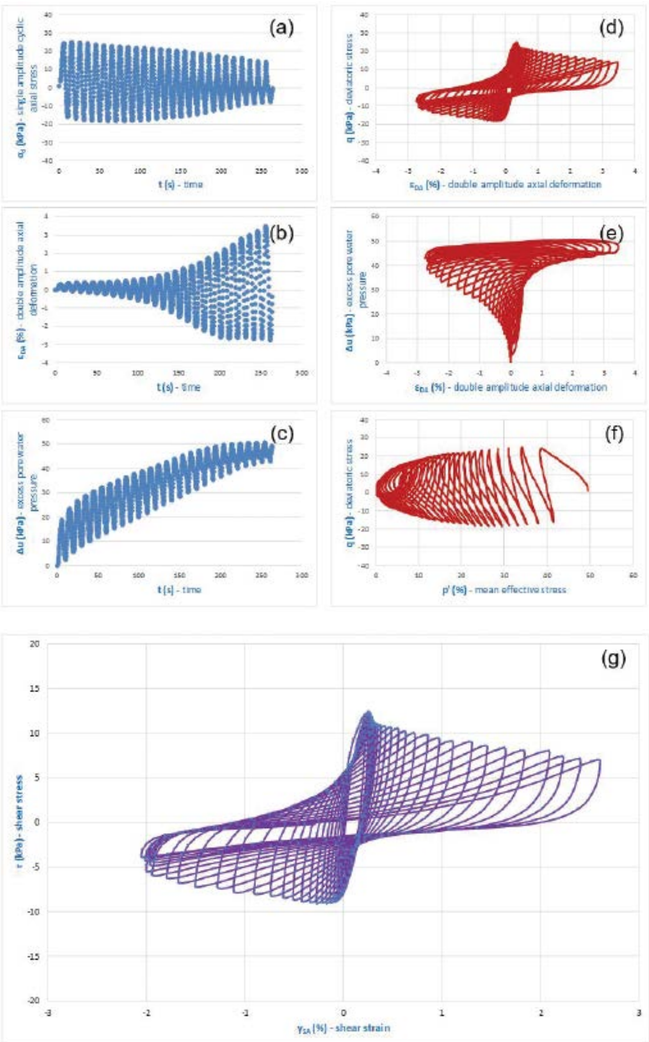


Figure 8: CTX test results on sample 2-A-50

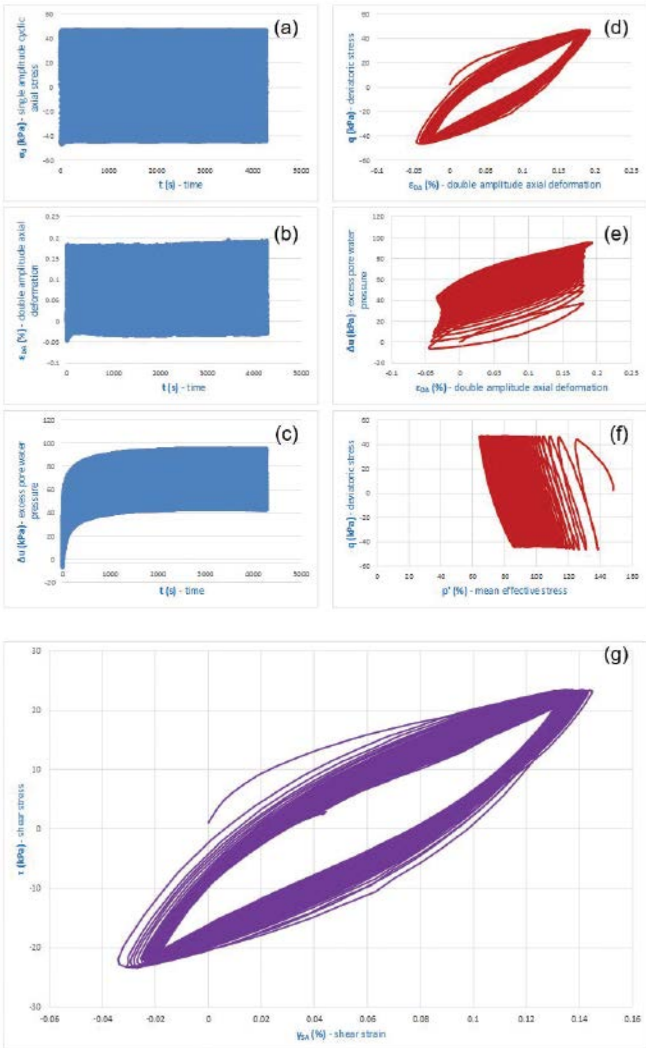


Figure 9: CTX test results on sample 4-A-150

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- The Solinst Levelogger is a water level and temperature recording device.
- Uses include ground water monitoring from pumping and slug tests; stream gauging; level monitoring to tidal fluctuation; and long term water level monitoring.
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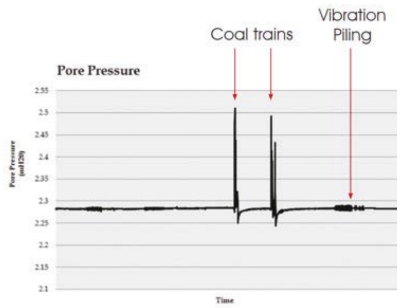
Liquefaction Monitoring

Monitoring liquefiable material in the Waikato River during vibration piling

- Construction of a new railway bridge.
- Leveloggers installed in sand pockets in the Waikato River and adjacent railway embankment.
- Preferred to vibrating wire piezometers because of required frequency of 0.5 second readings.
- Involved live, continuous monitoring of pore pressure during vibration piling embankment and train events, with software plotting every 0.5 seconds.

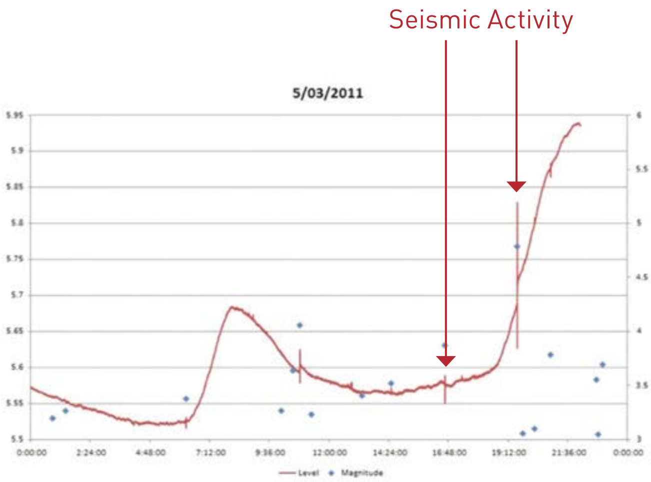
Interpretation of data:

- Results from monitoring showed a small amount of energy from the piling technique and a large amount of energy in the embankment from the coal train!



Seismic Activity Monitoring

Response of material to earthquake events in the Port Hills, Christchurch



- Located in a small estuarine area at the foot of the Port Hills, with a geology of coarse sands and gravels.
- Leveloggers installed at a depth of 6m below ground level, in a sand cell with bentonite seal in column.
- Ground water level at 2-4m below ground level.
- Leveloggers measured the effects of seismic activity on pore water pressure.
- Data points collected every 0.5 seconds.

Interpretation of data:

- The higher the magnitude of the aftershock, the higher the spike on the plot.
- Tidal and rainfall effects were also observed due to pressure increase.

The results for each triaxial compression test performed after cyclic loading, are presented in Figure 10 for the above samples, showing:

- the variation of (a) deviatoric stress, q, and (b) excess pore water pressure, Δu, with axial deformation, ε_σ and
- (c) their stress paths, in terms of q and p'

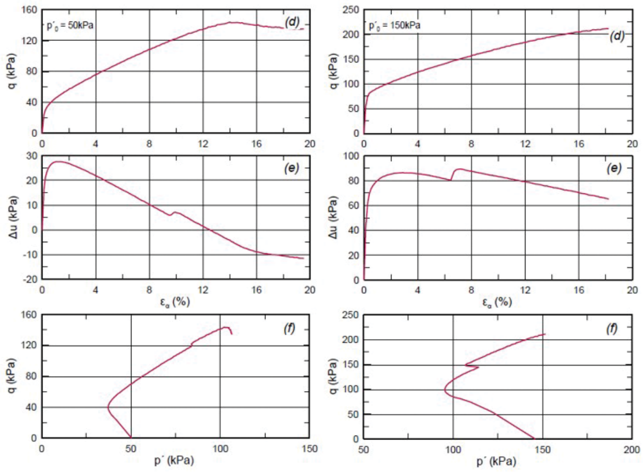


Figure 10: Post-cyclic monotonic triaxial test results on samples 2-A-50 and 4-A-150

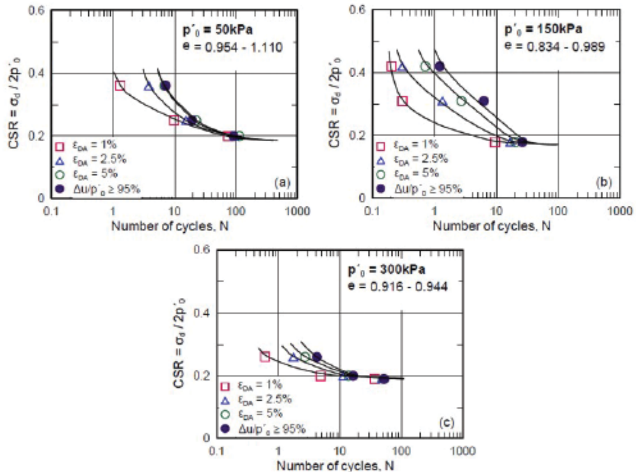


Figure 11: Variation of CSR with number of cycles, N, for tested samples at (a) p'_o = 50kPa, (b) 150kPa and (c) 300kPa

Figure 12 presents the variation of CRR_{15} with void ratio, e for samples tested under p'_o = 50kPa, 150kPa and 300kPa. It is shown that for the studied void ratio range, CRR_{15} is practically unaffected by void ratio (density). Furthermore, with increasing p'_o, liquefaction resistance of the tested samples decreases, as shown also in Figure 14, since soil specimens becomes more contractive at higher confinement pressures.

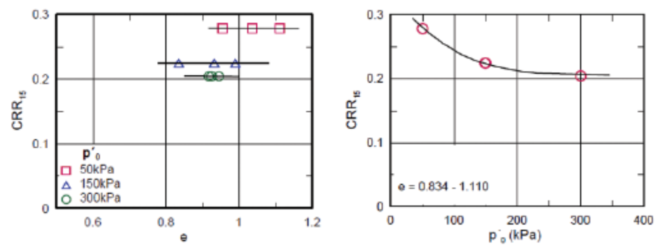


Figure 12: Variation of CRR_{15} with void ratio, e, for tested samples at (a) p'_o = 50kPa, (b) 150kPa and (c) 300kPa and mean effective stress, p'_o

Figure 13 presents the effect of liquefaction on the undrained shear strength, S_{umax} of the tested samples. For the studied density range (void ratio), it is shown that the normalized post-cyclic undrained monotonic strength over p'_o is not significantly influenced by density – void ratio. The variation of S_{umax}/p'_o with p'_o is also presented in Figure 13 and it can be seen that the normalized post-cyclic S_{umax}/p'_o decreases with increasing p'_o

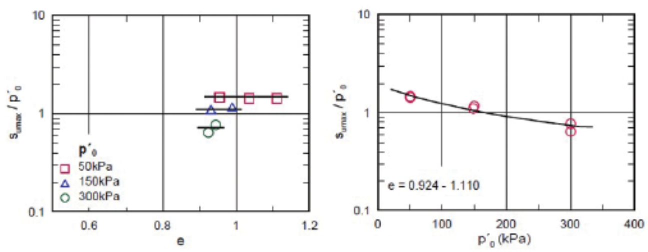


Figure 13: Variation of the normalised post-cyclic S_{umax}/p'_o with void ratio and mean effective stress p'_o

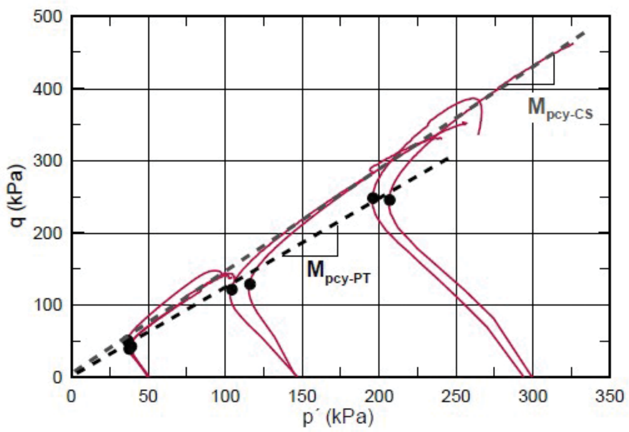


Figure 14: Post-cyclic stress paths of the tested samples

Figure 14 presents the post-cyclic stress paths for the tested samples. The $q_{pcy\text{-}PT}$ and $p'_{pcy\text{-}PT}$ values corresponding to the Phase Transformation State (point of transition from contractive to dilative, minimum p') were calculated according to the equation:

$$q_{pcy\text{-}PT} = M_{pcy\text{-}PT} \cdot p'_{pcy\text{-}PT} \quad (r^2=0.998) \qquad [1]$$

According to the above equation, the post cyclic stress ratio at the Phase Transformation state, $M_{pcy\text{-}PT}$ was derived equal to 1.209 and the friction angle at that state, $\varphi'_{pcy\text{-}PT}$=30.2°.

4. CONCLUSIONS

In-situ and laboratory investigations were carried out to evaluate determine the liquefaction resistance of the micaceous clayey silt / sandy silt laminated lake sediments in Queenstown. This includes undertaking cyclic triaxial testing (CTX) on selected specimens of typical lake Wakatipu soils from the Frankton area near the existing Kawarau Falls Bridge.

The results from the conventional laboratory tests to determine liquefaction susceptibility were inconclusive and the CPT-based methods of assessing liquefaction triggering produced significantly varied results.

Based on the current assessment, we consider that these soils do not exhibit flow liquefaction but rather cyclic mobility with the following important characteristics:

- It was shown that regardless of the p'o level, at relatively low levels of CSR the required N to reach the liquefaction criteria practically coincides, whereas at higher CSR the N value at each ε_{DA} is distinctive from another;
- For the studied void ratio range (tested samples), CRR_{15} is practically unaffected by void ratio;

- With increasing the mean effective stress p'o, liquefaction resistance of the tested samples decreases;
- For the studied void ratio range, it is shown that the normalized post-cyclic undrained monotonic strength over p'_o is not significantly influenced by void ratio;
- The normalized post-cyclic S_{umax}/p'_o decreases with increasing p'_o.

The published empirical triggering curves based on the routine penetration-based procedures used throughout New Zealand to assess liquefaction triggering may lead to overestimating the liquefaction risk for sites in the Queenstown area. However, further investigation, sampling and testing would be required to confirm these findings beyond the tested Frankton area and its applicability for the majority of the Wakatipu lake sediments.

5. ACKNOWLEDGMENTS

The experimental work on the lake sediments performed by the Soil Mechanics, Foundation and Geotechnical Earthquake Engineering Laboratory of the Aristotle University of Thessaloniki (AUTh-SMFGEE) under the direction of Prof. Theodora Tika.

