UoA research with a Wellington resilience lens

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Built environment research

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There are numerous ongoing research programmes at UoA to improve the resilience of the built environment…

- Understand natural hazard-induced demands (seismic, tsunami, flood) on vertical and horizontal infrastructure.
- Develop analytical methods for quantifying performance of new and retrofit structures.
- Quantification of infrastructure component and structural system fragility and vulnerability from case history observations and modelling.
- Develop methods to quantify system-level performance of infrastructure networks and interdependencies.
- Development of decision-making frameworks to inform resilience investments.

Linkages to Wellington

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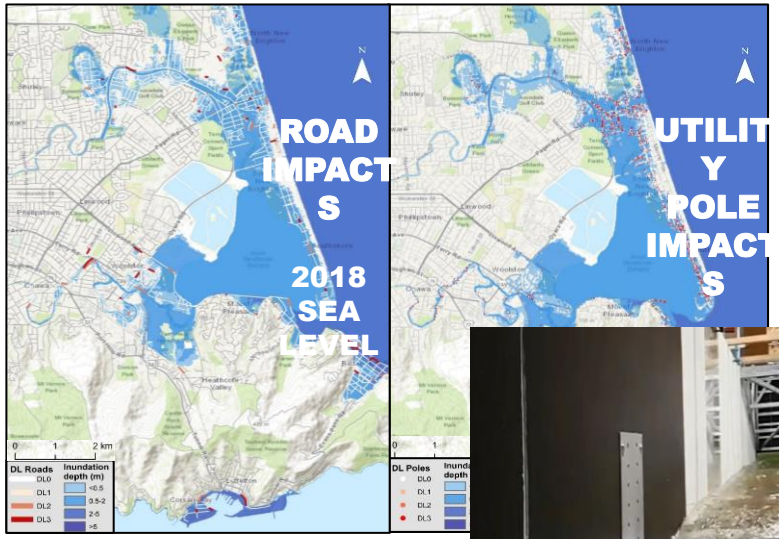
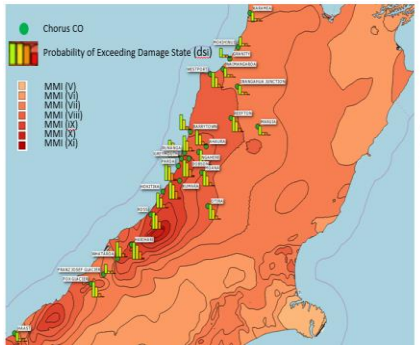
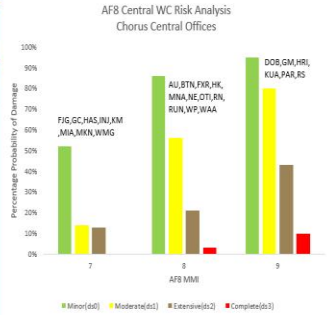
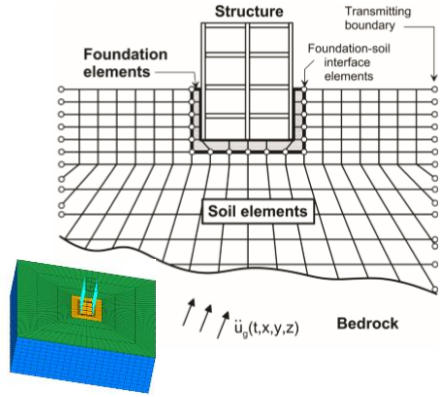
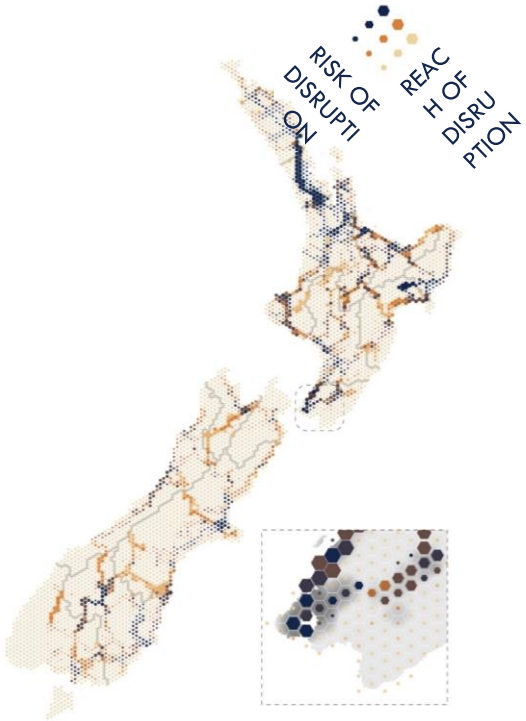
- Many projects are focused on the modelling/development of advanced numerical methods to quantify performance of infrastructure and buildings
- These tools either directly apply to Wellington, or are scalable to the Wellington context











Linkages to Wellington

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- **Roadmap…**
  - Horizontal infrastructure network modelling
  - Seismic and seismic induced hazards on transportation infrastructure
  - Regional modelling of seismic building impacts
  - Probabilistic seismic hazard tools for timber framed housing
  - Horizontal infrastructure disruption from coastal flooding
  - Tsunami impacts

Infrastructure network modelling

A range of concurrent projects modelling infrastructure impacts from natural hazards:

