QuakeCoRE Wellingtton Research Accomplishments 2022

David Johnston
on behalf of the QuakeCoRE community

10 November 2022

Centres of Research Excellence (CoRE)

*"To encourage the development of **excellent tertiary education-based research** that is **collaborative**, **strategically focused** and creates significant **knowledge transfer** activities."*
– Tertiary Education Commission

Bioprotection Aotearoa

Brain Research New Zealand – Rangahau Roro Aotearoa

Dodd-Walls Centre for Photonic and Quantum Technologies

Te Mana Tangata Whakawhanake – MacDiarmid Institute – Advanced Materials & Nanotechnology

Maurice Wilkins Centre for Molecular Biodiscovery

MedTech CMDT

Ngā Pae o te Māramatanga

Riddet Institute – Kōkiri – Te Hā o te Kai

Te Pūnaha Matatini – Complexity is at our heart

Research Programme

Technology Megatrend Capability Areas

coordination mechanism

- **TM1** Computational Science
- **TM2** Machine Learning
- **TM3** Sensing and Monitoring
- **TM4** Materials Science and Manufacturing

Disciplinary Themes

- **DT1** Integrated Seismic Geohazards
- **DT2** Whole-of-Building Seismic Performance
- **DT3** Law, Planning, Economics
- **DT4** Cultural and Social Factors Shaping Resilience
- **DT5** Mātauranga Māori and Earthquake Resilience

Inter-disciplinary Programmes

- **IP1** Functional Recovery with Repairable Multi-storey Buildings
- **IP2** Thriving Residential Communities
- **IP3** A Resilient Aotearoa New Zealand Transport System
- **IP4** Harnessing Disruptive Technologies for Earthquake Resilience

Regional Network Areas

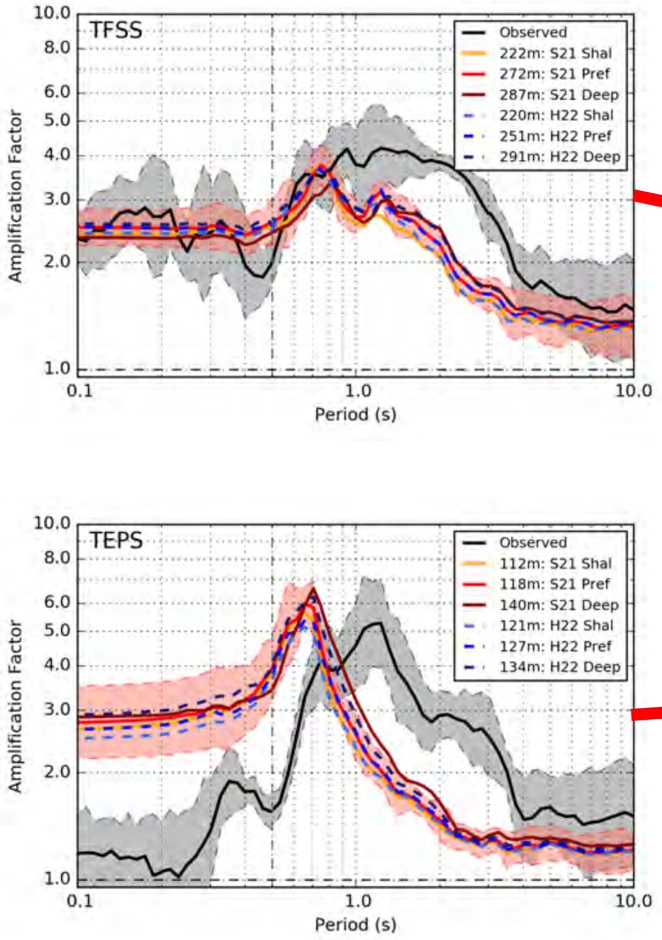
coordination mechanism

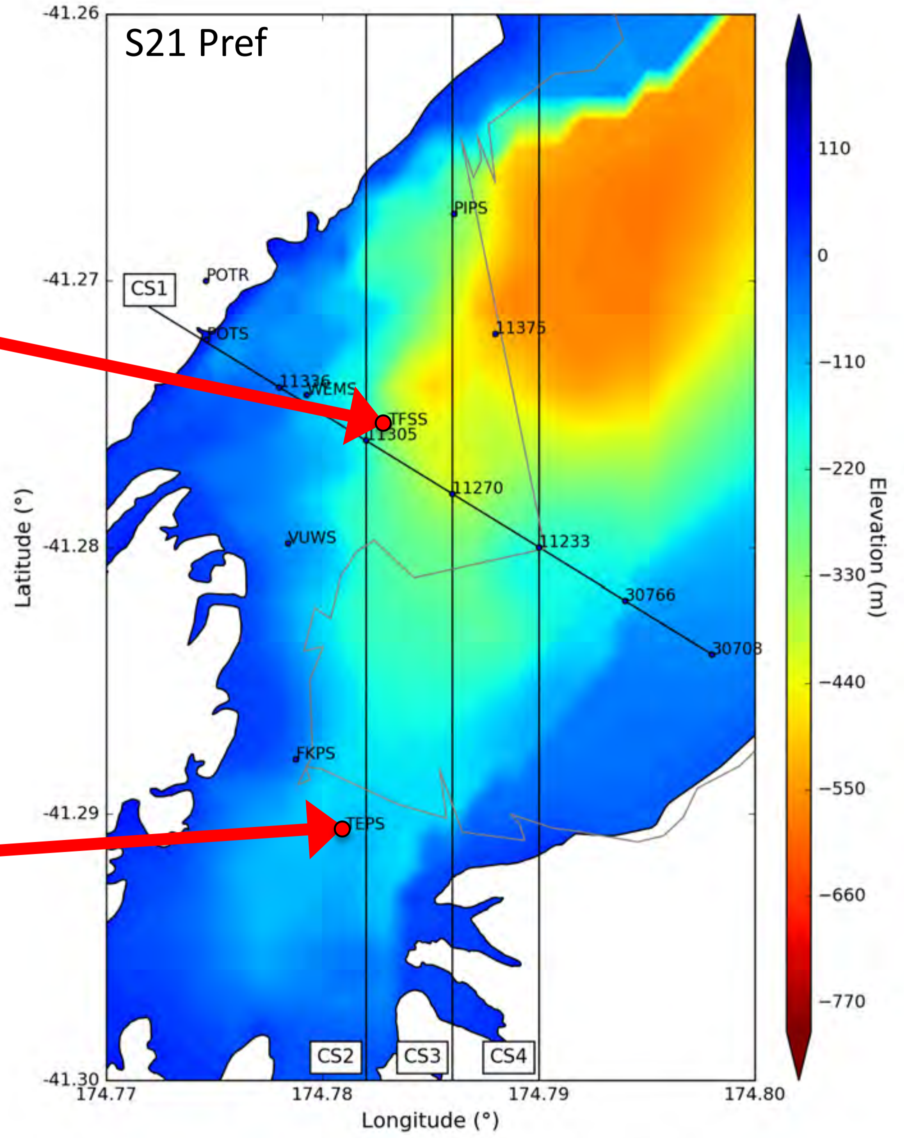
- **RN1** Alpine Fault *South Island-wide*
- **RN2** Wellington
- **RN3** Hikurangi subduction zone *North Island-wide*
- **RN4** Auckland
- **RN5** South Pacific

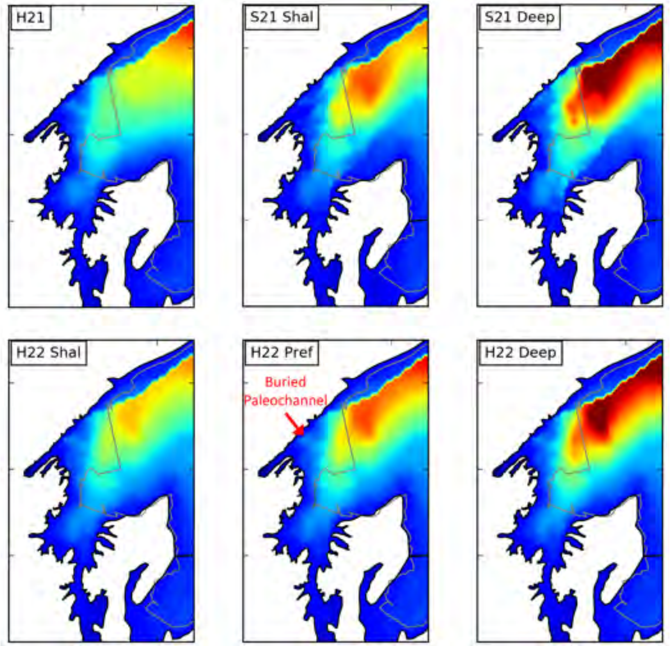
3D Ground Motion Simulation-based Site Amplification Considering Multiple Basin Geometries: A Wellington Case Study

Lee et al.

Spectral Site Amplification







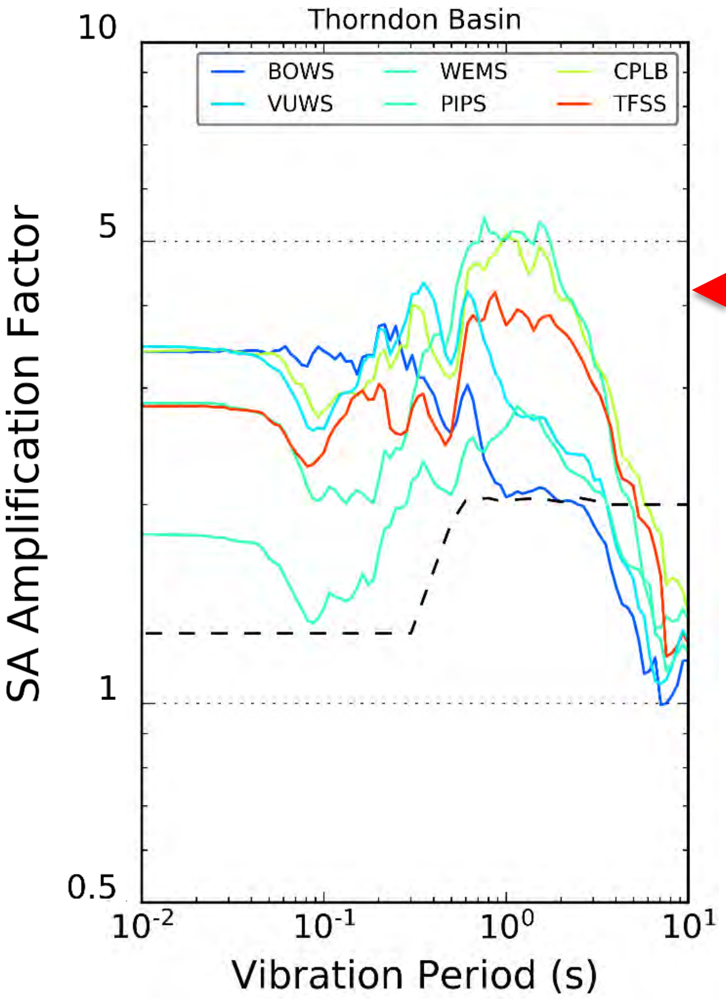
Accomplishments

1. Seven Wellington Basin Models. ✓
2. Six earthquakes M_w 5.5-6.6. ✓
3. High spatial resolution simulations (50m). ✓
4. Comparison of simulated and observed site amplification highlighting key causal features. ✓

How will the Wellington basin amplify ground motions for strong earthquakes?

de la Torre et al.