This research wouldn't be possible without the support and funding of Miyamoto International NZ Ltd.

The writer is grateful for the many discussions, feedback and valuable comments provided by Ass. Prof. Katerina Ziotopoulou, Dr. Peter Robertson (Professor Emeritus and Technical Advisor to Gregg Drilling & Testing), Ioannis Antonopoulos (Principal Geotechnical Engineer at Coffey Services, NZ) and Nick Barounis (Senior Geotechnical Engineer at Cook Costello).

6. REFERENCES

Awad, A., and Searle, J. (2016). Liquefaction potential of the micaceous lake sediments in the Queenstown area", 11th Young Geotechnical Professional Conference, Queenstown, New Zealand.

Boulanger, R.W., and Idriss, I.M. (2006) Liquefaction susceptibility criteria for silts and clays. Journal of Geotechnical and Geoenvironmental Engineering, 132(11), 1413-1426pp.

Boulanger, R.W., Idriss, I.M. (2007). Evaluation of cyclic softening in silts and clays. Journal of Geotechnical and Geoenvironmental Engineering, 133(6), 641-462pp.

Boulanger, R.W., and Idriss, I.M. (2014) CPT and SPT liquefaction triggering procedures. Report No. UCD/CGM-14/01, April 2014, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering at the University of California, Davis, California.

Bowen, H.J., Ashby, GL, and Stringer, M.E. (2015). Case study – Undisturbed sampling, cyclic testing and numerical modelling of a low plasticity silt. 6th International Conference on Earthquake Engineering, Christchurch, New Zealand.

New Zealand Geotechnical Society (NZGS) and Ministry of Business, Innovation and Employment (MBIE) (2016). Earthquake geotechnical engineering practice Module 1: Overview of the guidelines, March 2016.

New Zealand Geotechnical Society (NZGS) and Ministry of Business, Innovation and Employment (MBIE) (2016). Earthquake geotechnical engineering practice Module 3: Identification, assessment and mitigation of liquefaction hazards, May 2016.

Otago Regional Council (2015). Seismic Hazard in Queenstown Lakes District: Study Report, April.

Robertson, P.K. (1990). Soil classification using the cone penetration test. Canadian Geotechnical Journal, 27(1): 151-158

Robertson, P.K. (2009). CPT interpretation – a unified approach, Canadian Geotechnical Journal, 46: 1-19

Robertson, P.K., and Wride, C.E. (1998). Cyclic Liquefaction and its Evaluation based on the CPT Canadian Geotechnical Journal, 1998, Vol. 35, August.

Robertson, P.K, and Cabal, K.L. (2014) Guide to Cone Penetration Testing for Geotechnical Engineering (6th Ed), Gregg Drilling & Testing, Inc., California, USA

Tsuchida, H. (1971) Estimation of liquefaction potential of sandy soils. In Proceedings of the 3rd Joint Meeting, US-Japan Panel on Wind and Seismic Effects.

Youd, T.L., Idriss, I.M., Andrus, R.D., Arango, I., Castro, G., Christian, J.T., Dobry, R., Finn, W.D.L., Harder, L.F. Jr., Hynes, M. E., Ishihara, K., Koester, J., Liao, S.S.C., Marcuson, W.F. III, Martin, G.R., Mitchell, J.K., Moriwaki, Y., Power, M. S., Robertson, P.K., Seed, R. B., and Stokoe, K. H. II (2001). Liquefaction resistance of soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils, Journal of Geotechnical and Geoenvironmental Engineering, ASCE,127(4): 297-313

Slope Stabilisation using Stone Column Ground Improvement

– S. Reeves, Department of Geological Sciences, University of Canterbury

INTRODUCTION

Ground remediation methods have been used for many years to improve ground conditions to enable development. Ground remediation has become increasingly common as industrialisation has caused rapid development of cities. Areas within cities, previously undeveloped due to adverse ground conditions, can now be remediated to enable development. Adverse ground conditions can include, but are not limited to, organic, loose, soft, liquefiable and compressible soils. Remediation methods can be used on flat and sloping sites. Sloping sites may be prone to slope instability and can require stabilisation. Ground remediation methods have also been used in areas where the soils are susceptible to liquefaction induced ground deformation. Christchurch, New Zealand, is a city where such remediation methods are being used for this and other purposes.

Stone columns have been used in Christchurch as a ground improvement method and have numerous applications for improving ground conditions, including slope stabilisation. Factors that can cause slope instability include cyclic loading (associated with earthquake loading) that can result in the generation of excess pore water pressures within the soils, which can adversely affect the shear strength of the soil. Stone columns are capable of mitigating the triggering of liquefaction by providing drainage (which helps prevent the build up of excess pore water pressures) and by increasing the stiffness of the soils, which mitigates the amount of shear strain occurring in the soils during cyclic loading. Stone columns are also capable of addressing slope stability issues such as landslide mitigation or stabilisation (Aboshi et al., 1979; Goughnour et al., 1991). Goughnour et al. (1991) state that slope instability can be improved by increasing the shear resistance of the soil along a potential slip surface by replacing or displacing the insitu soil. Improved drainage of pore water pressures can also be achieved by providing a more permeable gravel column within the slope, increasing the strength of the insitu soils and improving stability (Abramson, 2002; Deb et al., 2012). Mechanically the shear resistance of stone columns is dependent on the applied load, or normal stress, and the shear displacement at the location of the failure plane (Alfaro et al., 2009).

An initial geotechnical assessment of the site was undertaken by Fraser Thomas Ltd to characterise the subsurface conditions of the site, determine the suitability of the existing foundation systems and provide information for preliminary ground remediation design details. Stone columns were selected to remediate the soils underlying the eastern part of the site which were considered to be prone to liquefaction and slope instability (under seismic loading conditions).

Field Observations

This research investigates the use of stone column ground remediation to stabilise the slopes at Trafalgar Street, St Albans, Christchurch. St Albans Creek is located in close proximity to the site. The slopes at the site are the western low angle river bank slopes of St Albans Creek. The crest of the western bank of St Albans creek is generally located along the eastern site boundary, which generally extends in a south-easterly direction. The approximate location and extent of the crest of the western bank of St Albans Creek, in the vicinity of the subject site, is shown on Figure 1.

The crest of the western bank of St Albans Creek is located a horizontal distance of between approximately 4.4 m and 8.8 m from the eastern edge of the footprint of the previously existing buildings. The western bank of St Albans Creek, in the vicinity of the subject site, is not retained and is up to approximately 1.75 m in vertical height. The topography immediately adjacent to the western bank of St Albans Creek is considered to be

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Simon is an engineering geologist at Fraser Thomas Ltd with 5 years experience. Simon has recently graduated with a Professional Masters in Engineering Geology (PMEG) from The University of Canterbury while working locally in Christchurch. Simon has been involved in a wide range of commercial and residential projects specialising in liquefaction mitigation and remediation.

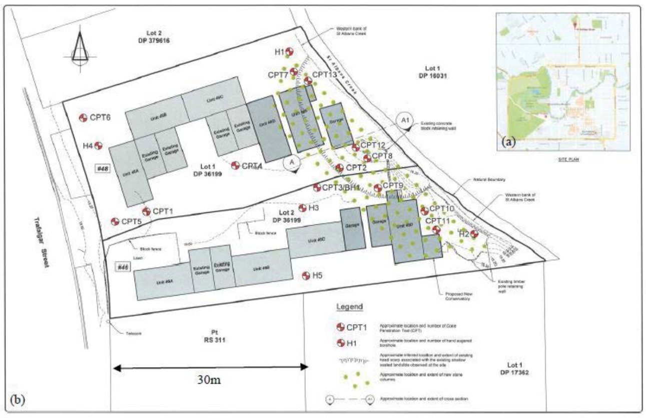


Figure 1: – (a) Location of study site in Christchurch (b) Site plan showing test locations, approximate inferred location of headscarp feature and associated shallow seated landslide. The approximate locations of the then proposed stone columns have also been illustrated.

slightly to moderately sloping (5°-14°). Although, under normal circumstances, this topography would not be considered to be potentially unstable slope failure of the western bank of St Albans Creek has occurred.

The initial geotechnical assessment indicated that the slope failure at the site was inferred to have been caused by cyclic loading associated with the February 2011 earthquake, part of the Christchurch Earthquake Sequence (CES), which caused the generation of excess pore water pressures in the soils. This caused a significant reduction to the effective stress along the failure plane (inferred to be approximately 2.4 m below the ground surface) which resulted in the rotational slumping of the western river bank at the site.

The low angle western river bank slopes and the sites' structures were significantly affected by lateral and vertical displacements of the shallow seated landslide, as shown in Figure 2. The free face provided no lateral confinement of the surficial soils in the area during liquefaction, resulting in lateral movement and deformation of the structures. In other locations around Christchurch the CES has led to extensive liquefaction induced land damage (Wotherspoon et al., 2015). The consequences of liquefaction include: slope instability as shear strength is lost; lateral spreading on slightly sloping ground; and settlement caused by reconsolidation of the liquefied soils (Boulanger and Idriss, 2006). The buildings within the eastern part of the site now require rebuilding due to the damage sustained during the slope failure.

Slumping Failure Mechanism:

It should be noted that liquefaction induced lateral ground spreading, which is discussed in the Ministry of Business, Innovation and Employment (MBIE) guidelines ((MBIE), 2012), is normally defined as large scale lateral ground movement adjacent to a "free-face". This type of lateral ground movement can affect gently sloping ground and can affect ground located hundreds of meters from the "free-face". The slope failure discussed in this paper is not considered to be associated with "lateral ground spreading" but is more accurately described as a localised rotational slide or slumping (Rauch, 1997; Zhang et al., 2004). Zhang et al. (2004) comment that a slope is more prone to slump failure with increasing proximity to a free face, due to the presence of higher static shear stresses.

An existing concrete block retaining wall was located at the eastern end of the site. The existing retaining wall appears to have been subject to significant vertical and lateral displacement causing tilting. The rotation of the retaining wall and other structures located in close proximity to the river bank and the development of a circular headscarp feature, as shown in Figure 1, confirm a rotational slumping slope failure mechanism.

Research Aims:

Fraser Thomas Ltd have effectively mitigated the liquefaction hazard using stone columns in accordance with the recommendations of Part C of the MBIE guidelines. The aims of this research are to understand and confirm the geotechnical controls on the observed

Figure 2: Photos showing damage sustained to the existing buildings in the eastern part of the subject site

slope failure, to determine if adequate slope stabilisation has been achieved from installing stone columns (under static and seismic loading conditions) and to determine the future dynamic loading capacity of the site.

Geological Setting:
Christchurch is situated on the Canterbury Plains, on the eastern coast of the South Island, New Zealand. The Canterbury Plains largely comprise of a series of alluvial fans spread in a west to east direction, toward the coast. During previous interglacial periods, climatic conditions caused the eastward transgression of the Canterbury Plains forming the present shoreline. Post glacial fluvial channels and overbank sediments spread throughout Christchurch in a layer referred to as the Springston Formation. The eastern transgressional glacial channels have subsequently interfingered with marine sediments below Christchurch and offshore (Brown et al., 1992). As a result, Christchurch is founded on a complex, interlayered sequence of alluvial soils and marine sediments of Holocene age (Wissman et al., 2015). Many of Christchurch's creeks and rivers, such as the Dudley and St Albans Creeks and Avon and Heathcote Rivers, although largely spring fed, are remnants of these glacial outwash channels. Whilst most of the Christchurch land mass has been drained (Brown and Weeber, 1992), the nature of the soils present has contributed to a precarious building substrate prone to liquefaction and slope instability.

METHODOLOGY

Site Characterisation

The initial field investigation undertaken by Fraser Thomas Ltd comprised a visual appraisal of the site, two Cone Penetration Tests (CPT), five hand augered boreholes and associated Dynamic Cone Penetrometer (DCP) scala tests and a topographic survey.

Four existing CPT probes and one machine borehole, understood to have been put down as part of the EQC "area wide Christchurch geotechnical investigations", are also located at the site. For the purposes of this paper the CPT's have been called CPT 1 to CPT 6 inclusive. The machine borehole has been labelled M1. The five hand augered boreholes have been labelled H1 to H5 inclusive. The locations of the test positions, existing head scarp and inferred landslide feature are shown in Figure 1. The results of the CPT probe and borehole investigation indicate that the surficial soils underlying the site are likely to comprise sediments of the Springston Formation of Holocene age and the groundwater level was inferred to be at a depth of approximately 1.1 m below ground level. This groundwater depth has been used for the various slope stability analysis conducted for this research.

Following the demolition of the existing buildings at the site an additional four CPT probes were put down to provide a baseline of the geotechnical properties prior to installation of the stone columns. The approximate locations of the designed stone columns are shown in

Before Stone Column installation							After Stone Column installation (between elements)			
Depth	**Soil Unit**	**Soil Unit Weight kN/m^3**	**Inferred Shear Soil Strength**	**Cone Tip Resistance (qt)**	**Apparent Cohesion**	**Inferred Angle of Internal Friction**	**Inferred Shear Soil Strength**	**Cone Tip Resistance (qt)**	**Apparent Cohesion**	**Inferred Angle of Internal Friction**
0m to 2.4m	Clayey Silts and Silty Clays	18	55-140 kPa	–	5	30	70-180 kPa	-	10	32
	interbedded				0	31-33			0	32-35
2.4m to 5.6m	with Silty Sands interbedded with Sandy Silts	20	-	3-6 MPa			-			
	O									
5.6 m to 9.8m	Sandy Gravel	22	-	20-50 MPa	0	40		20- 50 MPa	0	40
					0	37-40			0	37-40
9.8m to >20m	Deeper Sands and Silty Sands	20	–	15-25 MPa			–	15-25 MPa		

Table 1: Generalised subsurface conditions underlying the site before and after stone column installation.

Note stone column installation up to 5.95m deep.

Figure 1. The geotechnical properties determined from the CPT probes were converted into Mohr- Coulomb strength parameters (apparent cohesion (kPa) and friction angle (°)), using previous works provided by Carter and Bentley (1991) and Waltham (2009). The CPT probes used for the analyses are identified as CPT 7, CPT 8, CPT 9 and CPT 10, shown in Figure 1. The soil profile and geotechnical properties of the underlying soil before and after stone column installation are presented in Table 1. The results of the field investigations have been used to characterise the site and have also been used for the back analysis, slope stability analysis and psuedostatic analysis, for the slope profile $A-A^{1}$, as shown in Figure 1. It should be noted that the CPT probe testing was undertaken before and after ground remediation in order to confirm the densification of the liquefiable soils.

Slope Failure Back Analysis:
In order to understand the geotechnical controls on the slope failure, a back analysis has been conducted for the slope profile $A-A^{1}$. The back analysis has been conducted with Rocsciences 2D limit equilibrium software Slide version 7.0. The analysis has been undertaken to calculate the soil strength of the inferred liquefiable silty sands interbedded with sandy silts layer within the likely failure zone of the slope, encountered between 2.4 m and 5.6 m below ground level. It is understood that liquefaction and the observed slope failure occurred in response to the February 2011 earthquake event. The back analysis can be used to determine the soil strength parameters during failure of the slope at the site, in response to seismic loading associated with the February 2011 earthquake.

