

HKIE Geotechnical Division

Technical Visit (March 2019)



New Zealand Debriefing Session

28 May 2019

Mickey Goh
Helper
Geotechnical Engineering Office

Alex Leung
Helper
Golder Associates (HK) Ltd

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- ◆ Introduction
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- ◆ Remark 4: Advancement in geotechnical **research** on earthquakes
- ◆ Conclusion



Introduction

Background

- Tour dates: 4 – 8 March 2019
- Organising committee: Ir Ian Askew
Ir Dr S W Lee
Ir Tony Ho
- Helpers: Mr Alex Leung
Mr Mickey Goh
- Tour guide: Mr Ringle Wong
- Travel agency: Jardine Travel Limited
- No. of participants: **20** (excluding the above)

Supported by:

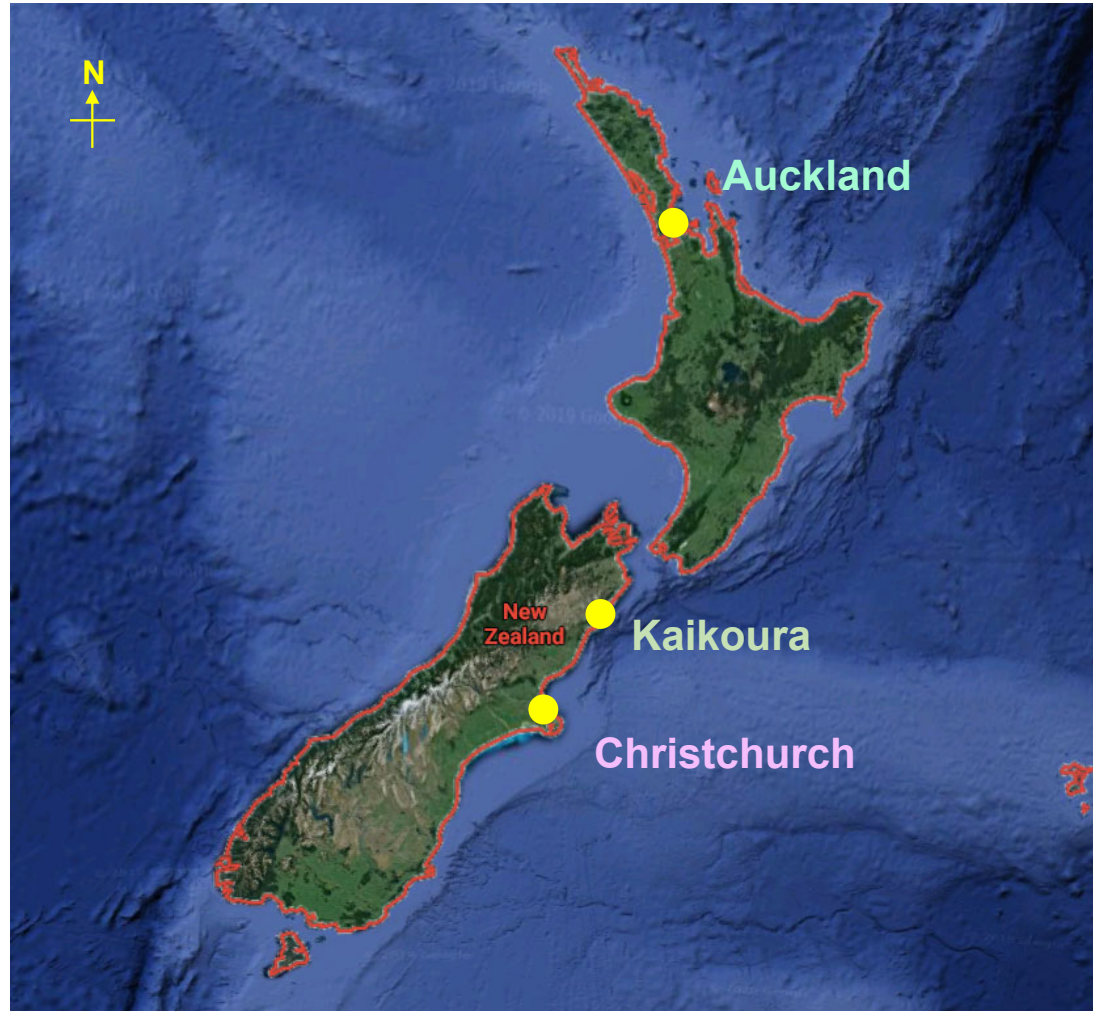
**Professional
Services
Advancement
Support Scheme**

under the Commerce and Economic
Development Bureau

Aims of the visit

- To enrich Hong Kong engineers' knowledge of applying **innovative technologies** to geotechnical engineering problems, especially for the urban railway construction in Auckland and recovery projects from previous **earthquakes** in Kaikoura and Christchurch
 - ✓ Building Information Modelling (BIM)
 - ✓ Automation
 - ✓ Drone photography
 - ✓ Remote Sensing (e.g. LiDAR)
 - ✓ Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR)

Places of visit



Learning activities



Auckland

4 – 5 March 2019

- City Rail Link Contracts 1, 2 and 6
- Northern Corridor Improvements
- Volcanic geology - Lecture & Tour



Kaikoura

6 – 7 March 2019

- 2016 Kaikoura Earthquake Intro
- NCTIR's Lectures & Demonstration on the development and use of innovative and digital technologies



Christchurch

7 – 8 March 2019

- Tour – Earthquake damages
- Lecture on earthquake research & Visit to UC's Geotechnical Lab
- Introduction to NZGD and CGD

Details of the activities

Auckland 4 – 5 March 2019

1. Visit to City Rail Link (CRL) Contract 1 – Britomart Station constructed under the 106-year-old Chief Post Office building



Underpinning works and diaphragm wall construction for tunnel station

Details of the activities

Auckland 4 – 5 March 2019

2. Visit to City Rail Link (CRL) Contract 6 – Mount Eden Stormwater Diversion



Micro-TBM tunnelling and pipe jacking for a 420-m long new pipeline

Details of the activities

Auckland 4 – 5 March 2019

4. Visit to Northern Corridor Improvements – Road widening works with reclamation



Enlarging existing motorways and providing new access to the West Ring Route and the Auckland International Airport

Details of the activities

Auckland 4 – 5 March 2019

5. Lecture & geological tour to Auckland volcanic geology



Lecture by **Dr Martin Brook** at the University of Auckland &
Guided tour by the Lead Geologist **Philip Kirk** at Aurecon New Zealand

Details of the activities

Kaikoura 6 – 7 March 2019

- Tour to earthquake recovery works along State Highway 1 by North Canterbury Transport Infrastructure Recovery (NCTIR), Aurecon and GNS Science**



Rock fall barriers, gabion and concrete protection bunds as landslide mitigation measures (temporary and permanent)

Details of the activities

Kaikoura 6 – 7 March 2019

2. Introduction to **2016 Kaikoura Earthquake** and its associated damages and the use of **innovative and digital technologies** by NCTIR, Aurecon and GNS Science



Demonstration and trying out the **VR and AR technologies** in landslide investigation and geological mapping

Details of the activities

Christchurch 7 – 8 March 2019

1. Tour to **Christchurch Red Zone, ANZAC Bridge and Sumner Red Cliff (permanent damages caused by 2011 Christchurch Earthquake)**

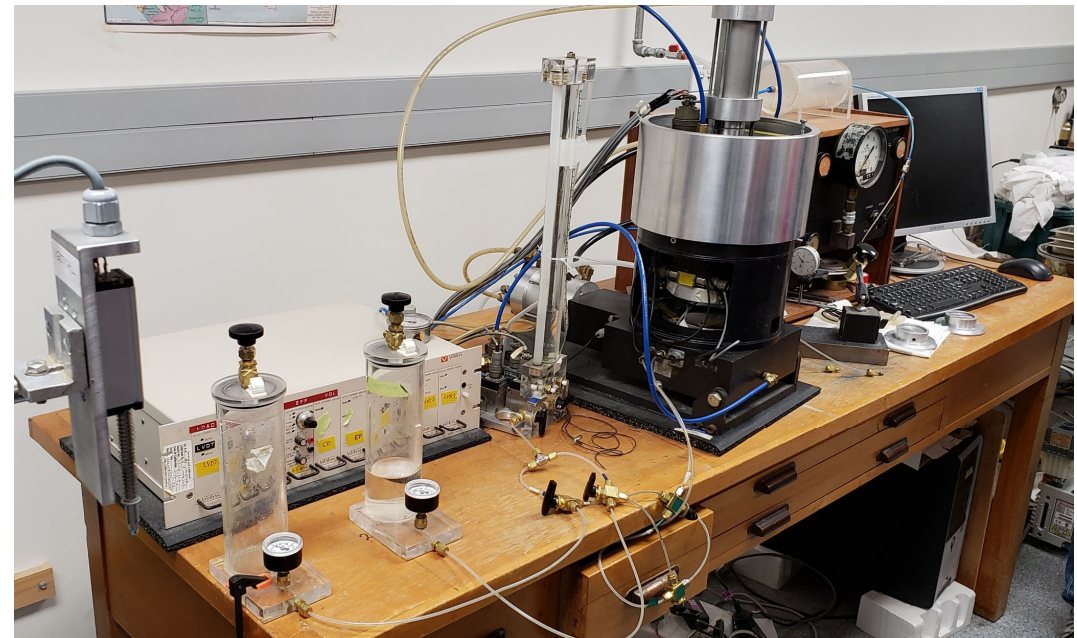


Tour guided by **Dr Gabriele Chiaro** of the University of Canterbury introducing the **structural damages** and **geotechnical hazards** related to earthquakes

Details of the activities

Christchurch 7 – 8 March 2019

2. Introduction to latest advancements in **geotechnical research** and visit to the **Geotechnical Laboratory** at the University of Canterbury



Introduction to the **field and lab tests** for the investigation of **seismic liquefaction** behaviour of silty sand and gravelly sand

Details of the activities

Christchurch 7 – 8 March 2019

3. Lecture on the 2011 Christchurch Earthquake and the New Zealand Geotechnical Database by Tonkin-Taylor and New Zealand Geotechnical Society



Thinking from the perspective of a **geotechnical engineer** & Sharing and documentation of **ground information**

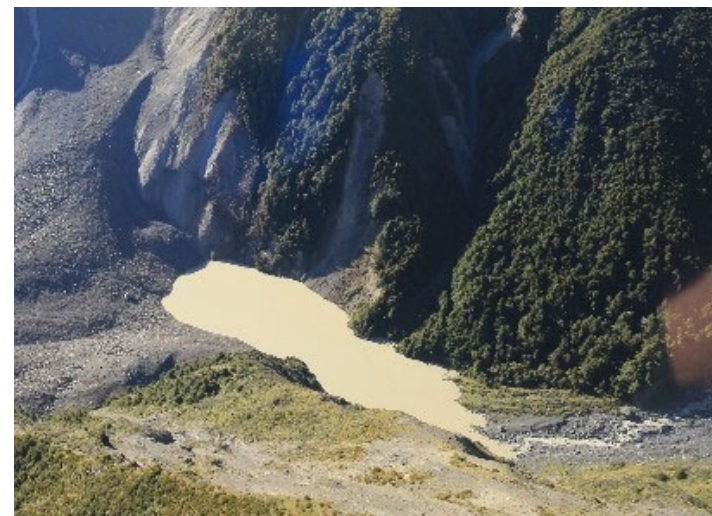
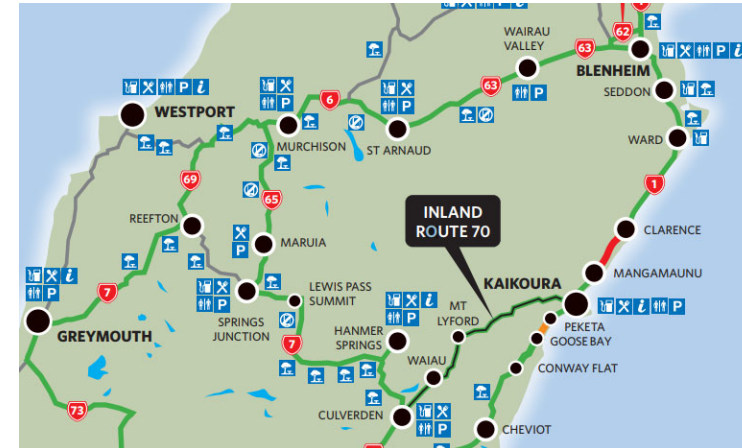