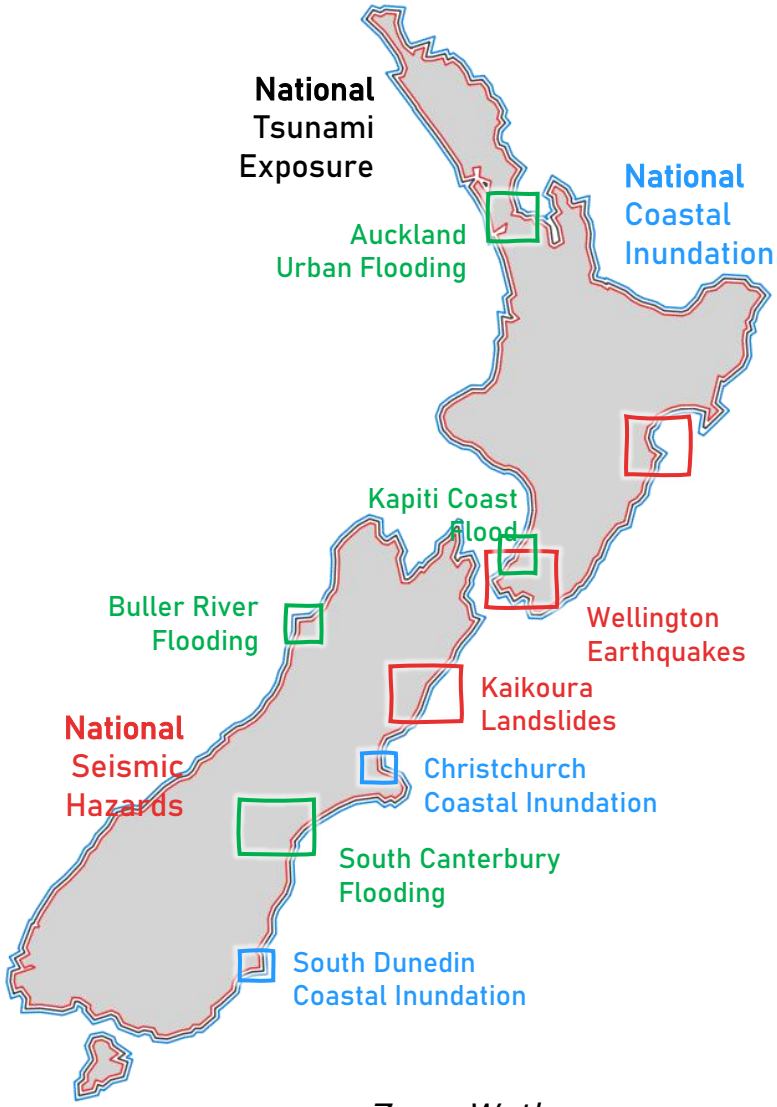
- Earthquake & co-seismic hazards (landslide, liquefaction)
- Coastal Flooding (2-1000yr + sea-level rise 0-200cm)
- Pluvial & Fluvial Flooding

Scale of Analysis

- Improving our existing national scale models
- Local case studies (higher resolution to answer specific questions)

Outputs:

- Direct (exposure and damage),
- Indirect (interdependencies, flow on effects & cascading failures, connectivity/access to key sites, supply-chains…)



Zorn, Wotherspoon

Wellington network modelling

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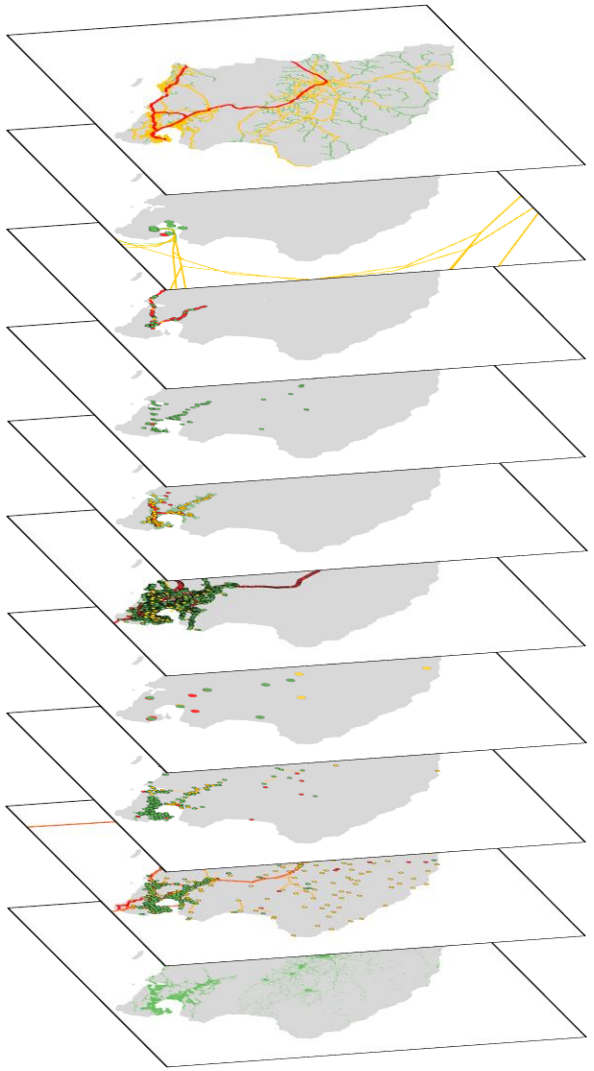
- Higher resolution than current national scale models
- Focus on representing object-level (individual assets) in
- network models
- Link to buildings as demand points so we can assess changes in demand post-disaster and recovery prioritisation
- Automated, reproducible analyses
- Hazard-agnostic
- Modelling the same scenarios with different levels of input data resolution to study how data resolution affects overall spatial-temporal metrics. Implications for other studies in NZ and internationally.