To identify the inferred liquefiable layer within the soil profile, an analysis has been undertaken using the computer programme CLiq to assess the theoretical liquefaction triggering potential of the underlying soils at the location of CPT 2 under Ultimate Limit State (ULS) seismic loading condition. It should be noted that liquefaction of the underlying sandy soils will significantly reduce the soil strength properties due to increases in pore water pressures and associated decreases in effective stress of liquefied soils. Therefore, reducing the liquefaction potential of the soils will also improve the stability of the slope.

Ground accelerations from an earthquake can be measured by Peak Ground Acceleration (PGA)'s. Earthquake modeling of future events is founded on past earthquake events and future predictions. Conditional median PGA's for the previous Canterbury earthquakes have been used for the analysis. These PGAs have been determined by ((EQC), 2016) for various earthquake events. The conditional median PGA's expected to have occurred at the subject site were 0.21 g, 0.38 g and 0.21 g, for the September 2010, February 2011 and June 2011 earthquake events respectively.

The back analysis model has been developed in the Slide software using the topographic survey data and geotechnical data during the site characterisation, using a circular failure surface. The back analysis model runs a range of soil strength parameters and determines which combinations of Mohr- Coulomb parameters, apparent cohesion (kPa) and friction angle (°), would lead to slope failure. The Bishop Limit Equilibrium Method (LEM) has been assessed during this analysis. The slope failure is inferred to have occurred during earthquake ground motions from the February 2011 earthquake event, PGA of 0.38 g. In order to replicate the worst case scenario this PGA value was input into both the horizontal and vertical Slide seismic load coefficient options.

Slope Stability Analysis:
In order to determine if adequate stabilisation from the installation of stone columns has been achieved, a

theoretical slope stability analysis has been undertaken for the slope profile A-A[1] after the stone column elements were installed. Hammouri et al. (2008) comment that slope geometry, soil properties, and the loads acting on the slope are critical parameters for the analysis of slope stability. There are many methods for assessing slope stability; of particular relevance are LEM and Finite Element Method (FEM).

LEM have been chosen for slope stability analysis in this research. The analysis output is a Factor of Safety (FoS), which is a calculated ratio between the driving and resisting force present on a user defined failure surface. The analysis is conducted by dividing the slide mass into smaller vertical slices (Hammouri et al., 2008). Abramson (2002) explains that the simplified Bishop (Bishop, 1955) and Janbu methods (Janbu, 1975) are the most popular methods because the FoS can be quickly calculated for most problems.

As noted by Hammouri et al. (2008) soil parameters are critical for slope stability assessment. Soil strength parameters have been calculated at the Trafalgar Street site using CPT probes before and after the installation of stone columns, using the tip cone resistance measurements, as recorded in Table 1. Slide was used to analyse slope stability following stone column installation (under static and seismic load conditions).

The design of the stone columns was generally undertaken in accordance with the recommendations of Part C of (MBIE, 2015). McMillan Civil were nominated as the contractor for installation. McMillan use a full displacement method that uses no vibration and a screw based installation method as described by Kupec (2014). This method was utilized to minimize the vibration to the neighboring residential sites.

Eight days following the installation of the stone columns, three CPT probes were undertaken to determine the improvement in the geotechnical properties of the soil within the treated area. For the purposes of this paper these CPTs are labelled CPT 11, CPT 12 and CPT 13. These material properties were input into Slide using the model from the initial topographic survey to determine the improvement in slope stability. The location and geotechnical properties of the post improvement CPT probes are shown in Figure 1 and Table 1 respectively.

Pseudostatic Analysis:
A pseudostatic analysis has been undertaken for the slope profile A-A[1] at the site. The analysis has been conducted using a range of PGA's. The PGA's used for the analysis are based on previous CES earthquake events and future predictions. Slide 7.0 has been used to conduct the pseudostatic analysis.

Predicted future PGA measurements for the Alpine Fault, Hope Fault and Porters Pass Fault earthquakes events have also been used for the analysis. The PGA's for the Alpine Fault and Hope Fault have been determined by Holden (2014) and the PGA for the Porters Pass Fault has been determined by Howard et al. (2003). It should be noted that these three faults are located more than 100 km from the subject site. Measured PGA values from the CES have been determined by ((EQC), 2016). The PGA's used for the psuedostatic analyses have been modified to normalise the PGA values for a earthquake magnitude (Mw) 7.5 earthquake event using the magnitude scaling factor (MSF) proposed by (Idriss and Boulanger, 2008). The ULS design earthquake event of 0.35g at Mw 7.5 has also been assessed to determine the sites suitability for redevelopment. The worst case scenario for each earthquake event has been used by inputting the same PGA value in the horizontal and vertical Slide seismic load coefficient input options. The input parameters for the pseudostatic analyses are summarised in Table 2.

It was decided to assess the slope for rotational failure only, as this was the inferred mechanism which likely resulted in the observed slope failure. The Bishop Limit equilibrium method has been assessed during these analyses. The Bishop method is understood to be more suitable for analysis of rotational failures. It was also decided to test the yield acceleration of the slope at the subject site, which is the ground acceleration required

Source	Earthquake Event	Earthquake magnitude (Mw)	PGA (g)	Magnitude Scaling Factor	Modified PGA Values
CES	September 2010	7.1	0.21	0.89	0.19
	February 2011	6.2	0.38	0.71	0.27
Future	Alpine Fault	8.2	0.08	1.20	0.096
	Hope Fault	7.1	0.08	0.89	0.072
	Porters Pass Fault	7.7	0.18	1.05	0.19
MBIE	Ultimate Limit State	7.5	0.35	1.0	0.35

Table 2: Pseudostatic analysis input parameters

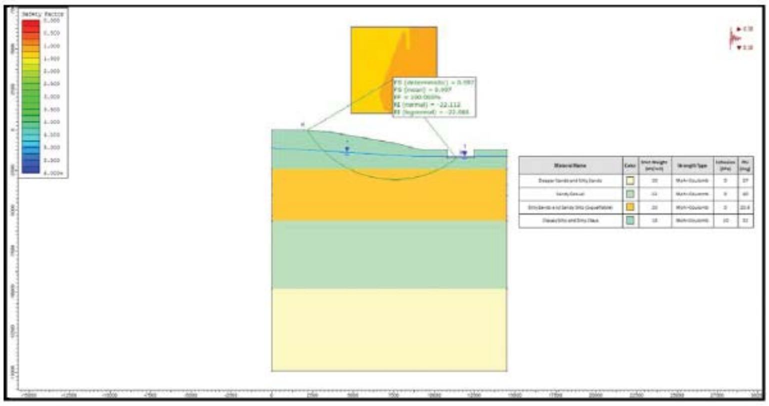


Figure 3: Rotational failure for Section A-A[1] determined for the back analysis under seismic loading (February 2011 earthquake event).

to reduce the FoS to below 1.0. This was conducted by increasing the seismic load coefficient for the horizontal and vertical seismic loads until failure occurred and FoS of below 1.0 was achieved.

RESULTS

Slope Failure Back Analysis

A back analysis was performed on the slope profile A-A[1] from the subject site, Figure 3. The assumed failure surface was within the inferred liquefiable layer. The liquefiable layer was determined using CLiq and was inferred to be located within the silty sands interbedded with sandy silts, at depths between approximately 2.4 m and 4.9 m below the ground surface (layer thickness of approximately 2.5 m), as illustrated on the strain plot of Figure 4. It should be noted that the small liquefiable layer between 1.7 m and 1.9 m has been excluded as it is understood to be cohesive soil and non-liquefiable. The back analysis conducted for the liquefiable layer yielded an effective friction angle of 20.6° and an apparent cohesion value of zero for the assumed layer under seismic loading conditions (using the medium PGA value calculated for the February 2011 earthquake), resulting in slope failure.

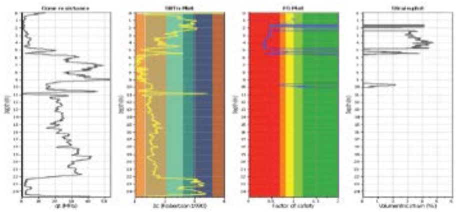


Figure 4: Theoretical liquefaction potential of the soils at the location of CPT 2 (under ULS loading).

Slope Stability Analysis:

In order to assess the theoretical slope stability (under static loading conditions) for the remediated ground a LEM analysis has been conducted using the Slide 7.0. The Slide analysis investigated rotational failure surfaces. The search for the lowest FoS from the rotational failures were analysed, which calculated the location of the critical failure surface for the failure mechanism determined in the back analysis, i.e. a shallow seated rotational failure. The limit equilibrium analysis used the Janbu and Bishop simplified methods to calculate the FoS, for rotational failure surfaces. The results of the slope stability analysis, following stone column ground improvements, are shown in Table 3.

Pseudostatic analysis:

The stability of the remediated ground has also been analysed under seismic loading conditions, using a pseudostatic analyses methodology. The FoS for each pseudostatic analysis scenario is presented in Table 4.

The modelling for the profile under the scenarios (displayed in Table 4) show that profile A-A[1], with stone column ground improvement, is expected to remain stable under seismic loading associated with the potential future earthquake events (including the ULS design earthquake) based on the information gathered from the earthquake fault ruptures investigated. Additional slope stability modelling was conducted to obtain the seismic loading capacity of the site. The seismic load coefficient, inputted as peak ground accelerations, was increased until the slope failed (i.e. with a FoS below 1.0). The results show that the yield acceleration for the slope section A-A[1] was 0.53 g (assuming M_w is 7.5).

DISCUSSION AND LIMITATIONS

Back Analysis

An initial geotechnical investigation and theoretical liquefaction analysis of the subsurface conditions determined that an underlying layer of silty sands interbedded with sandy silt layers (between 2.4 m and 4.9 m below ground surface) was likely to liquefy under seismic load conditions. The results of the back analysis showed the liquefiable soil layer had an effective friction angle of 20.6° and a cohesion value of zero. Background geotechnical soil strength parameters of the liquefiable

Type of failure surface	Potential failure surface identified	FoS (Bishop LEM)	FoS (Janbu LEM)
Rotational	Clayey Silts and Silty Clays	2.97	2.85

Table 3: Calculated minimum factor of safety values for Section A-A[1] (post stone column installation).

layer, before stone column improvement, indicates that liquefiable soils likely had an effective friction angle of between 31-33° and a cohesion value of zero under static load conditions.

The results of the back analysis confirmed that seismic loading from the February 2011 earthquake event caused the generation of excess pore water pressures and a decrease in the effective stress within the silty sands interbedded with sandy silt soils, which triggered a shallow seated landslide to occur at the site.The results of the back analysis confirm the initial findings from the Fraser Thomas geotechnical investigation. The failure surface is inferred to be located at a depth ranging between approximately 2.4 m and 3.15 m below the existing ground surface, as shown in Figure 3. The reduced soil strength parameters obtained during the back analysis are consistent with previous understanding of soil properties during liquefaction as described by Idriss and Boulanger (2008). The back analysis determined the geotechnical controls and material properties of the slope failure and the inferred depth of failure. This has provided a baseline of the sub-surface conditions, under seismic loading, which require remediation to enable redevelopment. This investigation was simplified to enable two dimensional analyses with a simplified soil profile and soil strength parameters.

Slope Stability Analysis

Results from the LEM slope stability analysis undertaken for cross section A-A[1] obtained FoS values between 2.85 and 2.97. Traditionally, if a theoretical FoS value of 1.5 can be achieved for the analysis, then the slope is considered to be stable under static conditions. The results confirmed that the site is stable against rotational failures following ground improvement, under static conditions. Translational slides along planar surfaces were not investigated as the slope is more susceptible to rotational/slumping failure, due to its proximity to the free face of St Albans Creek (Zhang et al., 2004).

The stability of the slope may be greater than the results suggest due to the improvement in the resisting force provided by the stone column. This improvement has resulted from the inferred increase in the soil's geotechnical strength properties, between elements, following stone column installation, as a result of soil densification and reinforcement. Adalier and Elgamal (2004) describe that stone columns densify and reinforce the surrounding soils during construction and provide a stiffened soil matrix that can restrict shear deformation. This has occurred at the site resulting in stabilisation and resilience of the slope to lateral movements. The improved soil strength will also provide increased shear resistance along a potential failure surface, as described by Goughnour et al. (1991). Additional resistance to slope instability has also been provided by the stone columns by way of the provision of lateral confinement of the soils between the elements, which increases the soil stiffness, and the provision of drainage paths. These findings are similar to those of Abramson (2002), (Adalier and Elgamal, 2004) and Deb et al. (2012). These improvements have not been quantified or included in the theoretical slope stability analyses. If additional works were to be conducted these improvements could be investigated.

It should be noted that the ground improvement quantification has only been assessed using the soil strength improvement of the soils between the stone column elements in the treatment area and excludes the addition of the stone columns themselves. An average stone column area replacement of 20% was achieved

Type of failure surface	Potential failure surface identified	Modelled scenario Earthquake	Seismic load applied (PGA, g)	FoS (Bishop LEM)
Rotational	Clayey Silts and Silty Clays	September 2010	0.19	1.64
Rotational	Clayey Silts and Silty Clays	February 2011	0.27	1.42
Rotational	Clayey Silts and Silty Clays	Alpine Fault	0.096	2.05
Rotational	Clayey Silts and Silty Clays	Hope Fault	0.072	2.21
Rotational	Clayey Silts and Silty Clays	Porters Pass Fault	0.19	1.64
Rotational	Clayey Silts and Silty Clays	ULS	0.35	1.28

Table 4: Pseudostatic analysis results for Section A- A[1]

within the treatment zone, i.e. 20% of the soils now comprise stone column material, to a maximum depth of 5.95 m below the existing ground surface. The slope is inferred to have had additional improvement in slope stability from the addition of stone columns added to the site. The additional resistance to slope instability provided by the physical presence of the stone columns has also has been excluded in the slope stability and pseudostatic analyses; however, could be included in additional works. Given that the resistance to slope instability provided by the stone column ground improvement has not been considered in the slope stability analyses reported herein, it is the author's opinion that the results of the slope stability analyses are conservative.

Pseudostatic Analysis

Results from the pseudostatic analysis obtained FoS values of between 1.28 and 2.21. This was based on the PGA values from the previous and predicted earthquake ground accelerations for the area. These results confirm that stabilisation of the slope has been adequately achieved under seismic loading. Improved shear strength soil parameters between elements following stone column installation resulted in the sub surface conditions being more resilient to slope instability under seismic loading. It should be noted that the pseudostatic analysis calculates stability based on an instantaneous seismic load, as inputted horizontally and vertically for peak ground acceleration. Seismic loading is cyclic and will have varying amplitude and duration dependent of depth, location, magnitude and nature of the source. For this reason the pseudostatic analysis is considered to be approximate only and subject to limitations of these factors. It should also be noted that the analysis does not take into consideration increases in pore water pressure and the corresponding decreases in the effective stress of soil strength properties providing additional limitations, the soil strength parameters could be reduced to account for the decrease in effective stress.

A yield acceleration PGA was calculated for the site to determine the seismic loading capacity of the slope following ground improvement with stone columns. This yield acceleration excluded any static shear stresses that may be present at the site following redevelopment. It is recommended that further analysis is conducted when the loads and proposed locations of the new structures are known. The results showed that the yield acceleration for the slope section A-A^1 is 0.53 g (assuming a M_w of 7.5). The calculated yield acceleration (PGA) indicates that the ground improved site can withstand a design earthquake event equivalent to approximately 1.51 times the seismic loading amount for a ULS design earthquake event.