Remark 1 – Adaptation in Handling Engineering Challenges



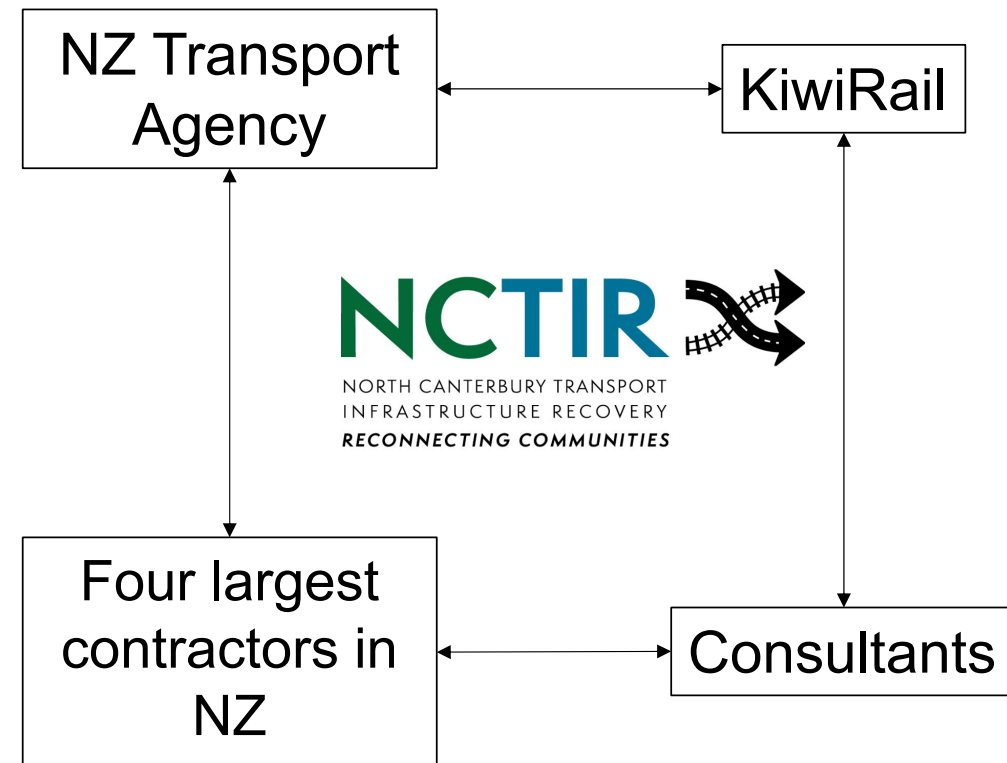
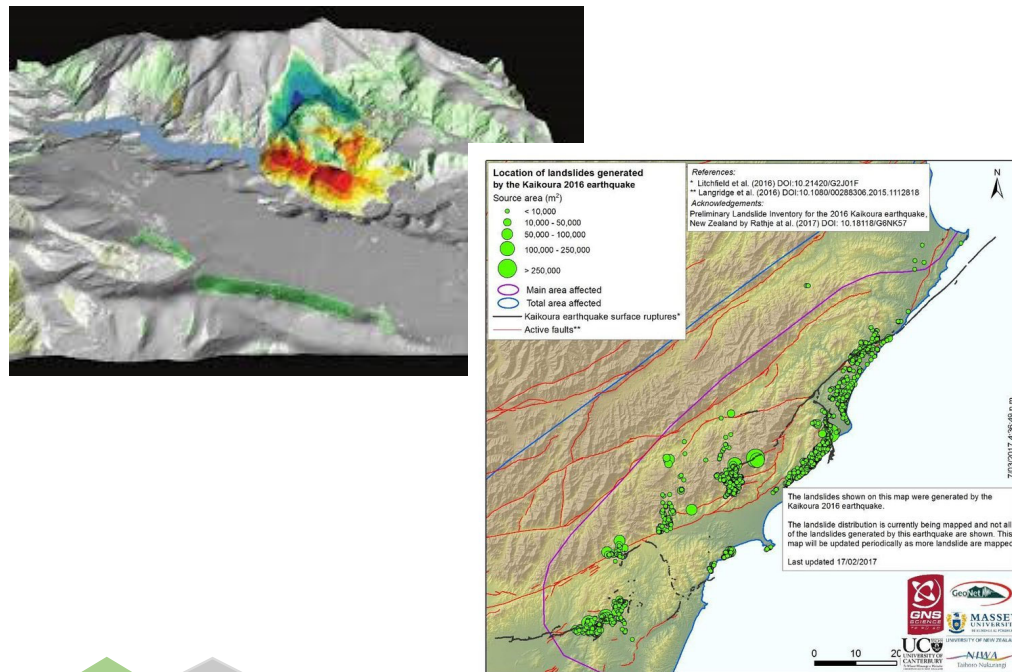
Kaikoura Earthquake 2016 Recovery

Aftermath of Kaikoura Earthquake 2016









Post-quake Hazard Analysis

- **3D** mapping by helicopter reconnaissance
- **Satellite imagery & LiDAR** with us of drones
- Rock-by-rock assessment



Forming an **Alliance** - NCTIR

Landslide Mitigation Measures (Active and Passive solutions)

Active solutions	Passive solutions	
 <p>Sluicing</p>	 <p>Rockfall/debris catch fence</p>	 <p>Ship containers</p>
 <p>Mesh and bolting</p>	 <p>Earth bund</p>	 <p>Hybrid fences</p>

Photos taken by us

Protection of Wild Life

Seal Management

- Seal handlers to keep seals away from road, railway and construction area
- New habitats for seals, rock at base of new seawall



Ohau Rock Daisy

- Seeds are collected and replanted in daisy's natural habitat

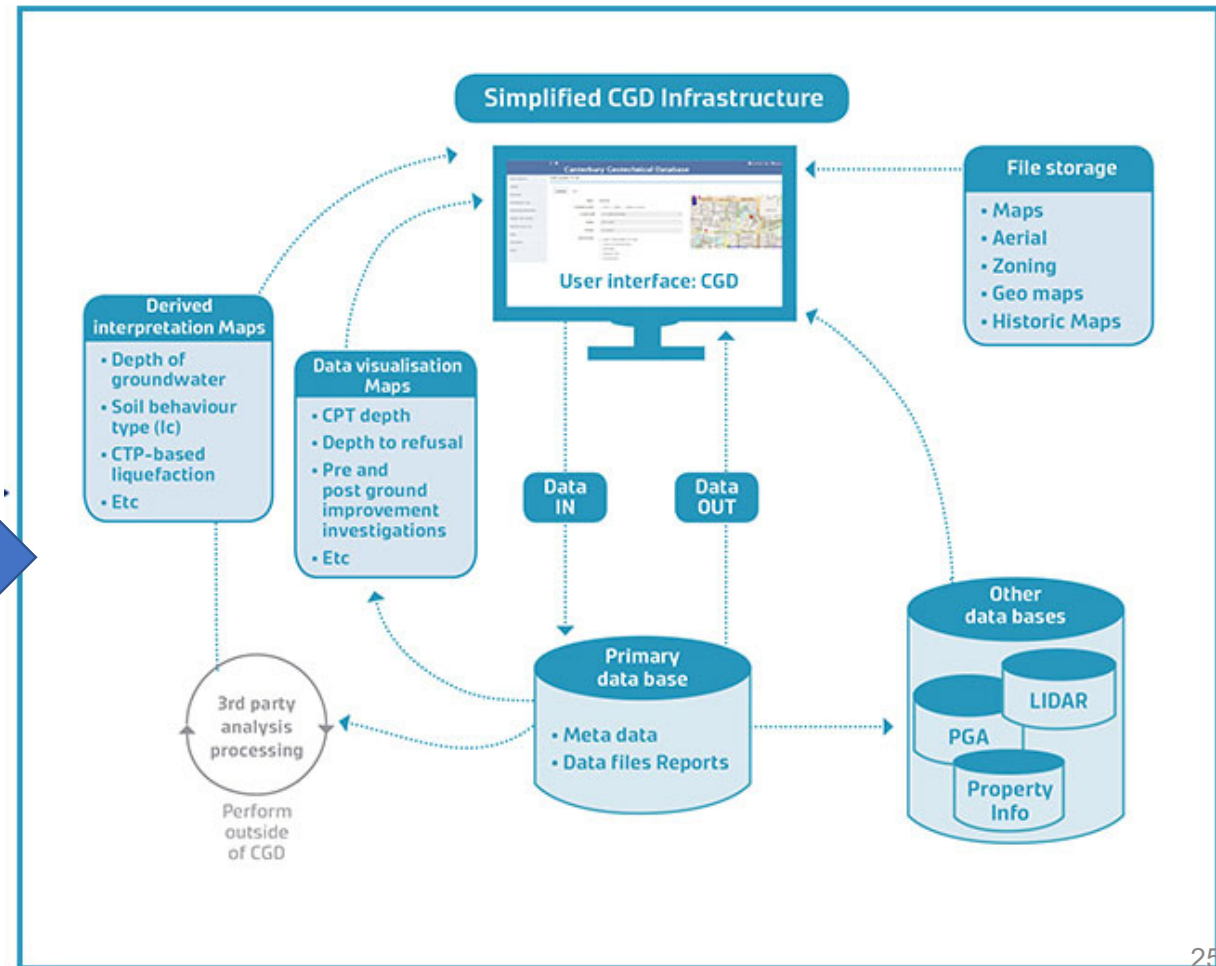
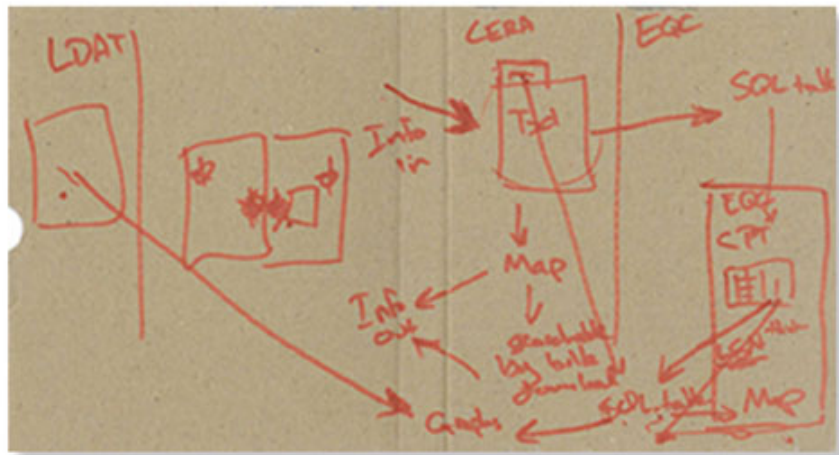


Christchurch Earthquake 2011 Recovery



Canterbury Geotechnical Database (CGD)

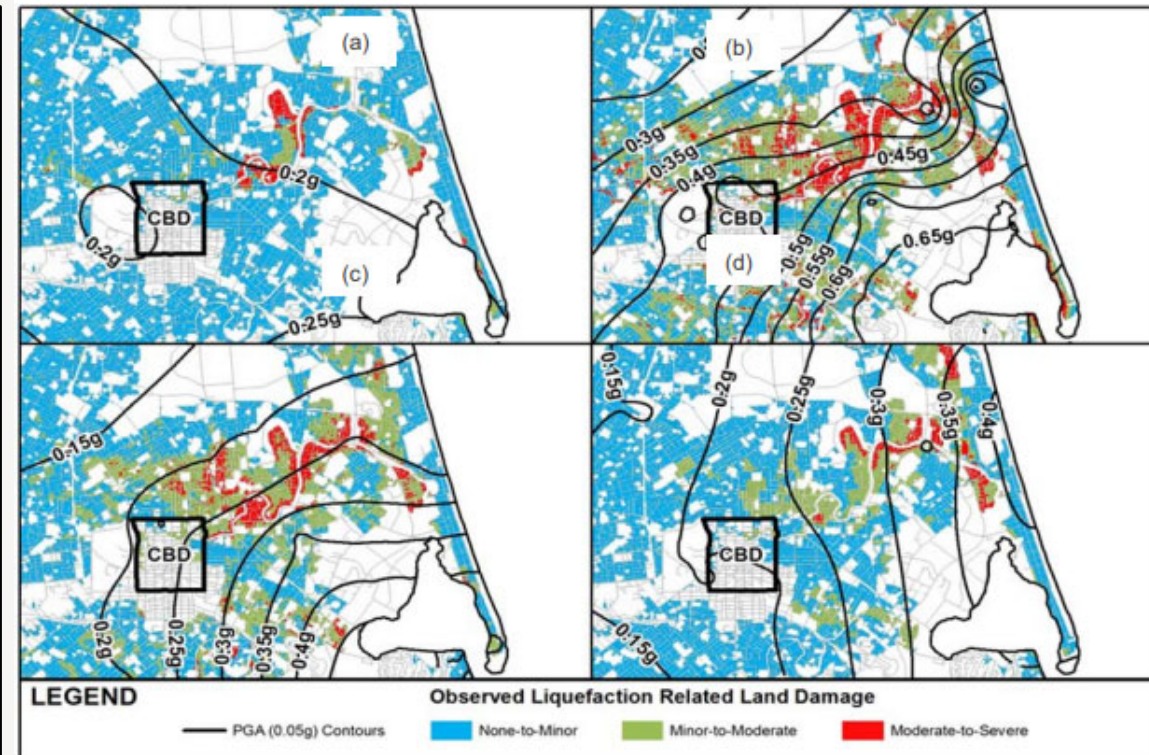
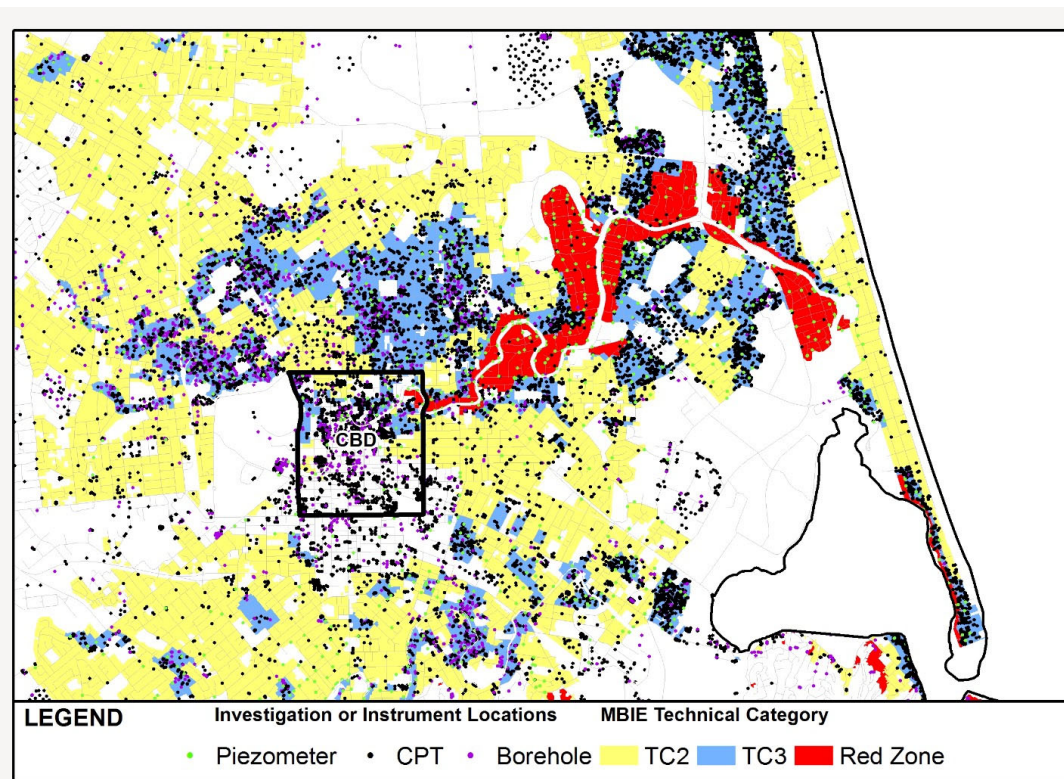
- Established in 2012 after the earthquake
- Objective: Make best use of **geotechnical data, accessible by all partners** to enhance quality of engineering design