Zorn, Wotherspoon

Impacts of seismic induced hazards on highway network

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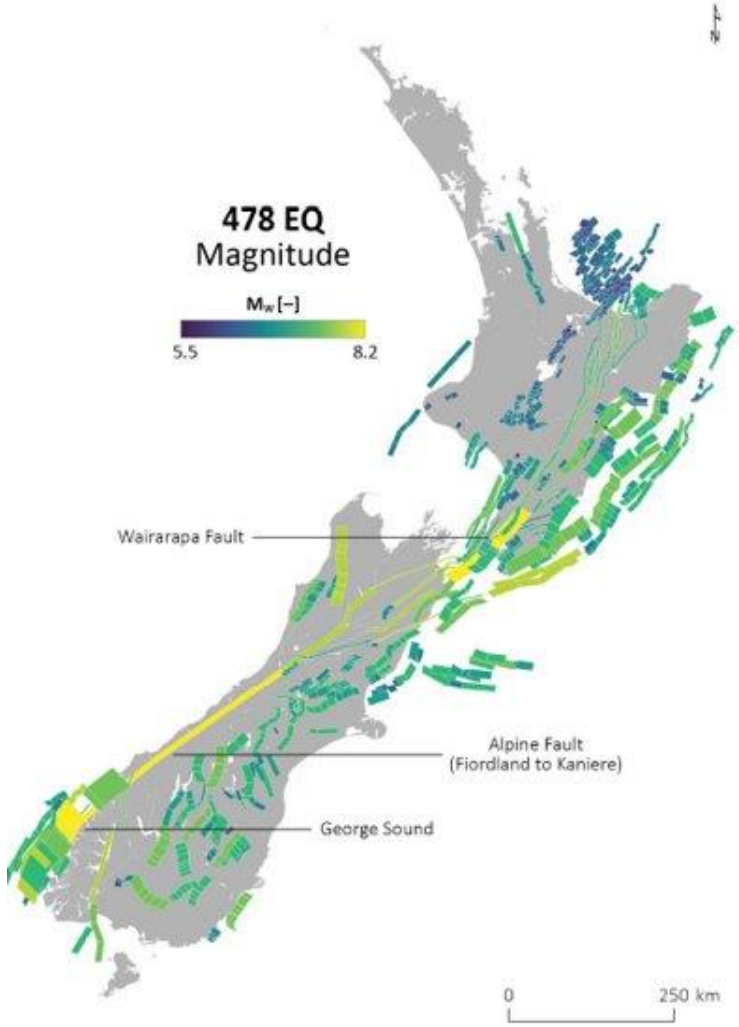
- Liquefaction and landslide exposure across national networks
- Single scenarios
  - Probability or manifestation of hazards
- Combination of multiple scenarios
  - Impact on network rather than individual points
  - Multiple different ways to assess this



EQC EARTHQUAKE COMMISSION Kōmihana Rūmaki | QuakeCoRE NZ Centre for Earthquake Resilience Te Hīranga Rū

Lin, Wotherspoon

Impacts of seismic induced hazards on highway network

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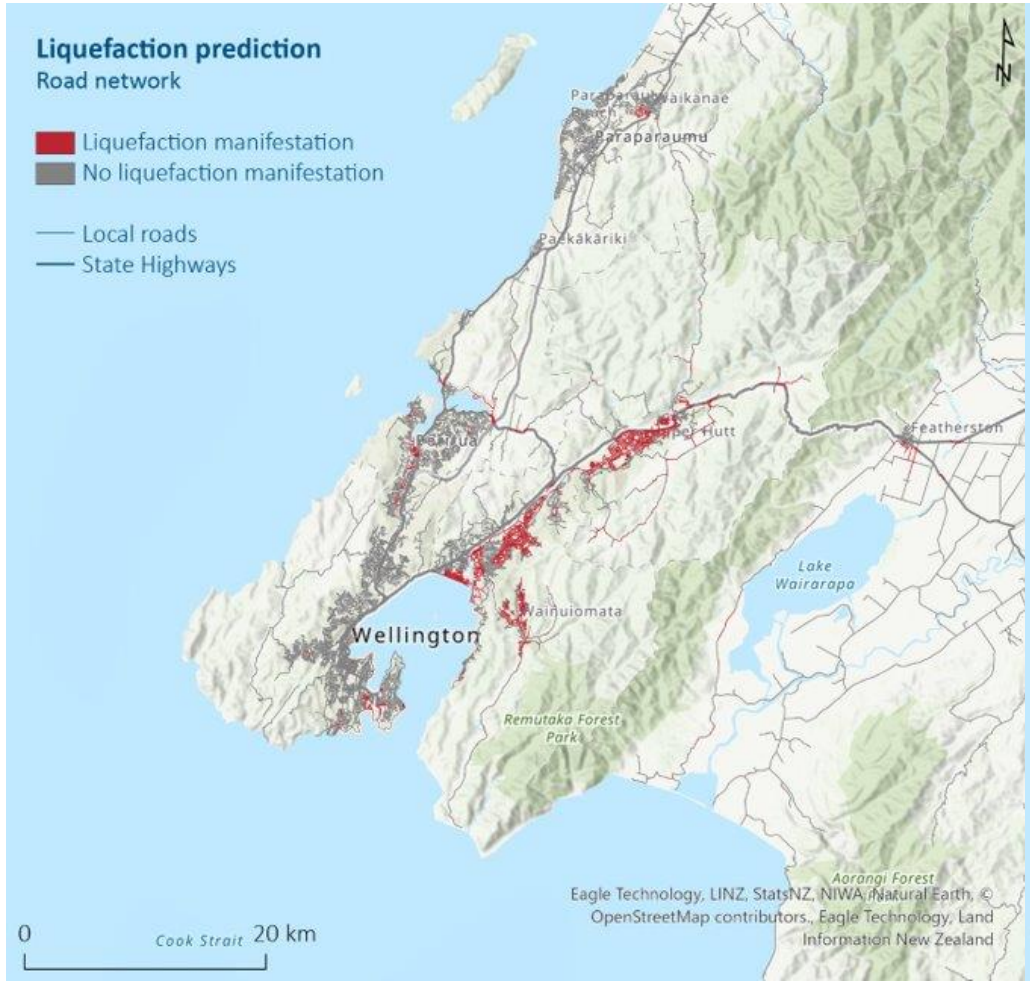