CONCLUSIONS

This research assesses the effectiveness of stone columns for slope stabilisation under static and dynamic loading conditions. To enable redevelopment of complex sites subject to adverse ground conditions, a range of ground remediation methods are available, dependent on the site characteristics. At Trafalgar Street stone columns were selected to remediate the sub soils where mitigation of liquefaction and slope stabilisation were required. In order to effectively remediate the slope the failure surface had to be adequately stabilised.

The geotechnical controls of the initial slope failure were determined using a combination of geotechnical testing, topographic survey, theoretical liquefaction potential software and slope stability software. These tools can be used to analyse other slope failures in Christchurch, where slope failure of this nature has occurred. To determine whether adequate slope stabilisation had been achieved by stone column ground remediation works, slope stability analyses have been undertaken. The soil strength inputs for the analyses were calculated using the tip resistance data obtained by CPT probe testing, conducted between the stone column elements within the treatment area. The slope stability analyses undertaken for static and seismic loadings provided verification that adequate ground improvement had been achieved so as to mitigate the risk of future slope instability occurring under static and seismic load conditions and also determined the capability of the site.

The results of this research illustrate that stone columns have been effectively used to stabilise the slope at Trafalgar Street and enable redevelopment of the site. This research only concerned testing one cross section to evaluate the effectiveness of stone columns for slope stabilisation. It is recommended to conduct trials at additional study areas. It is also recommended to consider conducting 2-Dimensional and 3-Dimensional FEM analyses to further investigate the effectiveness of stone columns for slope stabilisation.

REFERENCES

(EQC), E. C., 2016, New Zeland Geotechnical Database. Sourced from www.nzgd.govt.nz.

(MBIE), M. o. B. I. E., 2012, Repairing and rebuilding houses affected by Canterbury earthquakes.

Aboshi, H., Ichimoto, E., Enoki, M., and Harada, K., The compozer—a method to improve characteristics of soft clays by inclusion of large diameter sand columns, *in* Proceedings Proc., Int. Conf. on Soil Reinforcement., ENPC1979, Volume 1, p. 211-216.

Abramson, L. W., 2002, Slope stability and stabilization methods, John Wiley & Sons.

Adalier, K., and Elgamal, A., 2004, Mitigation of liquefaction and associated ground deformations by stone columns: Engineering Geology, v. 72, no. 3, p. 275-291.

Alfaro, M. C., Blatz, J. A., Abdulrazaq, W. F., and Kim, C.-S., 2009, Evaluating shear mobilization in rockfill columns used for riverbank stabilization: Canadian Geotechnical Journal, v. 46, no. 8, p. 976-986.

Bishop, A. W., 1955, The use of the slip circle in the stability analysis of slopes: Geotechnique, v. 5, no. 1, p. 7-17.

Boulanger, R. W., and Idriss, I., 2006, Liquefaction susceptibility criteria for silts and clays: Journal of geotechnical and geoenvironmental engineering, v. 132, no. 11, p. 1413-1426.

Brown, L. J., and Weeber, J. H., 1992, Geology of the Christchurch urban area, Institute of Geological and Nuclear Sciences Limited, Lower Hutt, New Zealand.

Brown, L. J., Weeber, J. H., Reay, M. B., Institute of, G., and Nuclear Sciences, L., 1992, Geology of the Christchurch urban area, scale 1:25 000, Lower Hutt, N.Z, Institute of Geological & Nuclear Sciences, v. Book, Whole.

Carter, M., and Bentley, S. P., 1991, Correlations of soil properties, Pentech.

Deb, K., Dhar, A., and Bhagat, P., 2012, Evolutionary approach for optimal stability analysis of geosynthetic-reinforced stone column-supported embankments on clay: KSCE Journal of Civil Engineering, v. 16, no. 7, p. 1185-1192.

Goughnour, R. R., Sung, J. T., and Ramsey, J. S., 1991, Slide correction by stone columns, Deep Foundation Improvements: Design, Construction, and Testing, ASTM International.

Hammouri, N. A., Malkawi, A. I. H., and Yamin, M. M., 2008, Stability analysis of slopes using the finite element method and limiting equilibrium approach: Bulletin of Engineering Geology and the Environment, v. 67, no. 4, p. 471-478.

Howard, M., Nicol, A., Campbell, J., and Pettinga, J., Recent Paleoearthquakes of the Porters Pass Fault and Hazard Posed to Christchurch, New Zealand, *in* Proceedings Proceedings of the Pacific Conference on Earthquake Engineering2003, Volume 69, p. 1-8.

Idriss, I., and Boulanger, R. W., 2008, Soil liquefaction during earthquakes, Earthquake engineering research institute.

Janbu, N., Slope stability computations: In Embankment-dam Engineering. Textbook. Eds. RC Hirschfeld and SJ Poulos. JOHN WILEY AND SONS INC., PUB., NY, 1973, 40P, *in* Proceedings International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts1975, Volume 12, Pergamon, p. 67.

Kupec, D. P. M. a. J., 2014, Stone column ground improvement field trial: A Christchurch case study.

Rauch, A. F., 1997, EPOLLS: an empirical method for prediciting surface displacements due to liquefaction-induced lateral spreading in earthquakes.

Waltham, T., 2009, Foundations of Engineering Geology, Third Edition, Taylor & Francis.

Wissman, K., van Ballegooy, S., Metcalfe, B., Dismuke, J., and Anderson, C., Rammed aggregate pier ground improvement as a liquefaction mitigation method in sandy and silty soils, *in* Proceedings 6th International Conference on Earthquake Geotechnical Engineering2015, p. 1-4.

Wotherspoon, L., Cox, B., Stokoe II, K., Ashfield, D., and Phillips, R., 2015, Utilizing Direct-Push Crosshole Testing to Assess the Effectiveness of Soil Stiffening Caused by Installation of Stone Columns and Rammed Aggregate Piers.

Zhang, G., Robertson, P. K., and Brachman, R., 2004, Estimating liquefaction-induced lateral displacements using the standard penetration test or cone penetration test: Journal of Geotechnical and Geoenvironmental Engineering, v. 130, no. 8, p. 861-871.

YGP Poster Competition 2016

This year we're extending the deadline for the posters through to end January 2018 to capture all students in geo engineering in New Zealand! Don't forget to get your applications to us in November and your posters to us by the end of January 2018.

THE NEW ZEALAND Geotechnical Society Student Awards are presented to recognise and encourage student participation in the fields of geotechnical engineering and engineering geology, and to introduce our best student talent to potential employers.

For these awards, students of a recognised tertiary institution in New Zealand prepare an A1 size poster that clearly and concisely presents their work on any aspect or topic in the fields of geotechnical engineering or engineering geology. The posters are judged on technical content, layout, and overall poster appeal and ranked by a panel nominated by the management committee of the NZGS.

This year the posters were displayed during the Auckland Branch meeting on Tuesday 16th May at the Tonkin and Taylor office. The high quality of the submissions made the judges choices difficult, but they managed to come to a unanimous decision.

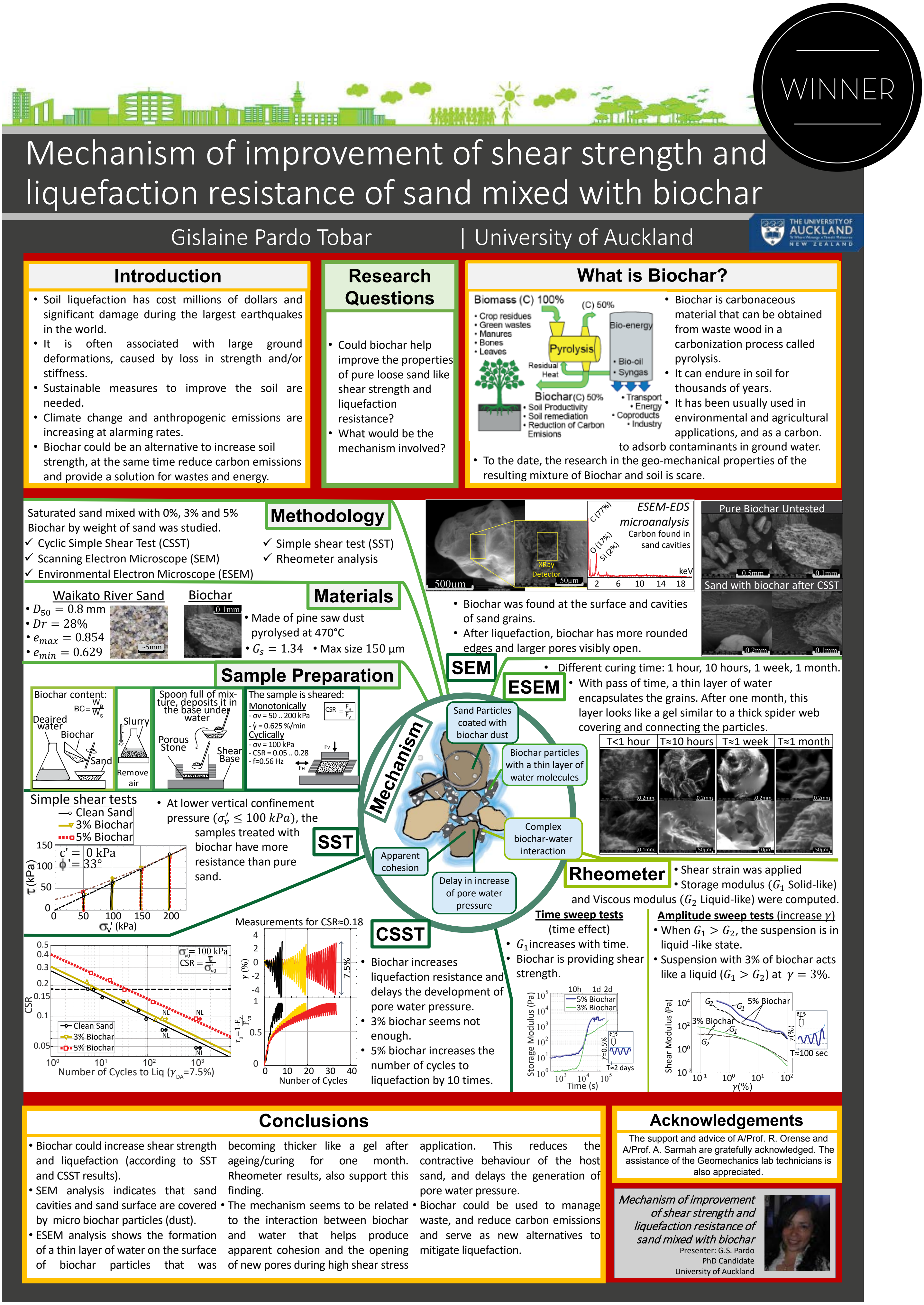
First prize went to **Gislaine Pardo Tobar** for her poster entitled Mechanism of improvement of shear strength and liquefaction resistance of sand mixed with biochar.

SECOND AND THIRD PLACES WENT TO:

- **Lauren Boyd** and **Liam Ross** and for their poster entitled Centrifuge Modelling Of Dam Core Deformation
- **Francesca Spinardi** for her poster entitled Examining faults within the Hamilton Basin and understanding their seismic history, influence, and potential risk

Ross Roberts presented the winner with her certificate on behalf of the NZGS committee, and each will receive a generous cash prize. The winner will receive $1000 prize, with second and third place receiving $500 and $300 respectively.

Sally Hargraves
sally@tfel.co.nz



Above: First place Gislaine Pardo Tobar

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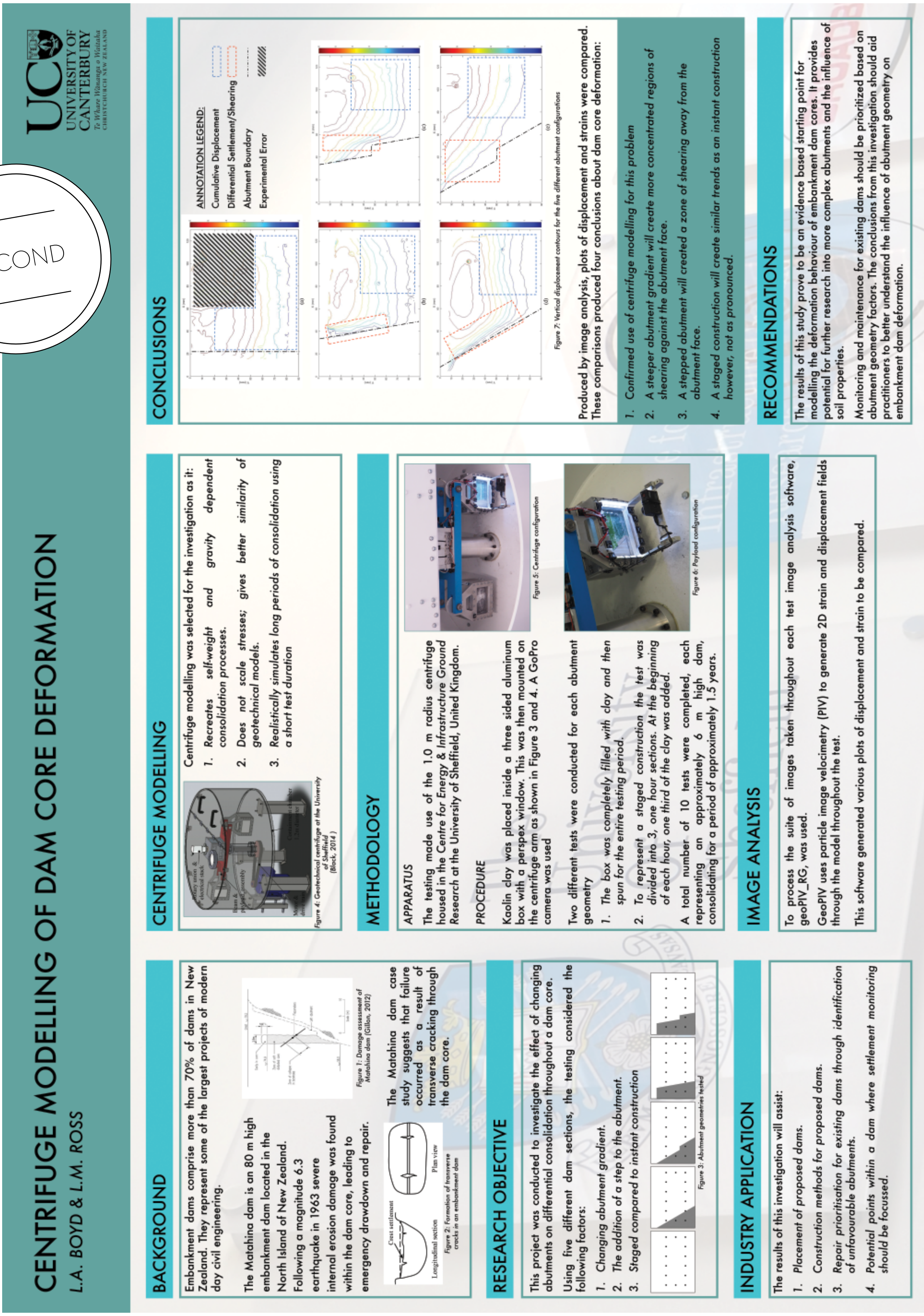
SECOND



Above: Second place Lauren Boyd and Liam Ross

Examining faults within the Hamilton Basin and understanding their seismic history, influence, and potential risk

Francesca Spinardi | University of Waikato
Advisor | Dr. Vicki Moon

THIRD

Introduction

Hamilton has long been considered an area of low seismic risk due to the absence of local active faults in the National Seismic Hazard Model (Fig. 1). With the recent discoveries of an extensive system of faults running through Hamilton City, together with paleoliquefaction structures within the alluvial sediments of the Hamilton Basin, it is clear that earthquake hazards do exist within the region. To better understand the risk and hazard potential of a seismic event along these faults, extensive study is needed to determine the rate of reoccurrence of these events and their potential magnitudes. My project will be examining the inferred fault traces within the Hamilton Basin, as indicated by the geomorphology, seismic line data, existing borehole data, and geological and geomorphical ground-truth mapping in order to create an updated seismic hazard model for the region.