Presentation given by
 NZGS Chair
 Tony Fairclough




Canterbury Geotechnical Database (CGD)



Key learnings on Remark 1

- ✓ **Cost-effective** engineering solutions
- ✓ **Harmony** with the environment
- ✓ Forming an **alliance**
- ✓ **Sharing** of geotechnical information



Remark 2 – Development and Application of Digital Technologies

Visit to NCTIR Village – Demonstration of Digital Technologies



Visit to NCTIR Village – Demonstration of Digital Technologies

Virtual Reality



Photo taken by us



Video taken by us



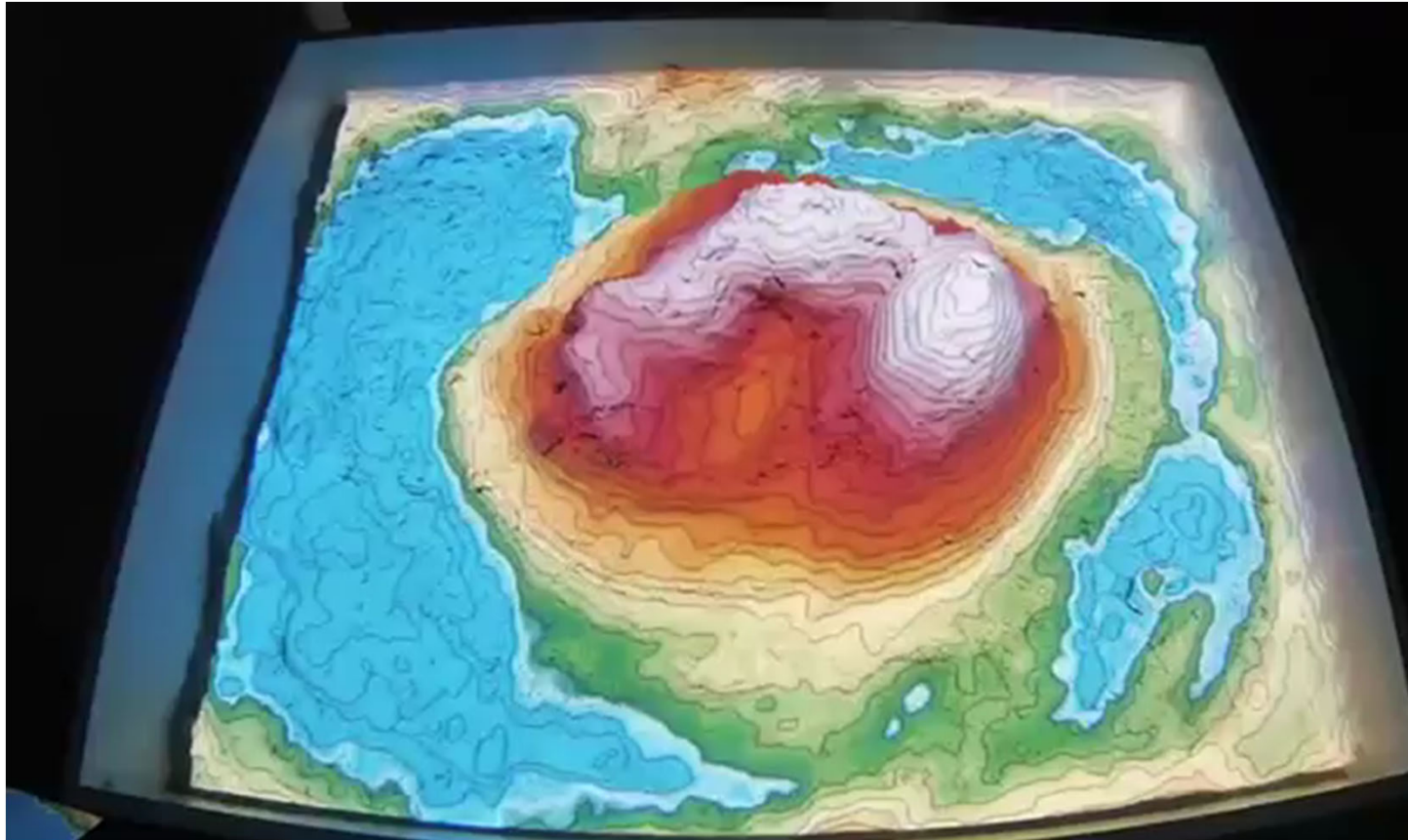
Visit to NCTIR Village – Demonstration of Digital Technologies

Augmented Reality



Courtesy of Billy

Visit to NCTIR Village – Introduction to Digital Technologies under Development Augmented Reality



Video from Aurecon

Visit to NCTIR Village – Demonstration of Digital Technologies

Unmanned Aerial Vehicles (UAVs)



Photo taken by us



Photo from Aurecon

Visit to NCTIR Village – Demonstration of Digital Technologies

Augmented Reality + Common Digital Devices



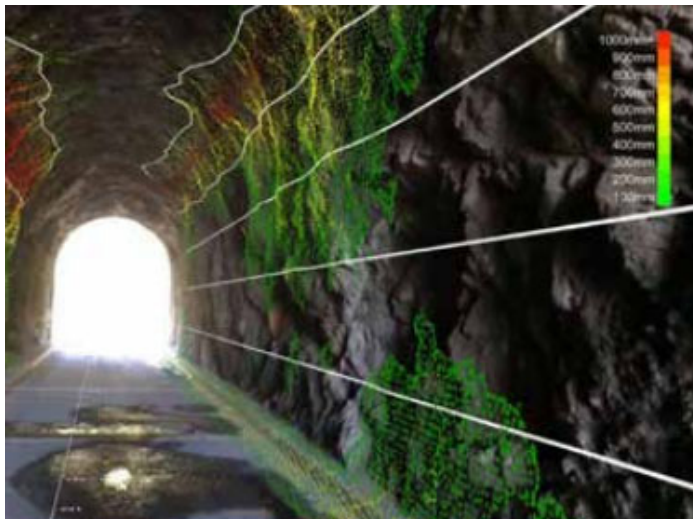
Photos taken by us

Use of Digital Technologies on Kaikoura Earthquake Recovery Works

Augmented reality in tunnelling widening works—

- 3D laser scan to obtain tunnel **dimensions**
- Compare with **widened** dimensions
- Information is **visualized in augmented reality**
- **Common** smart phones/mobile tablets

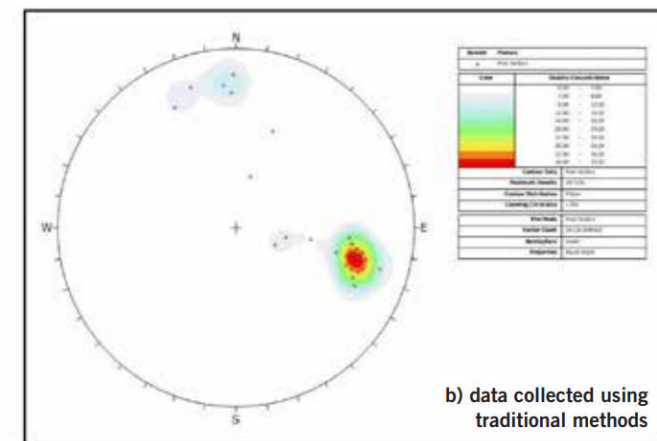
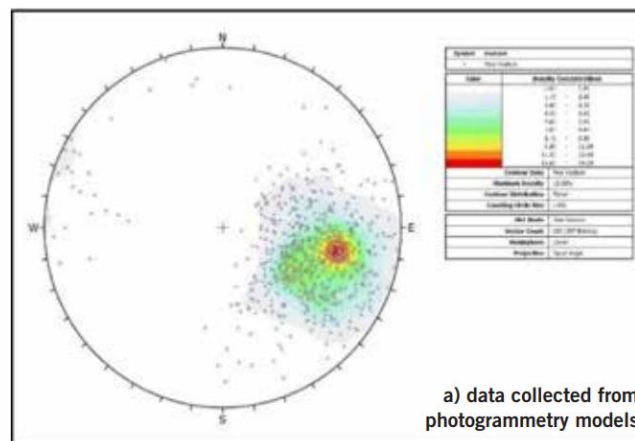
- ✓ Less manual than traditional survey method
- ✓ Better visualization
- ✓ Better communication of key information
- ✓ Optimised amount of work to be done



Photos from NCTIR

Use of Digital Technologies on Kaikoura Earthquake Recovery Works

- Photogrammetry on slope
 - Use of drones
 - Rock mass mapping
-
- ✓ Minimised time on site
 - ✓ Complete 3D information
 - ✓ Accurate design and analysis



Photos from NCTIR

Key learnings on Remark 2

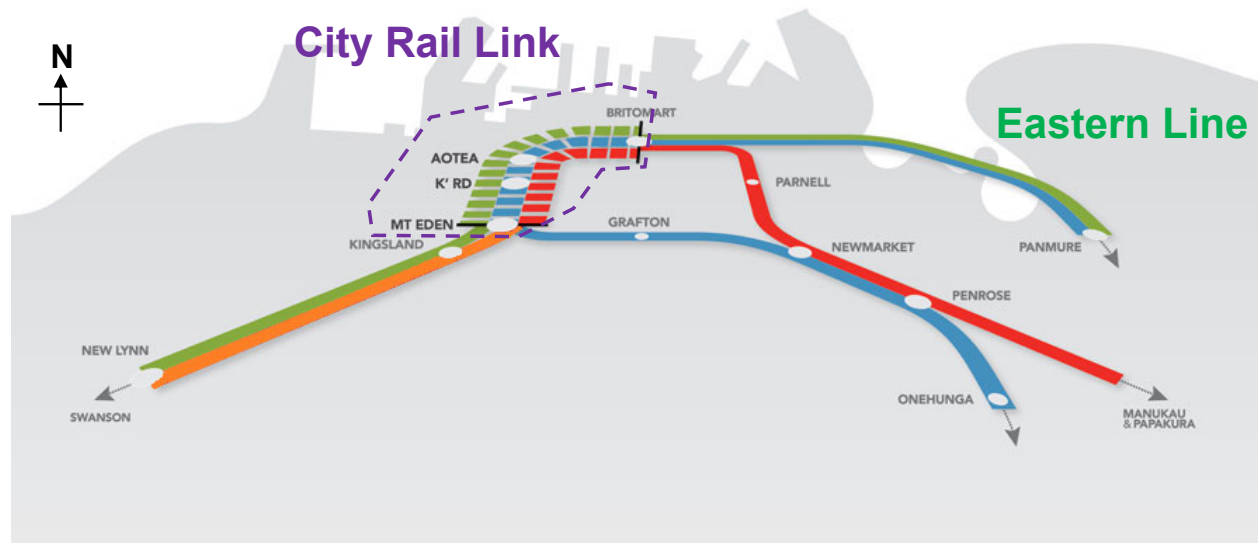
- ✓ Improve **health and safety** with digital technology
- ✓ Preserve **key** information
- ✓ Aid design and analysis with **improved accuracy**
- ✓ Digital **visualization** and **communication**
- ✓ Application:
 - Tunnel profile scanning, rock joint mapping, reclamation monitoring, AR to engage in communication with interested parties & client