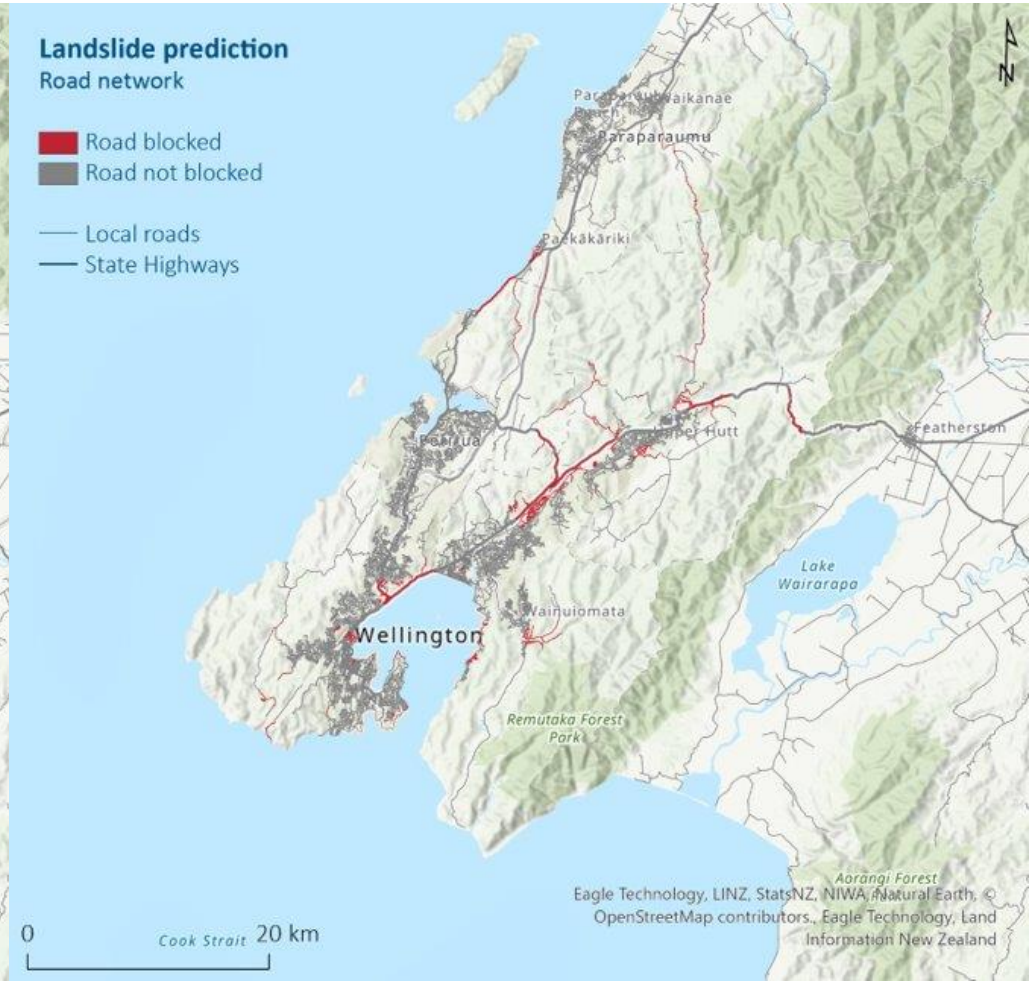

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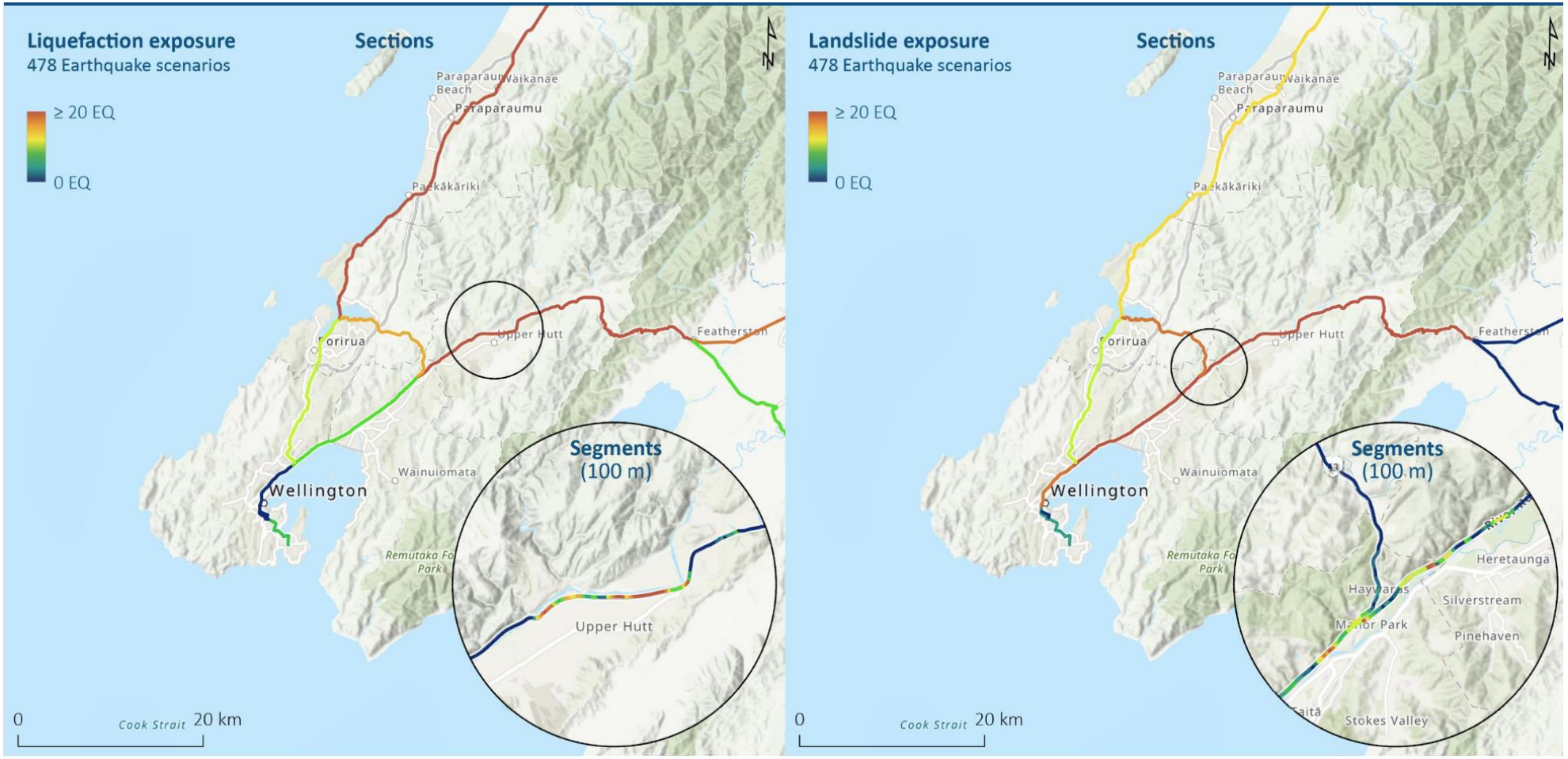

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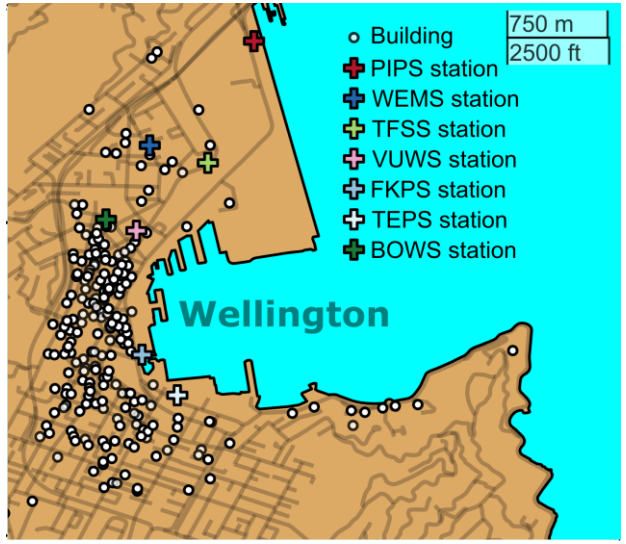
NZ Centre for Earthquake Resilience