Objectives

- Determine the location of these faults through remote sensing technics and existing seismic line and bore hole data.
- Create a targeted geomorphic and geological mapping programme to fully elucidate the characteristics of the Hamilton Basin faults.
- Closely examine the faults to determine their total offset and rate of occurrence.
- Examine known surrounding faults to determine if or how they may be influencing faults in the Hamilton Basin.

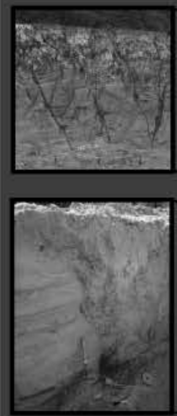
Methods

- Use LiDAR Data and ground surveying to look for geomorphic features indicative to fault traces, such as river terrace offset, abrupt changes in river orientation, and linear alignment of drainage systems, river bends, and ridges. Updated locations will be marked on a GIS map.
- Compare location of possible fault traces to exisitng seismic line and bore hole data that has been collected over the past 40 years.
- If there is a possible match between the geomorphic traces and the additional data, ground-truthing will be conducted in accessible locations of the identified areas using geological and geomorphic tools.
- If the fault is confirmed, a ground model for specific areas will be developed.

Figure 1. The 2010 National Seismic Hazard Model created by the Institute of Geological and Nuclear Sciences with the Hamilton Basin Circled in yellow (Sterling 2010).

Discussion

- Remote sensing data reveals over 10 possible fault traces within the northern region of the Hamilton Basin. Recent seismic data from the Waikato River reveal 25 areas with geomorphic evidence for faulting as indicated by the red stars in Figure (2) . There are four locations on land that either possess paleoliquefaction deposits or actual fault zones as indicated by the green stars and photos in Figure (2). One of these deposits cross cuts the 20,000ka Hinuera Formation, indicating the fault system is active.
- Older Seismic line data reveals a system of splay faulting within the Basin (Fig. 3)



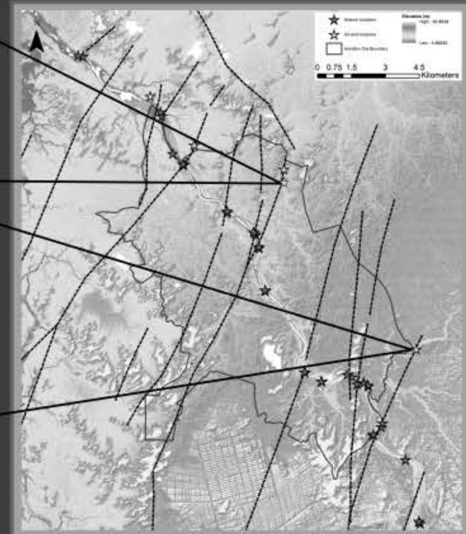


Figure 2. ArcGIS map showing the location of confirmed and possible fault traces. Above are photos of the paleoliquefaction deposits and fault zones found.

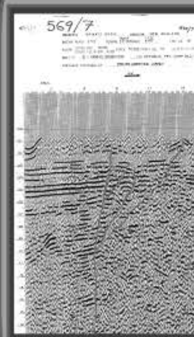


Figure 3. Seismic Line conducted in 1971 during economic geologic exploration of the Hamilton Basin. Evidence for a splay faults is outlined in red.

Conclusion

Preliminary data collection shows that there are several fault traces within the Hamilton Basin that appear to be active. However, further investigation is needed to determine the age and magnitude of past seismic events. Once this information is gathered, an updated hazards model can be constructed for the Hamilton Basin and CBD.

Acknoledgements

We would like to thank the Waikato Regional Council and the Hamilton City Council for providing funding for this project.

Reference:

Stirling, M.W., McVerry, G.H., Gerstenberger, M.C., Litchfield, N.J., Van Dissen, R.J.; Berryman, K.R., Barnes, P., Wallace, L.M., Villamor, P., Langridge, R.M., Lamarche, G., Nodder, S.; Reyners, M.E., Bradley, B., Rhoades, D.A., Smith, W.D., Nicol, A., Pettinga, J., Clark, K.J., Jacobs, K. 2012. National Seismic Hazard Model for New Zealand: 2010 Update. Bulletin of the Seismological Society of America, Issue 102(4): Pp. 1514-1542.

Obituary for Dr. António Gomes Coelho

IAEG Vice-President for Europe 1998/2002

ANTÓNIO GOMES COELHO *passed away last 21st February. Graduating in Geology at the Lisbon University, he started his Engineering Geology activity as Trainee at the Civil Engineering Laboratory (LNEC) in Portugal, in 1972.*

He followed a bright research career at LNEC, where he attained the degree of Specialist (PhD level) in Engineering Geology (1980) submitting the thesis "Engineering Geological Mapping of the

Setubal area" and of Principal Research Officer (Full Professor level) in Geotechnics (1991) submitting the research program "Seismic Microzonation".

He became Head of the Engineering Geology Division in 1990 and was Director of the Geotechnical Department from 1998 until his retirement from LNEC in 2002. Since then, he became Senior Consultant of COBA, Engineering and Environment Consultants, until his decease, namely in the field of seismotectonic subjects related mainly to Dams, Underground Works and Motorways.

He gave the outstanding Memorial Manuel Rocha Lecture "The problem of active faults in Civil Engineering" in 2005. He was President of the Portuguese Association of Geologists (APG),

Vice President of IAEG for Europe, Vice-President of the Portuguese Geotechnical Society (SPG), member of the Portuguese Academy of Engineering, and of the Association of Engineers.

He attended more than 60 national and international Congresses and Symposia all over the world and was author of more than 50 scientific and technical papers and 90 LNEC reports. He taught some MSc courses at universities in Portugal and Brazil and he was Examiner of several PhD and MSc theses.

He was a brilliant person, very kind and intelligent, having an outstanding culture and a remarkable sense of humour. These were the main reasons why he made so many friends in Portugal and all over the world.

We miss him very much.

By Ricardo Oliveira
Past President of the International Association of Engineering Geology and the Environment (IAEG)

Obituary for Professor Milan Matula (1924 – 2016)

PROF. *MILAN MATULA, professor of Engineering Geology, died December 26, 2016. He was 92. Professor Matula was a key person in the development of Engineering Geology when this discipline was emerging in the Geoengineering field. He was vice president of IAEG in the 80's and had a most contributing role in IAEG activities during its first period of its development and thereafter. He was the president of the commission of Engineering Geological Maps a commission with so useful outcome and a guide book published by UNESCO.*

Throughout his career, Prof. Matula held positions at the Faculty of Natural Sciences, Comenius University in Bratislava. He is considered to be the father of modern Engineering Geology in Slovakia both as scientific discipline as well as an important tool for practitioners dealing with various kinds of constructional activities. Under his guidance, since 1952, the Department of Engineering Geology, initially within Czechoslovakia, became an internationally recognized centre of education and research. He focused his research on regional studies closely connected with engineering geological mapping, namely with standardization of principles, systems and methods for their preparation. This effort resulted in the multi-authored-guidebook (M. Arnould, W.R: Dearman, etc.) prepared for UNESCO by the IAEG Commission on Engineering Geological Maps under the chairmanship of Prof. Matula. The guidebook published in 1976 gives the state-of-the-art of the experience from various countries where engineering geological mapping was already undertaken at an advanced level and later on served as a practical tool for assessing and implementing engineering geological phenomena affecting the engineering use of different terrains around the world.

Prof. Matula was the first who described the engineering geological conditions of Western Carpathians in the book Regional Engineering Geology of Slovakia, published also in English (1969), later on was the chief-editor of engineering geological maps at the scale 1:200 000 covering whole territory of Slovakia (1988).

Prof. Matula was the author of more than 160 papers, 12 monographs and several text books.In 1968 at the occasion of the 23th International Geological Congress in Prague Prof. Matula was elected within new created IAEG as the chairman of the Commission on Engineering Geological Maps (1968-1984), in 1982 in New Delhi was elected as the IAEG vice-President and in 2001 in Helsinki he was given the

IAEG honorary membership. During his international activities mostly within IAEG he delivered 40 general and panel reports (Prague 1968, Montreal 1972, Sao Paulo 1974, Sydney 1976, Madrid 1978, Newcastle 1979, Paris 1980, New Delhi 1982, Moscow 1984, Buenos Aires, 1986, Beijing 1987, etc.).

Prof. Matula had retired in 1989. However his activity and interests on several issues concerning engineering geology remained and he wrote the book "Engineering Geology in Land-use Planning (1995).

It was a great pleasure to have known him as the teacher, supervisor and colleague, both for the majority of Slovak and Czech engineering geologists and international community, as well.

His scientific legacy is well rooted in the Comenius University.

By Jan Vlcko
Chairman of Slovak Association of Engineering Geologists

Paul Marinos
Past President of the International Association of Engineering Geology and the Environment (IAEG)

Upcoming two-day course in "Principles and Practice of Engineering Geology"

AUGUST-SEPTEMBER

AIM OF THE COURSE
The course will provide an overview of the basic principles underpinning the practical application of engineering geology. Attendees will gain increased knowledge of the geoscientific methodologies and practices required for successful interpretation of ground conditions and achievement of a greater understanding of "how to get the geology right". Benefits will aid the provision of appropriate engineering geology deliverables in the investigation, design and construction phases of ground engineering projects.

WHO SHOULD ATTEND?
The course is intended for engineering geologists with three to six years' experience, in particular those preparing for Professional Engineering Geologist (PEngGeol) registration. Geotechnical Engineers may also find the course useful to enhance their knowledge and understanding of engineering geology methodologies and practical application.

PRESENTERS
Engineering Geologists Stuart Read and Ann Williams from New Zealand and Fred Baynes from Australia have developed and will present the course on behalf of NZGS.

COURSE STRUCTURE
The course will run for two days:
- **Day 1:** Class-based modules and exercises.
- **Day 2:** Field practice and exercises.

COURSE LOCATIONS & DATES
The course will take place in the following locations and dates:
- **Auckland**, Thursday 31 August and Friday 1 September
- **Wellington**, Monday 4 September and Tuesday 5 September
- **Christchurch**, Thursday 7 September and Friday 8 September.

COST
The cost for the course per attendee is
- $800 plus GST, for NZGS members
- $950 plus GST, for non-NZGS members (consider this indicative need to cross check with my notes from the NZGS Committee meeting and update accordingly)

The above cost covers full attendance of both days, course notes and teaching material, transportation to and from course centre to the field exercise location(s), and morning tea, lunch and afternoon tea for Day 1.

NUMBERS
The course will be limited to a maximum of 20 – 25 students per centre. Places will be allocated on a first come, first served basis, with priority given primarily to Engineering Geologists and secondarily to Geotechnical Engineers.

FURTHER INFORMATION AND REGISTRATION OF INTEREST
For further information regarding the course and to pre-register your interest please contact Eleni Gkeli **eleni.gkeli@opus.co.nz**.

Please note:
- Details of the course structure and content as well as exact course times and venues will be published at a later date.
- Day 2 field exercises will be at locations in the wider Auckland, Wellington and Christchurch regions, respectively. Transportation to and from the field exercise locations will be organised by NZGS and is included in the cost of the course. Details of the itinerary for Day 2 will be announced at a later date.
- Other transportation and accommodation during the two days of the course, if required, is not included in the cost and should be organised by the attendees.

NZGS website

HAVE YOU USED the new NZGS website yet? It's packed with new features to make it more useful and relevant to our members.

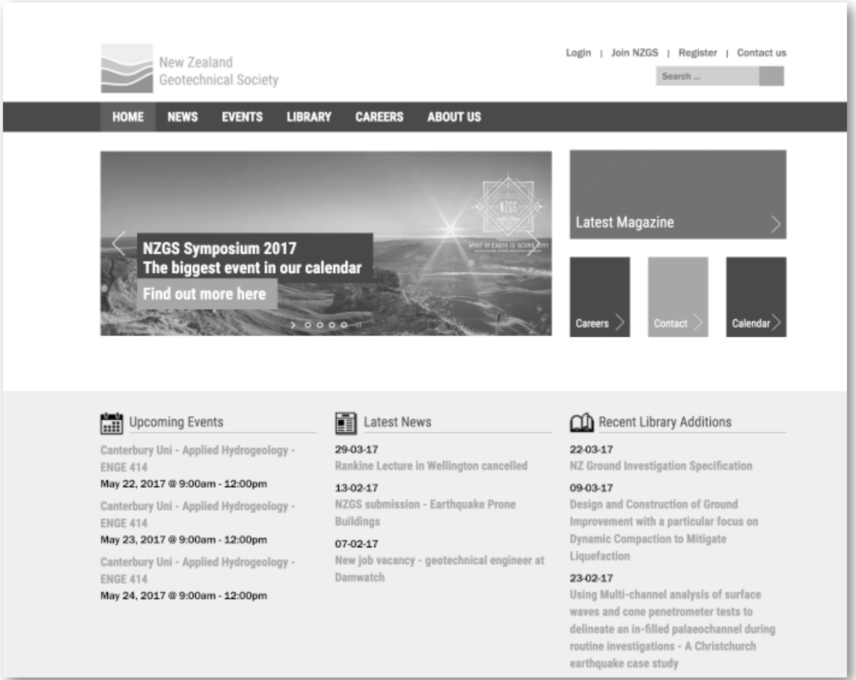
Here are some of the highlights:

- The library has 266 items, and is growing rapidly. It contains PDFs of the best guidance, technical articles and papers relevant to New Zealand practice.
- The events calendar is the primary source of information for all our events. You can filter to events relevant to you, and a simple click will add them to your own calendar.

New items in the library include the site are the Earthquake Geotechnical Engineering Modules (complete with links to download the documents, and to online training resources) and the NZ Ground Investigation Specification. It also contains every issue of NZ Geomechanics News and almost all the proceedings from NZGS symposia.

There are two ways to navigate the library; using filters or search. The filters allow you to quickly identify groups of relevant sources. For example, to re-watch an NZGS branch meeting that you know was recorded tick the boxes next to 'NZGS Branch Meetings' and 'Video'.

Make sure that you're registered on the site to make the most of the available content. If you see the screen below, you need to login. Because this site isn't hosted by IPENZ, you need to register on the site to get access using the "Register" link (at the top right). Once you've filled in your details we'll check that you're a current NZGS member then activate your account. If you see the "Member's Area" link, you're already registered and logged in.



