Seminar 2022

Resilience of Aotearoa New Zealand's Built Environment

How is research improving the resilience of our buildings and infrastructure networks to natural hazards?

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Presentation Overview

- The Challenges
- Built Environment Programme
  - Vertical Infrastructure
  - Horizontal Infrastructure
- Research Examples
- Next Steps
- Collaboration & Engagement

The Challenges

- The built environment plays a significant role in our resilience to natural hazard events

- Recent natural hazard events have had significant impact on the built environment and wider society

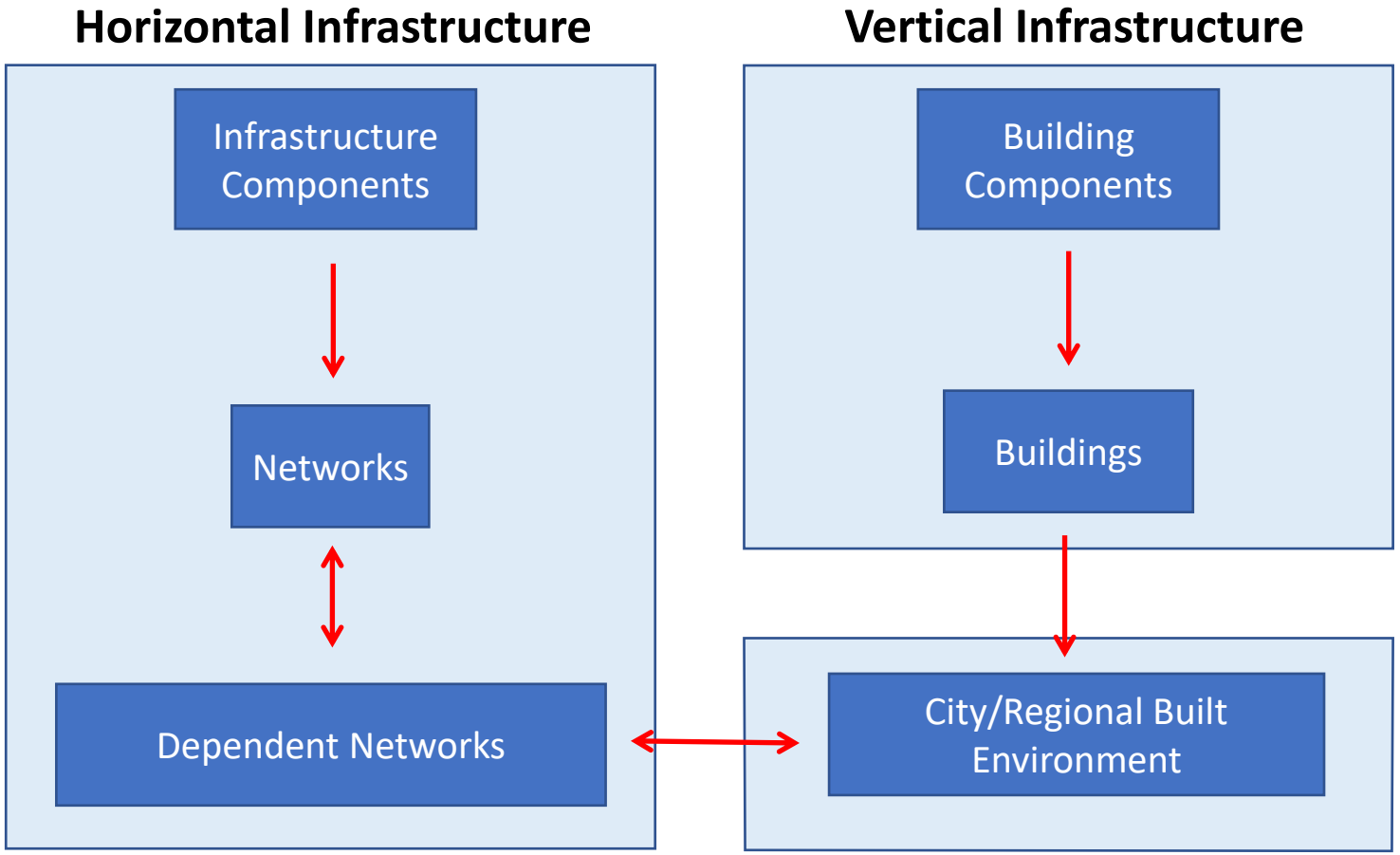
- A number of events nationally since 2010
  - Earthquakes
  - Storms
  - Flooding
  - Coastal Inundation
  - etc

- Many international events

Built Environment Programme - Aims

- Improve our understanding of the performance of infrastructure under various natural hazards
  - Buildings (Vertical Infrastructure)
  - Infrastructure (Horizontal Infrastructure)
- Improve our approaches for design, assessment and repair
- Develop new approaches to inform decision-making and investment
- Work alongside range of stakeholder partners to provide real-world context to the research

Built Environment Programme



Project Team

- Over 20 academics
- Over 30 postgraduate students
- Strong collaborations with stakeholders and industry groups
  - Regional focus
  - Network focus
  - Discipline focus

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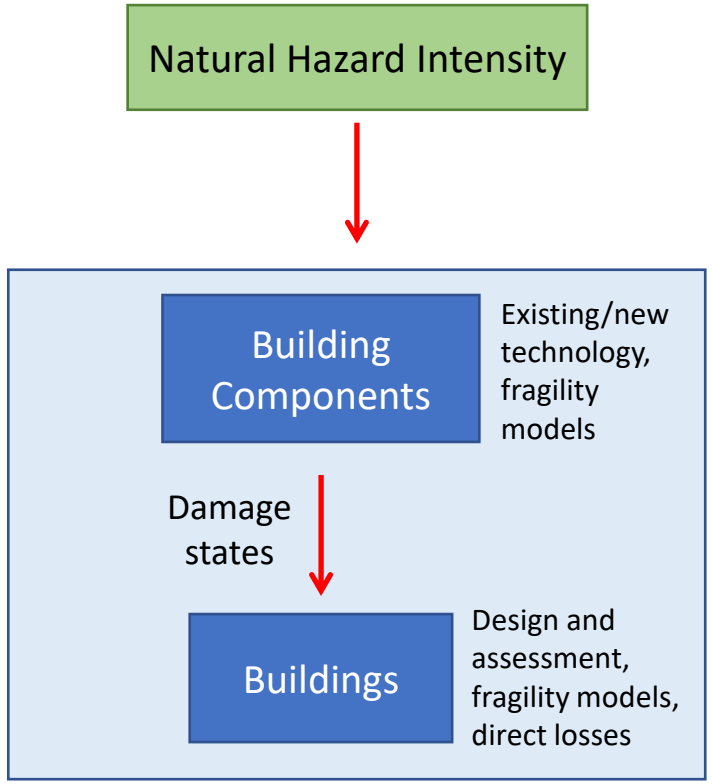
Vertical Infrastructure

- Range of building types:
  - Commercial buildings
  - Low-rise residential
  - Medium-density residential
- Range of materials:
  - Structural steel
  - Reinforced concrete
  - Timber
- Components to systems to portfolios
  - Info on structural & non-structural components connected to whole of building performance.
  - Building design criteria linked to performance – building specific and regional performance



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Vertical Infrastructure - Aims

- Understanding natural hazard-induced demands on vertical infrastructure
- Quantification of structural fragility and vulnerability from case history observations and modelling
- Advancing methods of natural hazard design and assessment
- Designing analytical methods for quantifying performance of new and retrofit buildings
- Examining future resilience trajectories and decision-making

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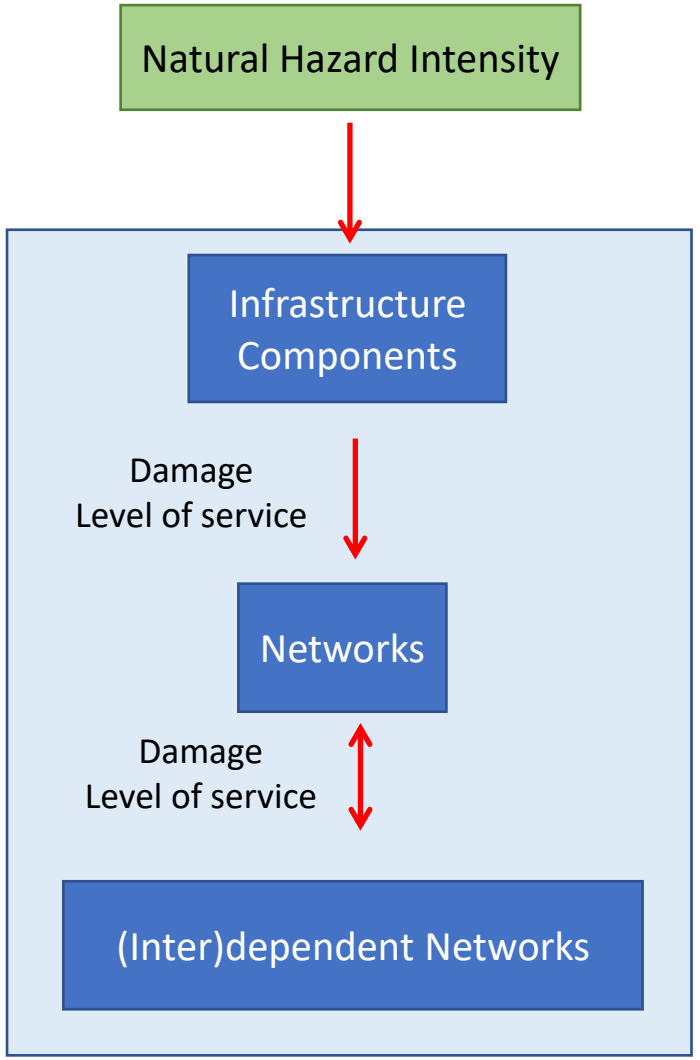
Horizontal Infrastructure

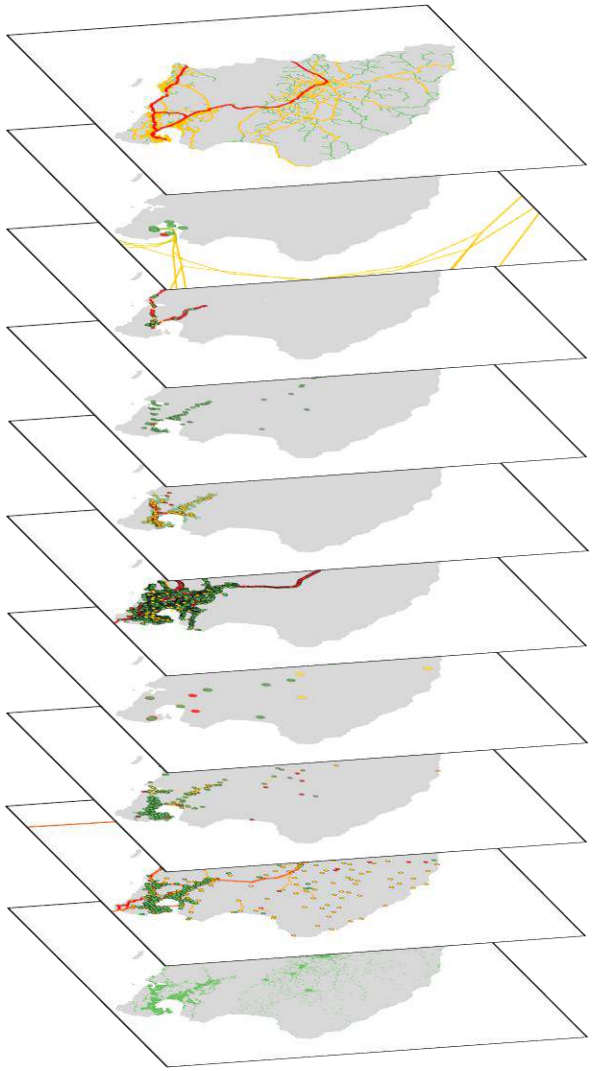
- Network Types
  - Transport
  - Energy
  - Communications
  - 3 Waters
  - Flood Defence
- Components
  - Damage and level of service under different hazard intensities
- Networks
  - Capture connectivity and flow of network
- (Inter)dependant Networks
  - Influence of outage on one network on another network



Horizontal Infrastructure - Aims

- Understanding natural hazard-induced demands on horizontal infrastructure
- Quantification of infrastructure component performance from case history observations and modelling
- Developing methods to quantify system-level performance of infrastructure networks and dependencies
- Examining future resilience trajectories and decision-making

Built Environment - Combined



Road

Ports (air/sea)

Rail

Fuel

Gas

Electricity

Solid Waste

Water & Wastewater

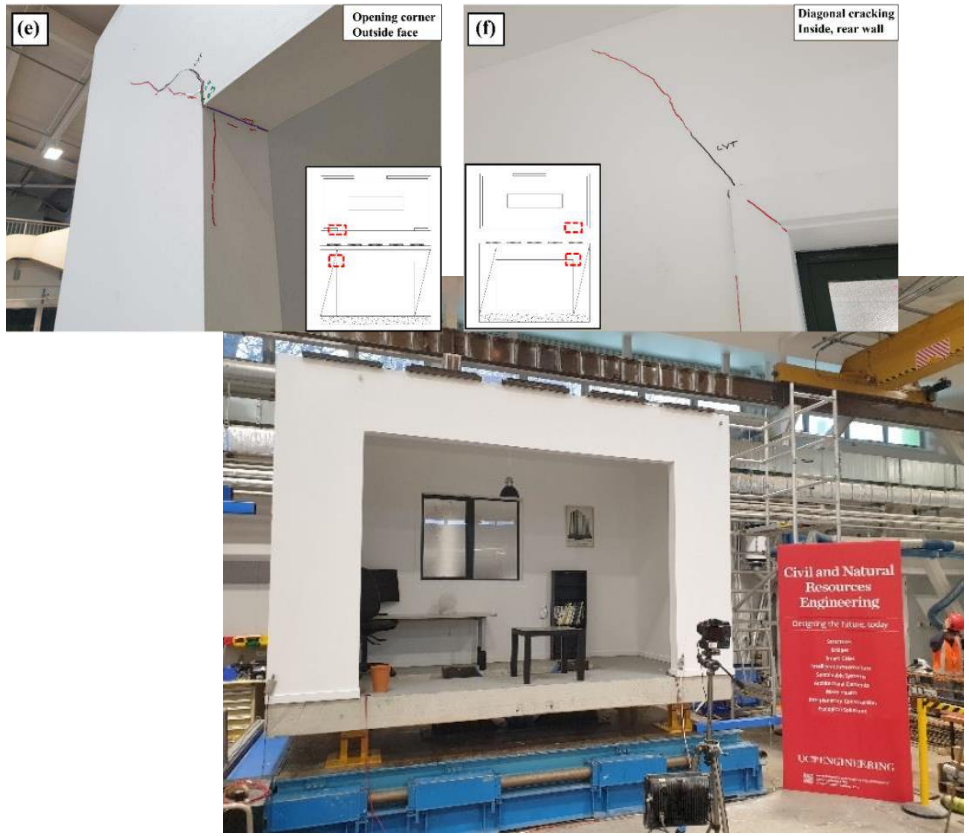
Telco.