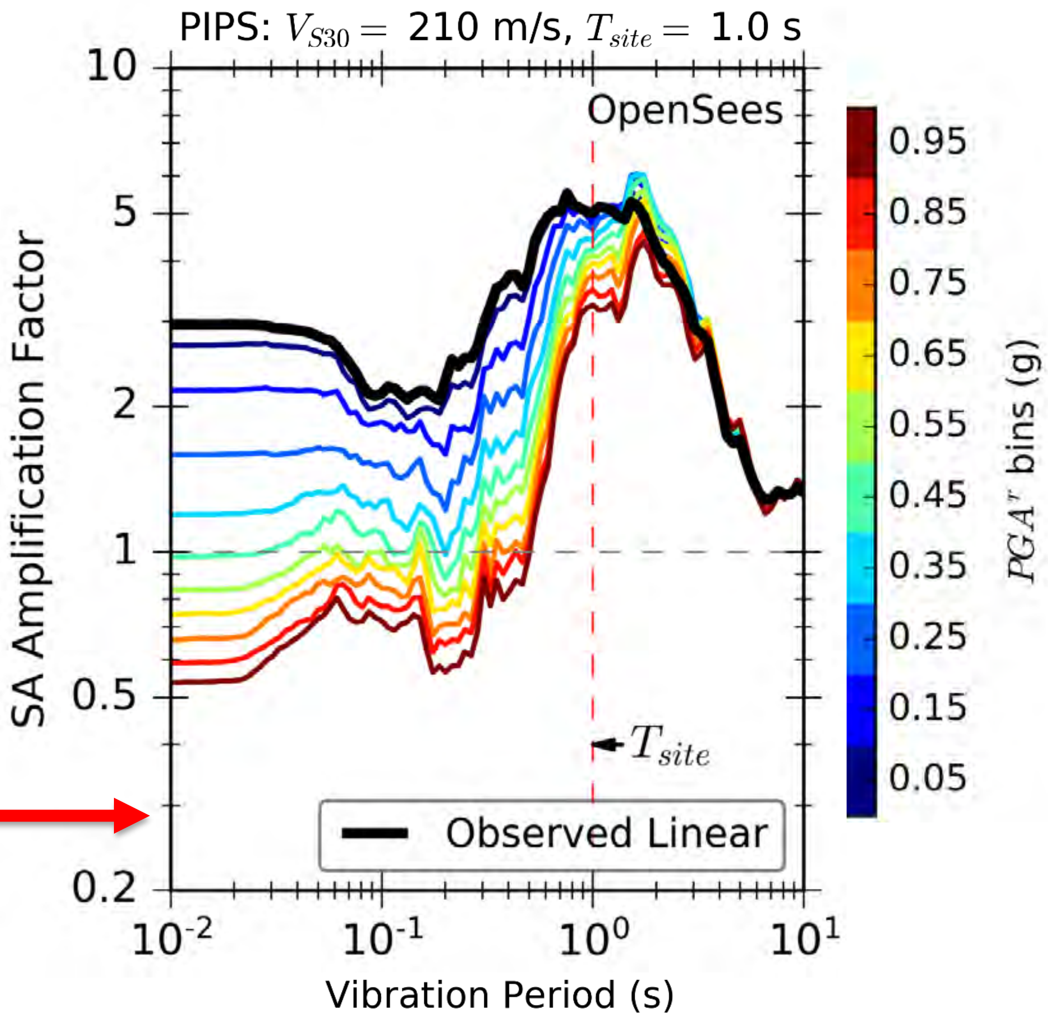
Observations
(6 sites)



- Strong basin amplification recorded in Wellington (e.g., Thorndon Basin).
- Only for weak to moderate ground motions.

- Combine with analyses to predict effects of soil nonlinearity under strong shaking.

Observations + Analyses
(1 site)



Simulation validation for small magnitude subduction earthquakes

Dupuis et al.

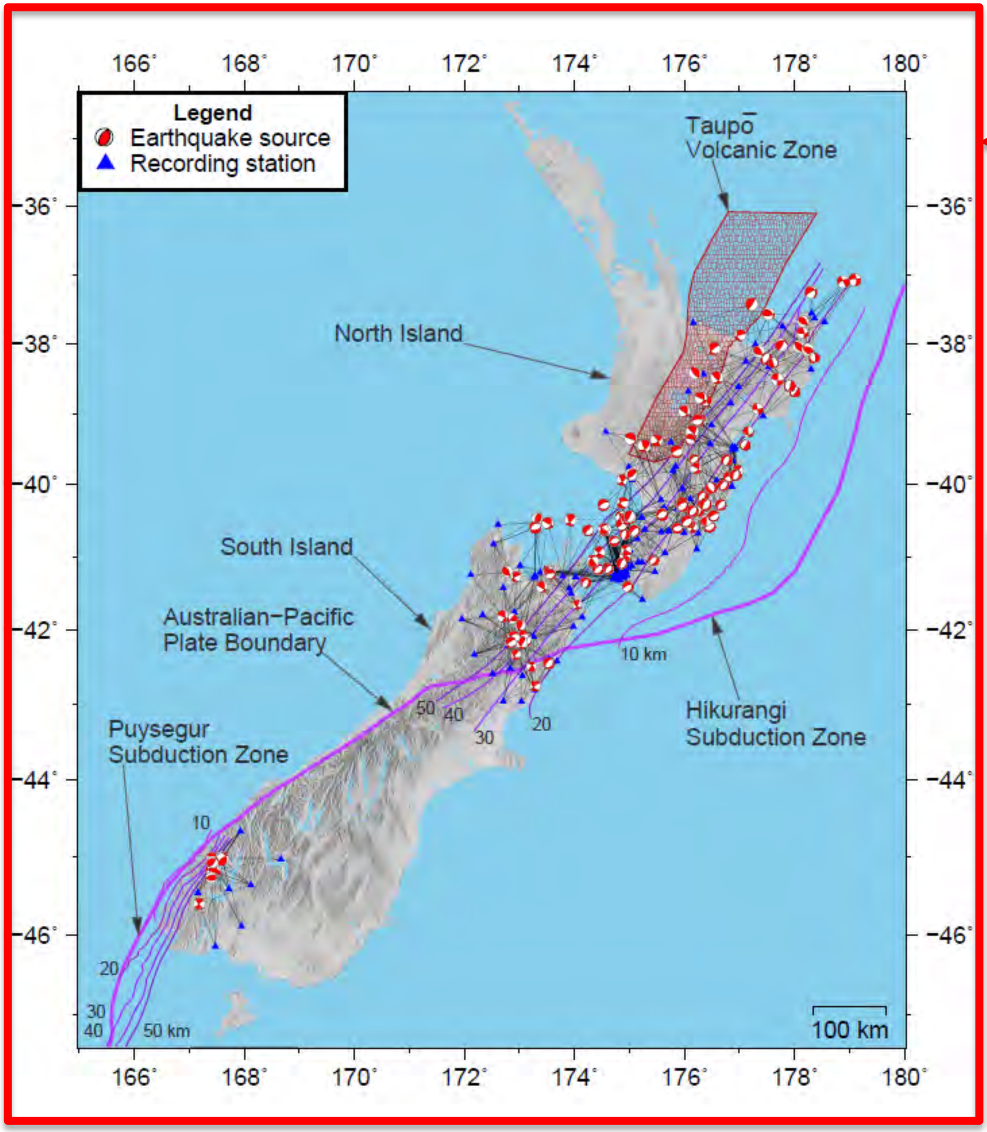
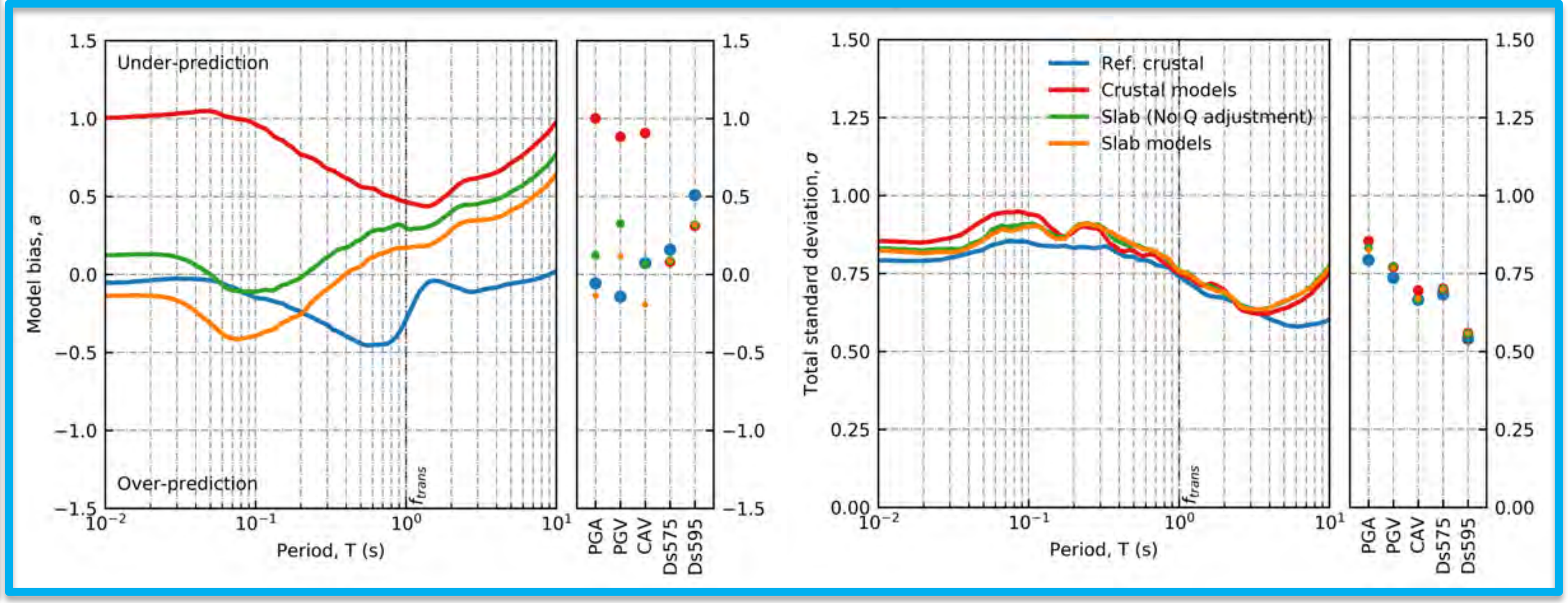


Table 1: Summary of high-quality observed ground-motion data used for validation

	Interface			Slab			
	Hikurangi	Puysegur	Total	Hikurangi	Puysegur	Total	Crustal[a]
Events	44	0	44	111	8	119	496
Sites	43	0	43	124	7	131	382
Records	269	0	269	957	33	990	5218

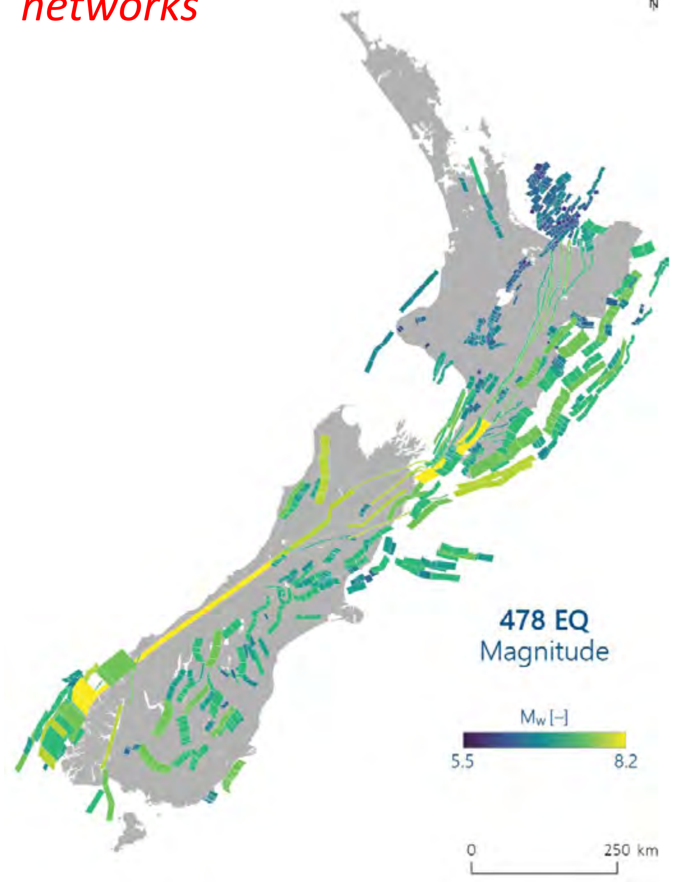
[a] Reference crustal ground-motion predictions by Lee et al. (2020b)