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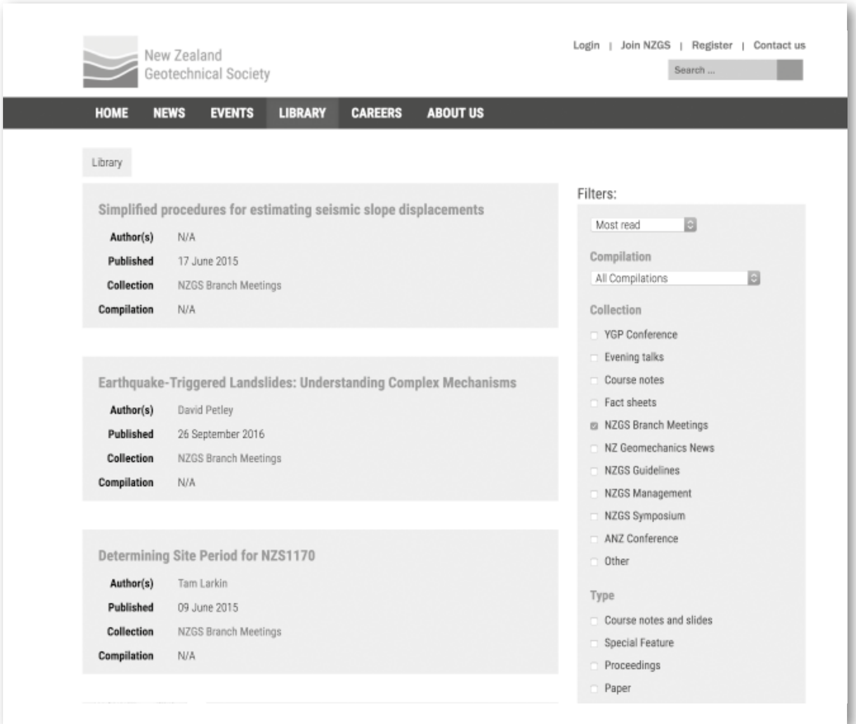


Library > NZGS Branch meetings

Ross Roberts
ross.c.roberts@gmail.com

NZGS Award Dates

NZGS SCHOLARSHIP (annual)

Sept 2017	Call for applications
End Oct 2017	Closing date for applications
End Nov 2017	Closing date for full submission
Feb 2018	Successful applicants announced (if any)

NZGS STUDENT POSTER AWARD
(Annual, note the change of dates for 2017)

June 2017	Call for applications
Mid Nov 2017	Closing date applications
End Jan 2018	Closing date for receipt of poster
February 2018	Judging & announcement of winner at a local NZGS evening event

NZGS YOUNG GEOTECHNICAL PROFESSIONAL (YGP) CONFERENCE AWARDS
To be awarded at next YGP Conference which will be hosted by Autralia in Tasmania in 2018 – dates to be confirmed soon

NZGS YOUNG GEOTECHNICAL PROFESSIONAL FELLOWSHIP
To be awarded at next YGP Conference in Tasmania, 2018

Other Awards

- NZGS Geomechanics Award (best paper) next award 2017-18
- NZGS Geomechanics Lecture (next award 2018)

IAEG Awards 2018 (Richard Wolters Prize, Hans Cloos Medal, Marcel Arnould Medal)
Closing date for nominees to NZGS committee will be April 2018.

ISRM Rocha Medal 2018
Deadline for applications was 31 December 2016. Next medal will be 2020.

ISSMGE Awards 2017 (various)
Closing date for nominees closed July 2016. Next round likely due July 2019.

Congratulations to Pip Mills on joining David Buxton in being selected to attend and present at the international YGP conference in Seoul later this year. I'm sure they'll do a conference report when they get back!

Geotechnical Modules 5 and 6 Now Available

THE NZGS AND the Ministry of Business, Innovation & Employment (MBIE) have jointly released two new geotechnical engineering guidance documents as part of the Earthquake Geotechnical Engineering Practice series. This joint guidance has been published as Building Act s175 guidance.

The two new modules are:

- Module 5: Ground improvement of soils
  prone to liquefaction
- Module 6: Earthquake-resistant retaining wall design

These versions are being issued for public comment. Geotechnical, civil and structural engineers are encouraged to make use of these documents and return comments to **modulefeedback@nzgs.org** within six months for consideration by the editorial committee. Comments are also welcome from others working in earthquake engineering.

Module 5 This module covers the design of ground improvement and supports the Canterbury Earthquakes Royal Commission recommendations to prepare national guidelines specifying design procedures for ground improvement, so as to provide more uniformity in approach and outcomes.

Module 6 This module covers the seismic design of retaining walls of a routine nature throughout New Zealand and should be used in conjunction with established handbooks that cover other aspects of retaining wall design in all situations and soil conditions. It builds on and generalises the supplementary retaining wall guidance issued by MBIE supporting the Canterbury rebuild seismic design of retaining structures for residential sites in Greater Christchurch with accompanying worked examples.

Geotechnical engineering education programme
An education programme supporting the release of Modules 5 and 6 and the Field Guide will be developed and advertised in due course.

Find all the modules here:
http://www.nzgs.org/library/?sort_order=title+asc&_sft_book-collections=nzgs-guidelines&_sft_book-tags=earthquakes

View the geotechnical educational programme here:
https://www.building.govt.nz/building-code-compliance/geotechnical-education/

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

NEW ZEALAND GEOTECHNICAL SOCIETY INC

IPENZ revamps membership structure to include engineering geologists

THE INSTITUTION OF Professional Engineers New Zealand is revamping its membership structure to appeal to a broader range of engineering professionals, including engineering geologists.

From 1 October, the Professional Member category will be renamed Chartered Member, and will provide professional recognition and standing to the full spectrum of engineering professionals.

Categories of Chartered Member for engineering technologists, engineering technicians and engineering geologists will provide enhanced status and credibility for these important groups of engineering professionals.

While IPENZ currently operates registers of current competence for these groups (ETPract, CertEtn and PEngGeol), these have had very limited take up and will be discontinued. Anyone currently on one of these registers will be eligible for the equivalent category of Chartered Membership without any further assessment.

Similarly, current Technical Members (TIPENZ) and Associate Members (AIPENZ) will become Chartered Members in the equivalent category without any further assessment. And if you are a Professional Member (MIPENZ) now, you will automatically become a Chartered Member (CMIPENZ) on 1 October.

Another important change is that we are broadening our membership eligibility criteria to ensure that we provide a professional home for engineering geologists at all stages of their career. Currently, engineering geologists only have the option to join IPENZ as Affiliate members, but in the new pathway, they'll be eligible for all classes of membership from Student through to Chartered Member.

If you're not currently a member or on a register, becoming a Chartered Member will continue to involve an assessment of engineering competence to an internationally benchmarked standard. A more holistic approach will ensure that this assessment is accessible to engineering leaders, academics and other engineers in less design-focused roles.

As part of IPENZ's commitment to raising standards of ethics and professionalism, from 1 October all IPENZ members will be required to commit every year to the Code of Ethical Conduct and continuing professional development. Alongside this annual commitment, Chartered Members will be required to submit to a periodic review of their CPD practice after a two year transition phase.

These changes do not have any impact on Chartered Professional Engineer (CPEng) registration, which is separate from IPENZ membership. If you are CPEng plus Professional Member (MIPENZ) now, then on 1 October you will be CPEng plus a Chartered Member.

The Membership Pathway changes coincide with a name change for IPENZ, to Engineering New Zealand. The name change signals a major shift in the organisation's strategy, and makes it clearer to the public and other stakeholders who we are and what we do. We will continue to reflect our heritage by using the tagline "Institute of Engineering Professionals". Retaining the word "Professionals" helps reinforce it's at the core of everything they do – and removing the term "Professional Engineer" is key to being more inclusive, relevant and attractive to a broader range of engineering professionals.

Read more about the new membership pathway on the IPENZ website.

IPENZ
ENGINEERS NEW ZEALAND

Important Notice to Members: 2017 Management Committee

1 INTRODUCTION

The NZGS Management Committee structure comprises, as a minimum, 6 elected members and an appointed secretary. Up to 3 co-opted members may be appointed. In accordance with the Society rules, elected membership of the committee is for a two-year period.

Eleni Gkeli is mid-way through her two-year term; Sally Hargraves has completed one two-year term and will stand for re-election; Kevin Anderson will announce his plans for re-election at a later date; Guy Cassidy will be stepping down at the end of this term.

The current Chair, Charlie Price, will not stand for a second term as Chair, but will become Immediate Past Chair. The current Vice-Chair and Treasurer, Tony Fairclough, will move into the role of Chair. These changes necessitate that a further Committee position becomes available, making the total number of positions available on the Management Committee in 2017, four.

2 NOMINATIONS FOR 2017 MANAGEMENT COMMITTEE

Nominations for **four** elected members for the 2015 Management Committee are requested. A nomination form will be available on the website. A candidate for election must be nominated and seconded by two separate members of the society, and have the consent of the nominee. The form must reach the Management Secretary no later than **5 p.m. on Tuesday 4th July 2017**. Email or post is acceptable for forwarding completed nomination forms.

The Management Committee meets four times per year and is responsible for managing the affairs of the Society. Membership of the Management Committee is a rewarding experience and members are encouraged to give serious consideration to standing for election.

3 ELECTION OF MANAGEMENT COMMITTEE FOR 2017

Election of the Management Committee for 2017 will be via an online ballot if an election is necessary (i.e. more than **four** nominations are received). Results of the election will be announced at the **AGM to be held on Wednesday, 6th September 2017** in Christchurch.

A summary of the nomination forms will be sent to members, if an election is necessary, and the election shall be conducted via an online vote.

The following extract from Section 7 of the Society's rules is given below for your guidance, and a copy of the full Rules are on the website here:

http://www.nzgs.org/NZGS_Docs/rules_nzgs.pdf

"SECTION 7 MANAGEMENT OF THE SOCIETY

7.1 The affairs of the Society shall be managed by the Management Committee.

7.2 The Management Committee shall comprise not less than 7 and not more than 10 members of the Society. The minimum of seven members shall comprise the Management Secretary and six persons elected by the members of the Society. In addition, the Management Committee may co-opt up to 3 additional members to carry out specific tasks and/or to give the Committee a better balance in field of interest, occupational or regional classification. At the time of calling for nomination it shall be brought to the attention of the Society membership that the representation on the Committee should be maintained as broad as possible, both geographically and between engineers and geoscientists.

7.3 No fewer than three members of the Management Committee shall be full members of the Institution."

The current elected committee comprises three engineers and three engineering geologists, with one Auckland-based, one Nelson-based, two Wellington-based and two Christchurch-based. We currently have three co-opted committee members, Ross Roberts (Auckland, Website Manager); Marlène Villeneuve (Christchurch, Geomechanics News co-editor); and Frances Neeson (Christchurch, Young Geotechnical Professionals representative).

Ex-Officio members are the Vice Presidents of the three International Societies and the Immediate Past Chair. The Australasian VP roles for the period 2017-18 will be held by the following:

- Mark Eggers, Australasian VP IAEG, Sydney
- Gavin Alexander, Australasian VP ISSMGE, Auckland (nominated to assume the role at the end of the current term, from September 2017)
- Stuart Read, Australasian VP ISRM, Wellington

Teresa Roetman
Management Secretary

Chartered Professional Engineer (Geotechnical) Body of Knowledge and Skills Update

THE DRAFT CHARTERED Professional Engineer (Geotechnical) Body of Knowledge and Skills was distributed to our NZGS members and also to the IPENZ membership over the last six months. The BOKS is intended to define the minimum technical capabilities that a CPEng (Geotechnical) is expected to have in order to competently investigate, design and supervise the construction of geotechnical works in New Zealand. The BOKS is intended to complement and inform the Chartered Professional Engineer assessment process and has been developed to address concerns about the consistency and quality of geotechnical engineering in New Zealand. BOKS are also being developed for structural engineering and engineering geology.

The NZGS website link has seen over 400 hits. We are very encouraged that there has been such interest in the draft BOKS. Comments were received from nine members. We are taking careful consideration of these comments, as well as recent discussions with IPENZ and MBIE regarding professional membership and occupational regulation. As many of you will be aware, the government is considering options for potential changes to the way our professional engineering industry is regulated following recommendations of the Canterbury Earthquakes Royal Commission. 1 mentioned our draft BOKS and highlighted it as one of the improvements to safety critical engineering.

Feedback on the draft BOKS included recommendations to further discuss how the BOKS fits in with the wider competency assessment process, including areas such as ethics and working within competency. Concerns have been raised regarding the challenge in having opportunities to work on the complex geotechnical engineering examples listed. Concerns were also raised regarding engineers working outside their competency in complex geotechnical engineering. There is a need for balance between these conflicting views and also to maintain a high standard for specialist geotechnical engineering. There were also diverging views on insufficient definition and the need for further specialism versus the difficulty in defining any geotechnical specialism or complex engineering.

The need for education and training was raised. This is discussed at every NZGS management committee meeting and there is considerable ongoing effort in enabling and providing opportunities for professional development. We are leading the effort in training following the publication of our earthquake geotechnical engineering guidelines and looking forward to an another excellent symposium later this year. There are many further developments in progress as well as the ongoing organisation to bring leading international speakers to New Zealand.

The NZGS management committee and BOKS working groups would like to thank everyone who has contributed and for the interest in this important document. We will be consulting with IPENZ before finalising the first issue of the BOKS. We will keep you informed throughout this process.

Kevin Anderson

Kevin is a Principal Geotechnical Engineer with AECOM. He is the presenter of the IPENZ course 'Design Fundamentals of Retaining Wall & Foundation Design' and has been working with MBIE on behalf of the NZGS to develop NZ specific guidance for retaining wall design. He has been lead geotechnical designer for a wide variety of projects including the Mt Victoria tunnel, East Taupo Arterial and Victoria Park Tunnel.

Kevin has specialised in geotechnical and tunnel engineering since graduating in Glasgow in 1996. After 5 years working in Scotland, he has been based in Auckland, working in most sectors of civil engineering and many projects across NZ and overseas. Kevin has been an NZGS Management Committee member since 2013 and has spearheaded progress on a number of Seismic Design Guidelines. Kevin became CPEng in 2005 and is a practice area assessor for IPENZ.

International Association for Engineering Geology Environment

The next Board and Council meetings will be in Cape Town on 01 and 02 October 2017 in association with the AfriRock regional symposium.

MEMBERSHIP

ISRM individual membership worldwide remains at 7,800, with two new recently joined National Groups – Macedonia and Tunisia, making for a total number of countries of 62. Europe and Asia have the greatest individual membership (>25%), with Africa and Australasia (~5%) the smallest (265 Australia, 170 NZ). There are 150 Corporate memberships, with four from Australia and none from New Zealand.

ELECTION OF PRESIDENT FOR TERM 2019-2023

The ISRM Board (President, Regional Vice-Presidents, Vice Presidents at Large, Secretary General) is elected for four year terms – currently 2015 to 2019. The ISRM has a policy of electing the President for the following term ahead of that term so that the elected candidate becomes a member of the current Board as President-elect for two years. The intention of such an overlap is that the next term President becomes fully familiar with Society needs and Board protocols and leadership before formally taking up the Presidential role.