Demand (Buildings)

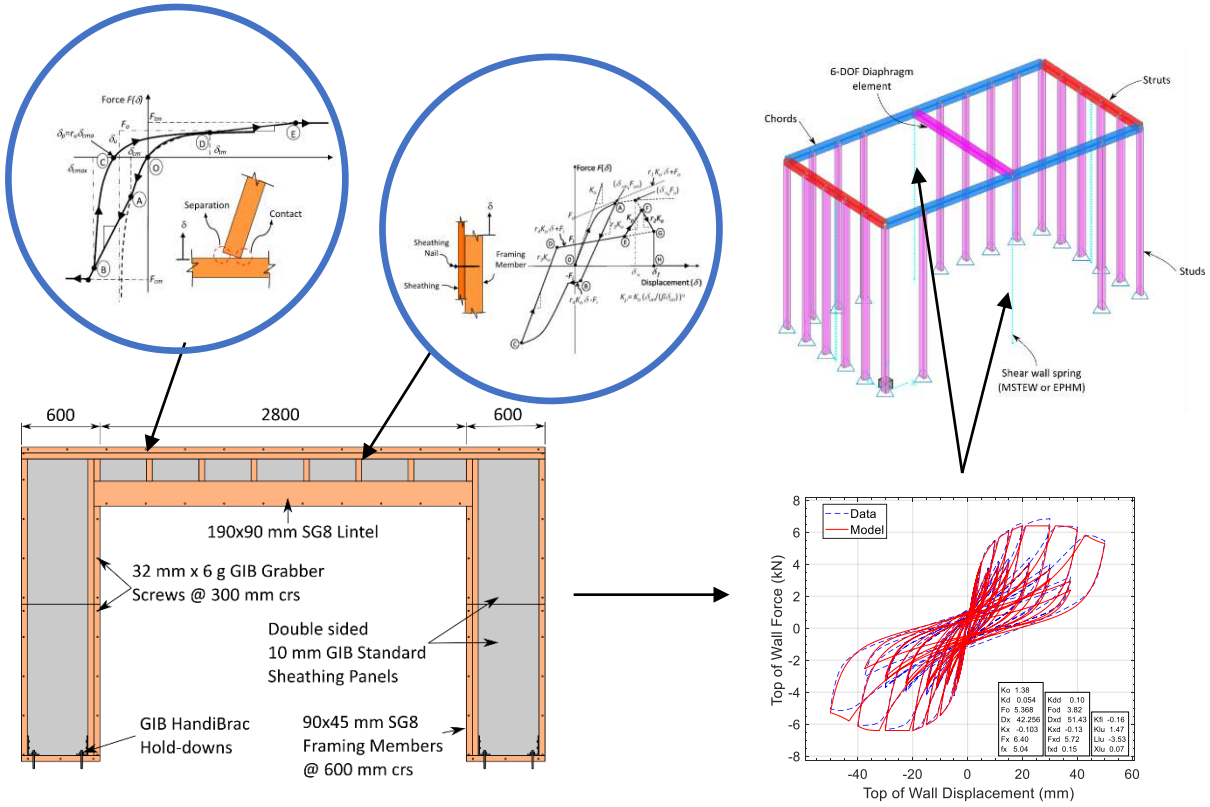
Project Examples

Vulnerability of existing housing to EQ shaking

- Improved insight into the vulnerability of modern timber-framed housing



Shake Table Testing



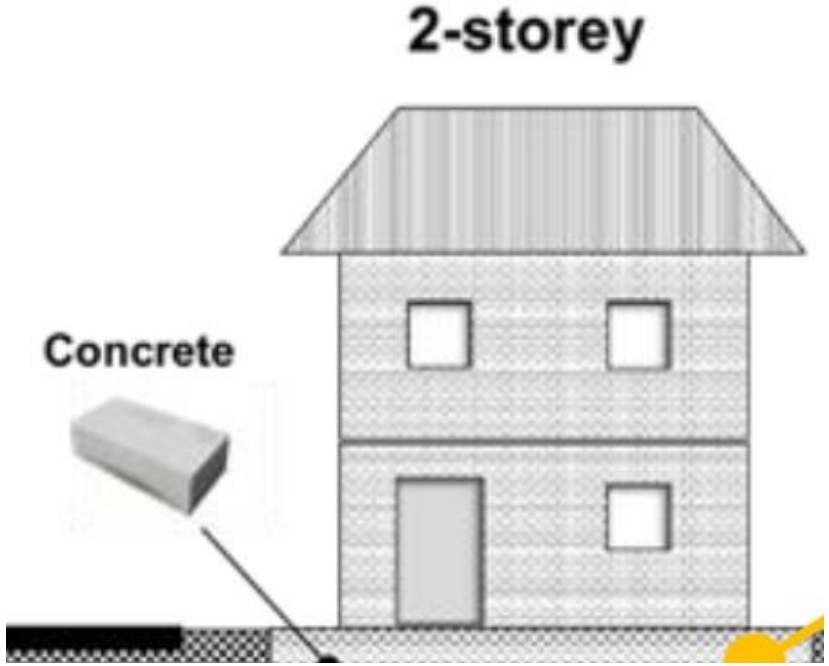
Numerical Simulations/Assessment

Francis et al.

Vulnerability of existing housing to EQ shaking

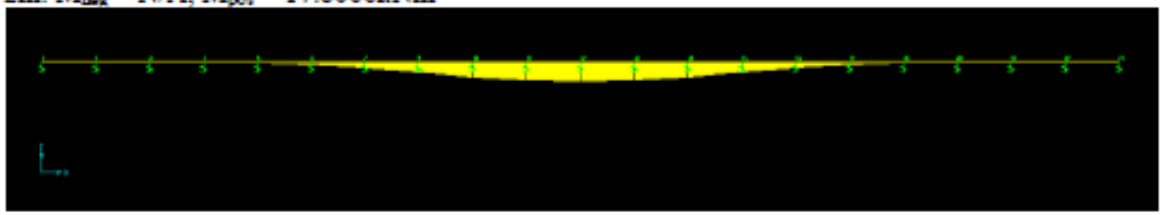
- Foundation performance

Do our prescriptive design provisions for foundations on liquefiable ground provide good protection against damage in future earthquakes?



R.1: Bearing Loss in Centre, 80% Loss

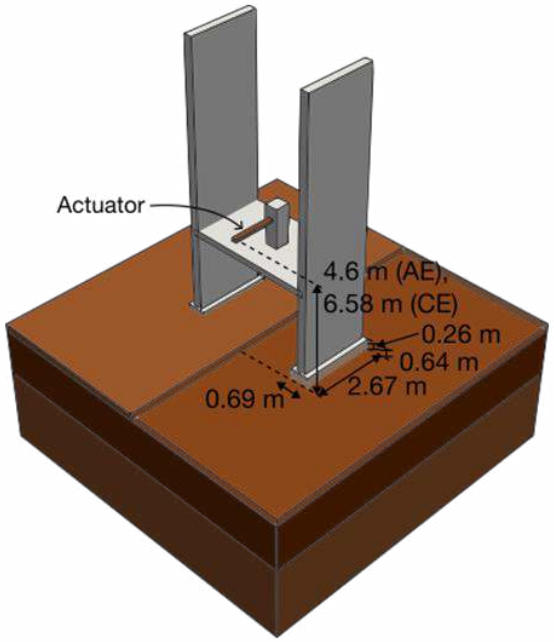
2m: M_{neg} = N/A, M_{pos} = 17.8066kNm



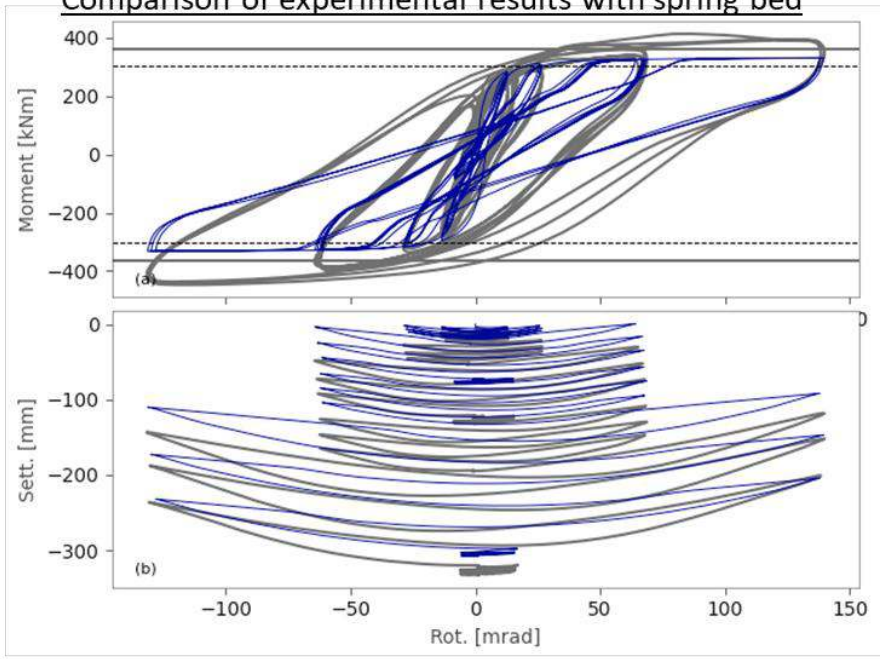
Dawson et al.

Experimental evaluation of numerical methods for soil-structure interaction

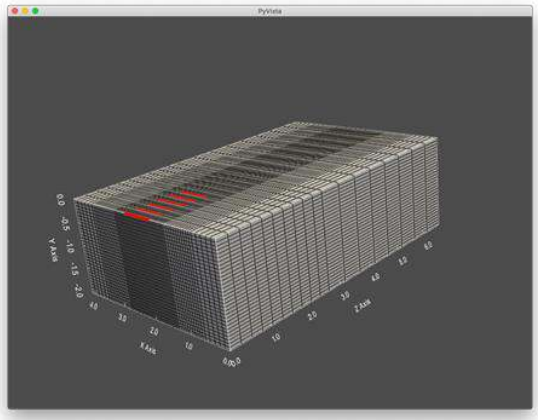
Experimental setup (prototype scale)



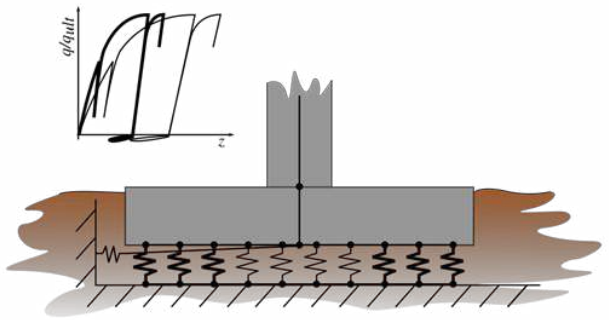
Comparison of experimental results with spring bed