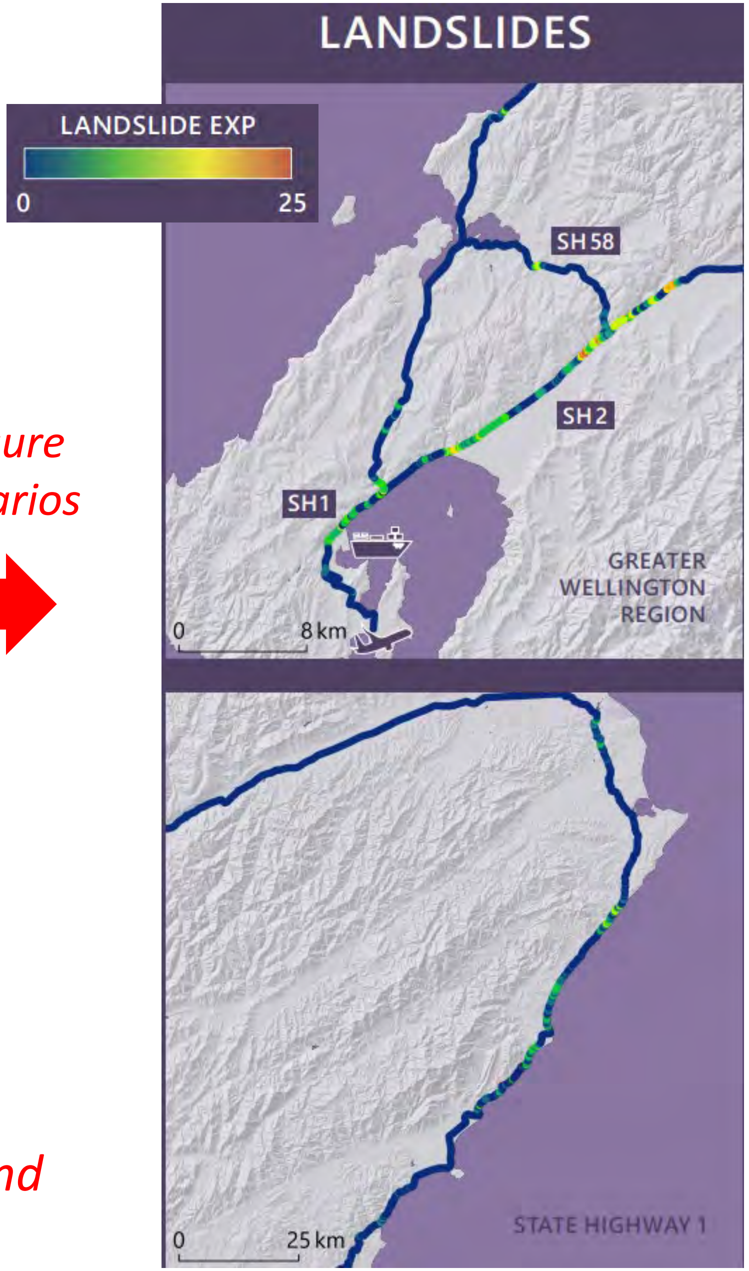
Geospatial Hazard Exposure

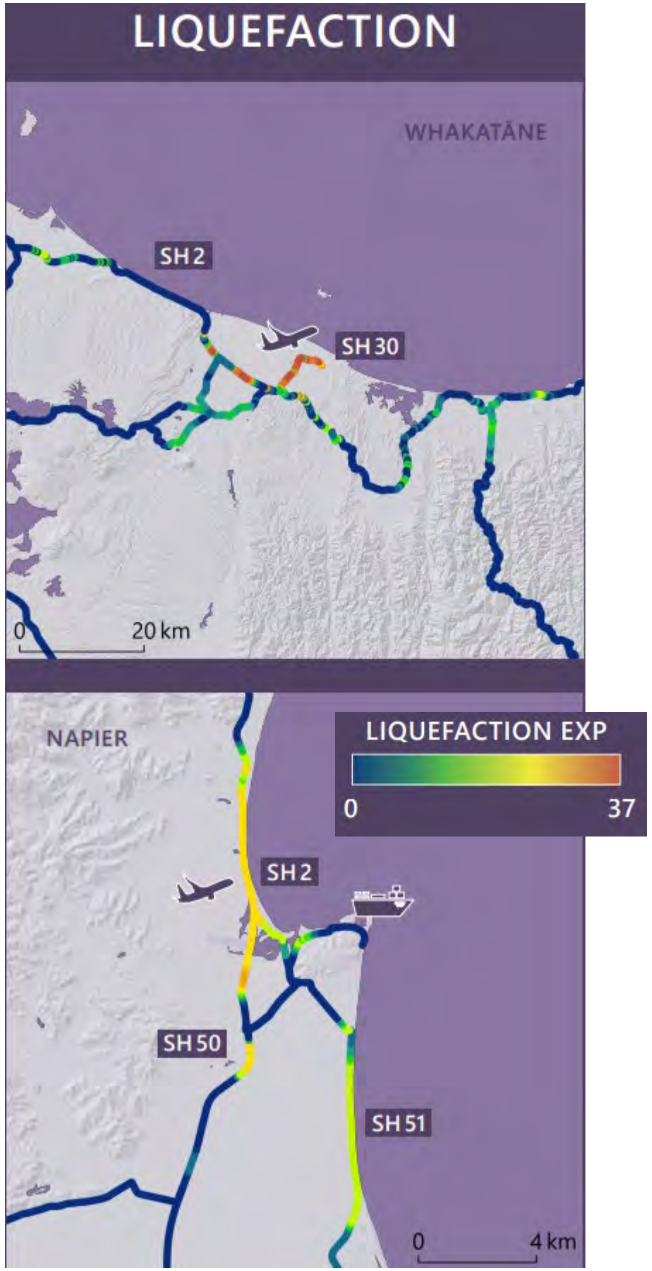
Lin et al. Poster #96

Development of approaches to link geospatial co-seismic hazard models to infrastructure networks



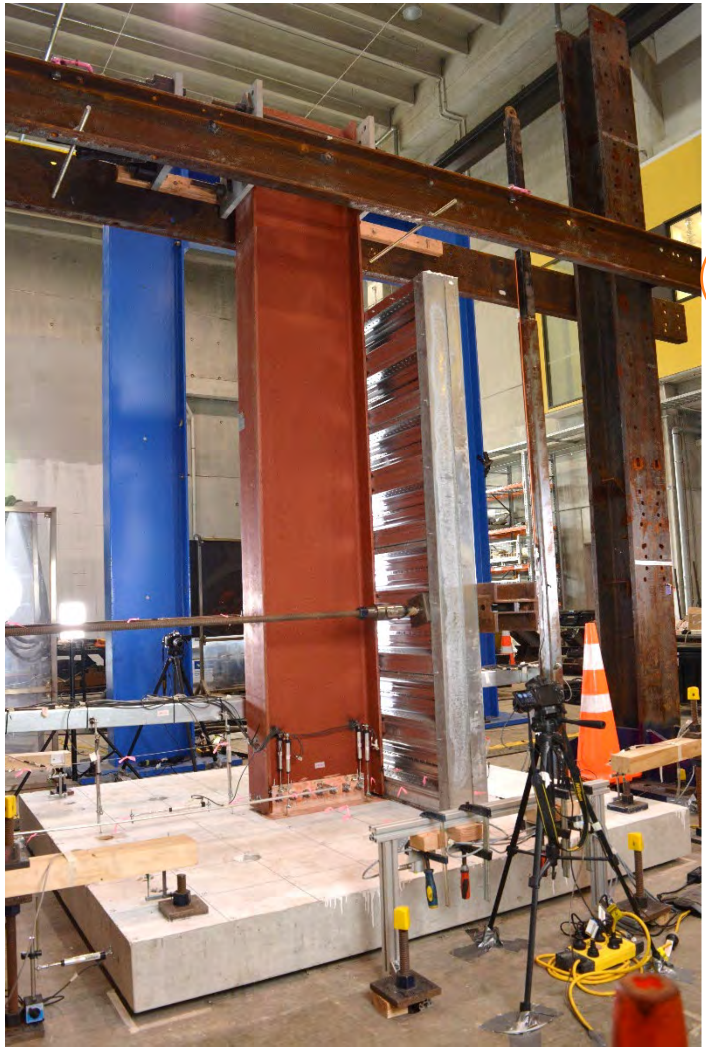
Combine exposure across all scenarios

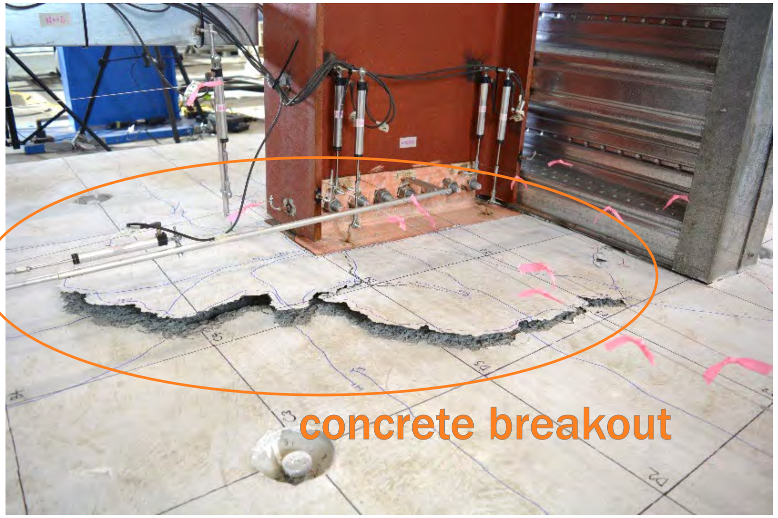




Result: *Highlight exposed routes for scenarios and cumulative exposure across multiple scenarios*

Seismic performance of concrete wall-steel frame buildings





Tests of beam-to-wall connections:

- ➢ Assess rotational capacity and failure mode
- ➢ Four tests with different connection detailing

Although the connection was designed for ductile failure, it failed in a brittle manner by CONCRETE BREAKOUT.