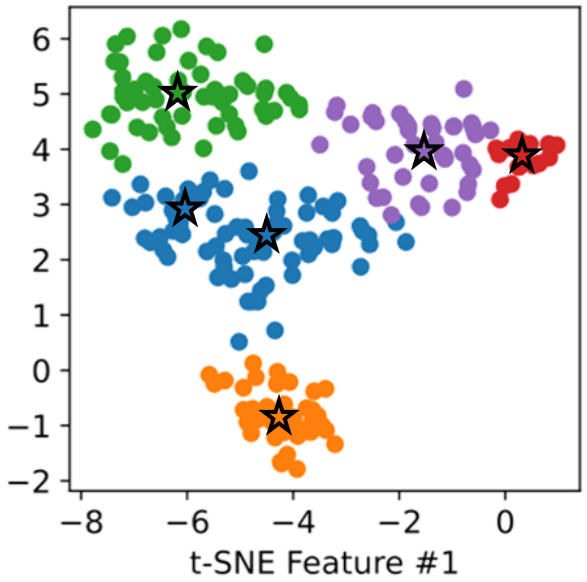
Lin, Wotherspoon

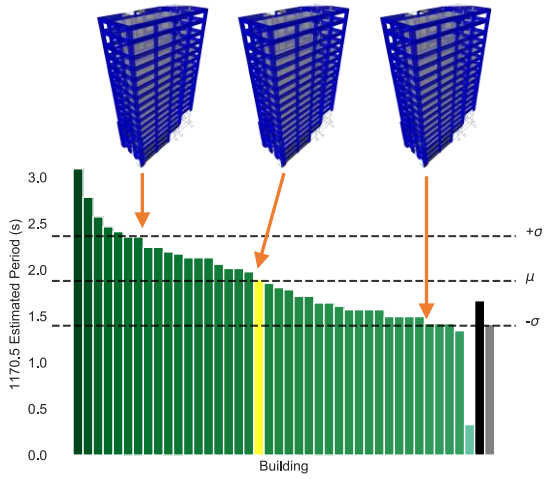
Regional building impacts

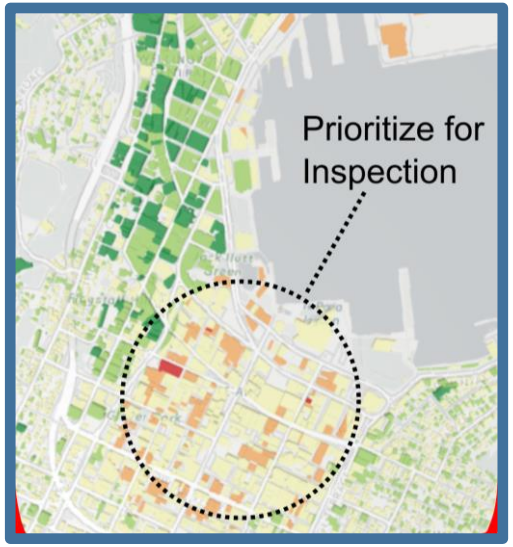
- Impact tool for pre-event scenario planning and post-event impact assessment
- Compiled detailed inventory of ~800 buildings in the Wellington CBD
- Unsupervised ML used to cluster buildings into typologically similar groups
- Representative indicator buildings selected from each group

'raw' database → ***clustering and indicator buildings*** → ***model development*** → ***impact maps***



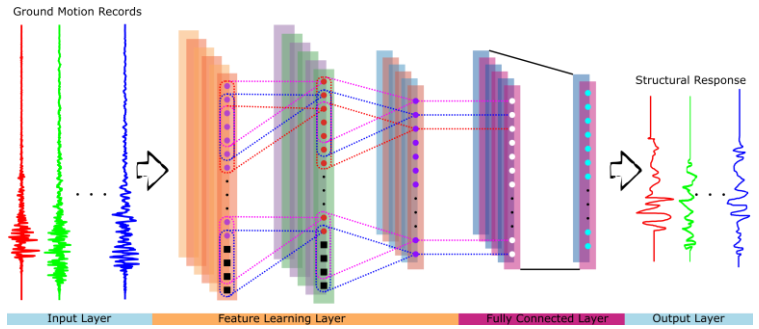






Regional building impacts

- Extending current work to incorporate ML surrogate models for structural analysis
- Requires a large database:
  - Structures
  - Physics-based models
  - Seismic demands
- Machine Learning surrogate models
  - Using Convolutional Neural Networks
- Framework to tie everything together