3D Finite element setup



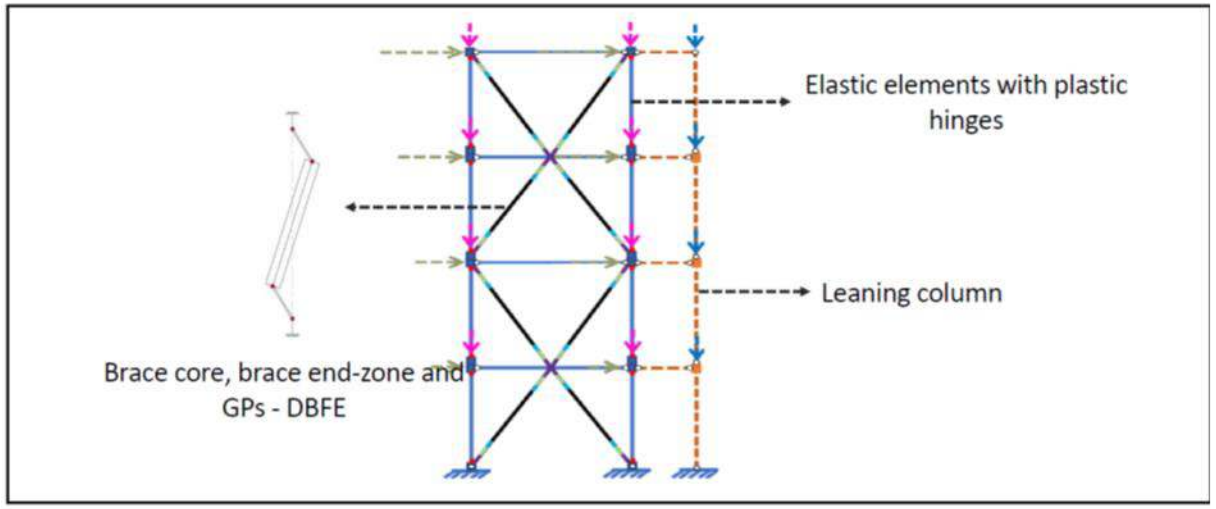
2D Artist rendering of spring bed model

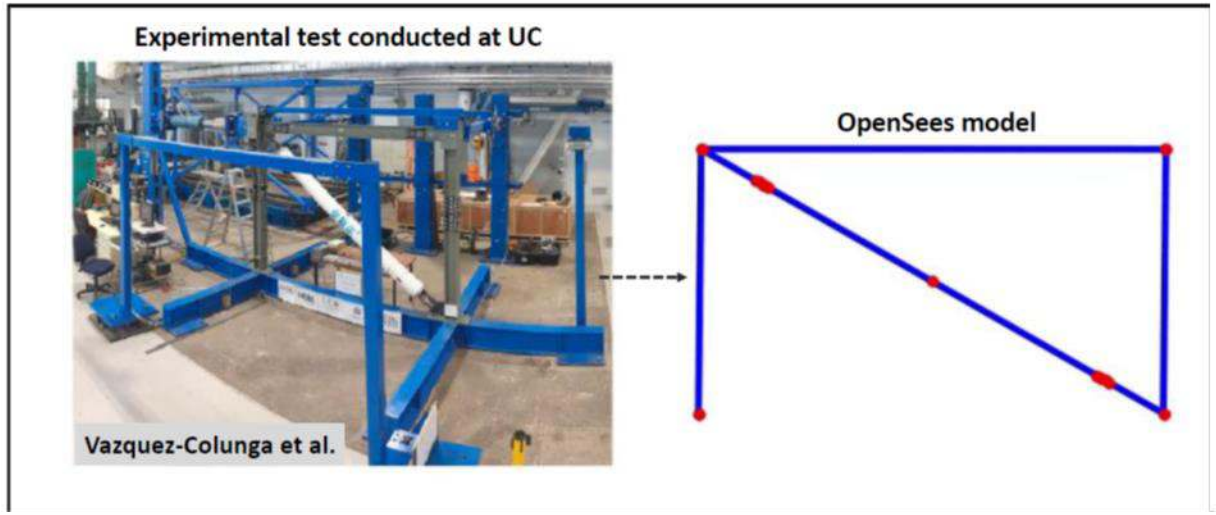


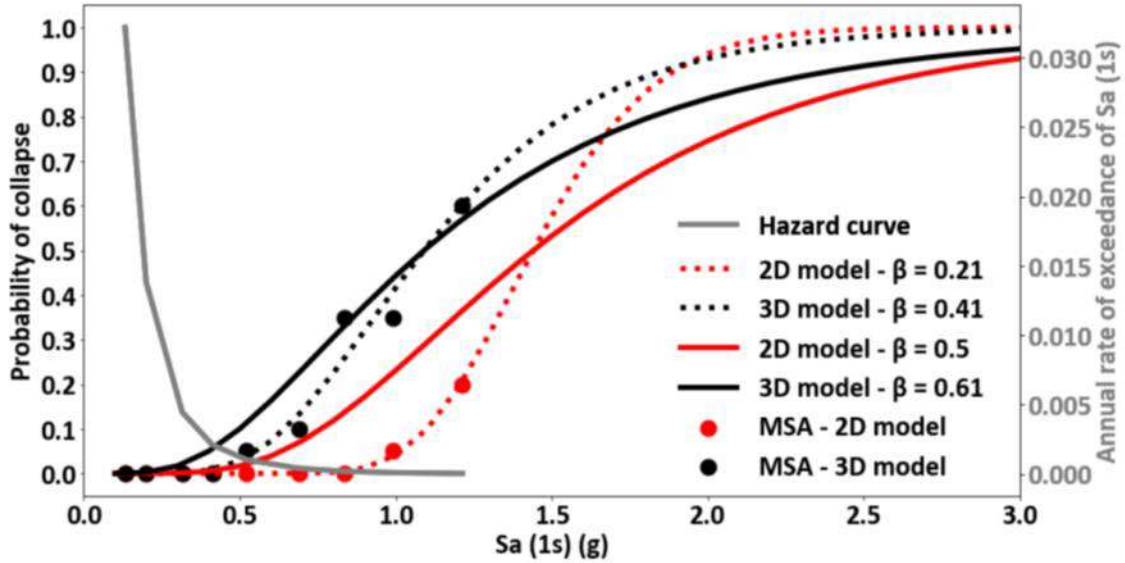
Millen et al.

Quantifying likely performance of modern commercial buildings

- Examples of benchmarking study for standard design - BRB







Annual rate of collapse (λ_c)				
Model	θ	β	λ_c	$\frac{\lambda_c}{\lambda_{c\_code}}$
2D	1.45	0.21	1.30×10^{-5}	0.13
	1.45	0.5	$\mathbf{1.31 \times 10^{-4}}$	**1.31**
3D	1.09	0.41	2.21×10^{-4}	2.21
	1.09	0.61	$\mathbf{5.95 \times 10^{-4}}$	**5.95**
$\lambda_{c\_code} = 10^{-4}$ to 10^{-5}				
θ is the median $S_a(T_1)$ causing collapse β is the standard deviation				

Sistla et al.

Loss assessment research – process?

Hazard analysis

Advanced structural analysis

Building damage model

Consequence assessment (cost)

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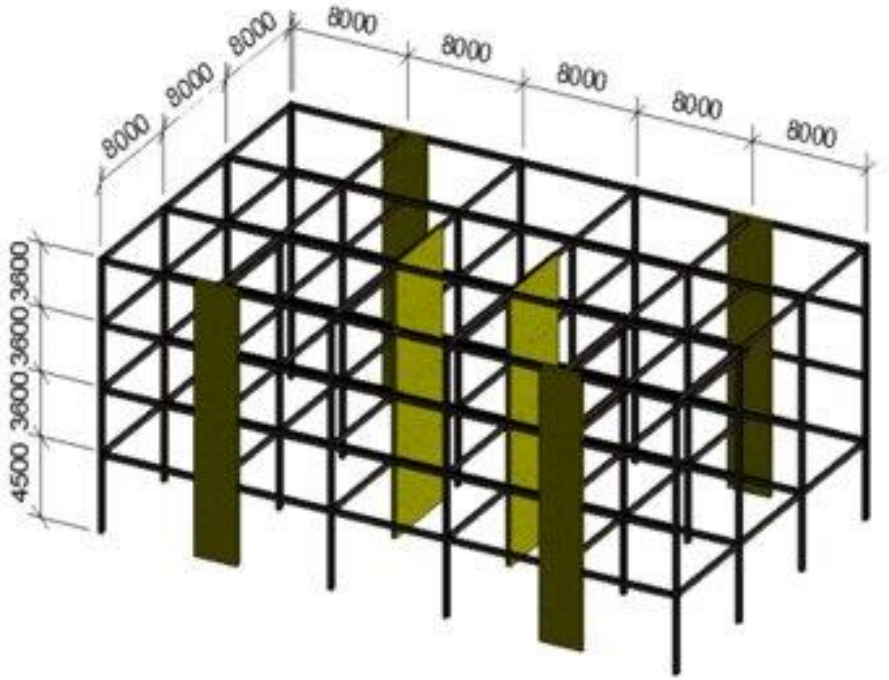
Comparing traditional and “low-damage” design options

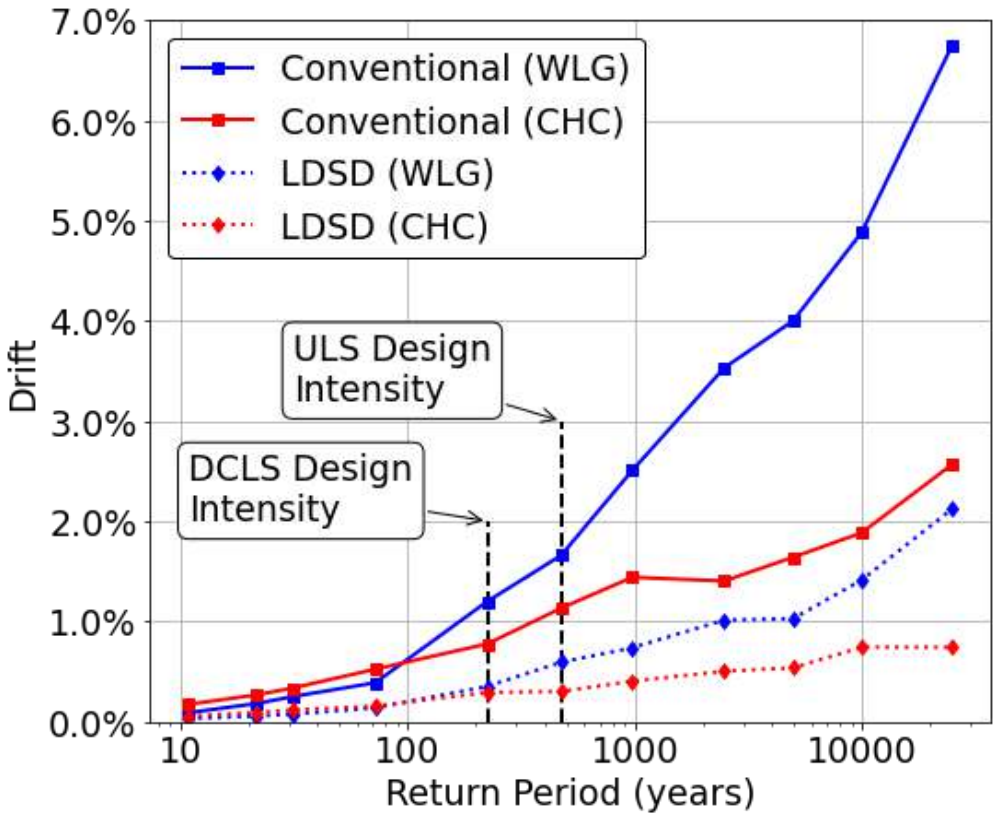
Example of Case study buildings

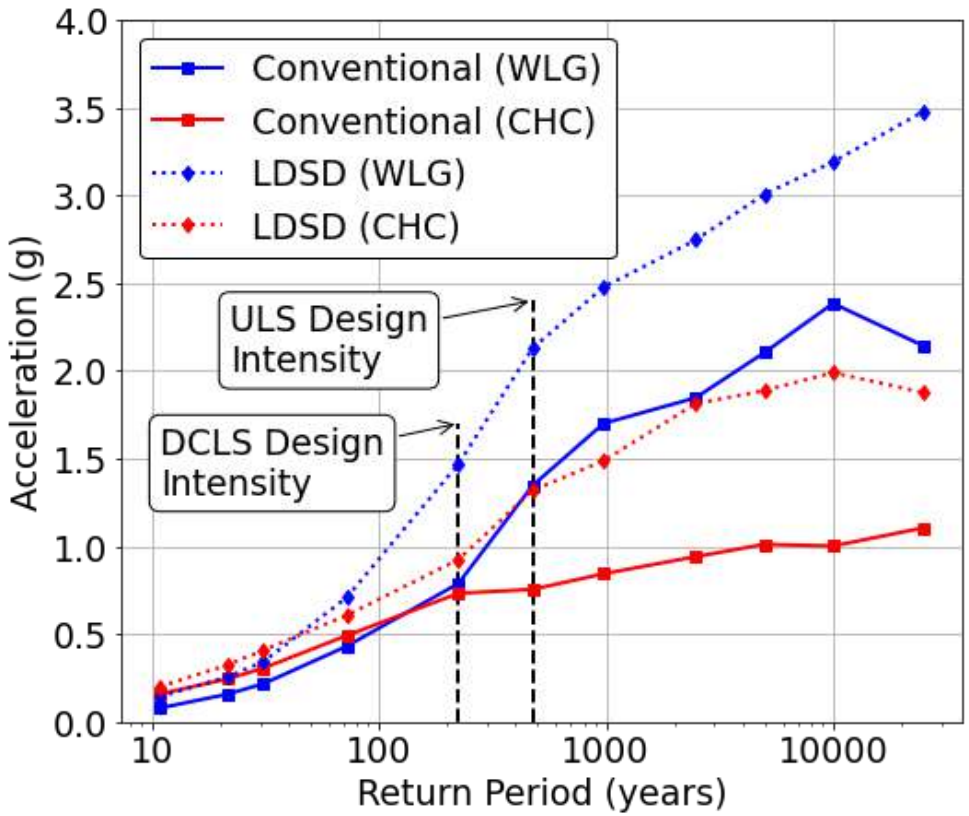
- Located in Wellington and Christchurch
- 4- and 12-storey commercial office buildings (IL2)
- RC walls as the lateral load resisting system
- Seismic design following NZS 1170.5 (equivalent static method) and NZS 3101
- Designed:
  1. as code-compliant (conventional case)
  2. to draft LDSD guidance (LDSD case)



Source: S. Kim and R. Slight (2019)

Comparing traditional and “low-damage” design options





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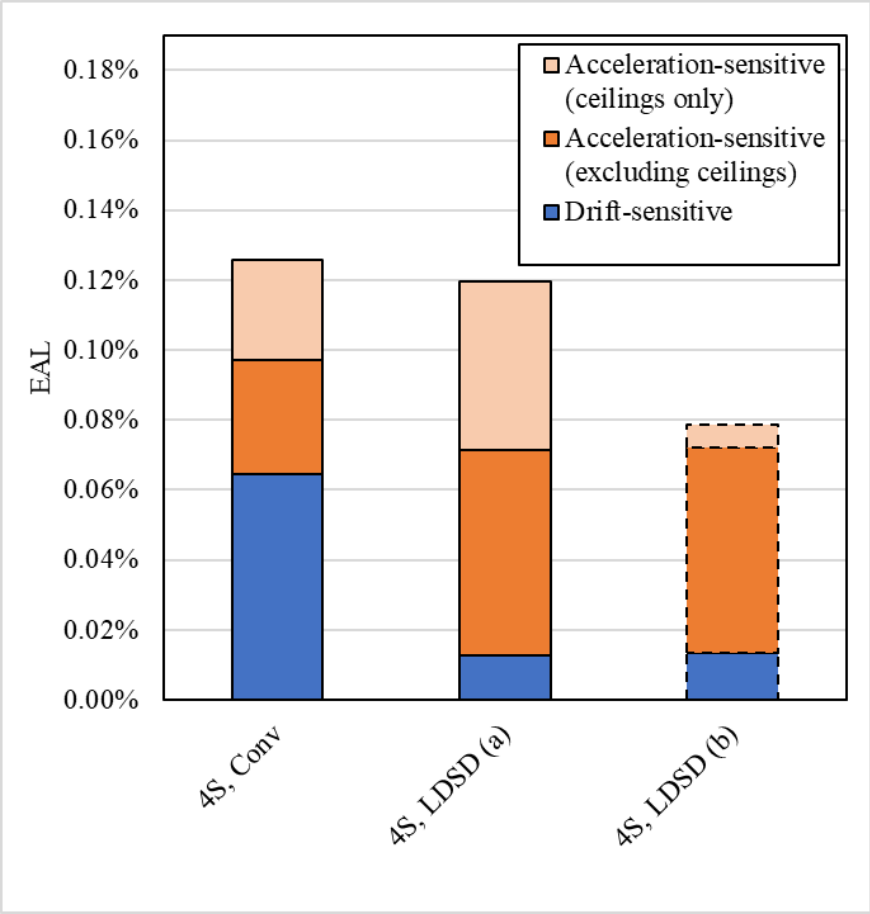
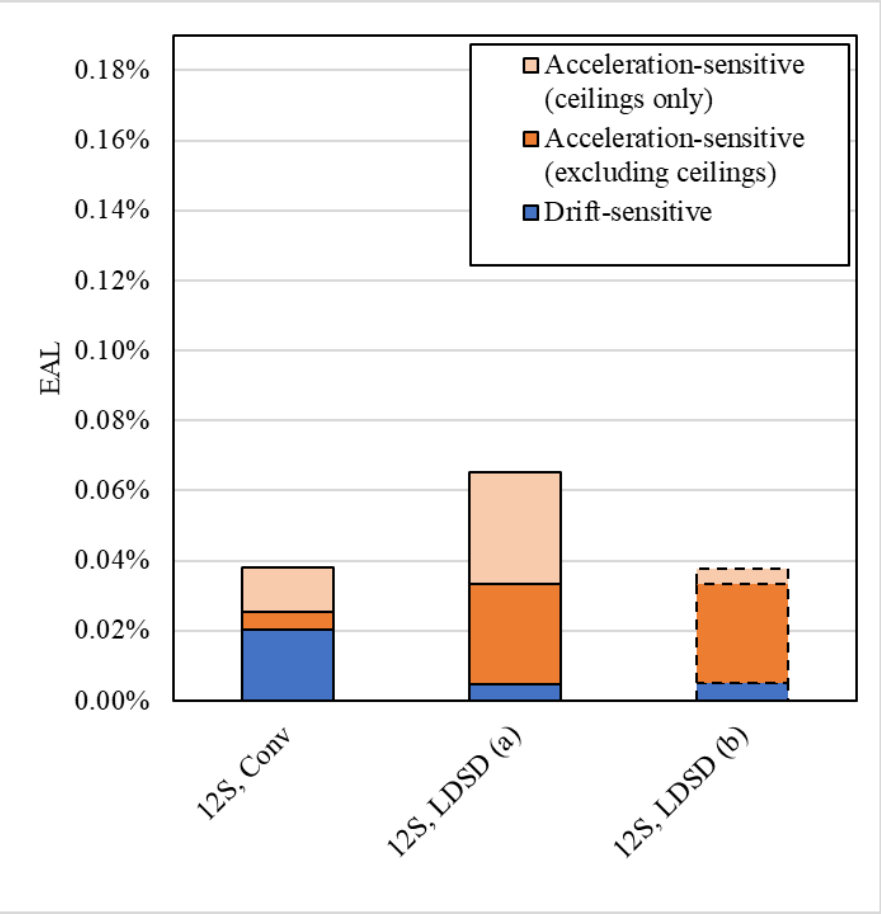
Williamson et al.