Next steps:

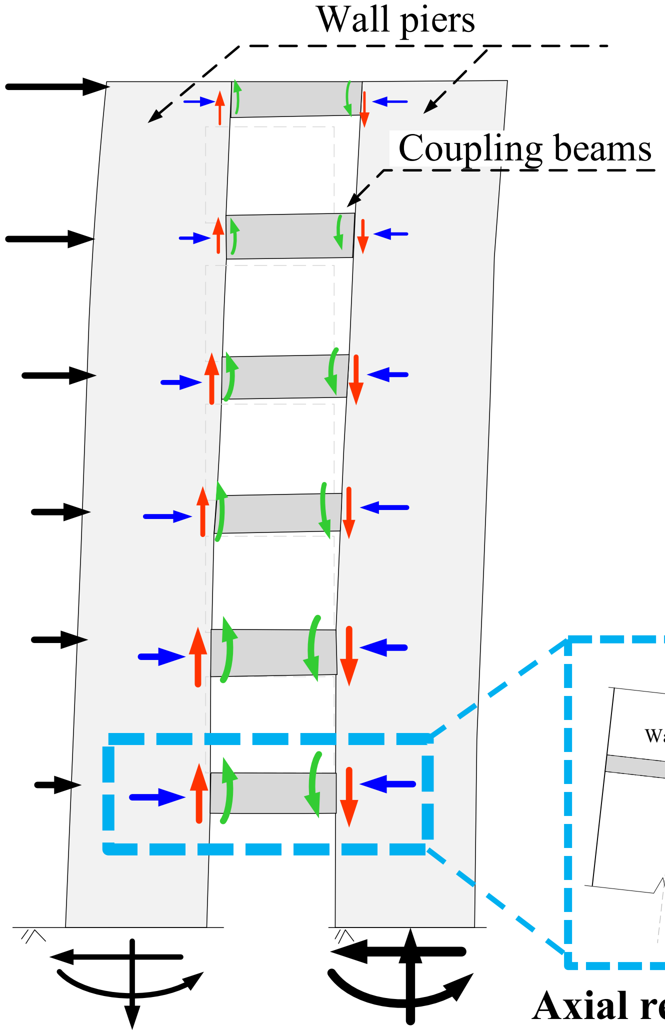
- ❑ Data analysis (ongoing)
- ❑ Numerical modelling (ongoing)
- ❑ Developing design procedure

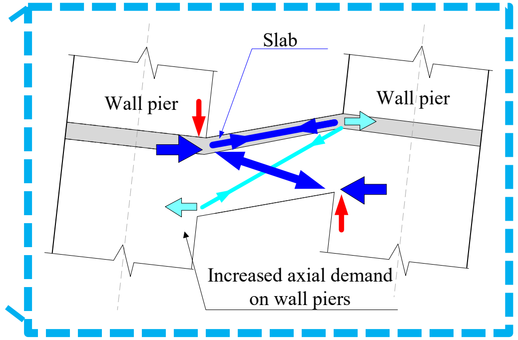
Tsai *et al.* Poster #38

System response of reinforced concrete coupled walls

Coupled wall system

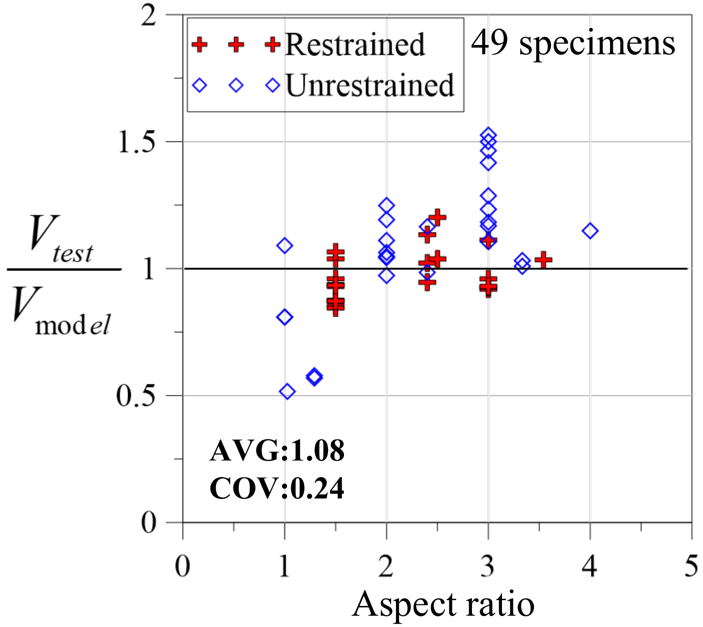
- Influence of axial restraint
- Interactions between components

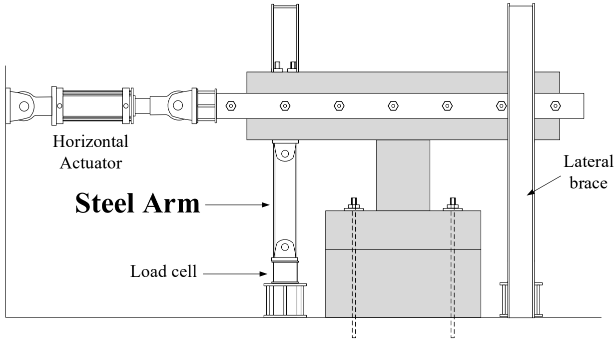




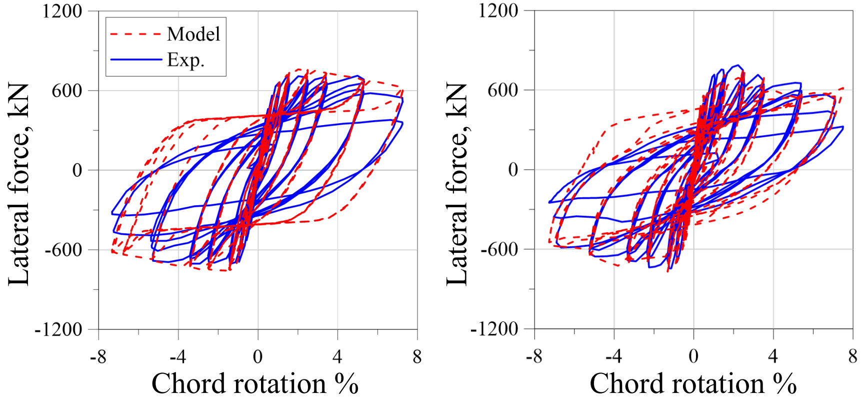
Axial restraint on coupling beams.

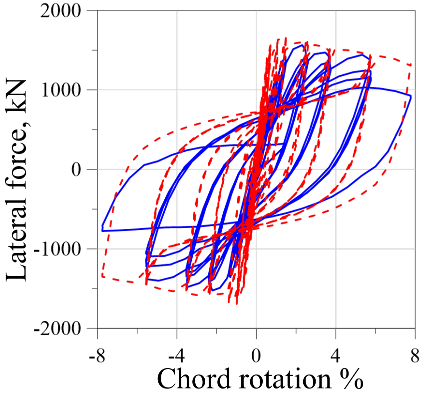
Database developed for tests of diagonally reinforced coupling beams

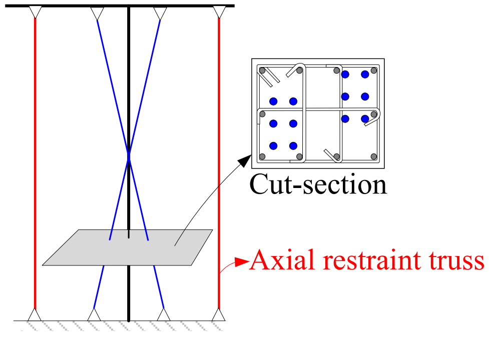




Previous test with axial restraint (Cheng, et al. 2019)







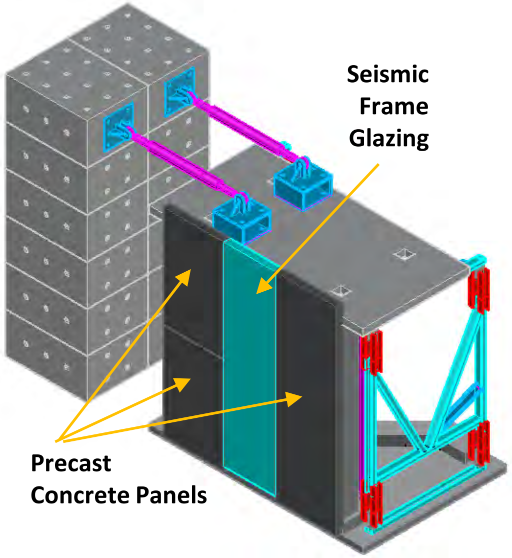
Coupling beam model.

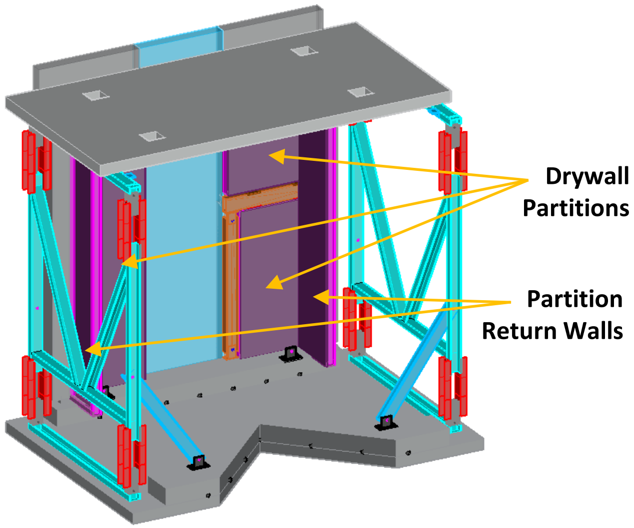
Validation of proposed numerical model

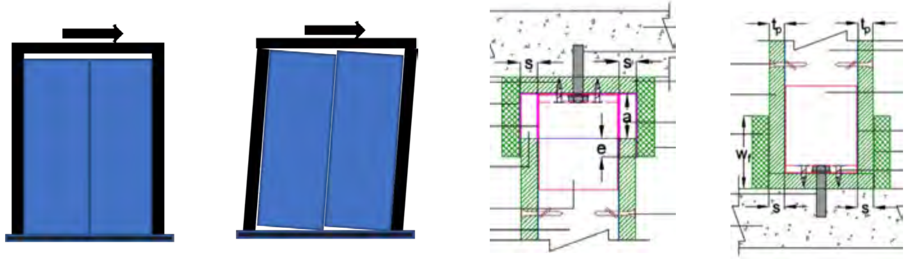
Clement *et al.*

Drift-Sensitive Non-Structural Elements (NSE) Interaction Testing

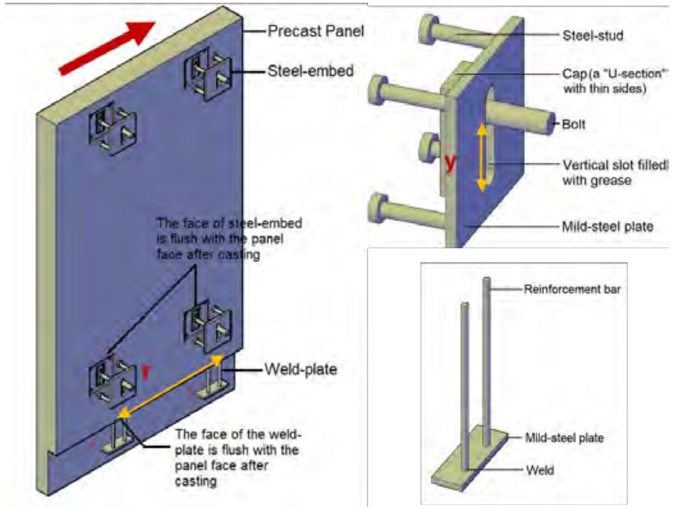
Water-tightness and seismic performance testing of low-damage drift-sensitive NSEs



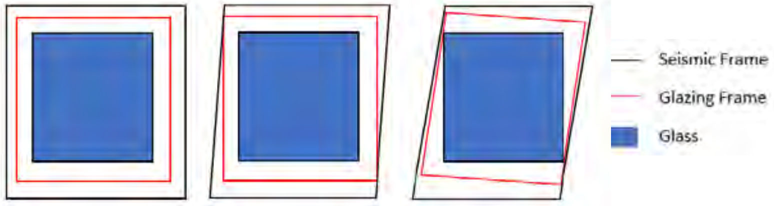




Dual-slot track (DST) for rocking partition walls (Bhatta et al., 2022)



Rocking precast concrete panels (Bhatta et al., 2020)



Seismic frame curtain wall glazing (Arifin et al., 2020)

Component	Length (mm)	Width (mm)	Depth (mm)
Precast Concrete Panel 1 (Top-Left)	1993mm	1200mm	120mm
Precast Concrete Panel 1 (Bottom-Left)	1935mm	1200mm	120mm
Precast Concrete Panel 1 (Right)	3902mm	1200mm	120mm
Seismic Frame Glazing	3820mm	1000mm	120mm
Plasterboard Partition Wall 1 (Top-Left)	1425mm	950mm	104mm (13mm board and 91mm studs)
Plasterboard Partition Wall 2 (Bottom-Left)	1640mm	800mm	104mm
Plasterboard Partition Wall 3 (Right)	3290mm	1000mm	104mm
Partition Return Walls	3310mm	600mm	117mm (two 13mm boards)

Note: The widths of the horizontal sealant joints between the two half-height panels, and the vertical joints between the partitions and the return walls, are 20mm and 6mm, respectively.