Computer Modelling
Data Processing

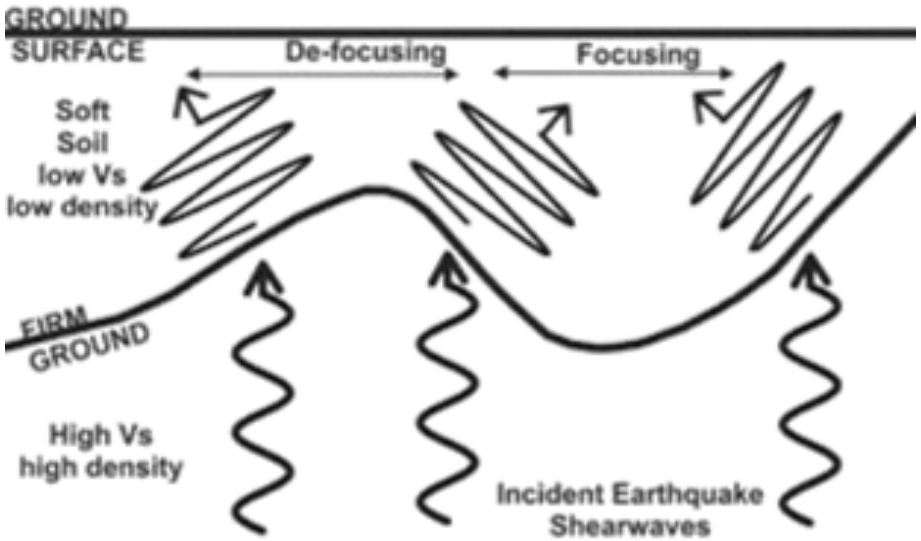
Deep Learning
Transfer Learning

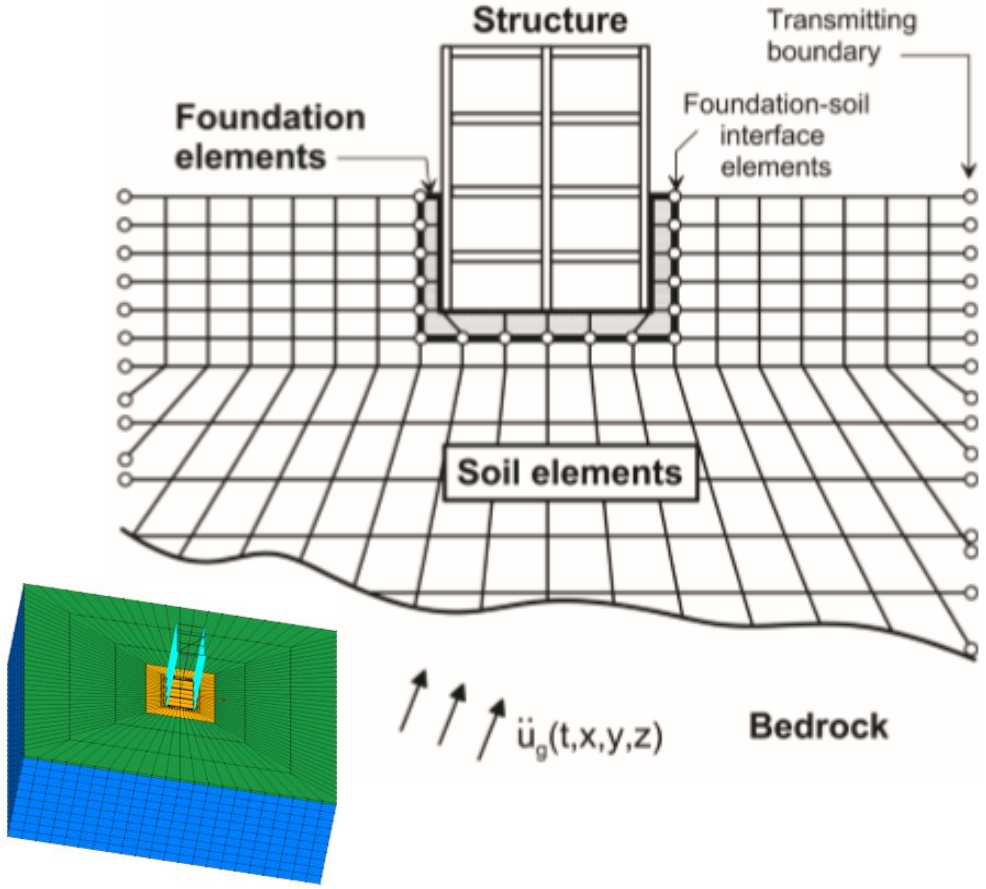
Raw Data → Augmented Data → Deep Learning Structural Surrogate Models → Seismic Evaluation Tool

Seismic Fragility Assessment
Near Real Time Impact Map

Regional building impacts

- Extending regional work to incorporate soil structure interaction
- Developing advanced numerical methods to capture soil nonlinearity
- These modelling techniques will be tied into existing framework





Forcellini, Wotherspoon, Stephens

Performance of timber framed houses

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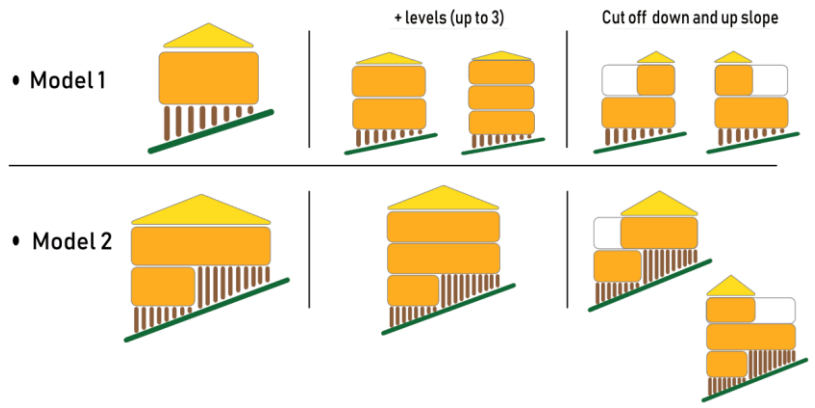
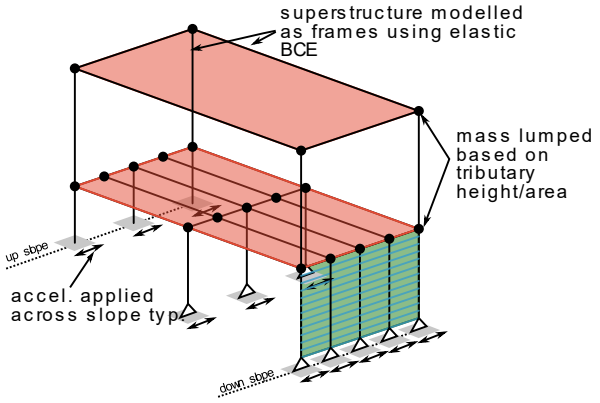
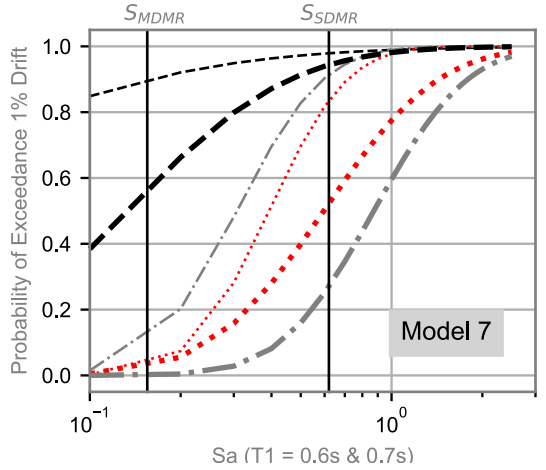
- Focused on developing probabilistic tools to estimate the seismic damage to timber framed houses on slopes
- Structural survey of Wellington homes used to develop common typologies
- Multiple stripe analysis used to estimate probability of exceeding multiple damage states
- Multidisciplinary research that links homeowner expectations of damage to probabilistic estimates