Comparing traditional and “low-damage” design options





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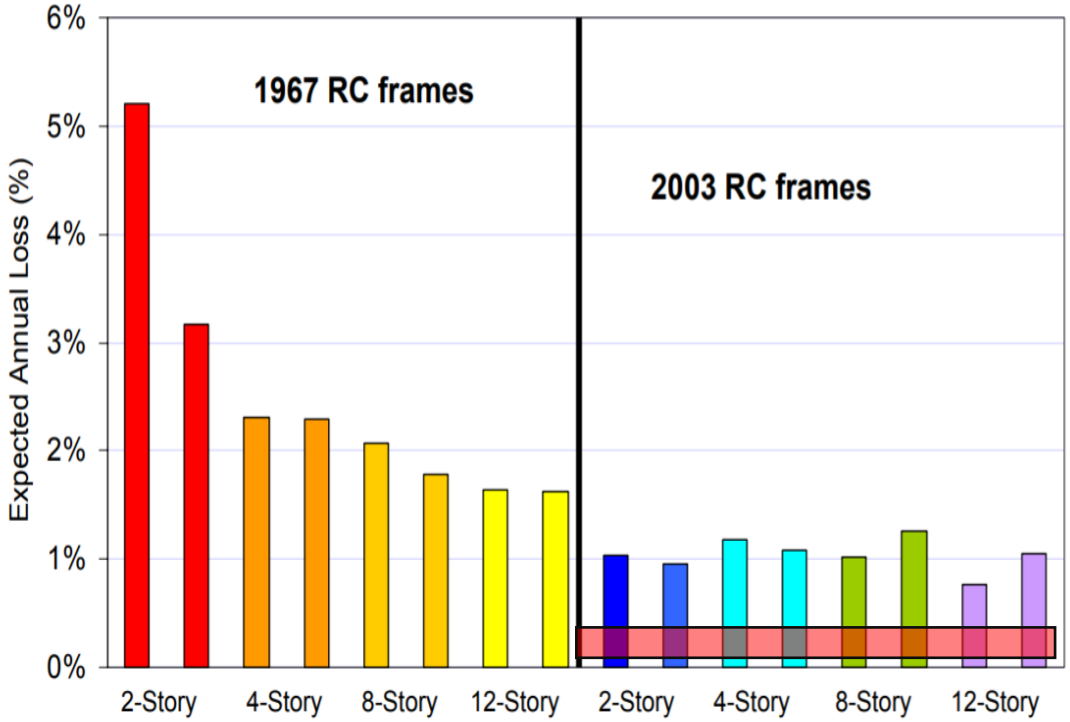
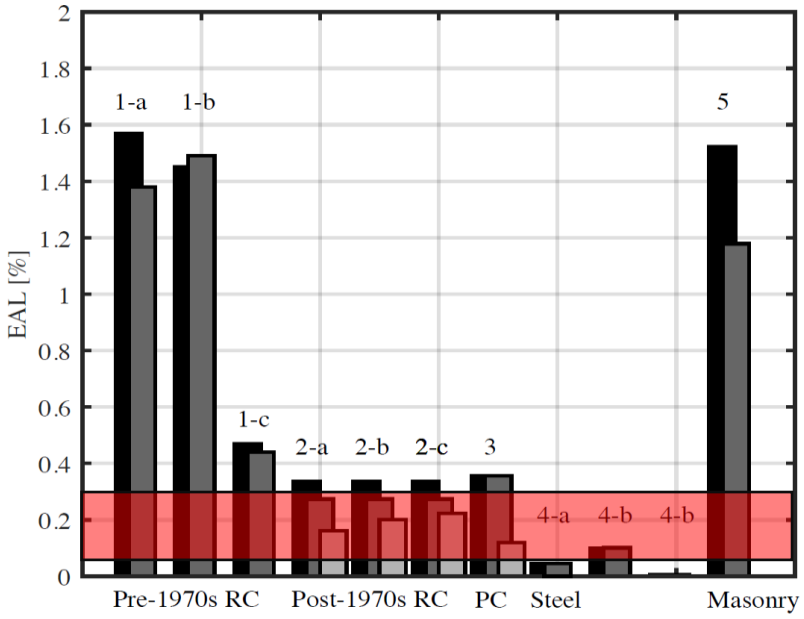
How do repair costs for NZ buildings compare internationally?

For code-compliant NZ buildings examined,
EAL found to vary from 0.03% to 0.30%.



RC Frame buildings in California
Leil & Deierlein (2007)



Buildings in Italy
O'Reilly et al. (2020)

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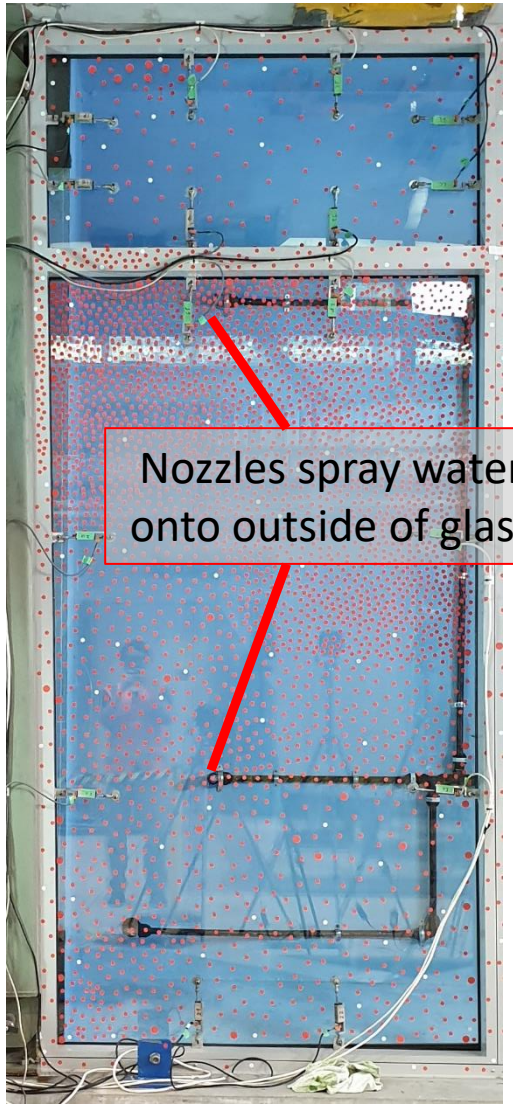
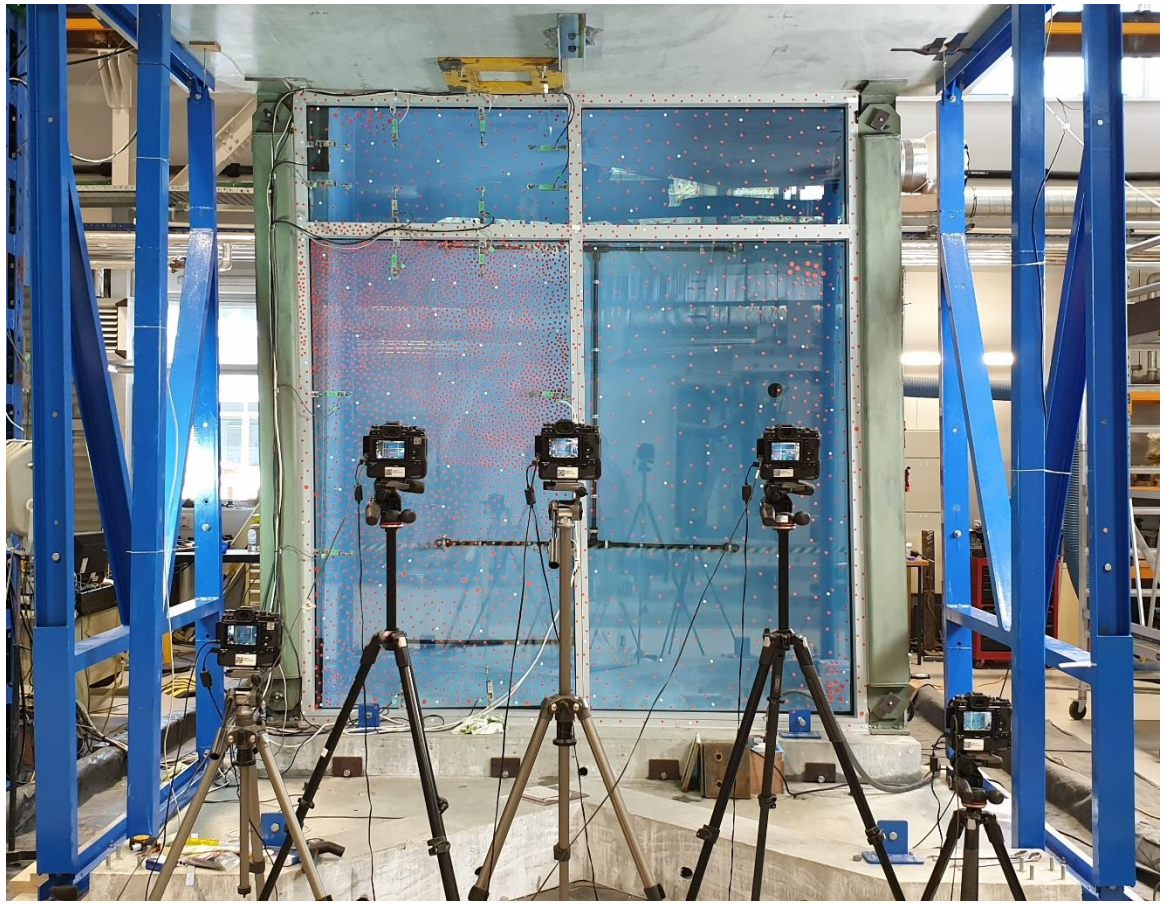
Fragility of Building Components

Example → glazing systems



Top slab is displaced laterally to increasing drift levels



Water box sprays glazing at controlled air pressure, in line with NZS4284

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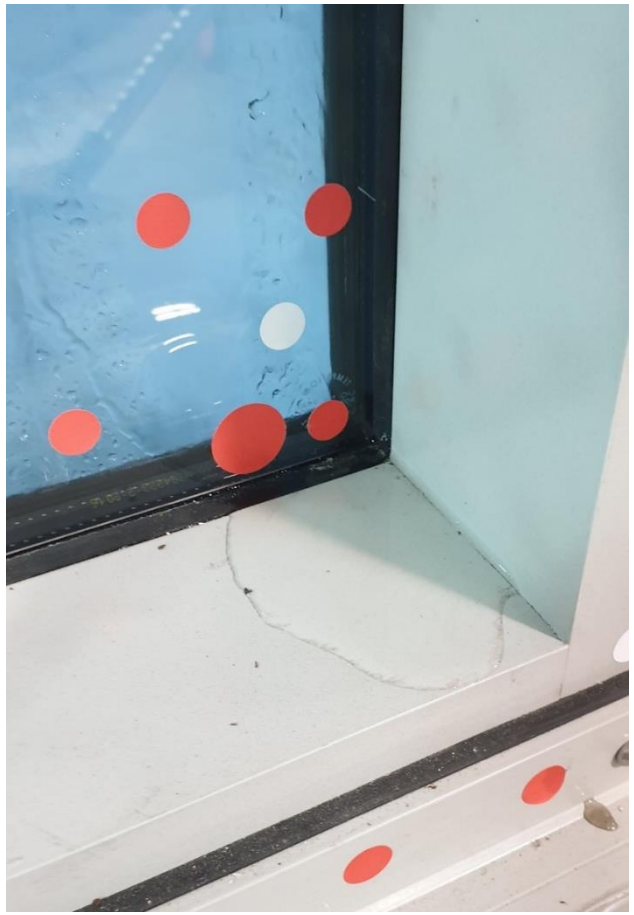
Fragility of glazing systems



First Specimen 0.15% Drift

Second Specimen 0.7% Drift

Third Specimen 0.4% Drift

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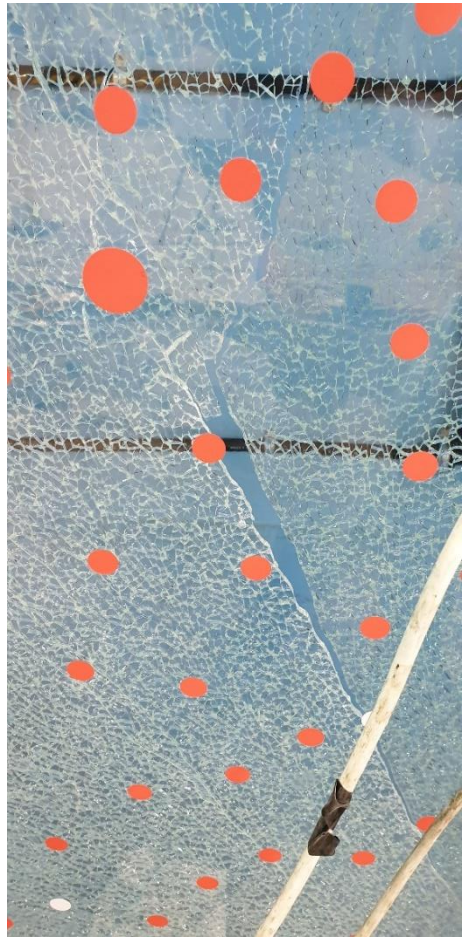
Arifin et al.