Remark 3 – Construction, Innovation and Preservation

City Rail Link (CRL) Project

- The largest railway project currently in New Zealand (Project cost: NZD 4.4B)
- 3.45 km from **Britomart to Mount Eden**



TIME SAVINGS THE CRL WILL MEAN LESS TIME TRAVELLING AND MORE TIME WHERE PEOPLE NEED TO BE:



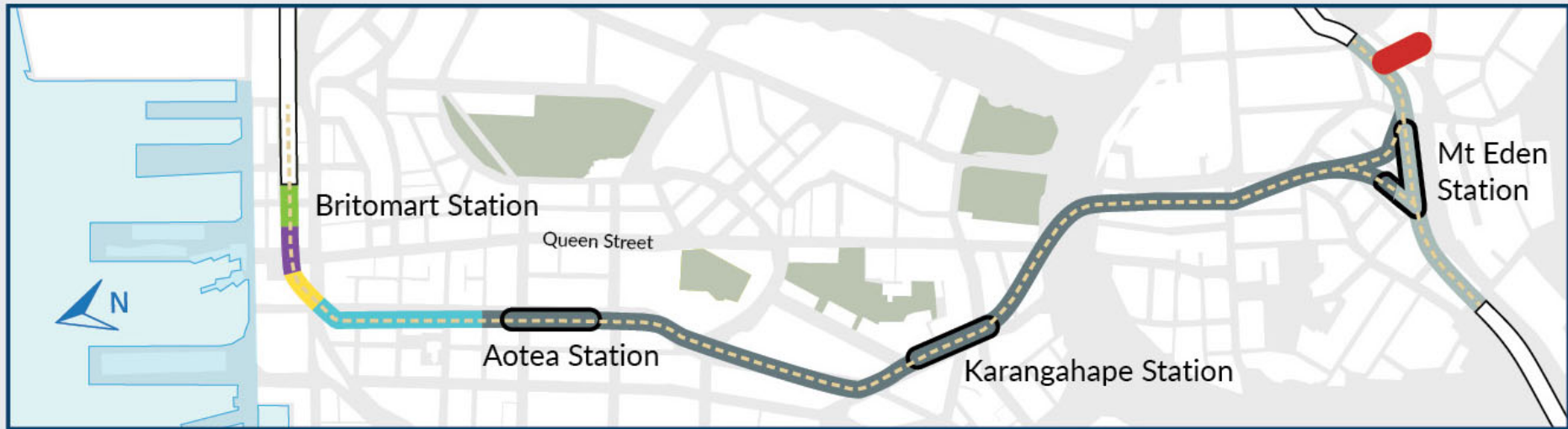
17 MINUTES
SAVED between
Henderson and Aotea

9 MINUTES
SAVED between
Glen Innes and Aotea

9 MINUTES
SAVED between
Papakura and Aotea

Britomart to
Mt Eden in under
10 MINUTES

Contracts of CRL Project



Currently Already Let/Under Construction:

- Contract 1 - Britomart Station/Lower Queen St
- Downtown Shopping Centre (DSC)
- Contract 2 - Albert St (Customs to Wyndham St)
- Contract 6 - Mt Eden Stormwater Main

Contract 3 - Alliance:

- Stations and Tunnels
- Western Line connection
- Rail Systems

Contract 9 - Britomart East

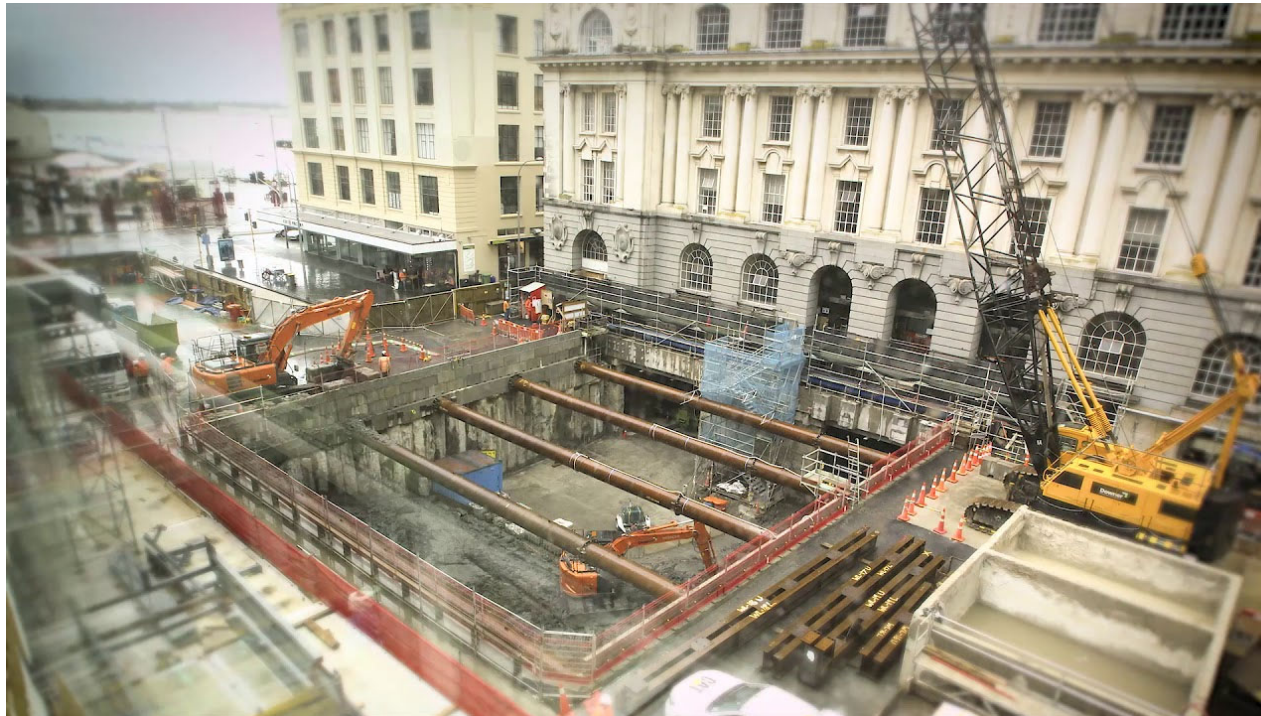
Wider network improvements (not shown):

- Strand & Otāhuhu improvements
- Newmarket improvements
- Henderson improvements

The construction sites that we visited

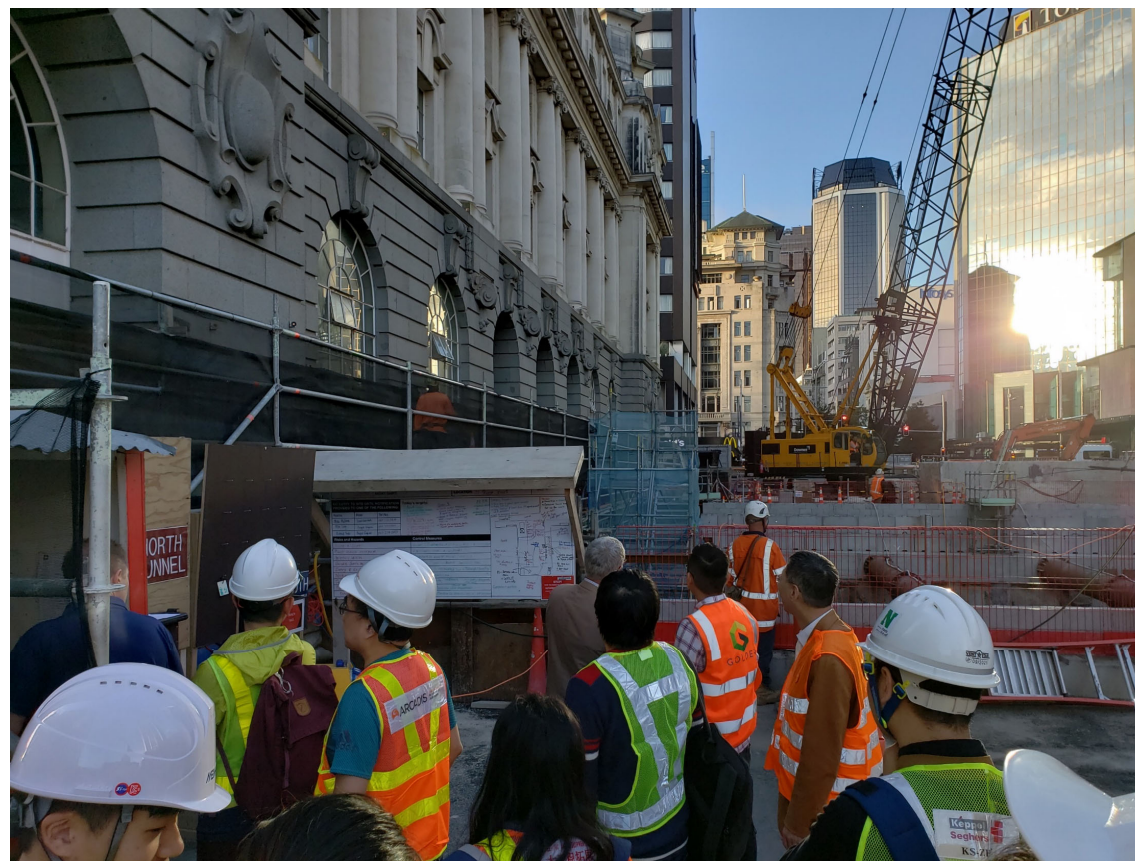
CRL Contract 1 – Britomart Station

- Construction of **tunnel station** (extended from original Britomart Station) under the **Chief Post Office (CPO)** and Lower Queen Street