Project Team:
Research Student (ME): Robert Clement
Main Supervisor: Rajesh Dhakal
Other Supervisors: Giovanni de Francesco, Muhammad Rashid, Mayank Tripathi and Tim Sullivan

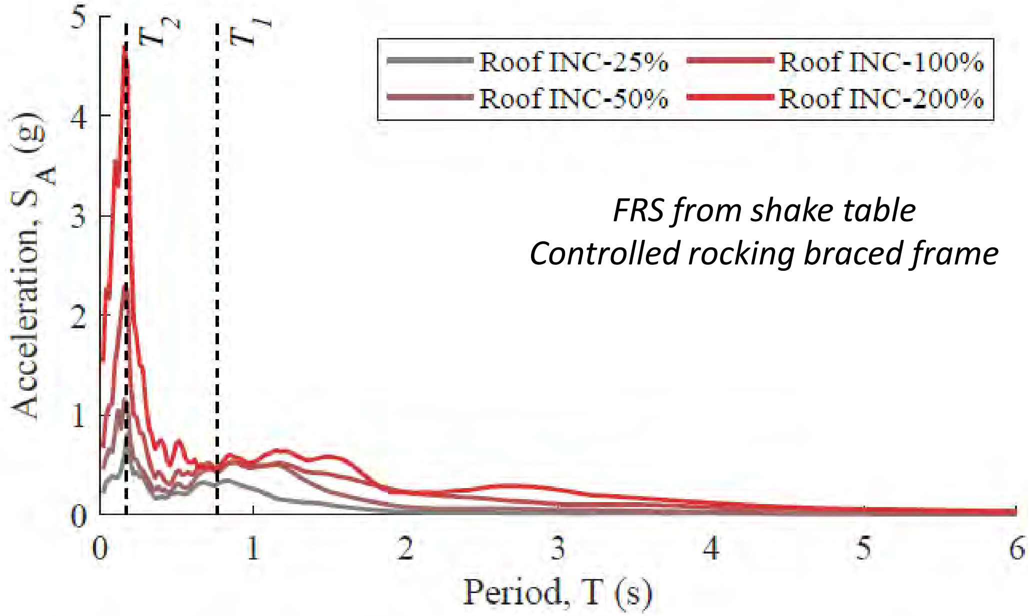
Floor Response Spectra in Buildings with Low Damage Technologies

Haymes et al. Poster #73

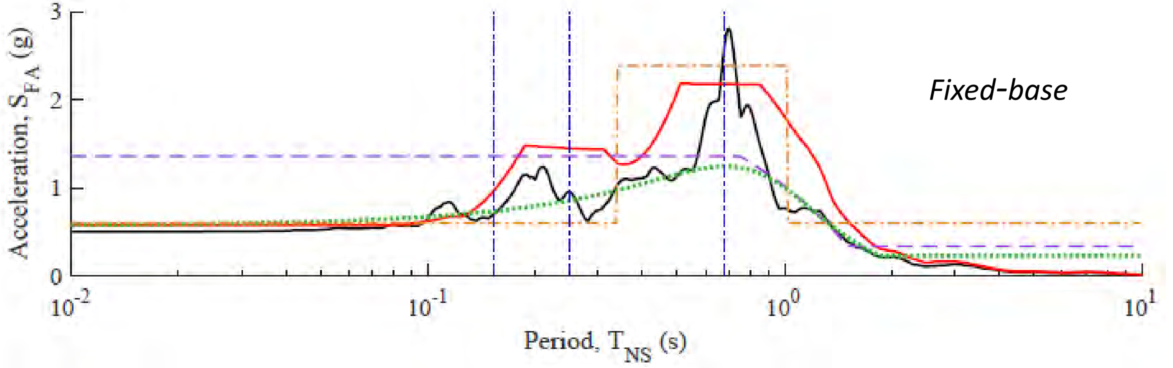
Seismic damage to non-structural elements can be expensive to repair, and can prevent serviceability.

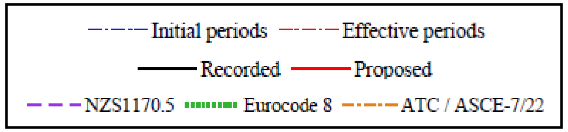
Examined the acceleration demands on non-structural elements in buildings with novel high performance lateral load resisting systems using floor response spectra.

Expected behaviours were inferred from numerical and shake table tests conducted internationally. Prediction provisions were developed and trialled.

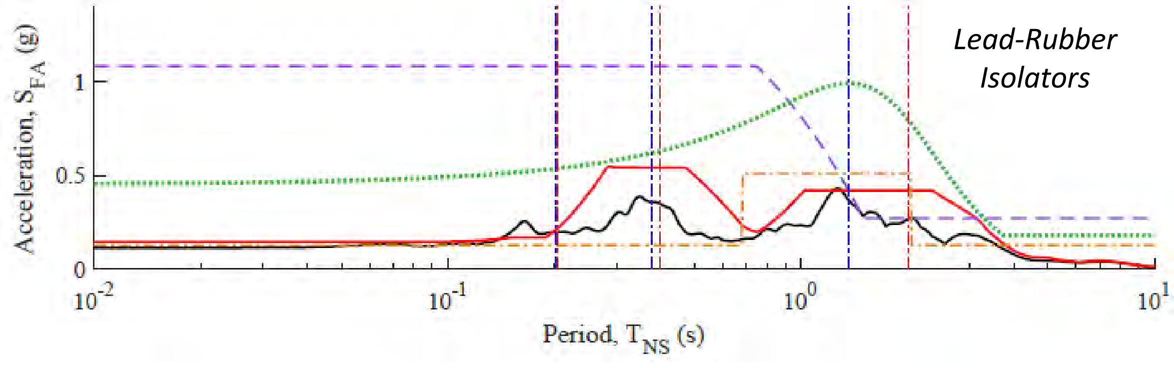


Trialled the application of a modal prediction method for numerical models and shake table test results





Predictions of FRS from EDefense shake table tests

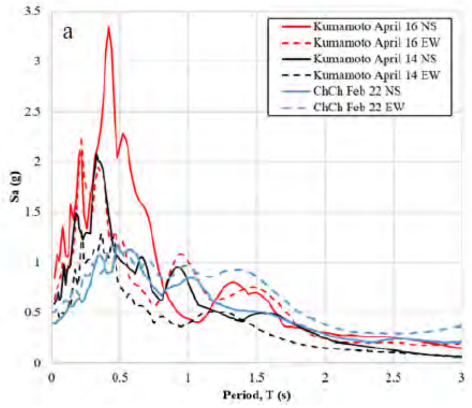


Pledger et al.
Poster #25

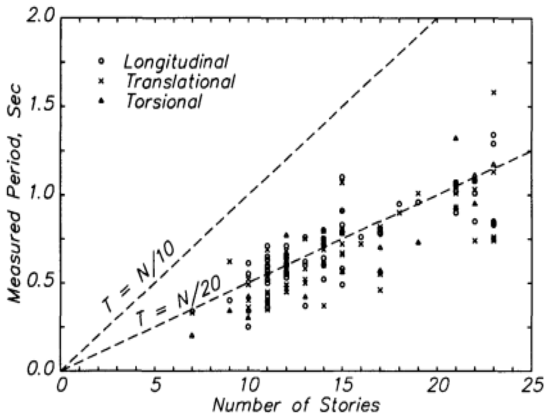
Mitigating seismic loss by increasing structural stiffness

Motivation

- Reconnaissance efforts from past earthquakes in Chile and Japan have identified minimal damage.
- Design philosophy in these countries leads to stiffer buildings.



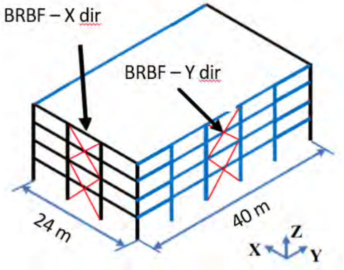
Comparison of the Kumamoto earthquakes response to the Christchurch 2011 earthquake



Measured periods of buildings in Vina Del Mar (Chile)

Methodology

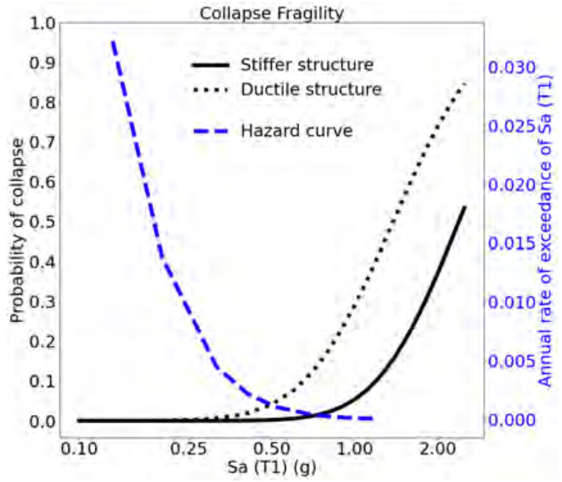
- Buildings will be designed to different drift limits to evaluate the influence of stiffness on seismic performance
- For this preliminary study, two BRBF models were developed and non-linear time history analyses were conducted to compute seismic loss and collapse risk.

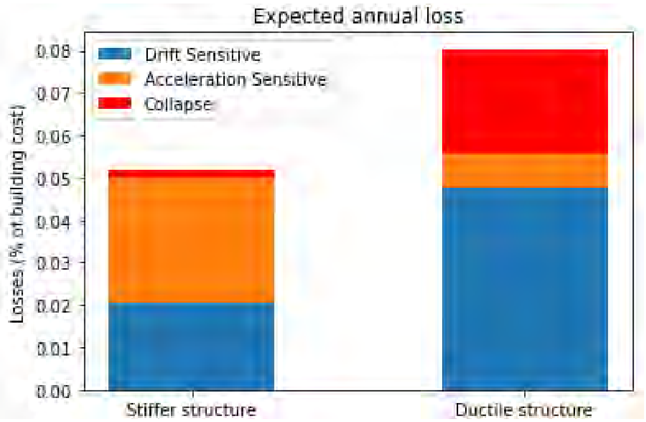


Building properties			
Model	Storey drift limit	Period (s)	Stiffness
Ductile structure	2.0 %	1.16	K
Stiffer structure	1.0 %	0.75	2.5K

Preliminary results

- The annual rate of the collapse for the ductile structure $\lambda_c = 2.5 \times 10^{-4}$ exceeds the code prescribed limit by a factor of 2.5
- The response of the stiffer building led to a reduction in overall seismic loss by nearly 40%.





Further research

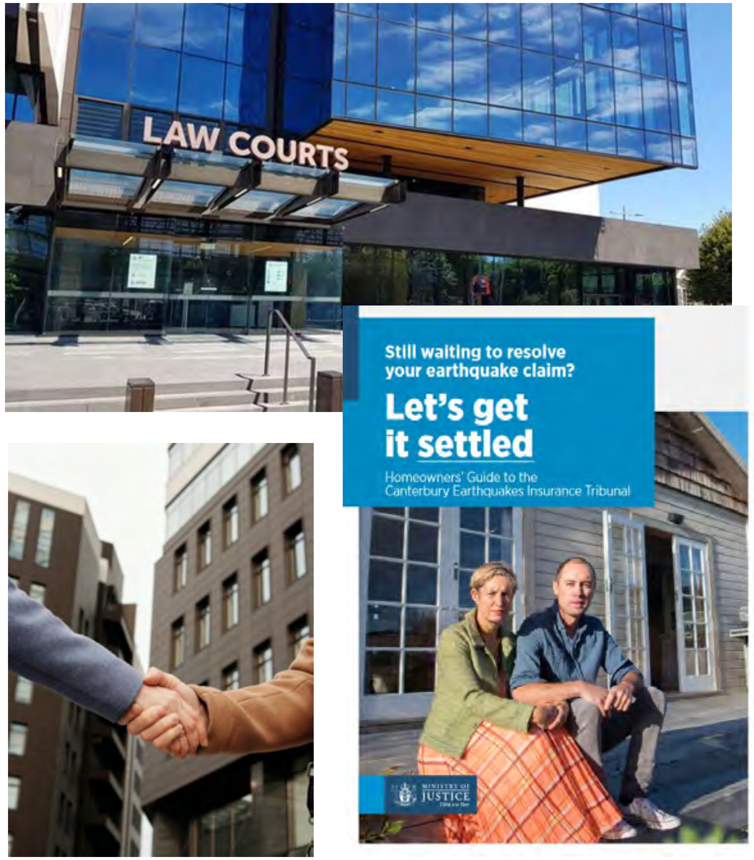
- A larger range of drift limits will be investigated.
- The effect of various lateral load resisting systems will also be explored (SMRF, RCSW, RCF).
- Aim to reduce losses attributed to 'acceleration sensitive' components.
- Explore methods to mitigate seismic loss to non-structural components.