Fragility of glazing systems

Other damage states observed:

Gasket Fallout

Frame Damage

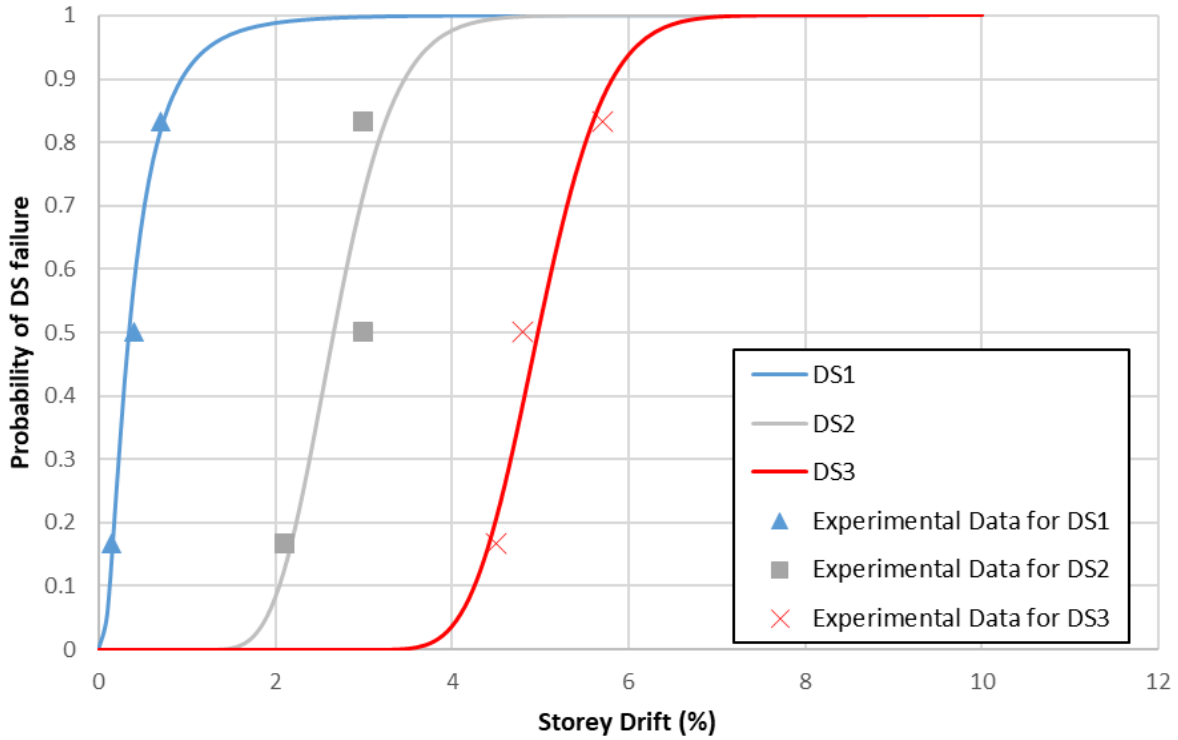


Glass Fallout

Arifin et al.

Fragility of glazing systems

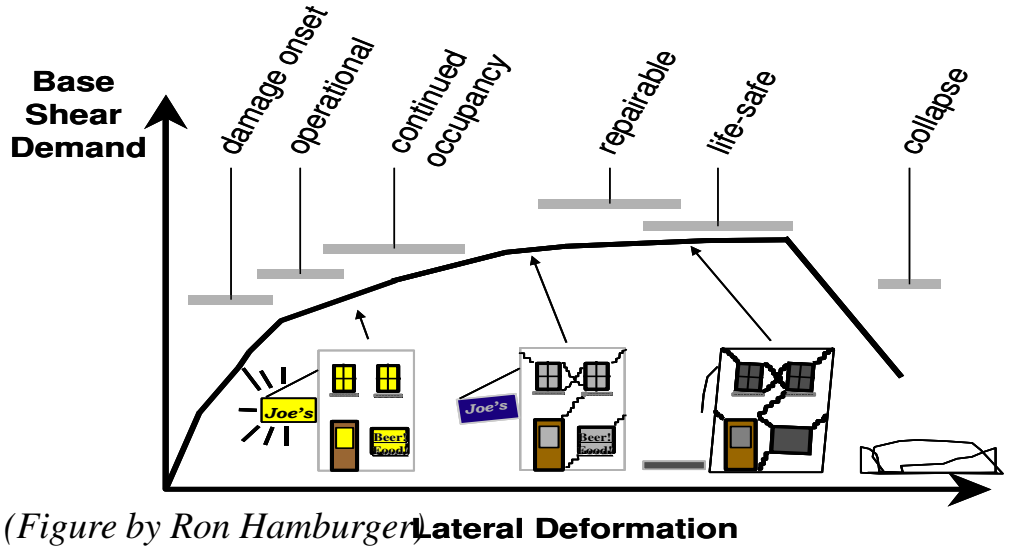
Specimen	Date	DS1 (Water Leakage)		DS2 (Gasket Failure)		DS3 (Glass Fallout)*	
		Drift (%)	Force (kN)	Drift (%)	Force (kN)	Drift (%)	Force (kN)
1	4-Oct	0.15	1.18	2.1	2.18	4.8	8.413
2	17-Oct	0.7	1.24	3	1.43	4.5	7.73
3	29-Oct	0.4	1.74	3	2.55	5.7	10.03



Arifin et al.

Recognized need for better communication

Traditional descriptions of performance



(Figure by Ron Hamburger)

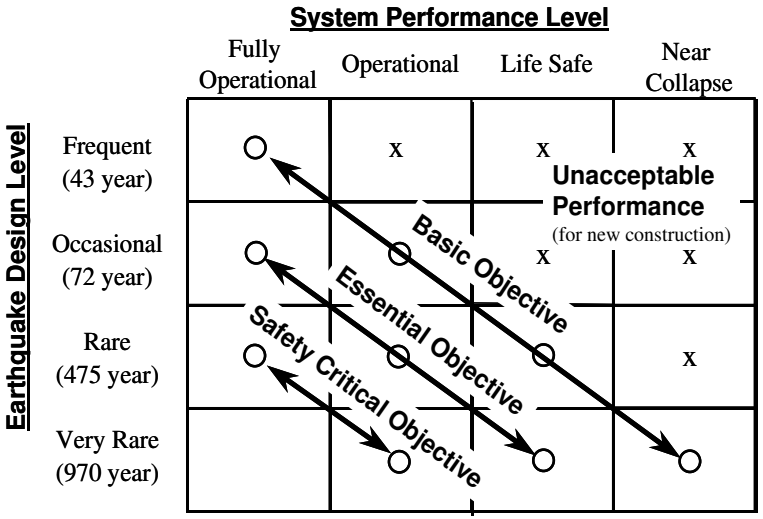
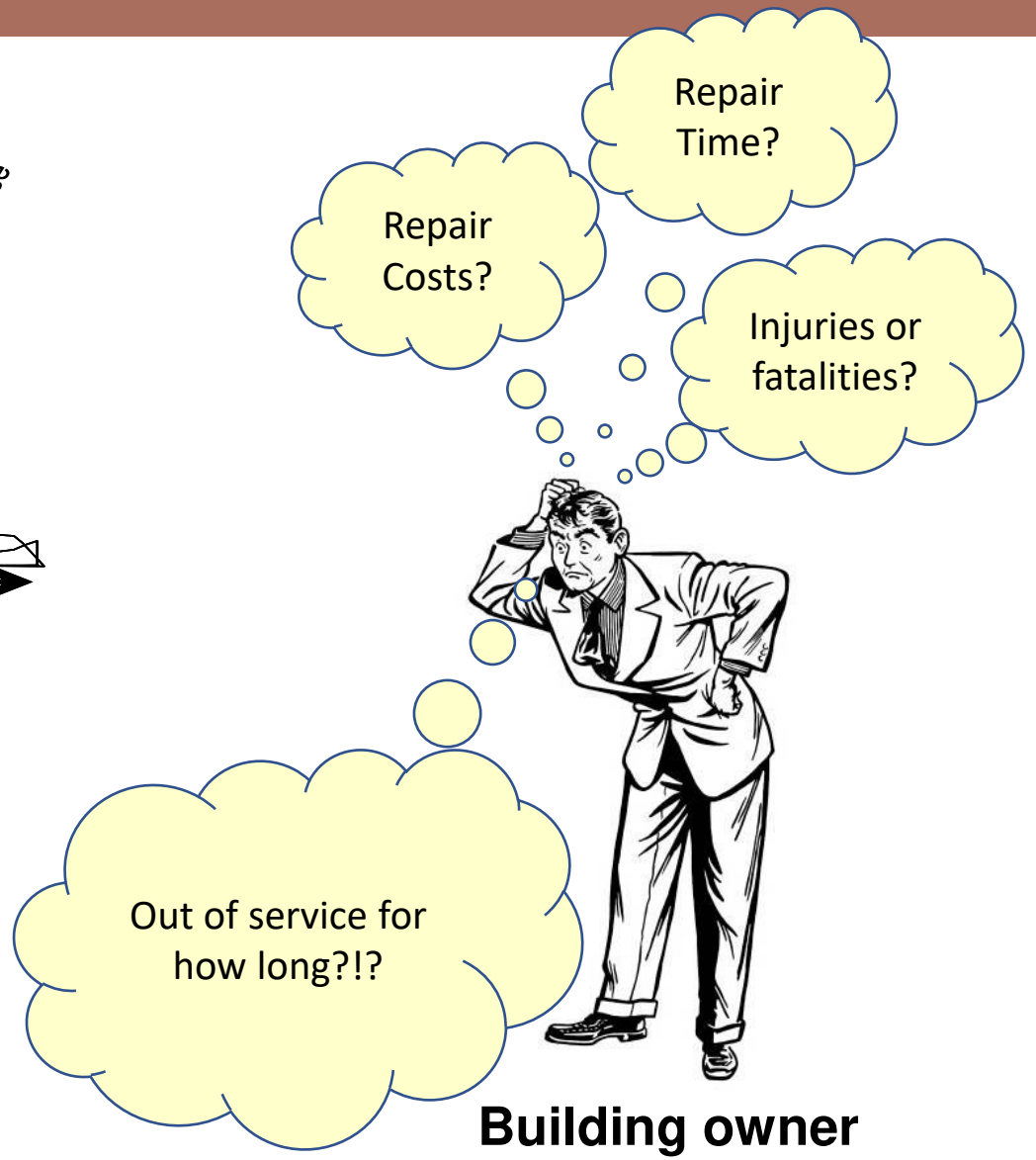


Figure from SEAOC Vision 2000 document

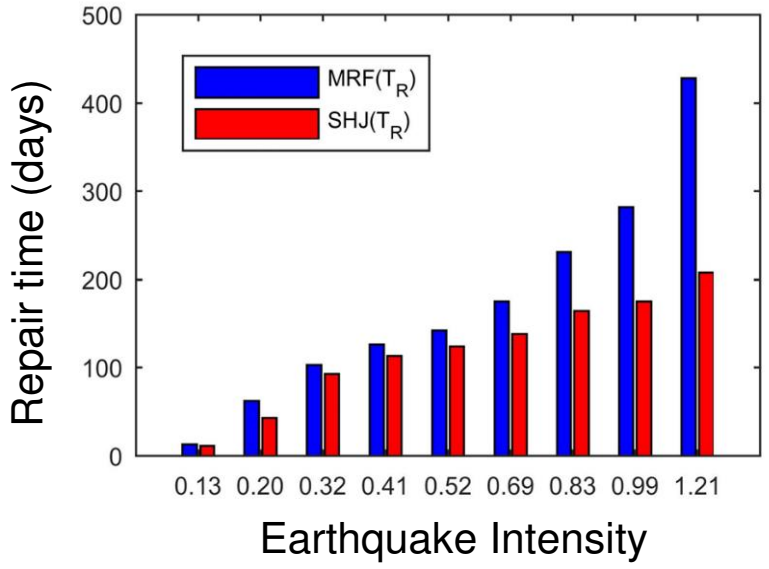


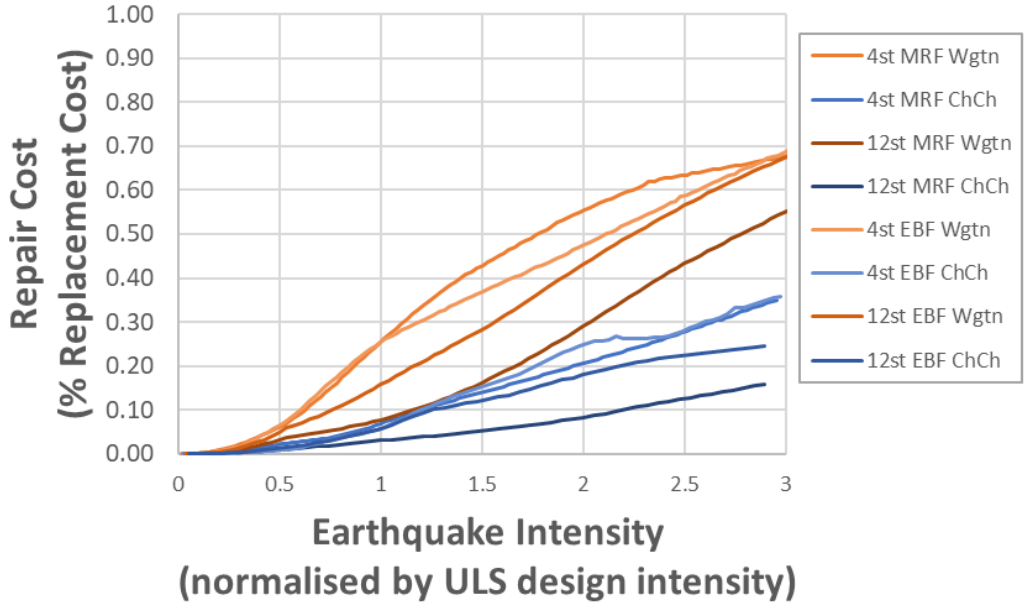
Building owner
Member of public

What options are there for better performance choices?

Research efforts continue to contribute to development of:

1. Engineering tools and guidelines to enable (i) low-damage buildings and (ii) improved assessment outcomes.
2. New strategies for communicating and designing for desired performance… life safety vs. losses vs. building loss of functionality.