Photos from CRL Website

CRL Contract 1 – Chief Post Office



Preserving 106-year-old Category 1-listed heritage building

Photos taken by us

CRL Contract 1 – Diaphragm walls and Underpinning

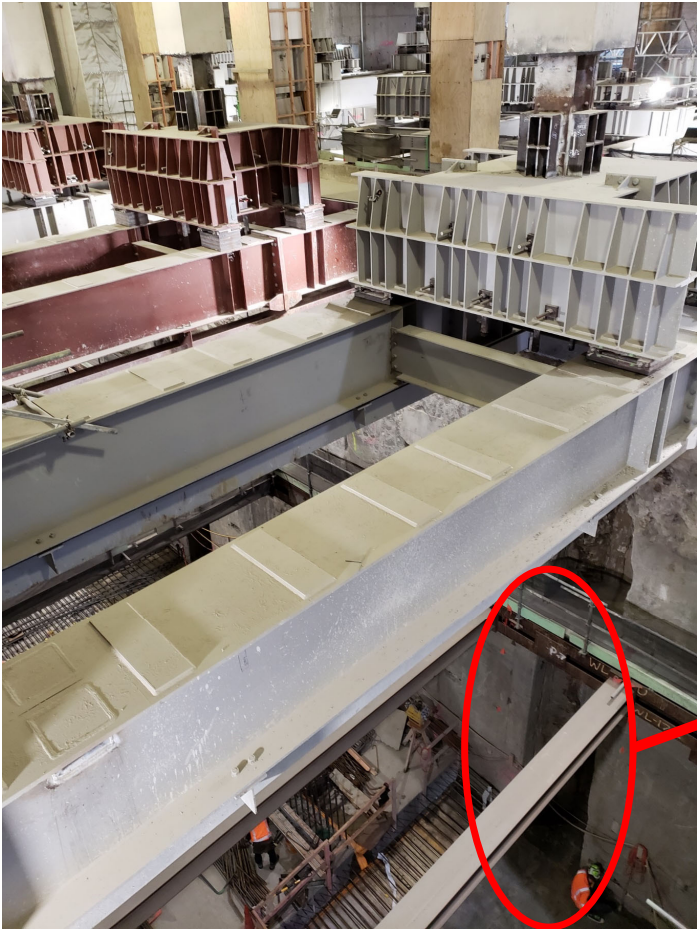


Hydraulic load cell and support frame



A close-up of the supporting frame

CRL Contract 1 – Diaphragm walls and Underpinning



Jet grouted column among diaphragm wall panels

Photos taken by us

CRL Contract 1 – Automatic Deformation Monitoring Systems



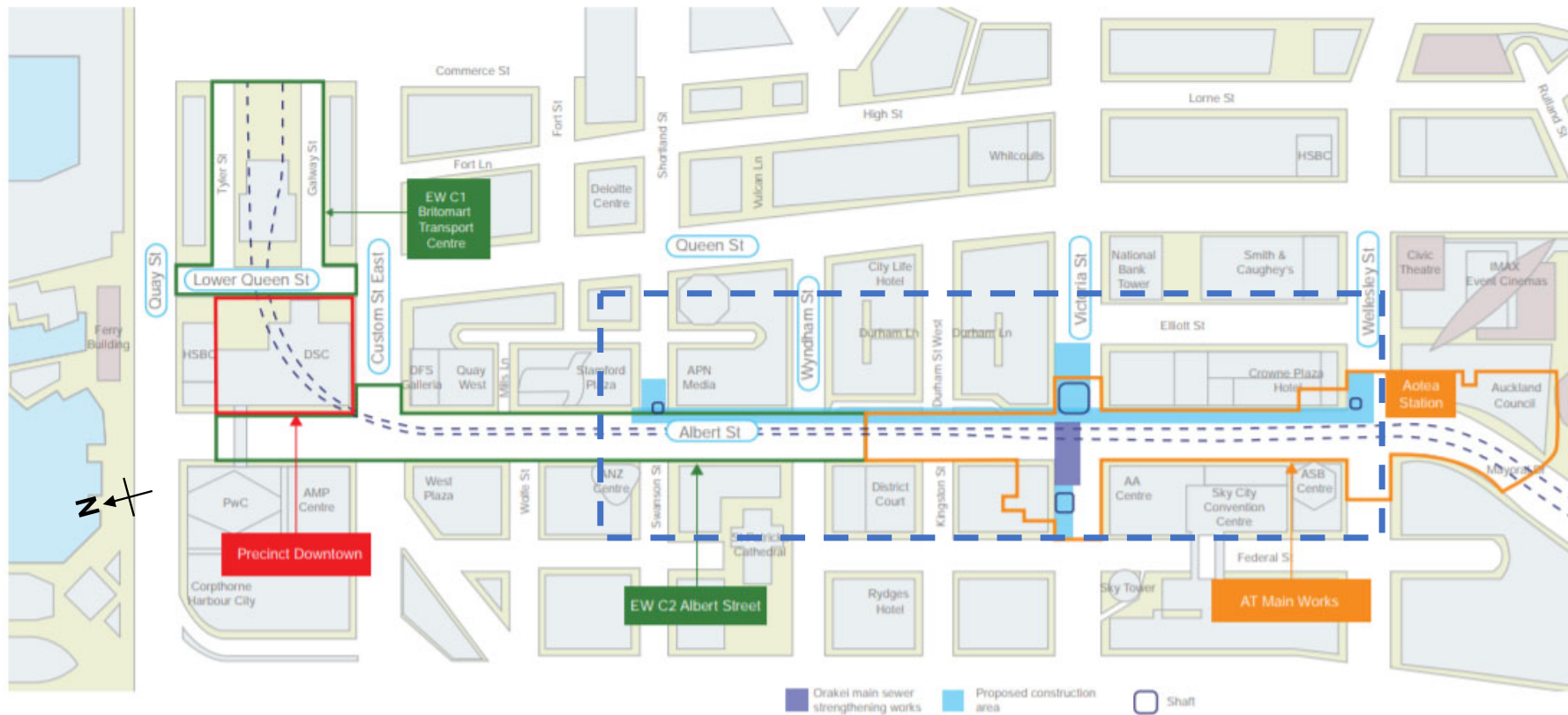
Total stations and prisms



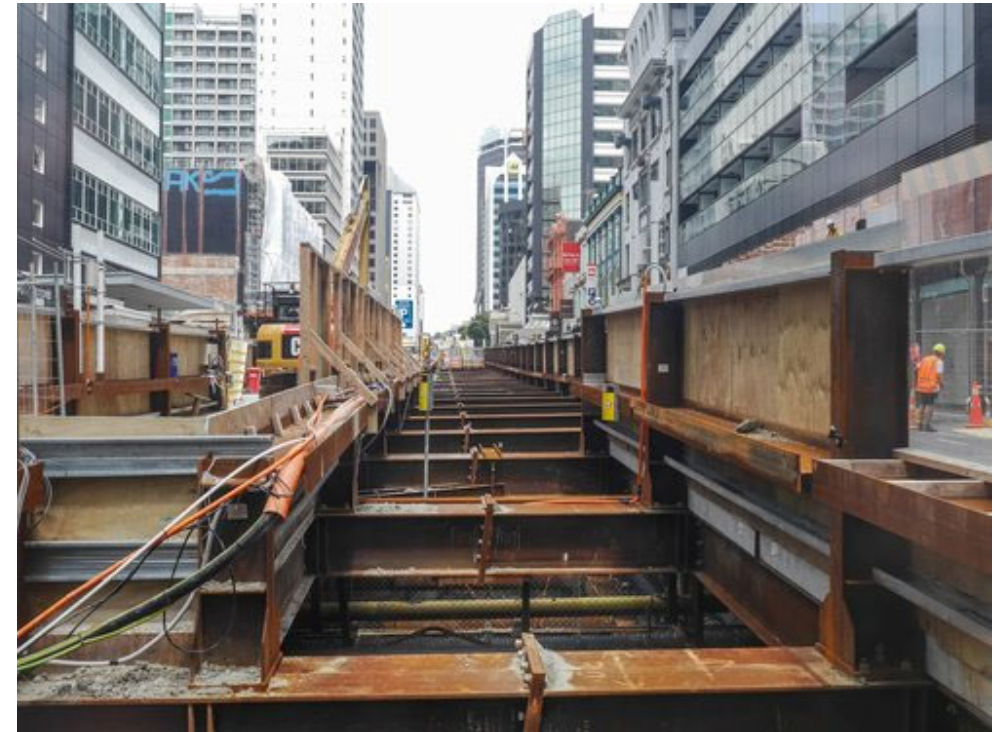
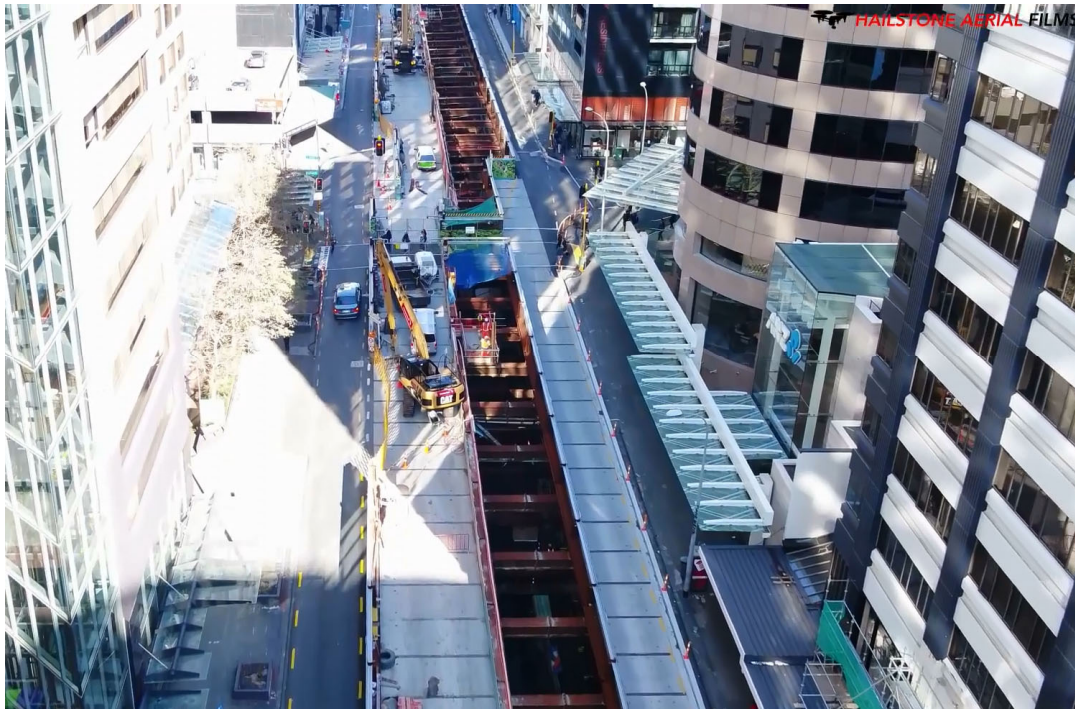
Total station (close-up)

CRL Contract 2 – Albert Street

- **Cut-and-cover tunnel** along Albert Street, with diversion of water mains



CRL Contract 2 – Cut-and-cover tunnel construction site

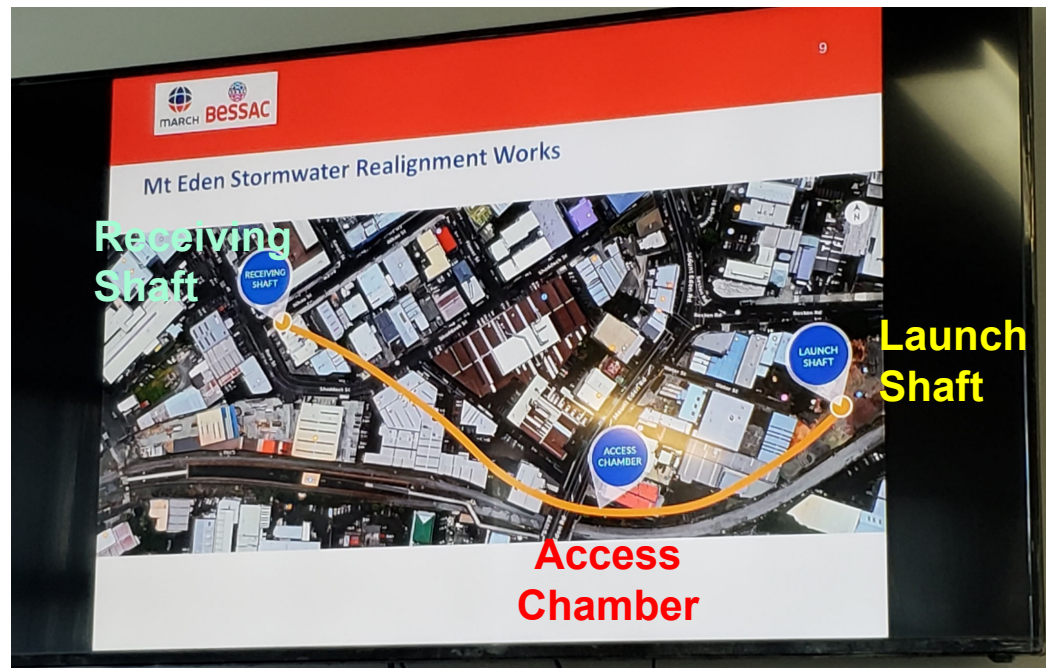


Excavation trench and lateral supports

Photos from CRL Website

CRL Contract 6 – Mount Eden Station

- Realignment of stormwater pipe for the Mount Eden Station redevelopment using **micro-TBM with pipe jacking** (420 m)
- **Sinking caisson in hard basalt** with drill-and-break techniques (Receiving shaft)