Outputs

- Provide recommendations regarding seismic drift limits, validated through numerical analyses and loss assessments.

Post-Disaster Dispute Resolution: A New Zealand Case Study

Collins and Hopkins



Project

- A base line assessment of the lessons to be learned from dispute resolution in the wake of the Canterbury Earthquake Sequence (CES)

Findings

- In line with existing disaster law theory, the CES exposed existing fault lines within the dispute resolution system of Aotearoa New Zealand, including complexity, cost, delay and formality
- This provided significant advantages to "repeat players"
- It proved difficult to adapt existing mechanisms to cope with the pressures of the post-CES environment
- The consequences for recovery in Canterbury were significant with a number of cases remaining unresolved over a decade after the event

Conclusions

- The current reform process assumes that a pre-planned post-disaster response system will be able to address the issues seen post-CES
- This research suggests that such a model may be insufficient and a more holistic approach to post-disaster dispute resolution may be required
- Fundamental changes to the dispute resolution system may be required to deliver a resilient model, capable of managing future seismic (and other disaster) events

Collins, T and Hopkins, WJ *International Handbook of Disaster Research* (Springer-Nature, 2022)

LEAD Institute of Law, Emergencies & Disasters

QuakeCoRE NZ Centre for Earthquake Resilience *Te Hiranga Rū*

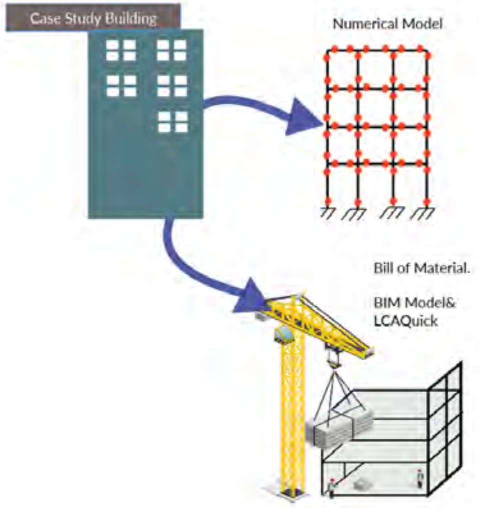
UC LAW *Te Kura Ture*

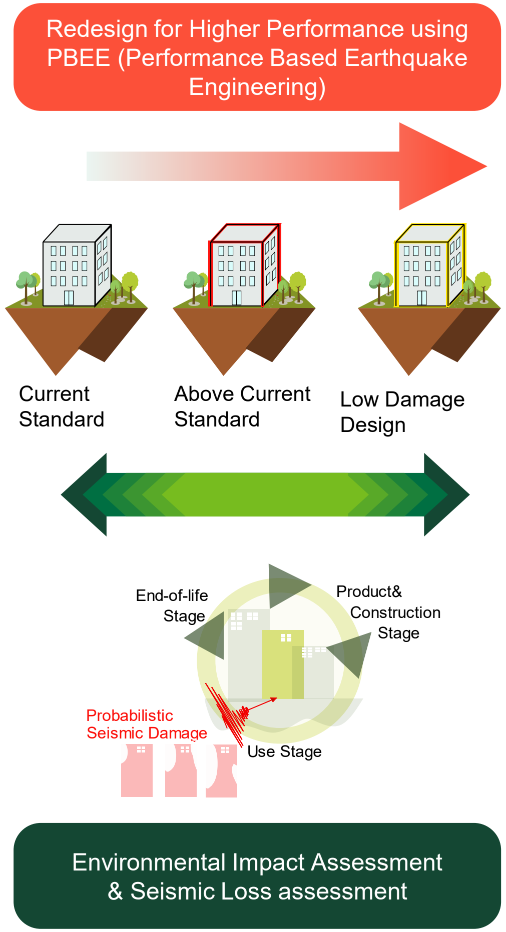
Building the Carbon Case for Resilient Design

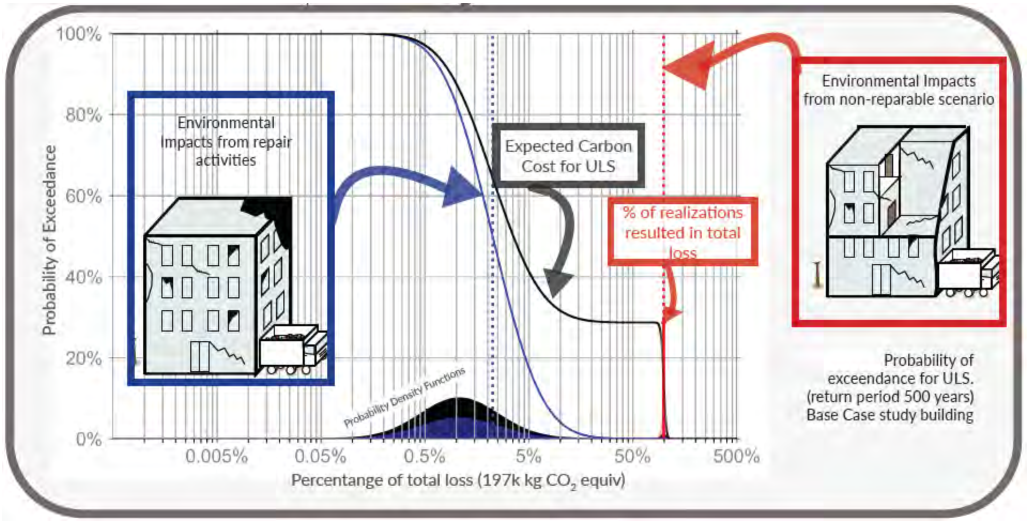
Gonzalez et al. Poster #71

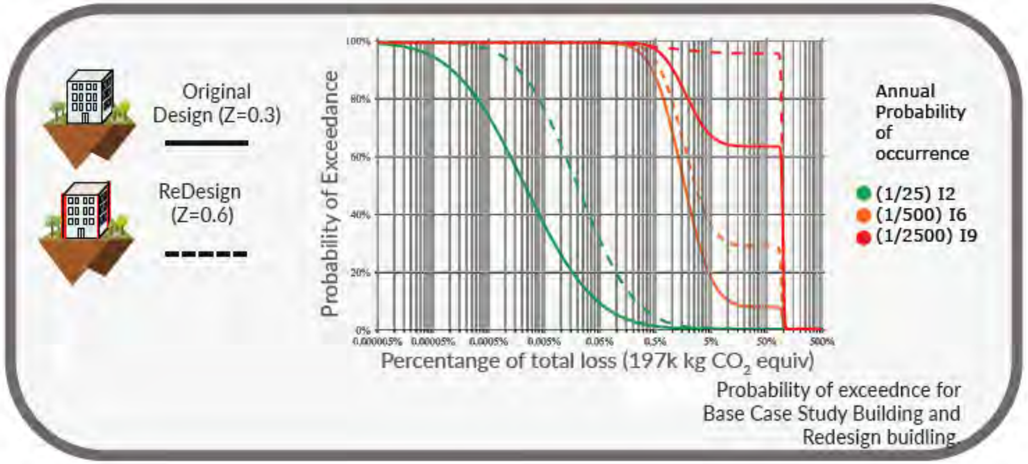
Goals and Scope of Study

This research aims to provide valuable insight into the **carbon cost of designing** seismically resilient buildings in New Zealand.









Investigating the interplay between seismic policy language and commercial property listings

Tong et al. Poster #45

Definition of EQPB → Definition of %NBS → Property listing → Bldg user perceptions

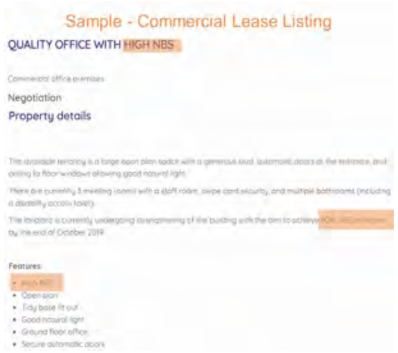
Building Act 2004
Building (EQPB) Amendment Act 2016

133AB Meaning of earthquake-prone building

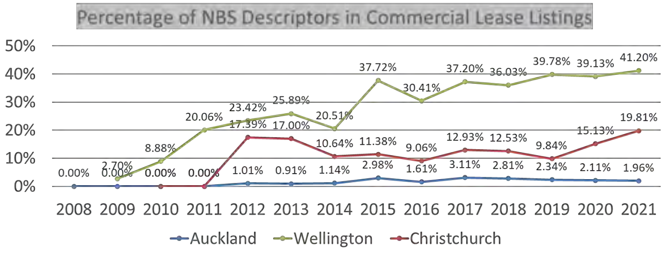
(1) A building or a part of a building is **earthquake prone** if, having regard to the condition of the building or part and to the ground on which the building is built, and because of the construction of the building or part,—

Engineering NZ

%NBS	0%	20%	33%	67%	80%	100%
Seismic Grade	E	D	C	B	A	A+
Relative Risk	High		Moderate	Low		
Designation as per Building Act 2004	Earthquake Prone Building (%NBS <=33)		Earthquake Risk Building (%NBS <67)	Low Potential Earthquake Risk (%NBS>=67)		