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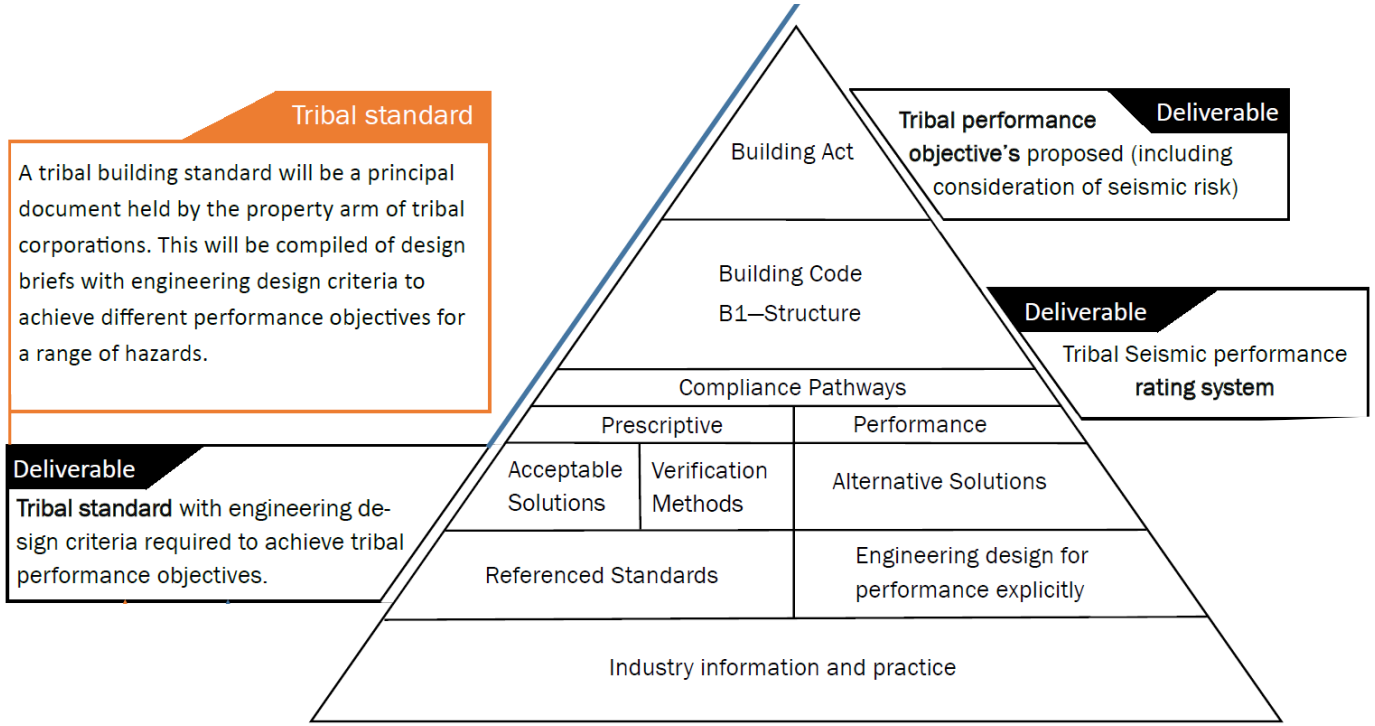
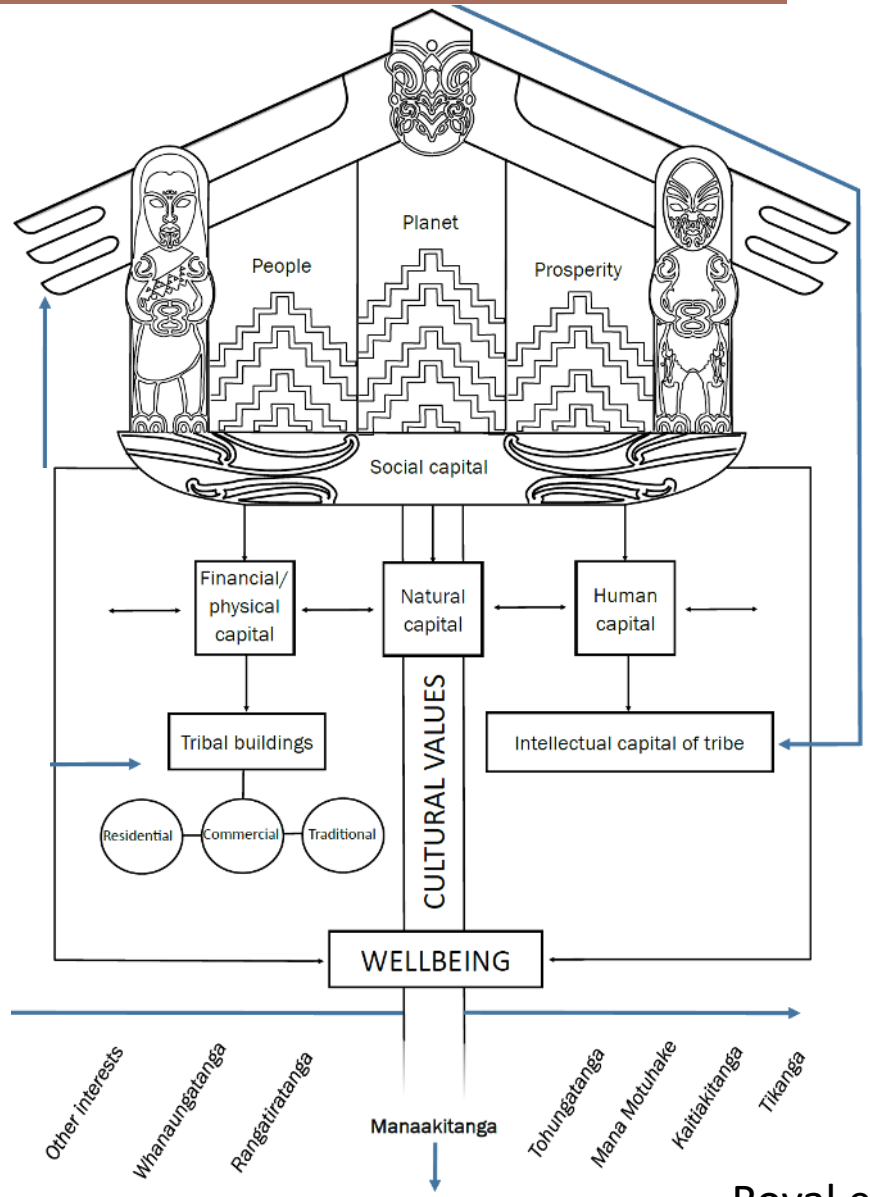
Seismic – Māori Performance Objectives

Exploring the interface between earthquake engineering and the indigenous Māori dimension.

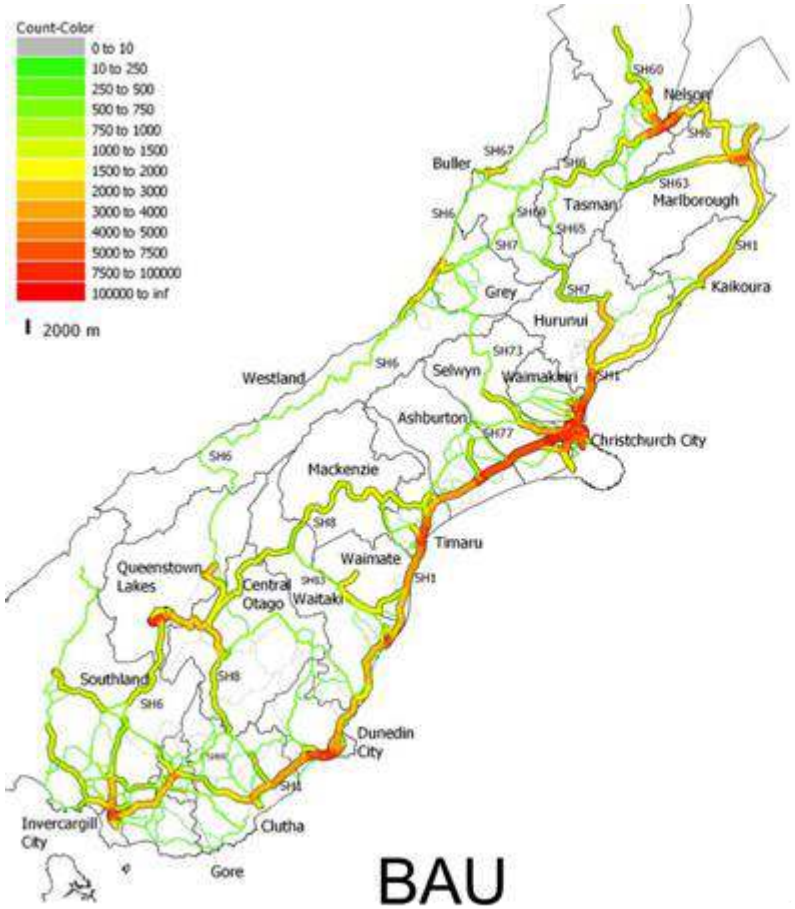




Royal et al.

Seismic – Transport Networks

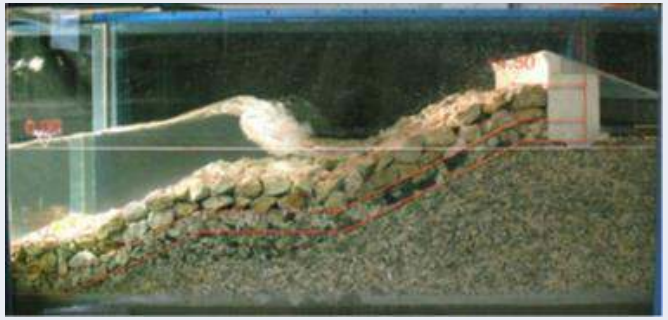
- Alpine Fault Scenario



Aghababaei et al.

Coastal - Protection

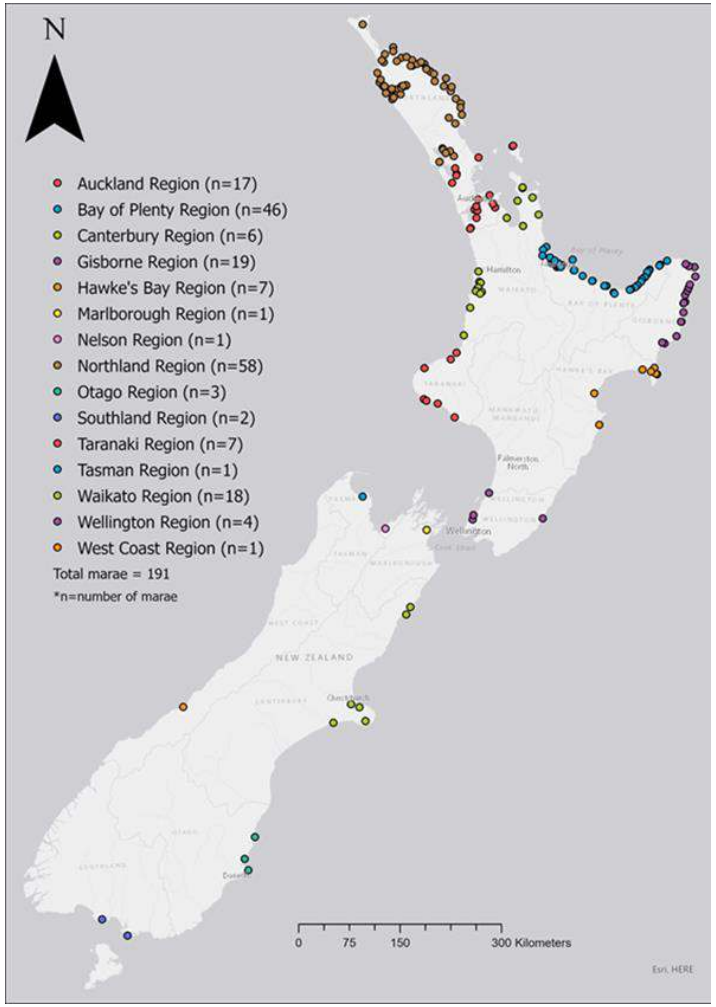
- Sea level rise and storm surge

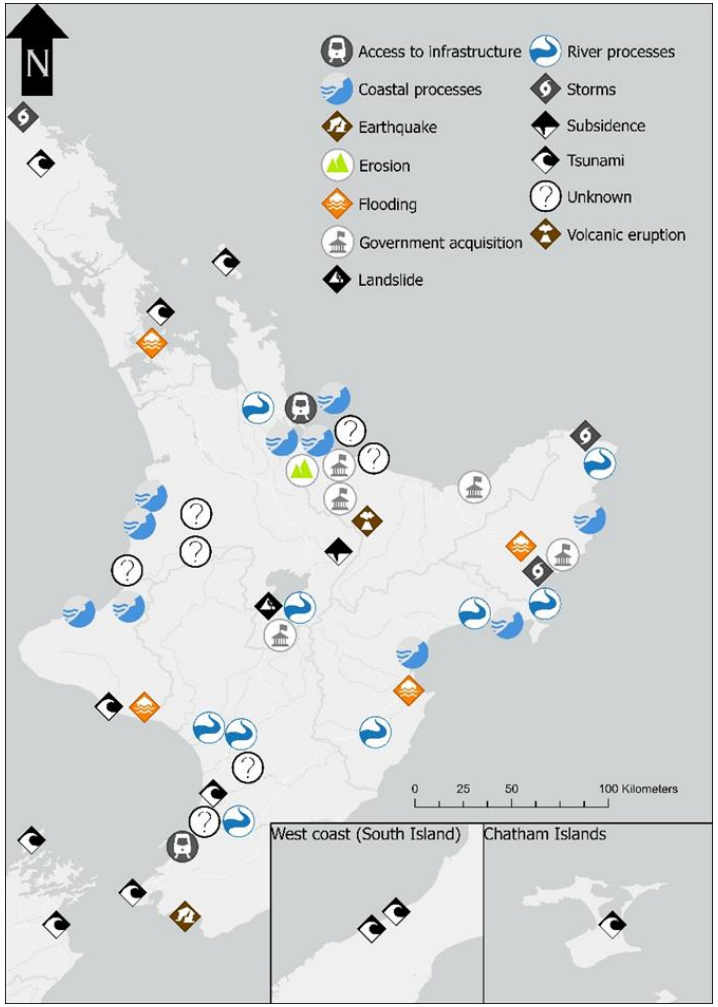
Stage	Overtopping	Structure stability
'what is happening now?'		
'what can we do about it?'		

Whittaker, Shand et al.