Election of the President for the 2019 – 2023 term will occur during the 2017 Council meeting in Cape Town on 02 October 2017. Two nominations have been received, so that a vote by National Groups is necessary. The candidates, both of whom were elected as ISRM fellows in 2015, are:

- Resat Ulusay, currently Professor at Hacettepe University, Ankara, Turkey (nominated by the National Group of Turkey), and
- Prof. Jian Zhao, currently Distinguished Academic Professor at Monash University Melbourne Australia (nominated by the National Group of Singapore).

ROCHA MEDAL (2017, 2018 & 2019)

The 2017 award "Investigating the evolution of rock discontinuity asperity degradation and void space morphology under direct shear" by Bryan Tatone from the University of Toronto, Canada will be presented at the AfriRock meeting in Cape Town in October 2017.

Nominations for the 2018 award closed on 31 December 2016, with 19 theses received. The winner will be announced at the Council Meeting on 02 October 2017.

Nominations for the 2019 award are currently open and will close on 31 December 2017 (for evaluation in 2018). The award recognises the most meritorious PhD thesis in rock mechanics, with further details on the ISRM and NZGS websites.

YOUNG PROFESSIONALS

Fostering of younger members (about 20% of members) is a recognised need, but there has been no progress on whether ISRM will more actively promote a young member (under 35) group in its profile. Consequently it may well remain a National Group activity (as it is in Australia and New Zealand).

Stuart Read

Stuart Read is an engineering geologist with GNS Science. He obtained his degree, in engineering geology from the University of Canterbury, in 1971. His 43 years of engineering geological consulting and research experience has been in the evaluation, investigation, construction and refurbishment of engineering and mining projects. He has taken a leading role in the development of the rock and soil mechanics laboratory for GNS Science and has research interests in the strength and deformation properties of rock and soil masses.

ISRM ON-LINE LECTURES

All on-line lectures are available on the ISRM website **https://www.isrm.net/gca/?id=1276**

Two new on-line lectures have been given over the last months:

a) 16th presented on 16th December 2016 by Prof. Giovanni Barla with the title "Challenges in the Understanding of TBM Excavation in Squeezing Conditions".
b) 17th presented on 26th April 2017 by Prof. Charles Fairhurst with the title "Why Rock Mechanics and Rock Engineering?"

COMMUNICATION

The ISRM website **(www.isrm.net)** has information on the society's intent, structure and activities, including conferences, commissions, awards, products and publications. For those NZGS and AGS members affiliated to ISRM as individual members there is a members area with access to further products. There is also Linked in, Twitter or RSS access.

The ISRM Digital Library, launched in October 2010 **(https://www.isrm.net/gca/?id=992)**, is intended to make rock mechanics material available to the rock mechanics community, in particular papers published from ISRM Congresses and sponsored Symposia. It is part of OnePetro (https://www.onepetro.org), a large online library managed by the Society of Petroleum Engineers (SPE). ISRM individual members are allowed to download, at no cost, up to 100 papers per year from the ISRM conferences (an annual registration is required for this – with a reminder recently circulated as a news item).

Regular means of communication (under ISRM information on the website) are:

- ISRM Newsletter, which has been published quarterly since March 2008
- ISRM News Journal, now under the editorship of Dr José Muralha (Portugal)
- ISRM News, which carries a listing of events and happenings.

The ISRM website heading "Links of Interest" carries a range of website addresses for:

- Fellow International Societies, (e.g. IAEG, ISSMGE, ICOLD)
- Rock Mechanics Journals (e.g. RMRE – Rock Mechanics and Rock Engineering)
- Websites with technical literature for free download (e.g. Rocscience – Hoek's corner)

The ISRM website heading "Products and Publications" carries a range of other ISRM-related items.

Another product that has recently become available is the five-volume set "Rock Mechanics and Engineering", edited by Prof. Xia-Ting Feng, with the editorial advice of Professor John A. Hudson. It is an update on the 1993 five-volume set "Comprehensive Rock Engineering", and is published by CRC Press with a 30% discount to ISRM members.

COMMISSIONS

There are 17 ISRM Commissions in the 2015 – 2019 term (not listed here but have been included in a previous edition). Commission purposes and anticipated products, along with membership, are given on the ISRM website heading "Commissions and JTCs" (links on **https://www.isrm.net/gca/?id=153**).

The Technical Oversight Committee (TOC) – Doug Stead, chair, Stuart Read and Norikazu Shimizu are continuing with their task of evaluating Commission activity (some are very active, others less so) and identifying gaps (mining, an important activity in Australia, being noted as one) or where there is overlap between commissions. New guidelines regarding the setting up and activities of Commissions are expected for the Board Meeting in October 2017.

Stuart Read

14 May 2017

International Association for Engineering Geology Environment

IAEG NZ LIAISON

As I'm sure most are already aware Doug Johnson from Tonkin & Taylor in Auckland has taken over as the NZ Liaison for the IAEG. The purpose of the Liaison role is to provide a local contact for communication and to coordinate engineering geology initiatives within the NZGS while the VP role is held in Australia. Doug's email address for correspondence is: **DJohnson@tonkintaylor.co.nz**

IAEG EXECUTIVE COMMITTEE MEETING APRIL 2017

The latest meeting of the IAEG Executive Committee was held in London over the weekend of 22-23 April 2017. The purpose of this meeting was to push ahead a number of actions at the international level so they can be prepared for discussion and approval at the next Council meeting scheduled for late November 2017 in Kathmandu, Nepal. This next meeting in Nepal will be held in conjunction with the 11th Asian Regional Conference of IAEG.

IAEG STRATEGIC PLANNING

Planning statements

The Mission, Vision and Strategic Objectives have now been finalised after receiving feedback from the draft statements circulated last year. These will be presented to Council in November for final ratification. The next phase of planning is now underway which involves collating the current and planned goals and actions into the Strategic Plan. This will include the work of the Executive, Management Committees, technical Commissions, website and Bulletin.

Management committees

Chairpersons have now been appointed for the Management Committees established last year as listed in the November 2016 IAEG report. Membership, goals, actions and procedures are currently being established for each committee. Contact details for each committee will shortly be available on the IAEG website or send me an email and I can provide details if you wish to get in direct contact with any of these committees.

YOUNG ENGINEERING GEOLOGISTS

The new Young Engineering Geologists committee is now up and running. Louise Vick from NZ is the Chair (Louise is currently in Norway on a post-doc) with great assistance from Pedro Martins from Beca in Auckland. Morley Beckman from the US is helping coordinate YEG activities at the San Francisco Congress in 2018.

Louise and Pedro are seeking regional representatives from around the world to sit on the YEG committee. The responsibility of the regional representative will be outreach within your community. As the committee is relatively new, they are looking for motivated people interested in networking and able to contribute to the ongoing development of the committee. If you are interested please contact Louise at **louise.m.vick@uit.no** or Pedro at **pedro.martins@beca.com**

XIII IAEG CONGRESS

The XIII IAEG Congress will be held in San Francisco 17-21 September 2018. The call for Written Paper Abstracts is now open. This call for abstracts is for papers to be published in the Congress Proceedings. An additional call for abstracts will be distributed in January 2018 for oral presentations and posters. Abstract submittal information can be found at the meeting website: **http://www.aegweb.org/SanFrancisco2018**

CLOSURE

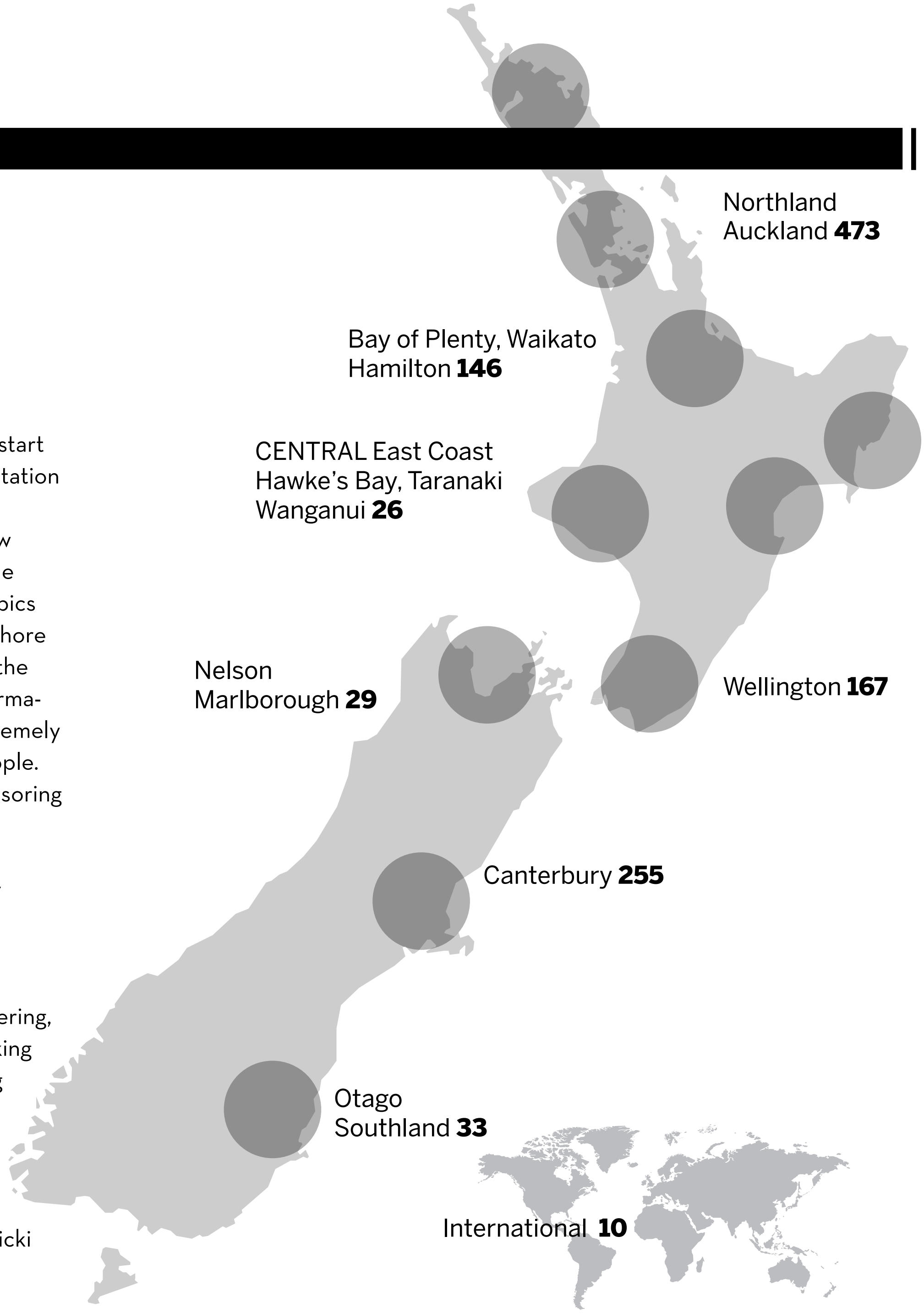
Any feedback or comments regarding IAEG matters please feel free to send me an email.

Mark Eggers
mark.eggers@psm.com.au
Vice-President for Australasia

Mark Eggers

Mark is is a Principal and Director at Pells Sullivan Meynink where he consults on large civil and mining projects across Australia, New Zealand and SE Asia. Mark has a keen interest in education and research through close associations with University of New South Wales and University of Canterbury. He also co-teaches field courses in engineering geology for the Australian Geomechanics Society.

Branch reports



AUCKLAND

The Auckland branch has great start to 2017 with the Rankine Presentation from Professor Richard Jardine. His presentation focused on how geotechnics relates to energy. He covered a diverse number of topics including design of piles for offshore platforms and wind turbines to the effects of climate change on perma-frost. The presentation was extremely well attended with over 160 people. Thanks to Geotechnics for sponsoring the catering.

Presentations in May and June include the student poster competition and talks from the new additions to the University of Auckland team Dr Ryan Yan, speaking on green slope engineering, and Dr Connor P. Hayden speaking on liquefaction-induced building performance.

WAIKATO

On Tuesday 4th April 2016 Dr Vicki Moon and Dr Willem de Lange kindly hosted a Waikato Branch Presentation titled **Faulting within the Hamilton Basin: Recent Progress** at the University of Waikato.

This presentation summarised recent work (over the last 2 years) by the University of Waikato. Three MSc students, an undergraduate student undertaking a special topic, and a Summer Scholarship student have been busy collecting data for the hidden faults project attempting to quantify the frequency and magnitude of local seismic activity in the Hamilton Basin. This has included a compilation of historical records of earthquake damage within the Hamilton Basin since 1853, geological mapping along the river, and resistivity

RANKINE LECTURE – AUCKLAND

Reported by: Eric Torvelainen

Left: Great turn out at the Auckland round of the 56th Rankine Lecture by Professor Richard Jardine. Professor Jardine is perched ready for questions post talk, at the front in the blue suit, as local branch representative James Johnson manages the eager crowd.

★ GEO-NEWS WEEKLY E-NEWSLETTER ★
Our new weekly email lists all notices and Branch announcements normally sent to members, but in one email. Please send items to include to **secretary@nzgs.org**

Above: Wellington Branch for the "Rockfalls -Debris flows -Landslides -Shallow landslides -Slope stabilisation" presentation on 3 May 2017. Approximately 40 people turned up to the event.

Do you have an idea for your local branch meeting? Your local coordinators are keen to hear your ideas and are always open to offers of assistance! See the following pages for a list of friendly contacts.

surveys at sites where faults identified within the river bed were inferred to cross the landscape. This work has been greatly assisted by access to faults exposed by the development of the Hamilton Section of the Waikato Expressway, and an opportunity to calibrate seismic resistivity equipment against a detailed set of CPT, borehole and trial pit data for the inland port development near the University. Associated research has focussed on "seismites" with peat lakes in the Hamilton Basin. If these represent the result of liquefaction of tephra layers within the lake beds, then they provide good evidence for the timing and magnitude of earthquakes.

It is clear from multiple lines of evidence that faults are common within the Basin, and some may be active. The data acquired also suggest an alternative explanation for the formation of the landforms within the Basin.

This talk summarised the recent findings and their implications for the evolution of the Hamilton Hills. The data obtained so far also allows an estimate of the maximum magnitude of a local seismic event (assuming the faults are active), but does not provide any indication of the probability of such an event.

This event was sponsored by CPT-It who generously provided refreshments to keep attendees fuelled.

Upcoming events are in planning including a possible site visits to some large infrastructure projects however these are very weather dependent. If members have any ideas for possible branch events then please don't hesitate to contact your friendly Waikato coordinators **Kori Lentfer KoriL@cmwgeosciences.com** or **Andrew Holland Andrew@hdc.net.nz**

CANTERBURY

We have had 3 presentations to Canterbury Branch since the start of the year with the Rankine Lecture presented by Richard Jardine on Thursday 30 March, about 40 people attended. Jason Le Masurier presented on the observational method for managing construction project uncertainties on Tuesday 14 March, about 30 people attended. Rori Green presented on a overview of rockfall design considerations for passive protection structures on Tuesday 28 February, about 30 people attended.

Upcoming we have a presentation by Joan Torrebadella on rock falls debris flows and slopes stabilisation on Tuesday 2 May and Martin Larisch and Timothy Pervan on Design and construction of ground improvement with a particular focus on dynamic compaction to mitigate liquefaction on Tuesday 16 May.