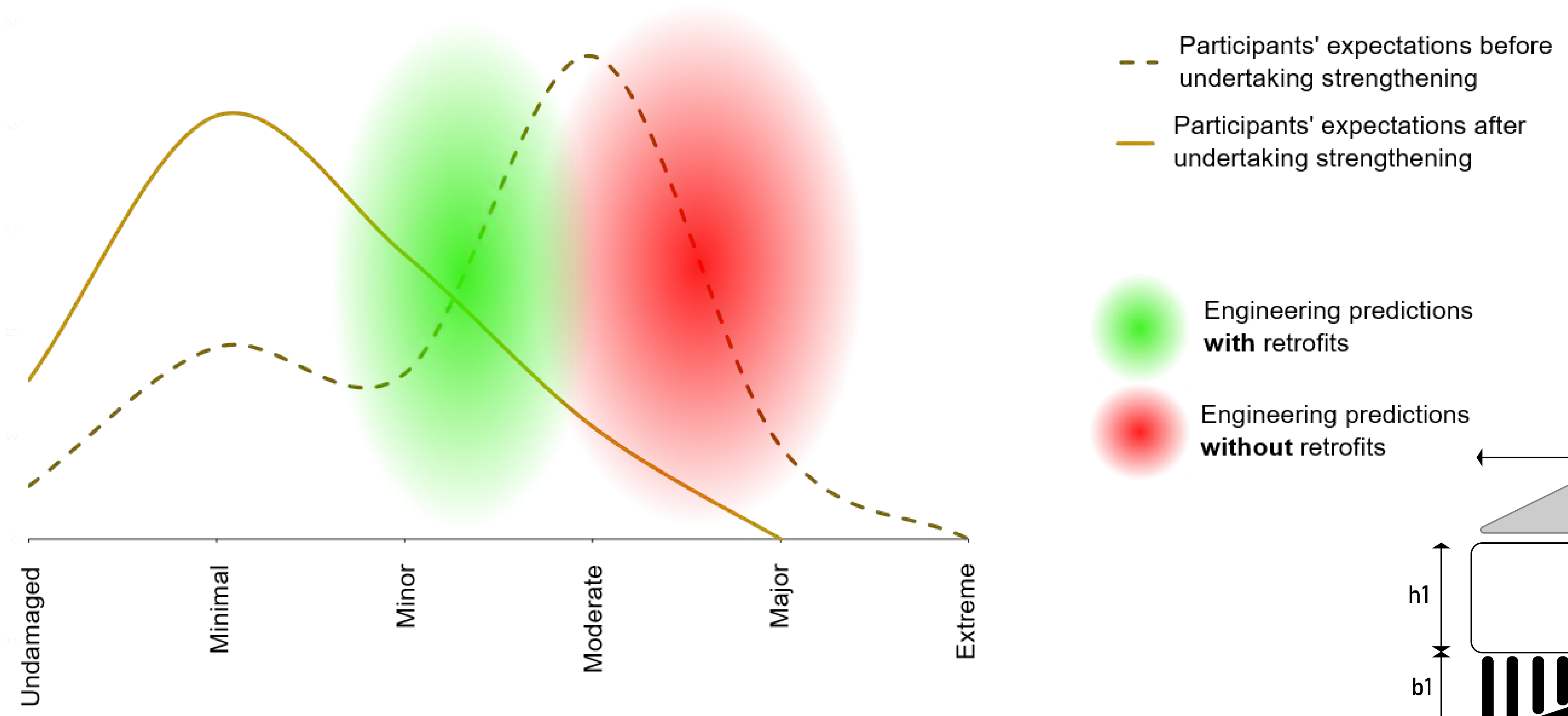


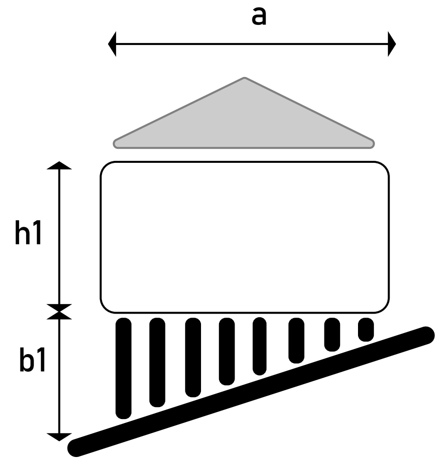
- Real estate agents interpret and communicate seismic policies to the market through property listings
- %NBS is often [mis]perceived as a building's ability to function after an earthquake
- We study the content of 55k office lease listings in Auckland, Wellington and Christchurch b/w 2009-21 with special focus on how agents communicate structural performance
- Measuring the differences b/w the intention and interpretation of seismic policies is important for better policy design



Miranda et al.
Poster #83

Aligning owners' expectation of damage and engineering predictions on timber housing after strengthening

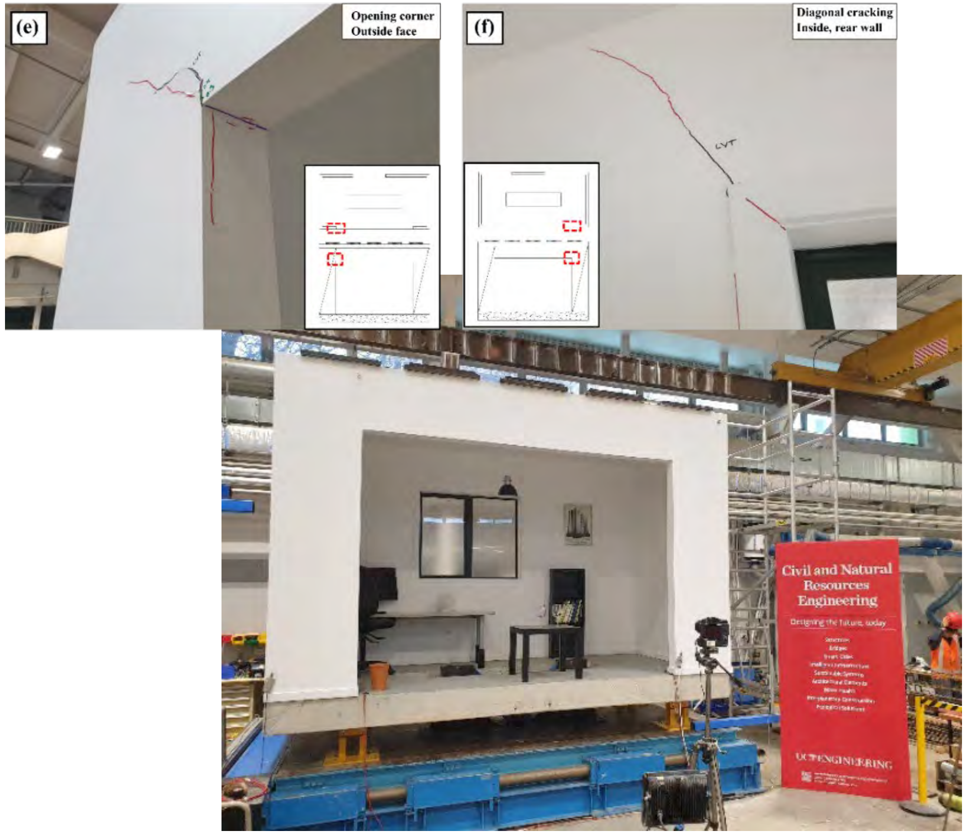




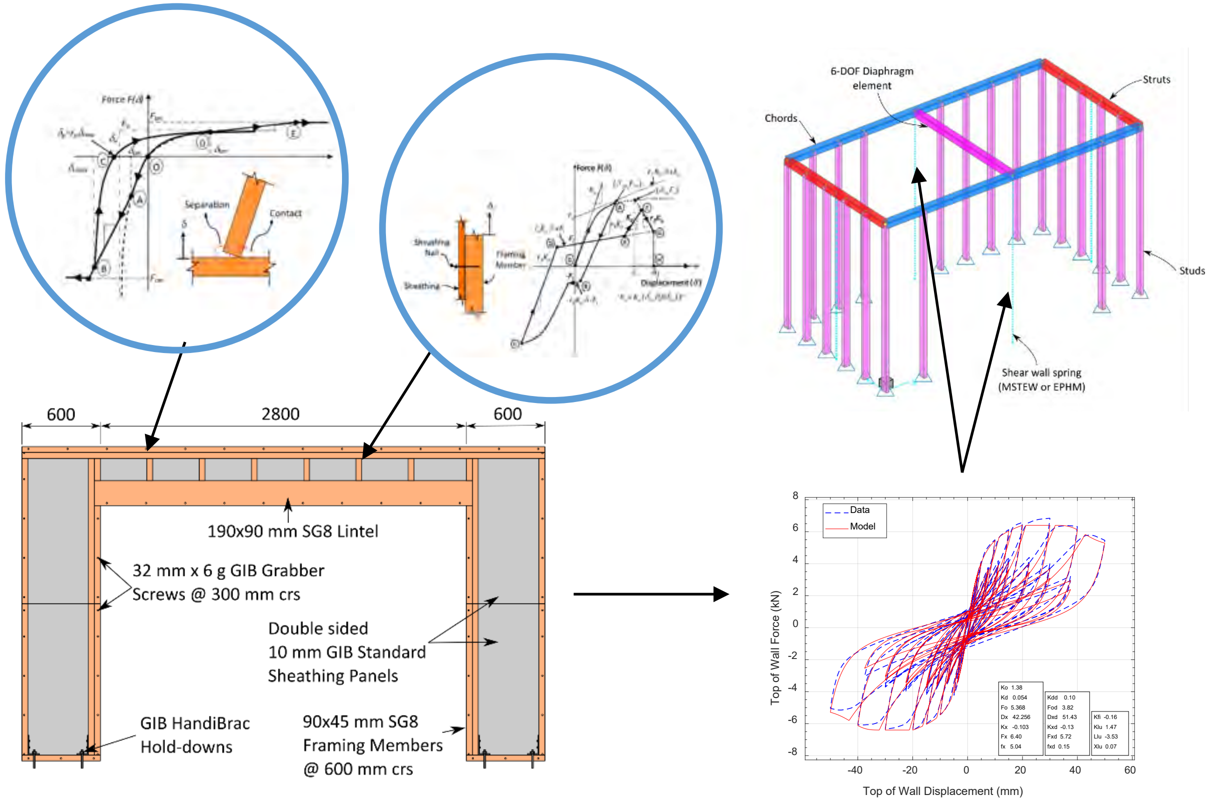
Thriving Residential Communities

Structural Engineering – Vulnerability of existing housing

Francis et al. → Improved insight into the vulnerability of modern timber-framed housing systems.



Shake Table Testing



Numerical Simulations/Assessment

"Saving Precious Seconds" - A Novel Approach to Implementing a Low-Cost Earthquake Early Warning System with Node-Level Detection and Alert Generation

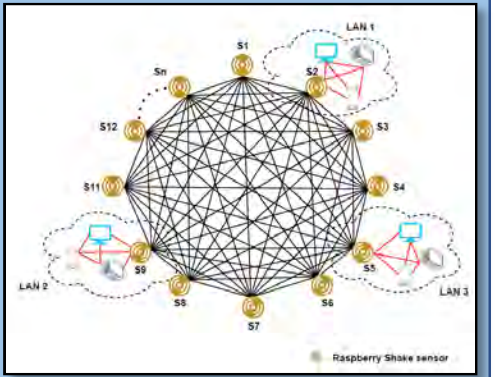
Prasanna et al. Poster #100

Sensors

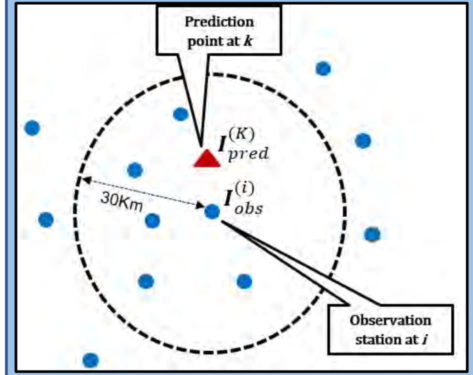
Raspberry Shake sensors are chosen as the ground motion sensors for the proposed experimental Earthquake Early Warning (EEW) system due to its openness to access and relatively superior processing capability.

EEW Network Architecture

Driven by SD-WAN-based hole-punching, this architecture supports entire data processing occurs at the sensor node, and **the communication takes place directly between the sensors without the support from any centralised cloud-based servers.**



Detection Algorithm



The PLUM (Propagation of Local Undamped Motion) algorithm has been selected for the earthquake detection algorithm. **This is an algorithm which recently become popular for EEW domain due to its robustness, lightweight design and easy to implement nature.**

Results

Results show that the proposed decentralised EEW architecture can outperform traditional centralised EEW architectures and can save valuable seconds when generating EEW, leading to a longer warning time for the end-user.