Initial design

Three shafts + 2 TBM runs in between shafts

Alternative design

Two shafts + single TBM run

Key feature

Largest bend in micro-TBM tunneling

Cost saving

Eliminated one shaft

CRL Contract 6 – Micro-TBM



Safety measures during maintenance

- Life vest
- Oxygen supply
- Gas monitor
- Emergency phone

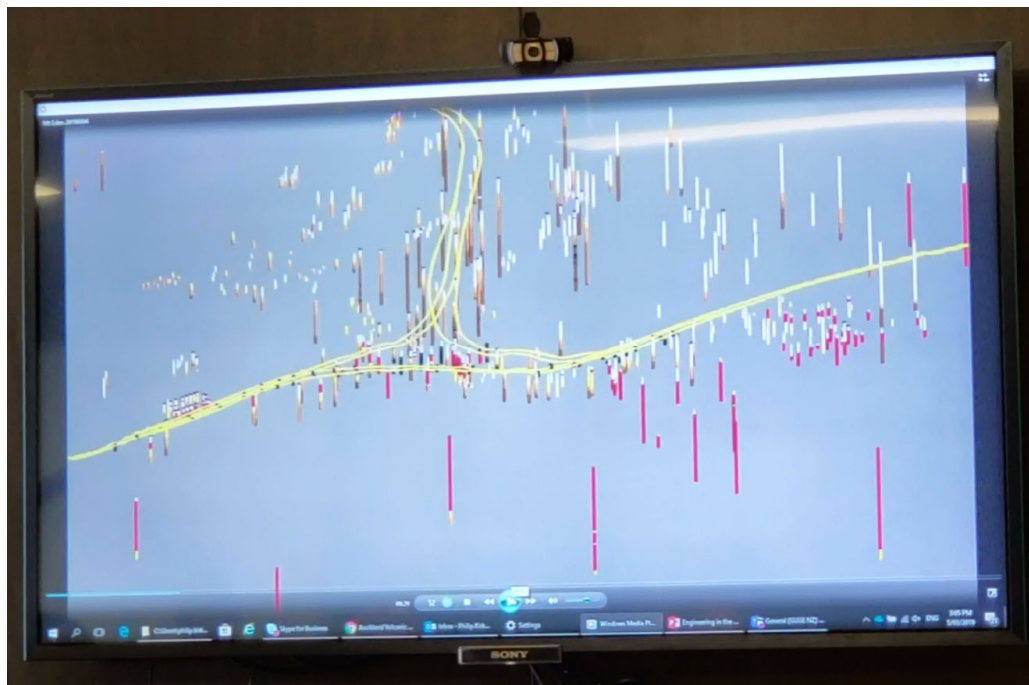
Photos taken by us and from CRL website

CRL Contract 6 – Basalt of varying thickness encountered

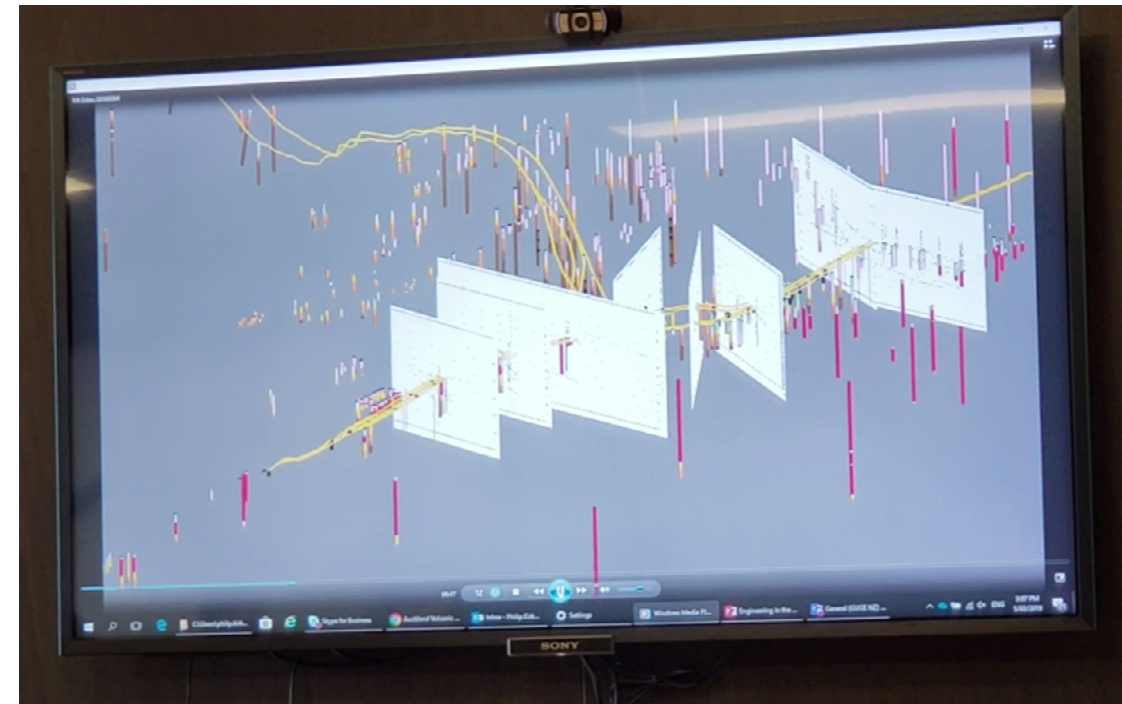


- Originally adopted blasting technique
- But not successful + risk of disturbing neighbourhood
- Adopted alternative caisson sinking method with drill-and-break technique to break the thick basalt layer

CRL – 3D Geological Modelling by Aurecon

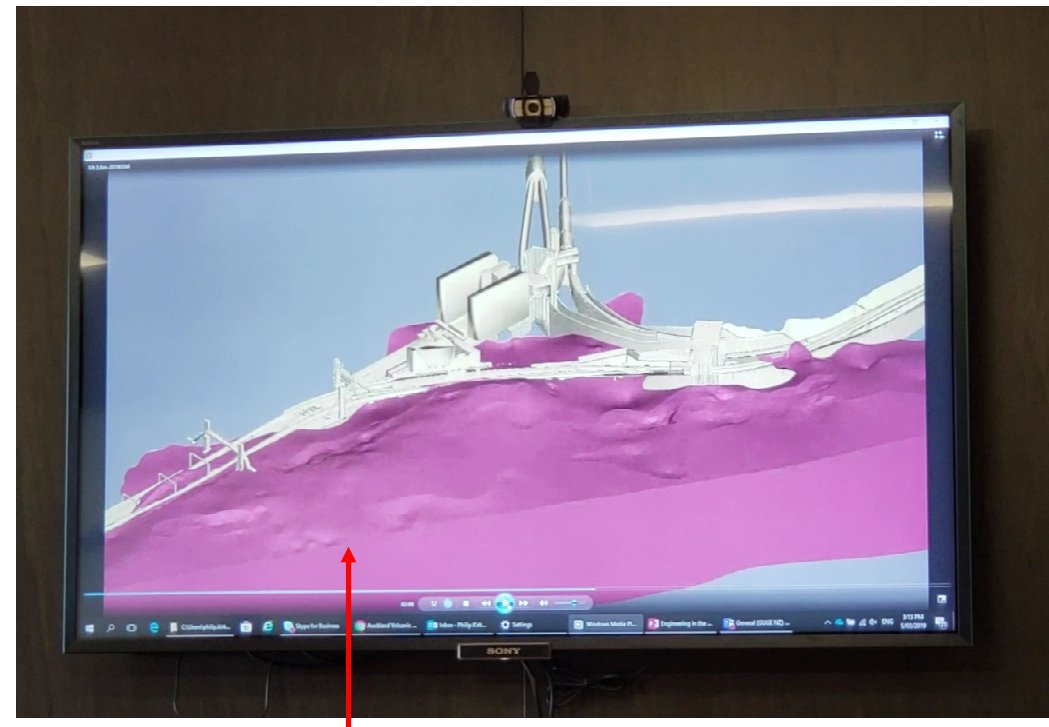
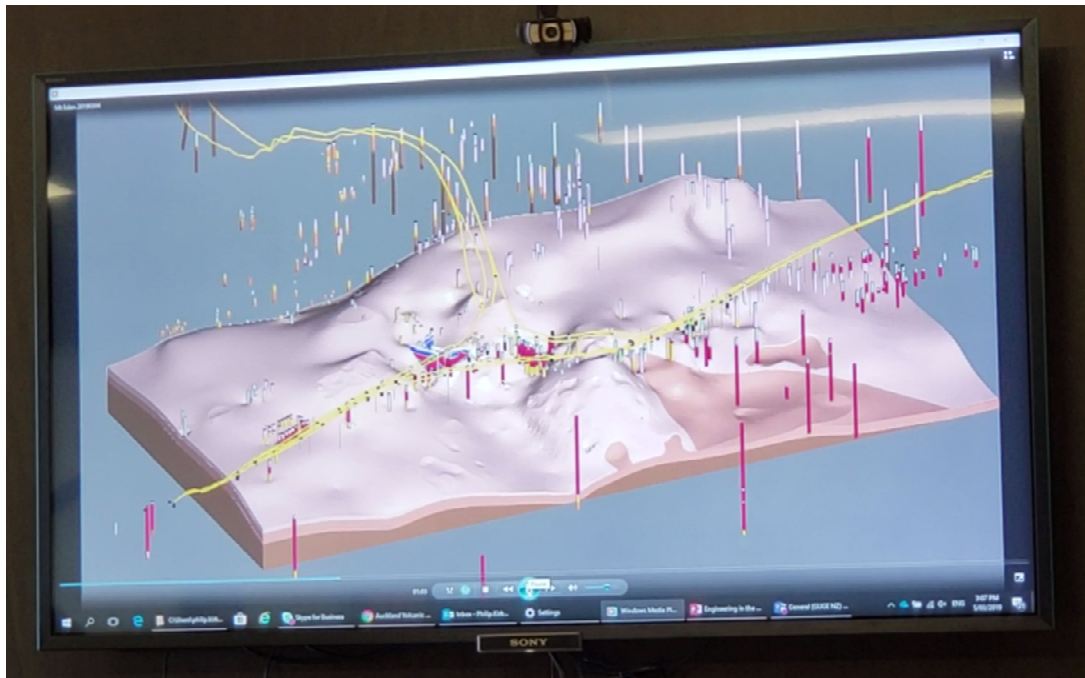


Using 3D geological model in CRL



Getting 2D geological sections from the 3D model

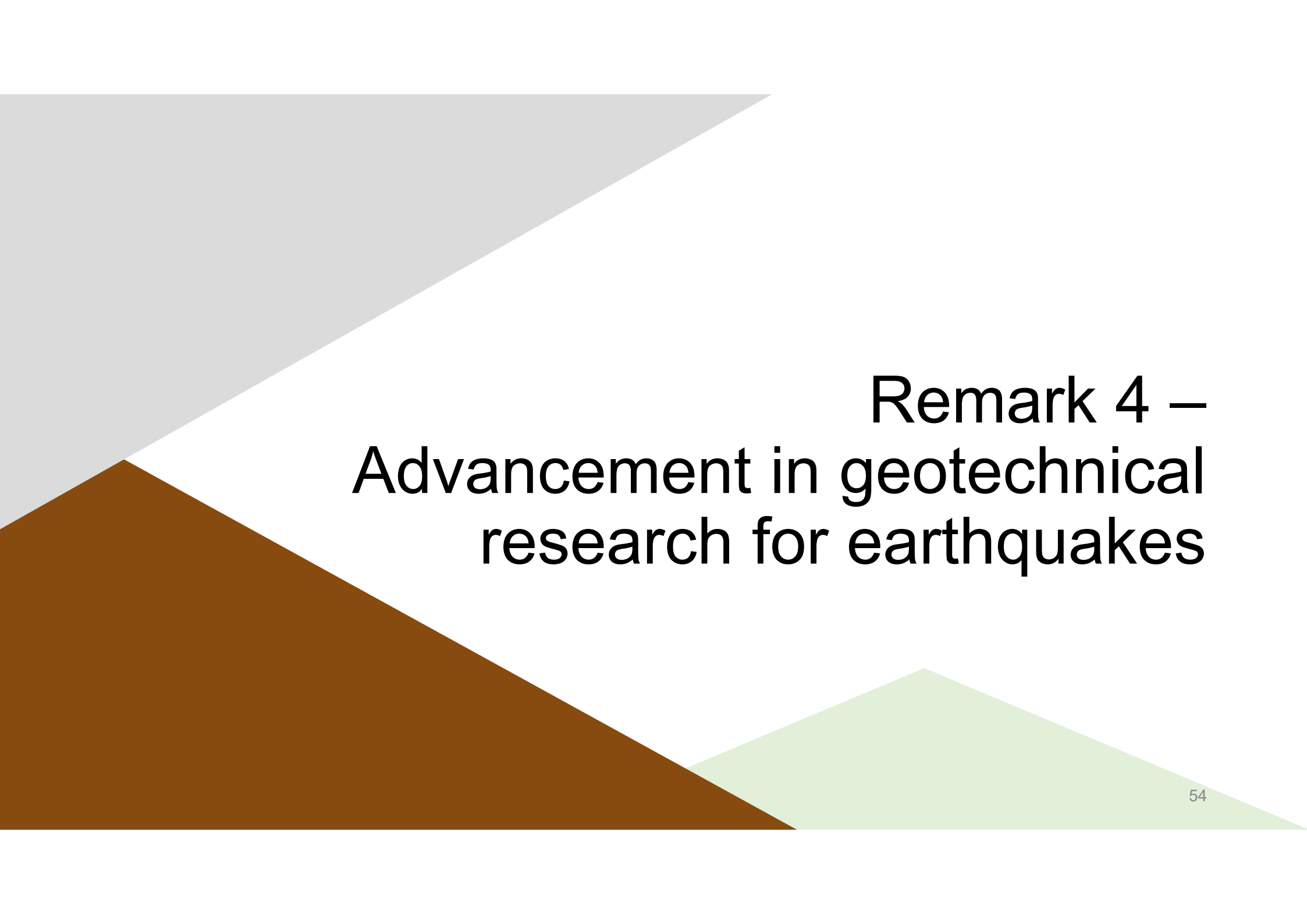
CRL – 3D Geological Modelling by Aurecon



Basalt layer with varying thickness

Key learnings in Remark 3

- ✓ Good **execution of works**
- ✓ **Innovation** when encountered **challenges**
- ✓ Very nice **housekeeping**
- ✓ Good **care for safety**
- ✓ **Harmony** with the public
- ✓ **Preservation** of an **historical** building