Coastal – Marae/Pā

- Co-development of decolonised managed retreat strategy





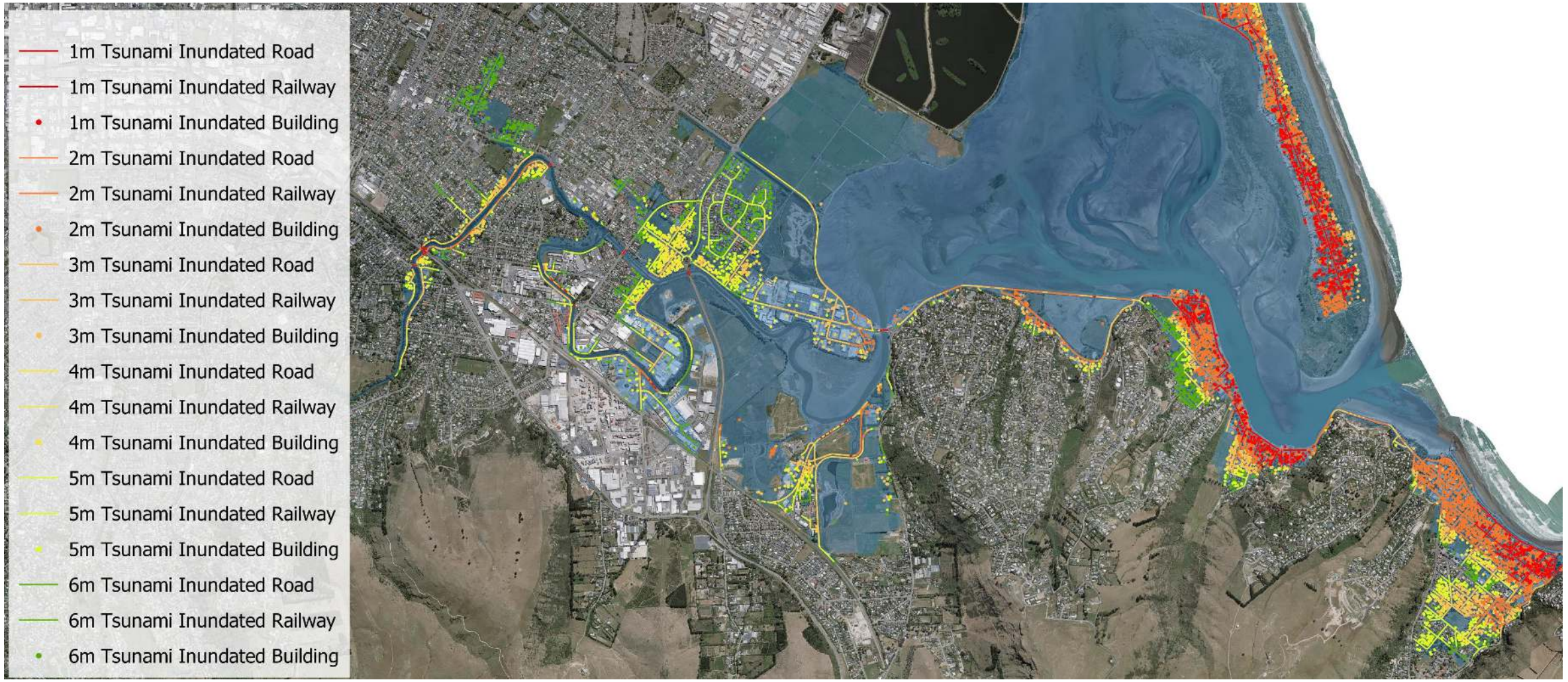
Māori have been adapting to natural hazards for centuries

- e.g., seasonal settlements, full relocation of marae, hapū and iwi, seawalls, dune vegetation
- These examples date as far back as the 15th century to present day

Bailey-Winiata et al.

Tsunami - Inundation

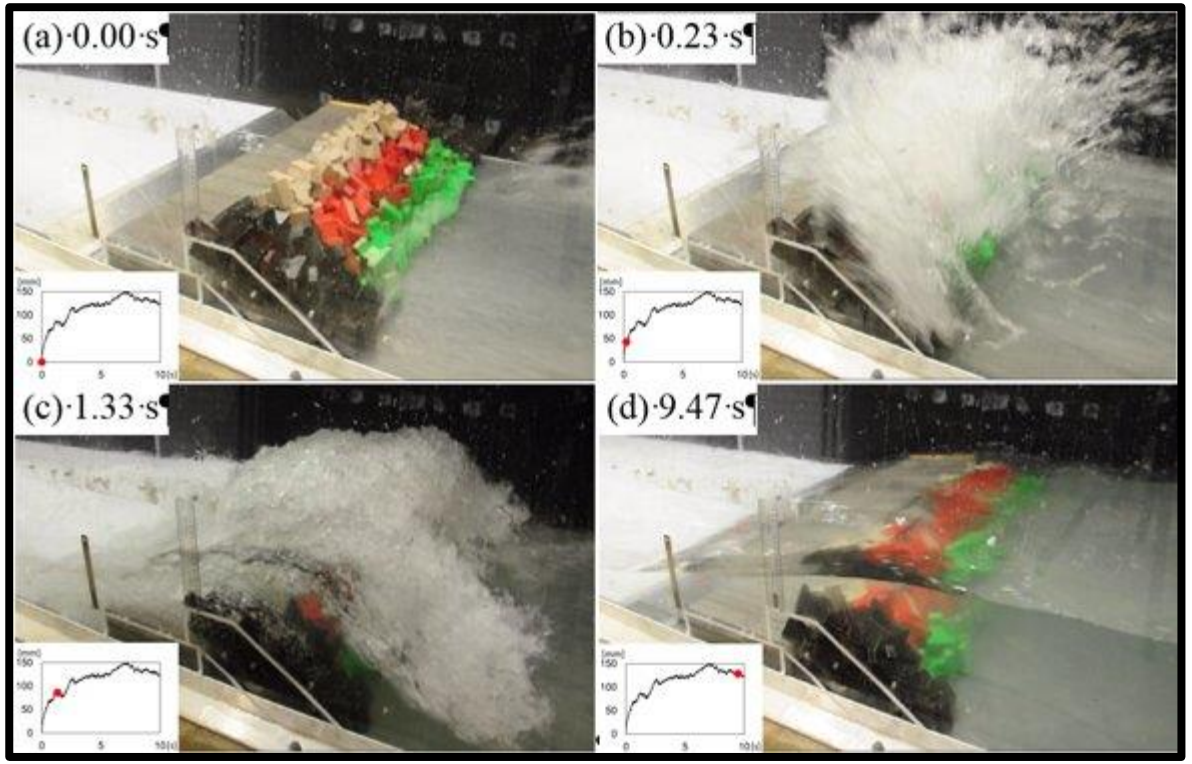
- Modelling – what might be exposed in different scenarios?

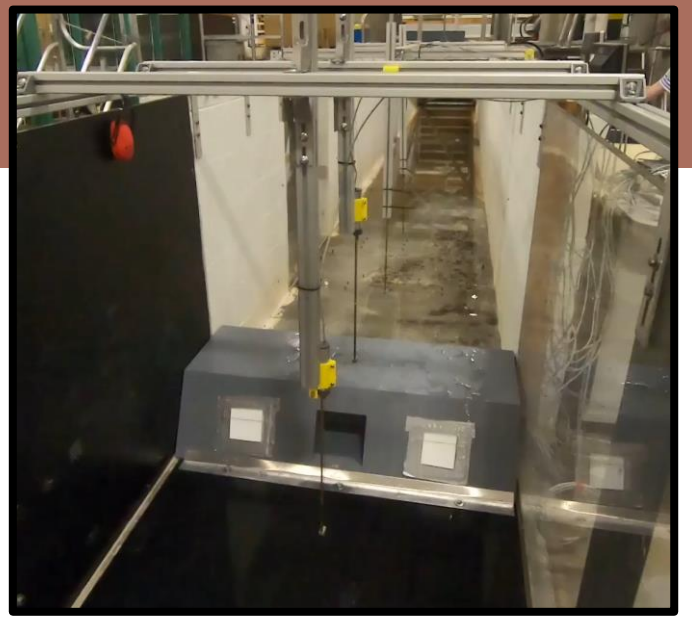


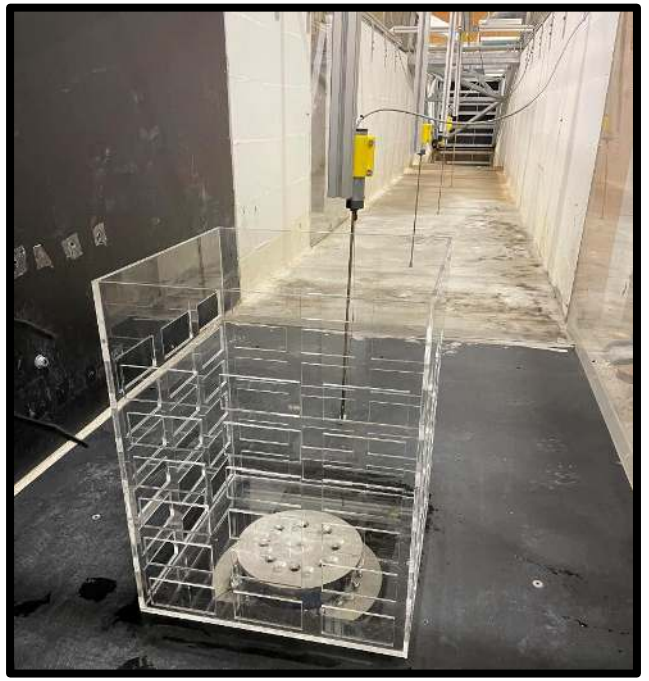
Kimpton et al.

Tsunami – Component Performance

- Infrastructure component performance
  - Case history data - international
  - Physical modelling – tsunami flume



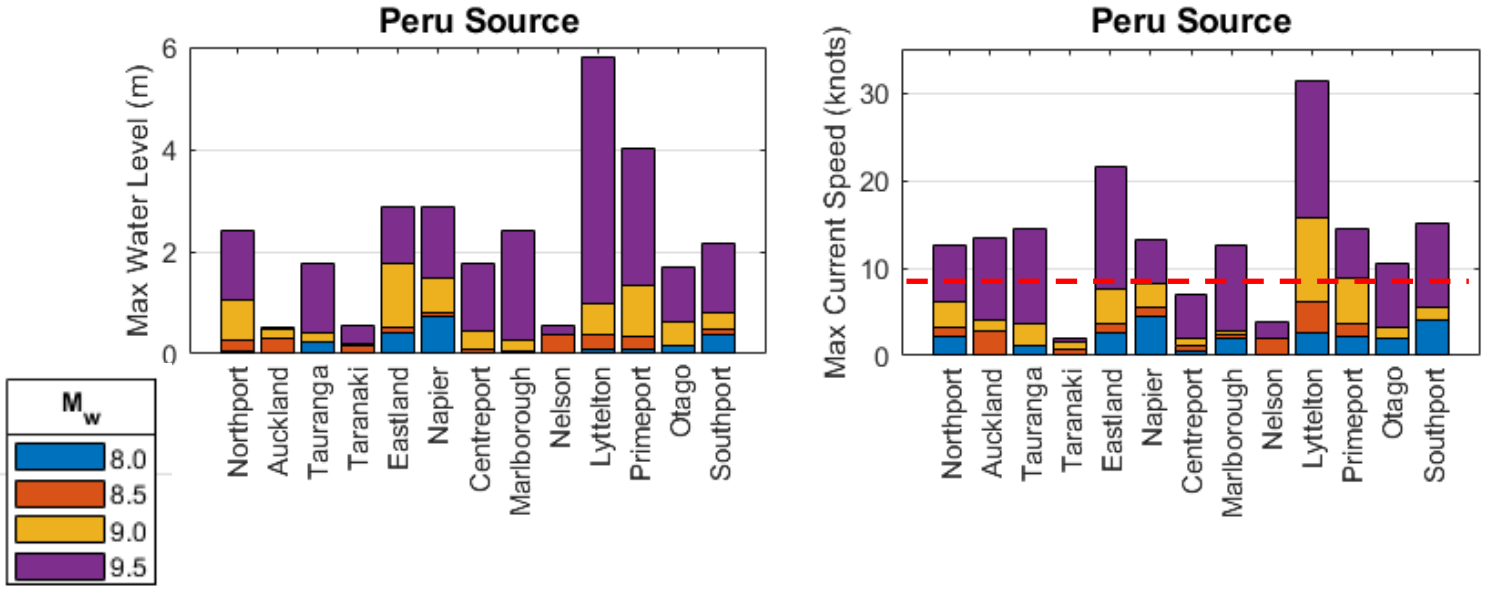


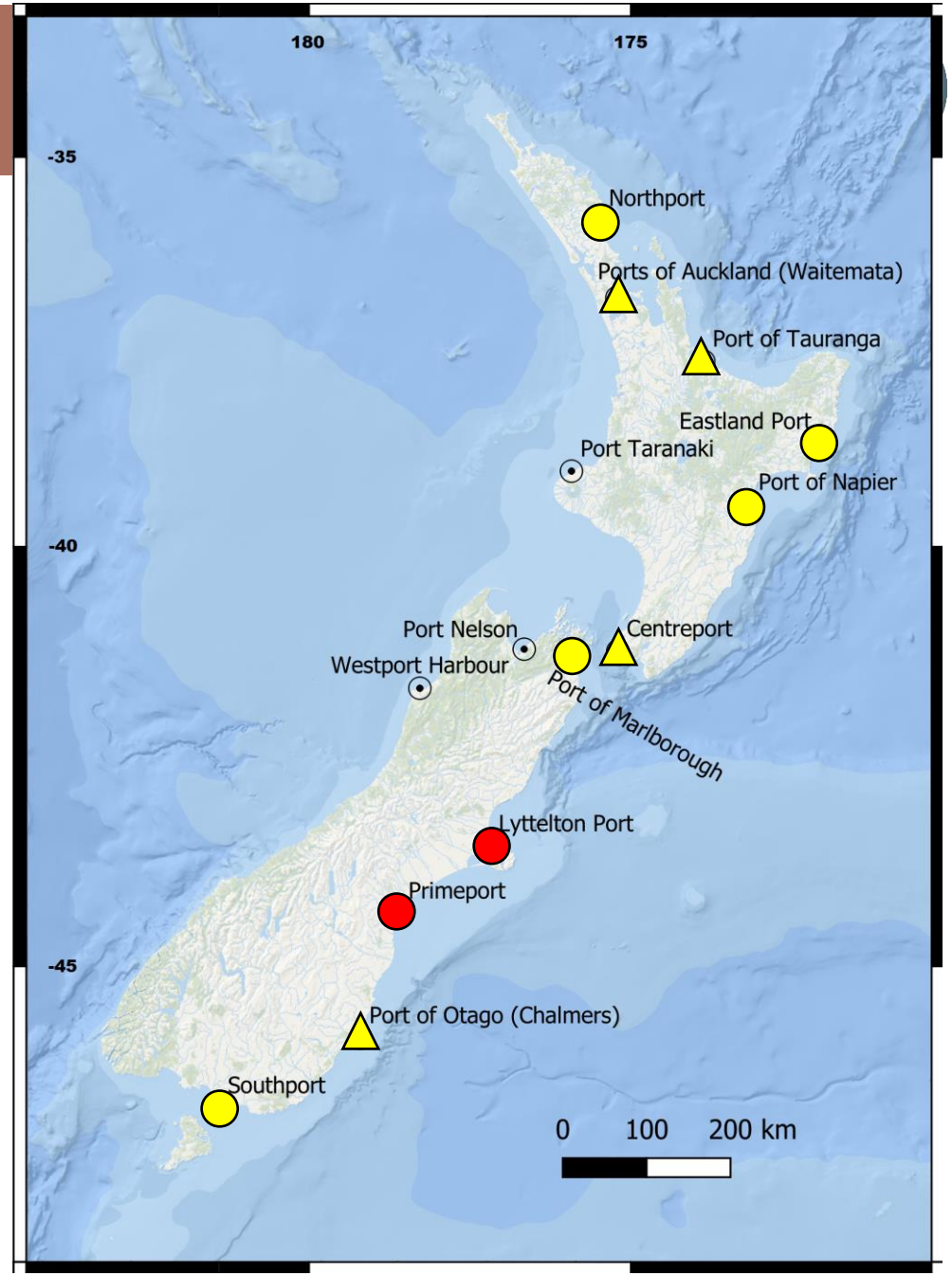


Kimpton et al., Till et al.