‘Seismometers in schools’ and hazards education engagement programmes

Tan et al. Poster #62

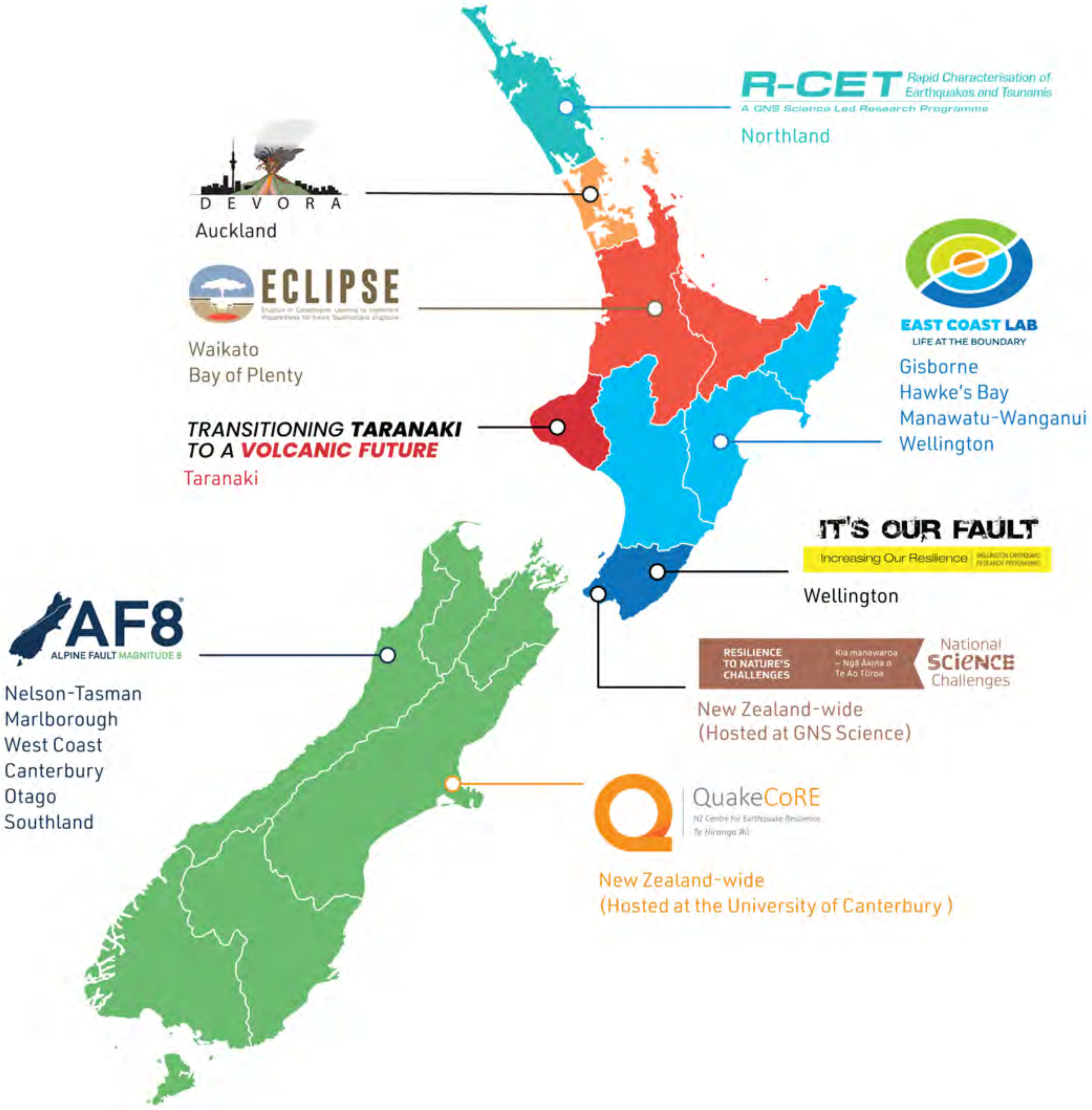
- Research programmes have engaged with schools with aims to improve resilience to hazards and to promote interest in science, engineering, technology, and maths.
- Although there are multiple benefits and opportunities in these hazard resilience engagement programmes, there is a **need to investigate the operational challenges and evaluation aspects of sustainably running such programmes**.
- A current project is reviewing how we do school engagements in Aotearoa New Zealand. The project is also working with schools at the Bay of Plenty to co-design and evaluate an engagement programme.
- The aim of the project is **to develop a framework or guidelines to improve engagements**; making them more sustainable and long-lasting.

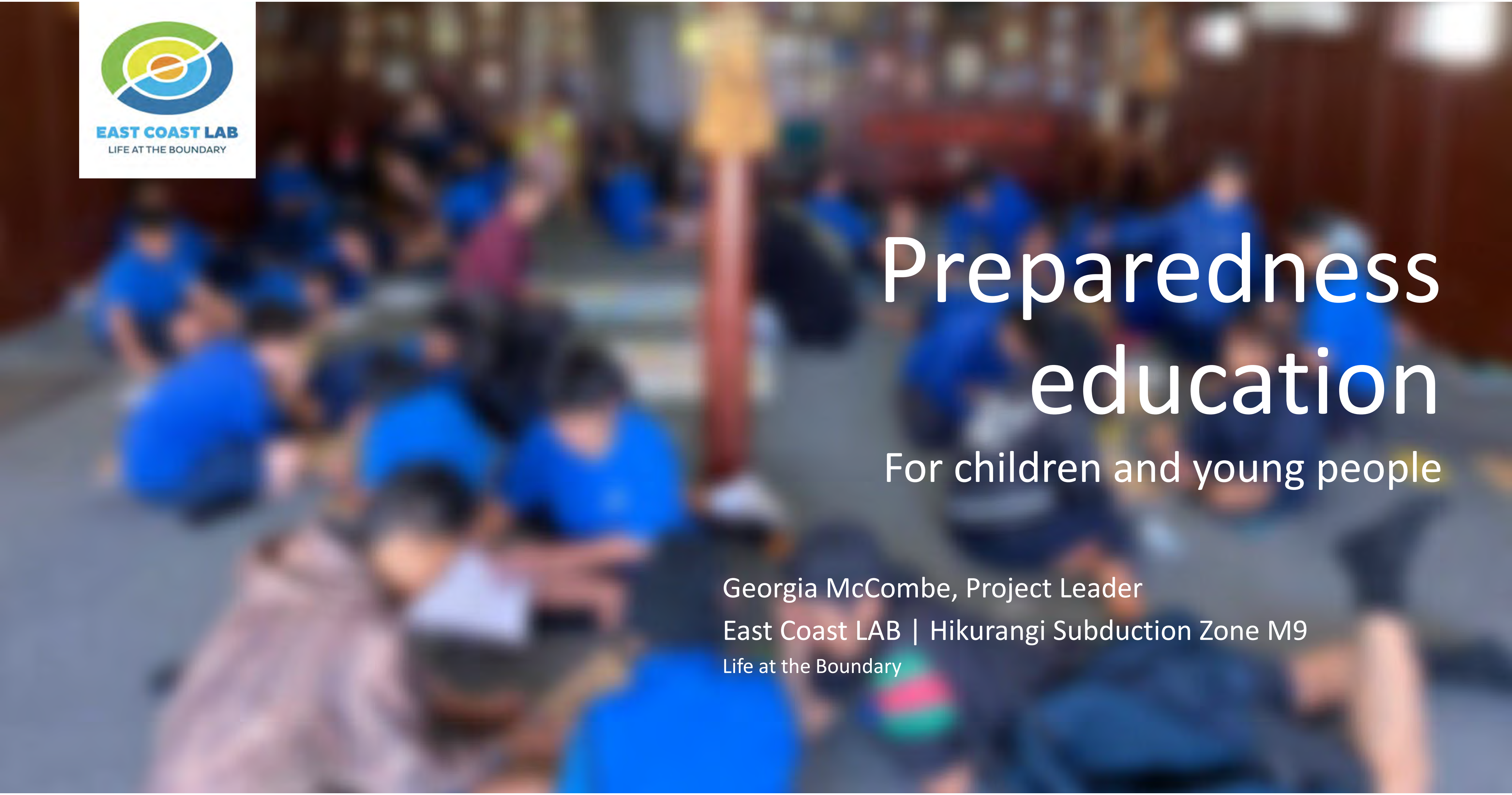
QuakeCoRE NZ Centre for Earthquake Resilience Te Hiranga Rū | Toka Tū Ake EQC | MASSEY UNIVERSITY TE KUNENGA KI PUREHUROA UNIVERSITY OF NEW ZEALAND | UC UNIVERSITY OF CANTERBURY

Contact: M.L.Tan@massey.ac.nz

Regional Hazard Science Engagement

Public Education + Communication





EAST COAST LAB
LIFE AT THE BOUNDARY

Preparedness education

For children and young people

Georgia McCombe, Project Leader
East Coast LAB | Hikurangi Subduction Zone M9
Life at the Boundary

EAST COAST LAB
LIFE AT THE BOUNDARY

Tsunami pou

Community, guardianship, lifelong knowledge

In this project, tamariki at the local school used their skills to create something that resonated with them and their community.

The longevity of the project, and the learnings the kids take from it is built into the project, as they will see their work regularly and the school has tasked them with maintaining the evacuation route.

School roadshow

Science literacy, passionate communication

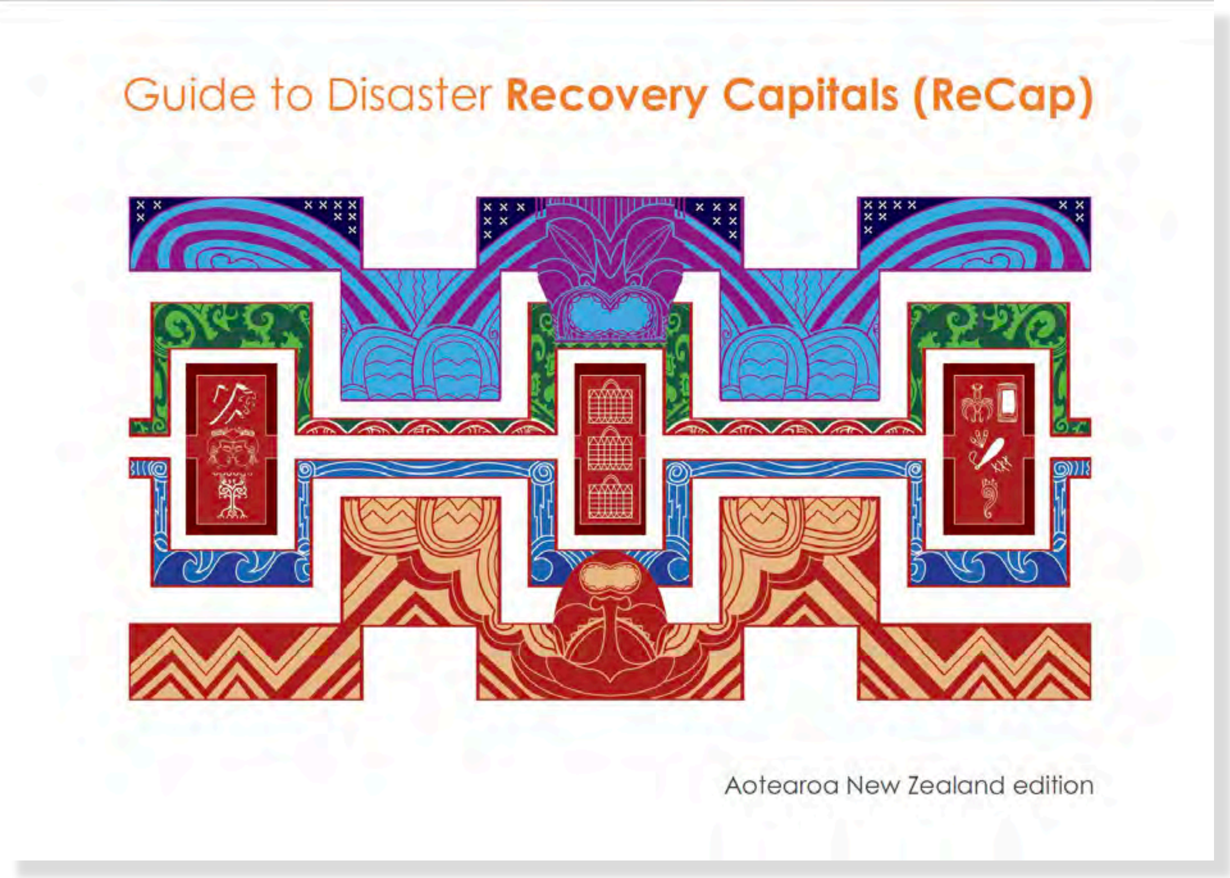
In this project, tamariki are taught preparedness messages as part of a fun science lesson.

By raising their scientific literacy kids can better navigate a complicated information environment and make safer choices, it is also an important skill for informing others of what a safe choice is and why.

Embracing complexity and **simplicity** in the development of **recovery resources**

Emily Campbell, David Johnston – Massey University
Denise Blake – Victoria University of Wellington
Lisa Gibbs, Phoebe Quinn – University of Melbourne
John Richardson – Australian Red Cross

An Aotearoa New Zealand Edition



EMPA Awards 2022

QuakeCoRE
NZ Centre for Earthquake Resilience
Te Hiranga Rū

QuakeCoRE Wellingtton Research Accomplishments 2022

David Johnston
on behalf of the QuakeCoRE community

10 November 2022