Remark 4 –
Advancement in geotechnical
research for earthquakes

Geotechnical Research Group of UC

UC Geotechnical Eng. Research Group

Core Members



Prof. Misko
Cubrinovski



Dr Gabriele
Chiaro



Dr Chris
McGann



Dr Mark
Stringer



Dr Xueyu
Geng

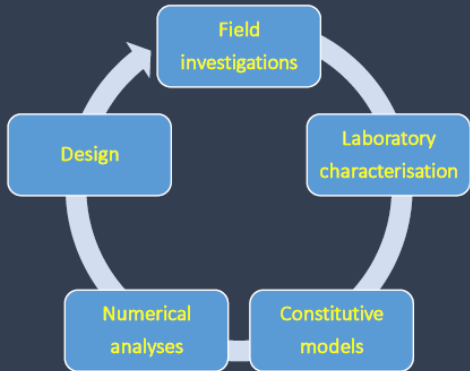
Associated Members



Prof. Brendon
Bradley



Dr Matthew
Hughes



UC Geotechnical Eng. Research Group

Technical Staff



Siale
Faitotonu

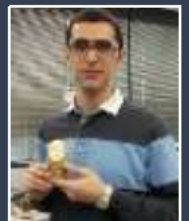


Dr Sean
Rees

Post-doc Researchers



Dr Maxime
Millen

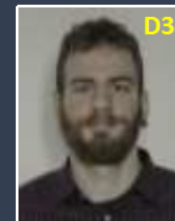


Dr Ali
Tasalloti

Postgraduate Students



Claudio
Cappellaro



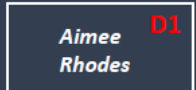
Nikolaos
Ntritsos



Ribu
Dhakal



Shaurya
Sood



Aimee
Rhodes



Kevin
Chew

Geotechnical Research Group of UC

- Duties and tasks including (not limited to):
 1. Earthquake reconnaissance
 2. In-situ investigation and testing
 3. Laboratory testing
 4. Close collaboration with the stakeholders and foreign researchers

Visiting the Red Zones



Away from the Red Zones – Redcliffs



Redcliffs – Volcanic cliffs with incipient instability



New Brighton – ‘Repaired’ bridge after the earthquake



New Brighton – ‘Repaired’ bridge after the earthquake



Horizontal cracks on the piers



Huge tensile crack
(size of > 600 mm)



Another persistent crack at a
pathway below the bridge deck

New Brighton – ‘Repaired’ bridge after the earthquake



Introducing new in-situ testing techniques

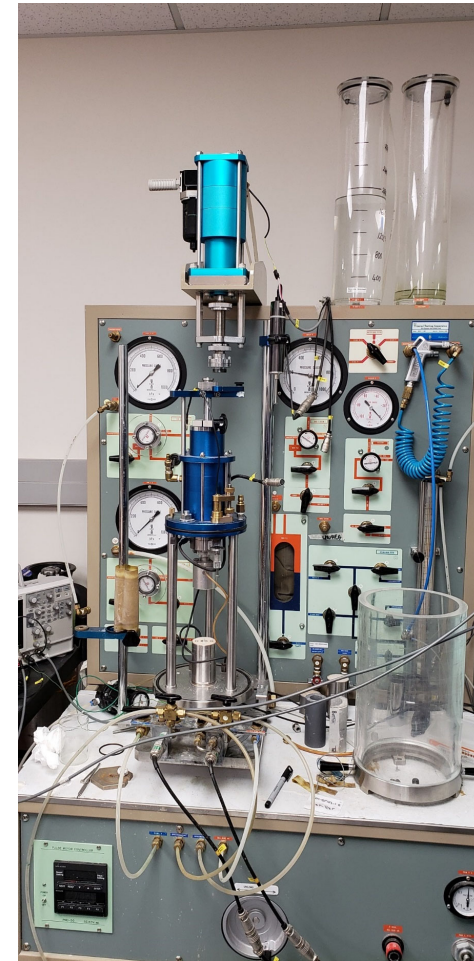
- For better understanding the **seismic liquefaction** of the silty, sandy, gravelly and volcanic soils in Christchurch and other parts of New Zealand, several in-situ testing techniques have been introduced:
 1. Dynamic Penetration Test (DPT)
 2. Gel-push Sampler
 3. Ground freezing

Advancement in laboratory testing

- Cyclic triaxial testing apparatus



- Torsional shear testing apparatus



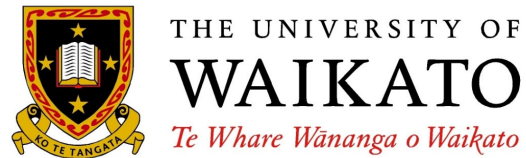
Industrial linkage (local consultancy firms)



Research supports (local and foreign)



Research collaborations



Teaching of laboratory testing



Key learnings in Remark 4

- ✓ Keenness in bringing in and **trying new** technologies
- ✓ Eagerness in **boosting** research and engineering development for handling the geotechnical **hazards**
- ✓ International and intra-national **collaborations**
- ✓ Nice environment for **nurturing young** geotechnical engineers and researchers at undergraduate level



Conclusion

Conclusion

- Wonderful experience of **learning**
- Wonderful natural **environment and people**
- Appreciation of how New Zealand's **geological and geotechnical context** affects engineering practice and research
- Appreciation of the nice **execution of design and construction works** and **alliance** among different engineering companies and government departments
- Appreciation of the **continuous development and application of digital technologies** in geotechnical engineering
 - ✓ 3D modelling
 - ✓ BIM
 - ✓ VR and AR
 - ✓ UAVs



Backup information

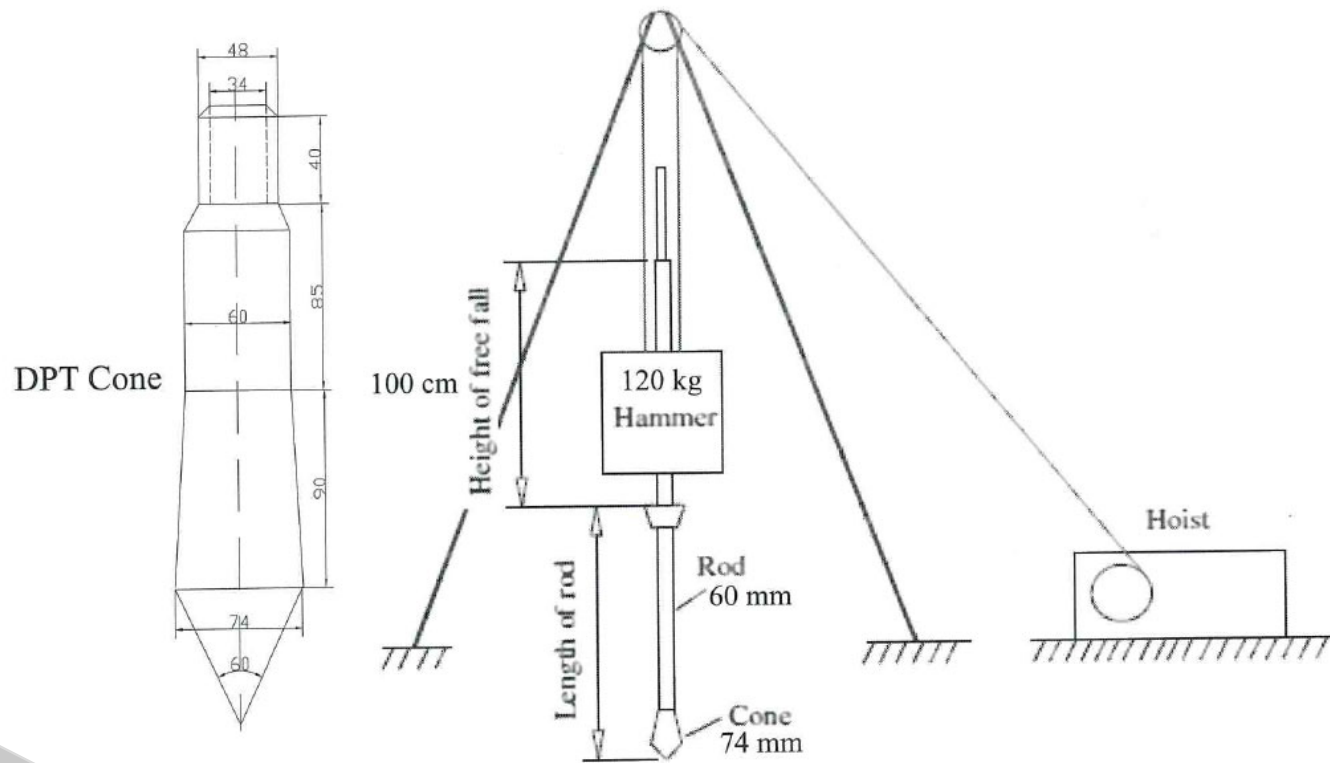
Introducing new in-situ testing techniques

• Dynamic Penetration Test (DPT)

- Combination of Standard Penetration Test (**dynamic**) and Cone Penetration Test (the cone **penetrometer**)
 - Symbolically
 - CPT is for softer soil (e.g. sediments)
 - SPT is for harder soil (e.g. soil from in-situ weathering)
- Developed in China for testing liquefaction resistance of gravelly soils
- Cheap, easy to use
- Famous for its use in 2008 Wenchuan Earthquake

Introducing new in-situ testing techniques

- **Dynamic Penetration Test (DPT)**



(Cao et al., 2013)

Introducing new in-situ testing techniques

- **Gel-push sampler**

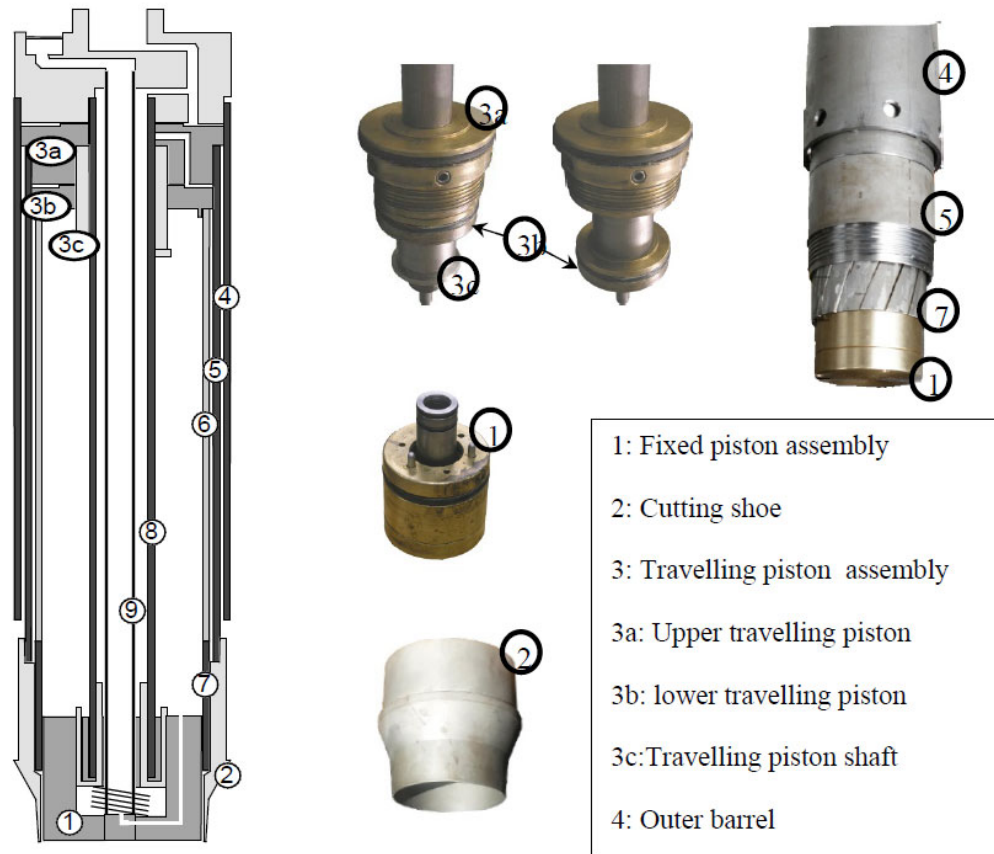
- Developed in Japan for sampling undisturbed gravelly sand samples
- 'Gel' = **a water-soluble polymeric lubricant**
- Sampler: Thin-walled sampler with a cutter shoe and catcher
- Type: fixed **piston** or **triple-tube core barrel** (rotary drilling)

Benefits:

- ✓ **Reduce** the *friction* between the sampler wall and the soil
- ✓ **Minimise** *contamination* of soil by the drilling fluid (the gel)