NEW NORTHLAND BRANCH!
We are pleased to announce our NEW Northland Branch.
Your coordinator is Mr Phil Cook who is keen to bring more information to our Northland members. Feel free to drop Phil an email at **phil@coco.co.nz**

THE ALL NEW HAWKES BAY BRANCH

~~We are pleased to announce our~~ Hawkes Bay branch is now up and running again with their first Presentation on the 23rd May. Tom Bunny and Tom Grace the Coordinators are interested in any ideas you have for Presentations and Speakers. You can contact them on email Tom Bunny on **Tom.Bunny@stantec.com** and **Tom Grace at tgrace@rdcl.co.nz**

SEE THE EVENTS DIARY OR WWW.NZGS.ORG FOR FUTURE EVENTS

NORTHLAND

Philip Cook

I am a Chartered Professional Engineer. I have an interest in risk assessment, landslides, Northland Allochthon geology, liquefaction, and seismic assessment for earthquake resistant foundations, foundation settlement.

Look forward to improving the geotechnical features of soils in Northland. Enjoy the coastal lifestyle of Northland

phil@coco.co.nz

AUCKLAND

Eric Torvelainen

Eric is passionate about soil stiffness, SSI and liquefaction. A Canterbury graduate, he works in T&T using numerical methods to solve complex problems, such as wind turbine foundations, bridges, multi-storey and in-ground structures.

ETorvelainen@tonkin.co.nz

James Johnson

ames is a Senior Geotechnical Engineer with Beca Ltd in Auckland. He has a BSc (Hons) (2009) in geophysics and mathematics and a MEngSt (Hons) (2012) in geotechnical engineering from the University of Auckland. He has worked on variety of large infrastructure projects around New Zealand, Europe, and North Africa where he has gained significant experience in soil-structure interaction.

James.Johnson@beca.com

WAIKATO

Kori Lentfer

Kori is a Engineering Geologist. He graduated in 1998 with a BSc(Tech) in Geology, followed by Masters study at Waikato University and an MSc thesis in Engineering Geology from Auckland University in 2007. Kori has worked for consultants based in the UK, Europe and the Middle East.

koril@cmwgeosciences.com

Andrew Holland

Andrew is a Director of HD Geotechnical. He studied engineering at the University of Auckland, graduating in 2002.

Andrew's experience includes geotechnical investigation, assessment and design for infrastructure, buildings and development. Andrew is a Chartered Professional Engineer (CPEng).

Andrew@hdc.net.nz

BAY OF PLENTY

James Griffiths

James is an Engineering Geologist with Beca in Tauranga. After a previous life working in outdoor education and guiding on the Fox Glacier for 7 years, James studied Geology at Otago University, graduating in 2014 with a BSc (Hons). James has worked on site hazard assessments, geotechnical site investigations and ground modeling for a broad range of clients and market sectors.

James.Griffiths@beca.com

Kim de Graaf

Kim is a Geotechnical Engineer with Beca Ltd. She completed a BSc(Hons) in Mathematics and Statistics at the University of Canterbury before working in accountancy for several years. Kim then returned to UC to complete a PhD in Geotechnical Engineering and has been working at Beca on various small projects over the last year while completing her thesis.

kim.degraaf@beca.com

HAWKE'S BAY

Tom Grace

Tom is a geologist who has worked for consulting companies on a large range of projects - predominately mineral exploration, mining feasibility & development and geotechnical projects in Southeast Asia, Canada, Australia and New Zealand. Tom has a strong interest in ground testing (CPT, surface and downhole geophysics, downhole testing).

tgrace@rdcl.co.nz

Tom Bunny

Tom is a Senior Engineering Geologist with MWH (now part of Stantec) and is the geotechnical discipline in New Zealand. His specialities include geotechnical investigation, site hazard assessment, ground modelling, risk management, earthworks and stability assessments for central and local government, SOE's, CCO's, commercial and panel partners throughout NZ, Pacific Region, and New Zealand.

Tom.Bunny@stantec.com

SEE THE EVENTS DIARY OR WWW.NZGS.ORG FOR FUTURE EVENTS

★

UPCOMING EVENTS

★

AUGUST – SEPTEMBER 2017

ENGINEERING GEOLOGY COURSE

AUCKLAND
Thursday 31 August and Friday 1 September

WELLINGTON
Monday 4 September and Tuesday 5 September

CHRISTCHURCH
Thursday 7 September and Friday 8 September

WELLINGTON

Nima Taghipouran

Nima is a geotechnical engineer at Beca in Wellington, with four years of experience following graduation from the University of Auckland. Nima has been involved in a wide range of projects in the North Island. His areas of interest include design of deep foundations and retaining structures in highly seismic areas and earthquake hazard assessments. **nima.taghipouran@beca.com**

Aimee Rhodes

Aimee is a graduate geotechnical engineer with Opus. She recently completed her Masters degree in Earthquake Engineering with the University of Canterbury. Aimee has experience with liquefaction analysis and soil characterisation having worked on modelling liquefaction in stratified soils for her Masters research.

aimee.rhodes@opus.co.nz

Shirley Wang

Shirley is a Geotechnical Engineer with 8 years of experience working at Tonkin & Taylor Wellington Office. She graduated from Canterbury University with a BE(Hons) in 2009. She has experience in seismic assessment, geotechnical and environmental investigation, slope stability, foundation design and construction monitoring.

SWang@tonkintaylor.co.nz

Jerry Spinks

Jerry is a chartered professional engineer who has worked in New Zealand and the UK. Returning to New Zealand in 2011, he has worked on a variety of building projects. Jerry recently joined Jacobs Engineering, where he has been undertaking a number of landslide assessments and is working on the Pinehaven Flood Protection Scheme.

Jerry.Spinks@jacobs.com

NELSON

Paul Wopereis
Paul is Principal Engineering Geologist with MWH Global based in Nelson.
Paul has worked at MWH since 2001 and is currently involved in projects in New Zealand and Fiji. Previously Paul was a senior exploration geologist with L & M Mining Ltd and has worked on mining and exploration projects in New Zealand and South America.
Paul.J.Wopereis@mwhglobal.com

CANTERBURY

Jennifer Kelly
Jen is a Senior Engineering Geologist working for Riley Consultants in Christchurch. She has a BSc (Hons) geoscience from St Andrews (2004) and an MSc in geotechnical engineering and management from Birmingham University (2011). She worked in the UK for 8 years on large infrastructure projects before moving to NZ in 2013 and gaining great experience here and in the Pacific islands.
jkelly@riley.co.nz

Sam Glue
Sam is a Geotechnical Engineer working for Tonkin & Taylor in Christchurch with 9 years experience working throughout New Zealand and Australia. Sam graduated from Canterbury with a BE (Civil) in 2006 and is passionate about being involved in the construction of major infrastructure projects that will withstand the test of time and earthquakes.
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OTAGO

David Barrell
David is a geologist and geomorphologist at GNS Science in Dunedin. South Island born and bred. Since joining GNS Science, he has specialised in Quaternary geology, landform evolution and landscape processes. David very much enjoys the mix of scientific research and applied geoscience that his work entails.
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NEW ZEALAND GEOTECHNICAL SOCIETY INC

The New Zealand Geotechnical Society (NZGS) is the affiliated organization in New Zealand of the International Societies representing practitioners in Soil mechanics, Rock mechanics and Engineering geology. NZGS is also affiliated to the Institution of Professional Engineers NZ as one of its collaborating technical societies.

The aims of the Society are:
a) To advance the education and application of soil mechanics, rock mechanics and engineering geology among engineers and scientists.
b) To advance the practice and application of these disciplines in engineering.
c) To implement the statutes of the respective international societies in so far as they are applicable in New Zealand.
d) To ensure that the learning achieved through the above objectives is passed on to the public as is appropriate.

All society correspondence should be addressed to the Management Secretary (email: secretary@nzgs.org).

The postal address is
NZ Geotechnical Society Inc,
P O Box 12 241,
WELLINGTON 6144.

Letters or articles for NZ Geomechanics News should be sent to editor@nzgs.org.

MEMBERSHIP
Engineers, scientists, technicians, contractors, students and others who are interested in the practice and application of soil mechanics, rock mechanics and engineering geology are encouraged to join.

Full details of how to join are provided on the NZGS website http://www.nzgs.org/about/

Teresa Roetman
I live up in the Waitakere Ranges in Auckland, far from the rush of traffic and noise. Sitting at my desk, looking out to the bush clad hills full of birds happily chirping in the sun I feel blessed to be part of this wonderful environment. I love these hills, hiking the tracks with my son and daughter, paddling in the rivers and streams, seeing weta's and glowworms, hearing the wildlife, not to mention the fantastic views of the surrounding city. We love the west coast beaches, the black sand, the wild surf. When I am not working for the NZGS I enjoy all the "wild west" has to offer.

Please remember to contact the Management Secretary (Teresa) if you wish to update any membership, address or contact details. If you would like to assist your Branch, as a presenter or sponsor, or to provide a venue, refreshments, or an idea, please drop a line to your Branch Co-ordinator or Teresa. If you require any information about other events or conferences, the NZGS Committee and NZGS projects, or the International Societies (IAEG, ISRM and ISSMGE) please contact the Secretary on secretary@nzgs.org You may also check the Society's website for Branch and Conference listings, and other Society news: www.nzgs.org

Management committee

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ISRM Australasian Vice President	Stuart Read	S.Read@gns.cri.nz Management Committee

EDITORIAL POLICY

***NZ Geomechanics News* is a biannual bulletin issued to members of the NZ Geotechnical Society Inc.**

Readers are encouraged to submit articles for future editions of NZ Geomechanics News. Contributions typically comprise any of the following:

- **technical papers which may, but need not necessarily be, of a standard which would be required by international journals and conferences**
- **technical notes of any length**
- **feedback on papers and articles published in NZ Geomechanics News**
- **news or technical descriptions of geotechnical projects**
- **letters to the NZ Geotechnical Society or the Editor**
- **reports of events and personalities**
- **industry news**
- **opinion pieces**

Please contact the editors (editor@nzgs.org) if you need any advice about the format or suitability of your material.

Articles and papers are not normally refereed, although constructive post-publication feedback is welcomed. Authors and other contributors must be responsible for the integrity of their material and for permission to publish. Letters to the Editor about articles and papers will be forwarded to the author for a right of reply. The editors reserve the right to amend or abridge articles as required.

The statements made or opinions expressed do not necessarily reflect the views of the New Zealand Geotechnical Society Inc.

NEW ZEALAND GEOTECHNICAL SOCIETY INC

NZGS Membership SUBSCRIPTIONS

Annual subscriptions cost $105 per member. First time members will receive a 50% discount for their first year of membership; and student membership is free. Membership application forms can be found on the website http://www.nzgs.org/membership.htm or contact the NZGS Secretary on secretary@nzgs.org for more information.

Advertisers Directory

ADVERTISING

NZ Geomechanics News is published twice a year and distributed to the Society's 1000 plus members throughout New Zealand and overseas. The magazine is issued to society members who comprise professional geotechnical and civil engineers and engineering geologists from a wide range of consulting, contracting and university organisations, as well as those involved in laboratory and instrumentation services. NZGS aims to break even on publication, and is grateful for the support of advertisers in making the publication possible.

TYPE	BLACK AND WHITE	COLOUR	SPECIAL PLACEMENTS		SIZE
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1. All rates given per issue and exclude GST
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5. Advertisers are responsible for ensuring they have all appropriate permissions to publish. This includes the text, images, logos etc. Use of the NZGS logo in advertising material is not allowed without pre-approval of the NZGS committee.

National and International Events

2017

25-28 JUNE 2017
San Francisco, California, USA
51st US Rock Mechanics Geomechanics Symposium (ARMA2017)

28-30 JUNE 2017
Athens, Greece
BCRRA 2017 – Tenth International Conference on the Bearing Capacity of Roads, Railways and Airfields

9-12 JULY 2017
Honolulu, Hawaii, USA
Grouting 2017 – Grouting, Deep Mixing and Diaphragm Walls

15-19 JULY 2017
Sharm el-Sheikh Egypt
GeoMEast 2017
Inovative Infrastructure Geotechnology

16-19TH JULY 2017
Vancouver, Canada
PBD-III Vancouver 2017 – The 3rd International Conference on Performance Based Design in Earthquake Geotechnical Engineering

6-7 SEPTEMBER 2017
University of Leeds, UK
Second International Symposium on Coupled Phenomena in Environmental Geotechnics (CPEG2)

12-14 SEPTEMBER 2017
Offshore Site Investigation & Geotechnics Committee 8th International Conference

16-17 SEPTEMBER 2017
Seoul – Korea
iYGEC6 – 6th International Young Geotechnical Engineers' Conference

17-22 SEPTEMBER 2017
Seoul – Korea
19th ICSMGE Unearth the Future Connect Beyond

2-7 OCTOBER 2017
Capetown South Africa
AfriRock 2017

28-30 OCTOBER 2017
Shaoxing, China
Shaoxing International Forum on Rock Mechanics and Engineering Geology (SXFRG)

12-15 NOVEMBER 2017
Dallas, Texas, USA
PanAm-UNSAT 2017: Second Pan-American Conference on Unsaturated Soil (Unsaturated Soil Mechanics for Sustainable Geotechnics)

26-26 NOVEMBER 2017
Napier, NZ
NZGS 20th Symposium What in Earth is Going On: Balancing Risk Reward, Regulation and Reality

28-30 NOVEMBER 2017
Kathmandu, Nepal
11th Asian Regional Conference (ARC-11) of IAEG: Engineering Geology for Geodisaster Management

29 NOV – 1 DECEMBER 2017
Lake Wanaka Centre, Wanaka
Geoscience Society NZ Conference

2018

3-5 AUGUST 2018
Hong Kong
7th International Conference on Unsaturated Soils (UNSAT2018)

2019

JUNE 2019
Rome, Italy
7 ICEGE International Conference of Earthquake Geotechnical Engineering

1 JULY 2019
Reykjavik, Iceland
ECSMGE 2019 – XVII European Conference on Soil Mechanics and Geotechnical Engineering

★
UPCOMING EVENTS
★
AUGUST – SEPTEMBER 2017

ENGINEERING GEOLOGY COURSE

AUCKLAND
Thursday 31 August and Friday 1 September

WELLINGTON
Monday 4 September and Tuesday 5 September

CHRISTCHURCH
Thursday 7 September and Friday 8 September

LINKS ARE AVAILABLE FROM THE NZ GEOTECHNICAL SOCIETY WEBSITE WWW.NZGS.ORG

The Earthquake geotechnical engineering guidelines

FEEDBACK is requested to modulefeedback@nzgs.org

Module 1: Overview of the Guidelines
Released March 2016

Module 2: Geotechnical Investigations for Earthquake Engineering
Released November 2016

Module 3: Liquefaction Hazards
Released July 2010 as Module 1, updated May 2016 as Module 3

Module 4: Earthquake Resistant Foundation Design
Released November 2016

Module 5: Ground Improvement of Soils Prone to Liquefaction
Released May 2017

Module 5a: Specification for Ground Improvement
Released November 2015

Module 6: Earthquake Resistant Retaining Wall Design
Released May 2017

Module 7: Earthquake Slope Stability
Development to commence in 2017

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

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