Tsunami – Port System

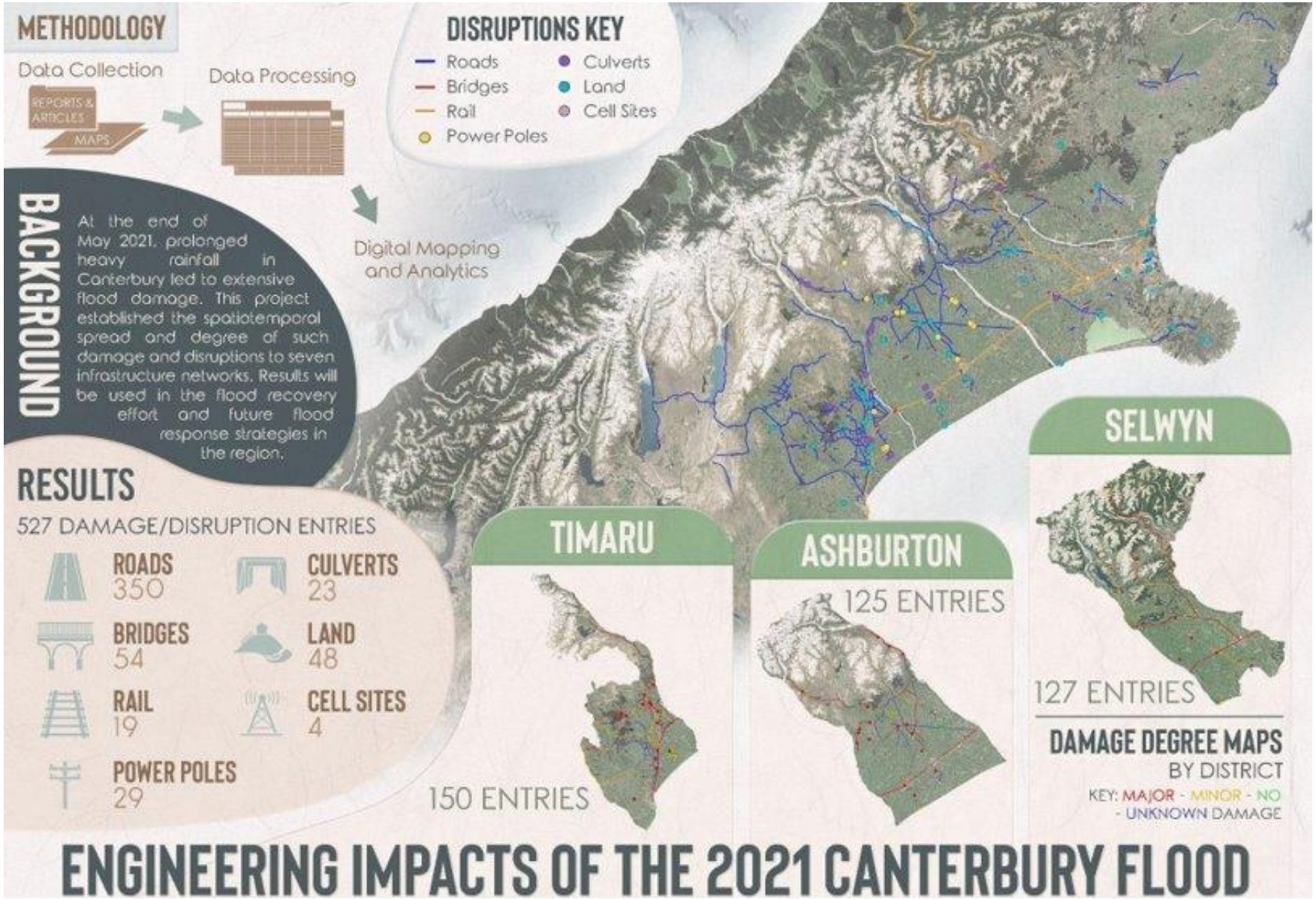
- Ports critical part of transport system
  - Tsunami scenarios could result in widespread disruption
- Peru source scenario
  - Wave related damage: 7 ports
  - Current related damage: 10 ports





Popovich et al.

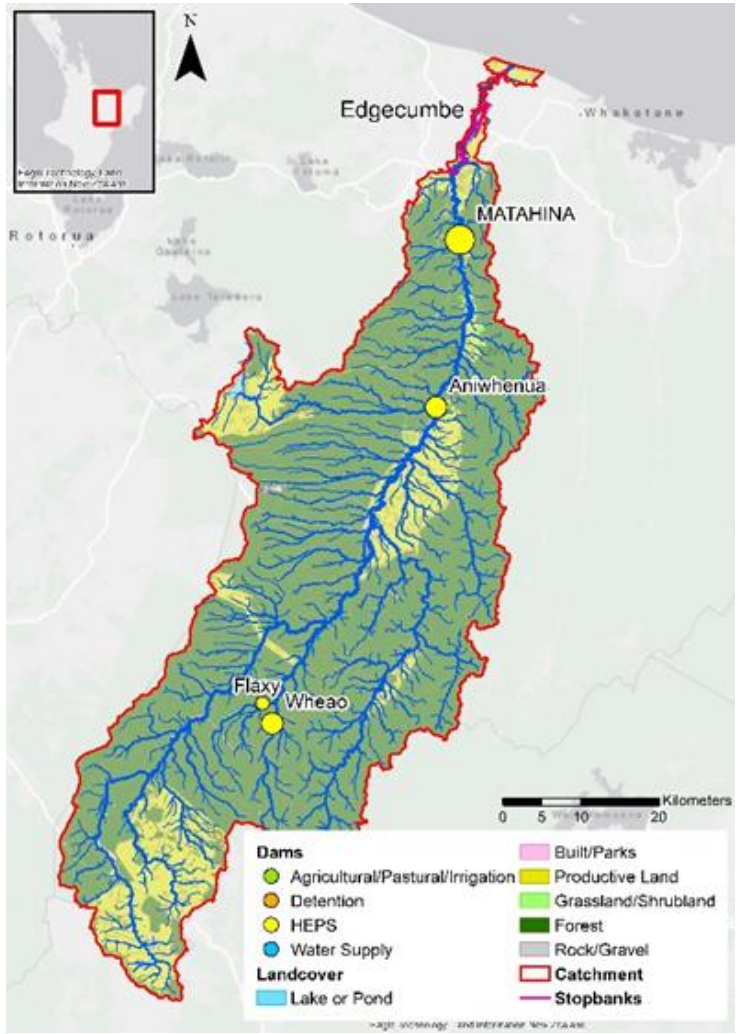
Flood – Case Histories

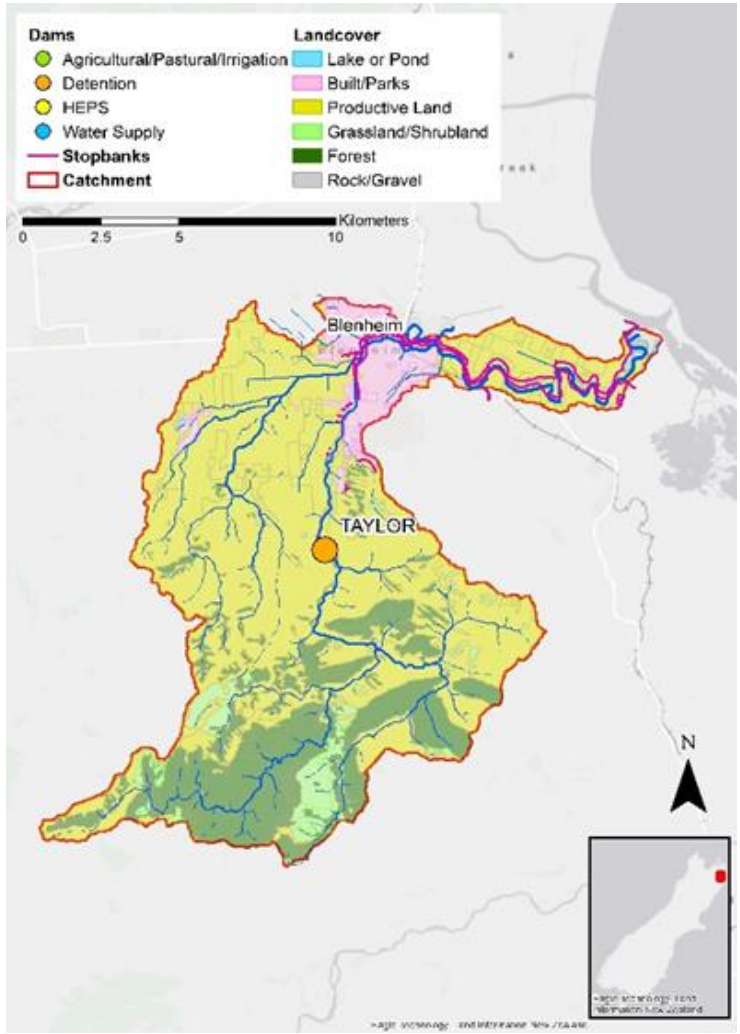


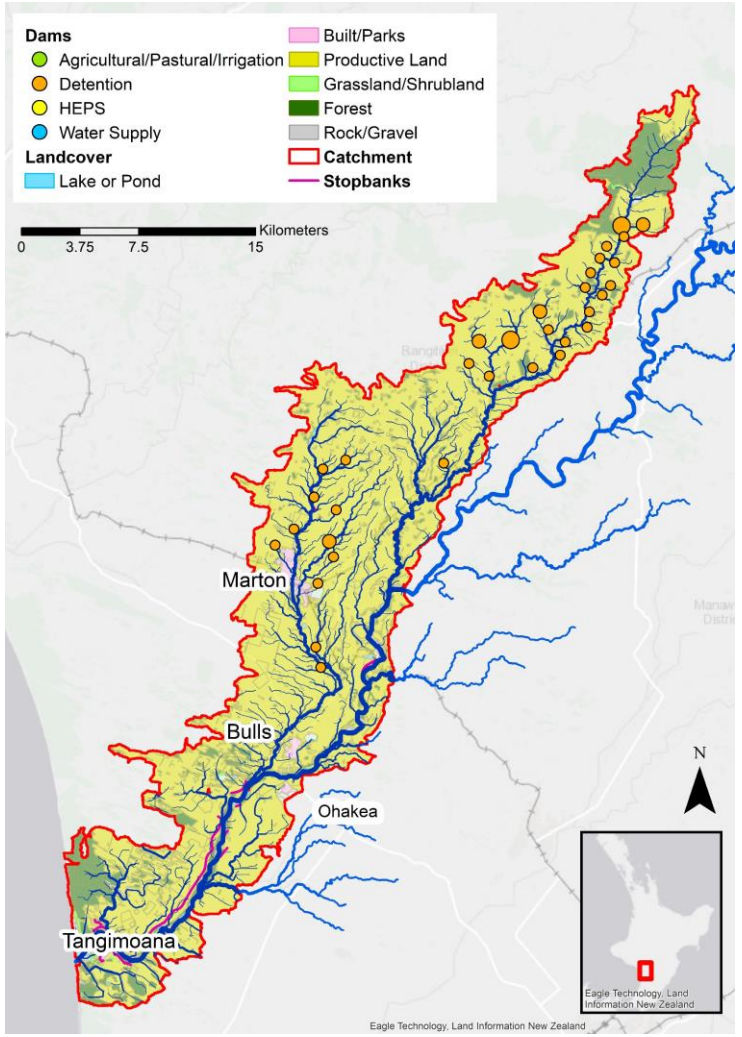
Lee et al.

Flood - Systems

- Dam-stopbank system management







Wallace et al.

Next Steps - Horizontal

- Infrastructure networks:
  - Electricity transmission and distribution
  - Telecommunications
  - Urban Stormwater
  - Dependencies across multiple networks

- Focus areas:
  - Across single and multiple hazards
  - Quantifying importance/criticality of infrastructure
  - Robustness and/or redundancies within networks
  - Adaptations for communities and hapū
  - Integrating asset management and resilience

Next Steps - Vertical

- Continue developing practical means of linking seismic design criteria to modern building performance measures

- Assess the performance of alternative design provisions on the performance of buildings (whole of building performance), also considering more severe loading scenarios

- Identifying cost-effective means of reducing the vulnerability of buildings

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Engagement

- Opportunities to get involved across range of projects
  - Research collaboration
  - Stakeholder partnership
  - Regional case study applications
- Engagement
  - Monthly meetings
  - Infrastructure Research Days
- Part of wider research eco-system
  - Strong collaborations ongoing

QuakeCoRE
NZ Centre for Earthquake Resilience
Te Hiranga Rū

National Science Challenges

EAST COAST LAB
LIFE AT THE BOUNDARY

THE DEEP SOUTH
Te Kōmata o Te Tonga

AF8
ALPINE FAULT MAGNITUDE 8

He Mounga Puia, Puea Ru, Puea Korero
volcanicfutures.co.nz

Mā te haumaru ō nga puna wai ō Rākaihautū ka ora mo ake tonu:
Increasing flood resilience across Aotearoa

Toka Tū Ake EQC

T

Accelerating Aotearoa New Zealand's resilience to ever-changing natural hazards

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

National Science Challenges

Thank You

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