Introducing new in-situ testing techniques

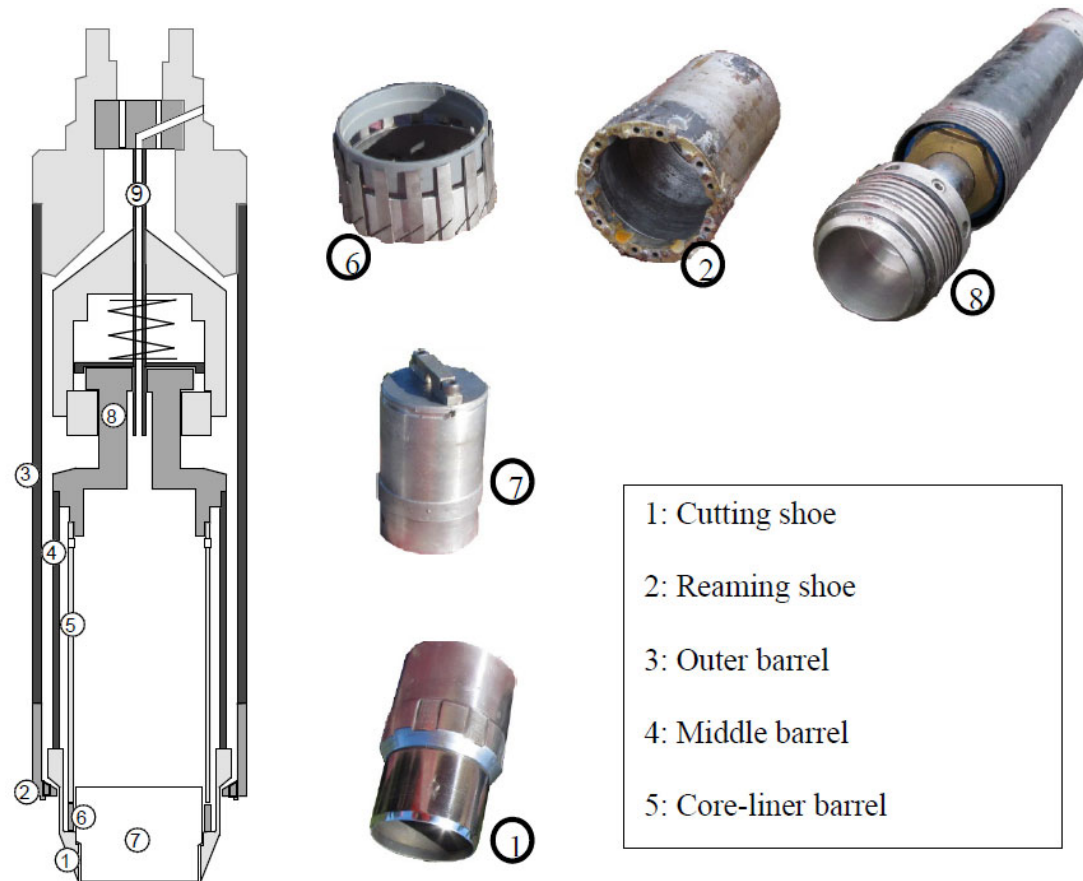
- Gel-push sampler (using a fixed **piston**)



(Stringer et al., 2015)

Introducing new in-situ testing techniques

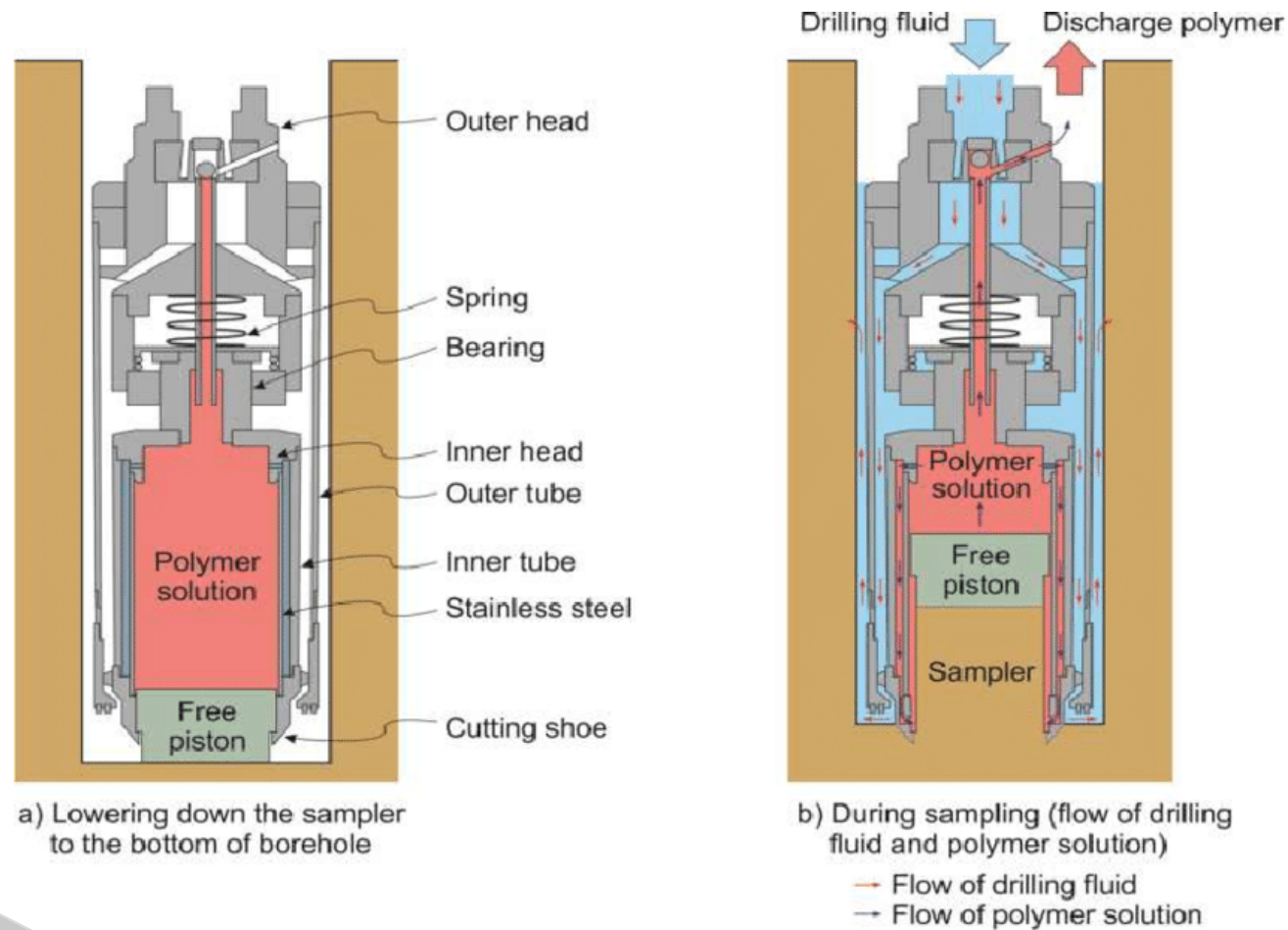
- Gel-push sampler (**triple-tube core barrel**, rotary type)



(Stringer et al., 2015)

Introducing new in-situ testing techniques

- Schematic sampling sequence using a gel-push sampler (rotary-type)



(Jamiolkowski and Masella, 2015)

Introducing new in-situ testing techniques

- **Ground freezing in undisturbed sampling**

- Traditional technique

- Two common types of freezing agent:

- **Liquid nitrogen**

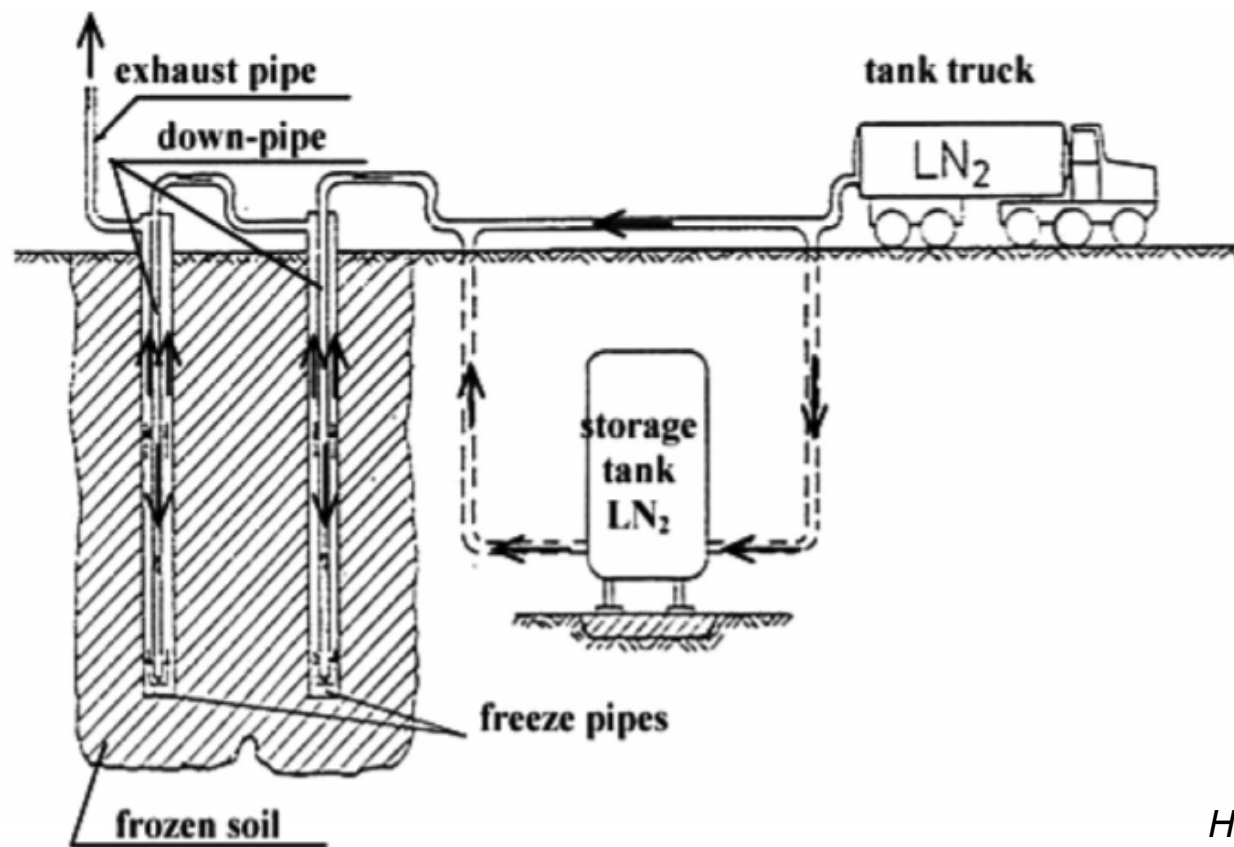
- **Brine** (salt water)

- Fundamental principle:

- Continuous heat exchange** (from the ground to the freezing agent)

Introducing new in-situ testing techniques

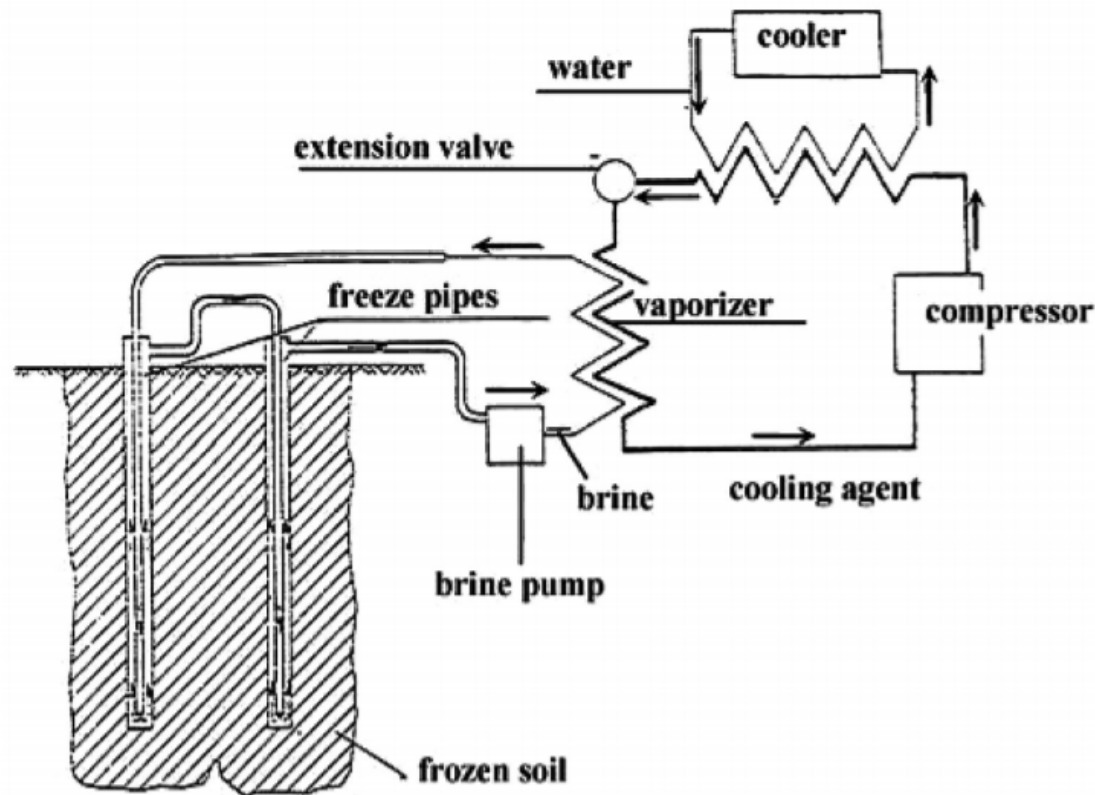
- Ground freezing in undisturbed sampling (using **liquid nitrogen**)



Haß and Schäfers, 2005)

Introducing new in-situ testing techniques

- Ground freezing in undisturbed sampling (using brine)



Haß and Schäfers, 2005)

Introducing new in-situ testing techniques

- **Ground freezing in undisturbed sampling**



Frozen soil sample



Installed freezing pipe (using liquid nitrogen)

(Kim et al., 2018)