Structural survey used to develop typologies → ***Structural modelling*** → ***Probabilistic tools***







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Infrastructure disruption from coastal flooding

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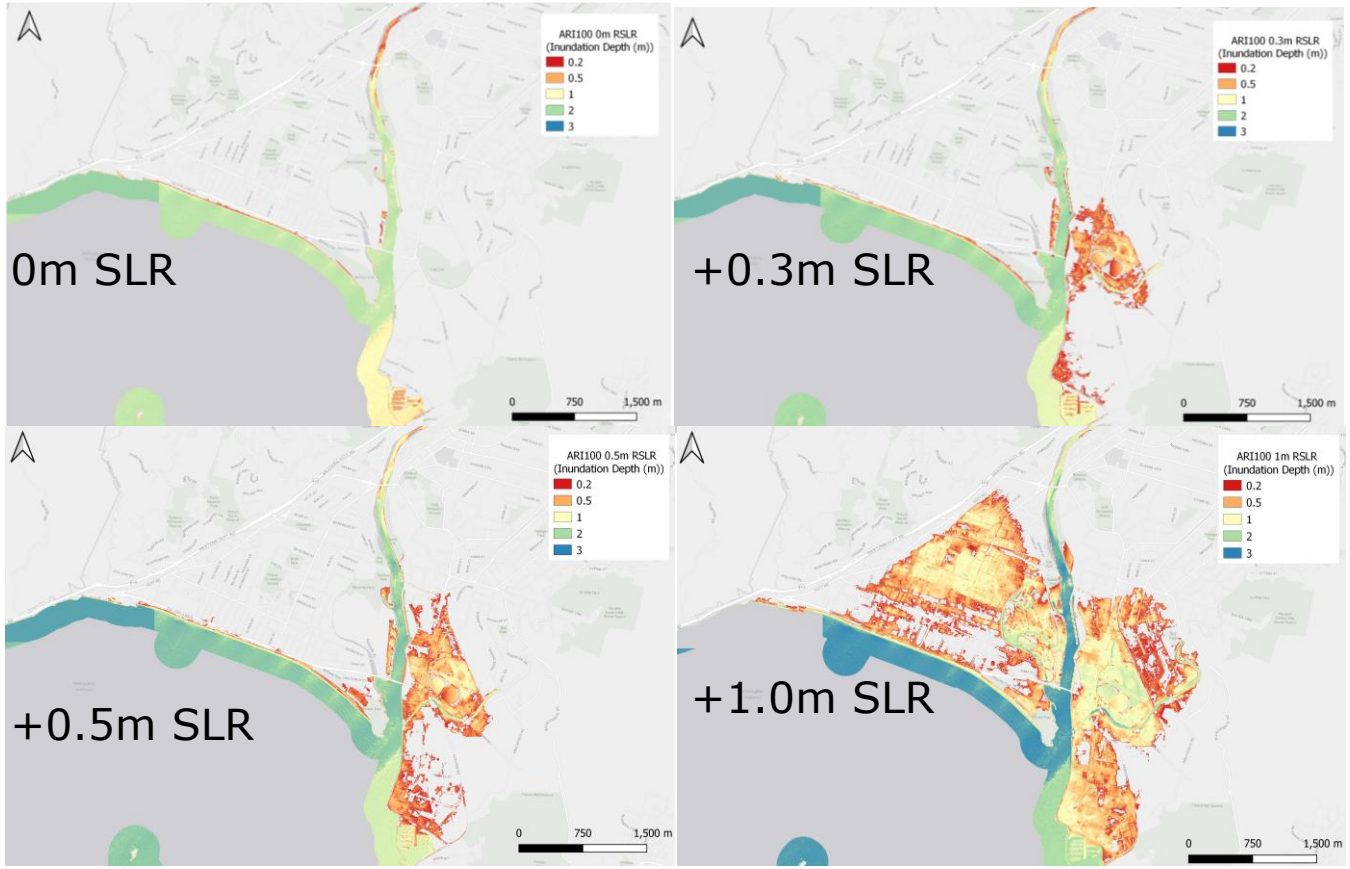
Te Herenga Mātai Pūkaha

- Coastal flooding maps for 9 extreme sea level annual recurrence intervals and 21 sea level rise scenarios
- National road network exposure and probabilistic loss analysis (In progress)
- National network and interdependency modelling of service disruption (In progress)

Lower Hutt 100-year Annual Recurrence Interval Flooding with Sea Level Rise (SLR)



Wotherspoon, Paulik

Tsunami modelling

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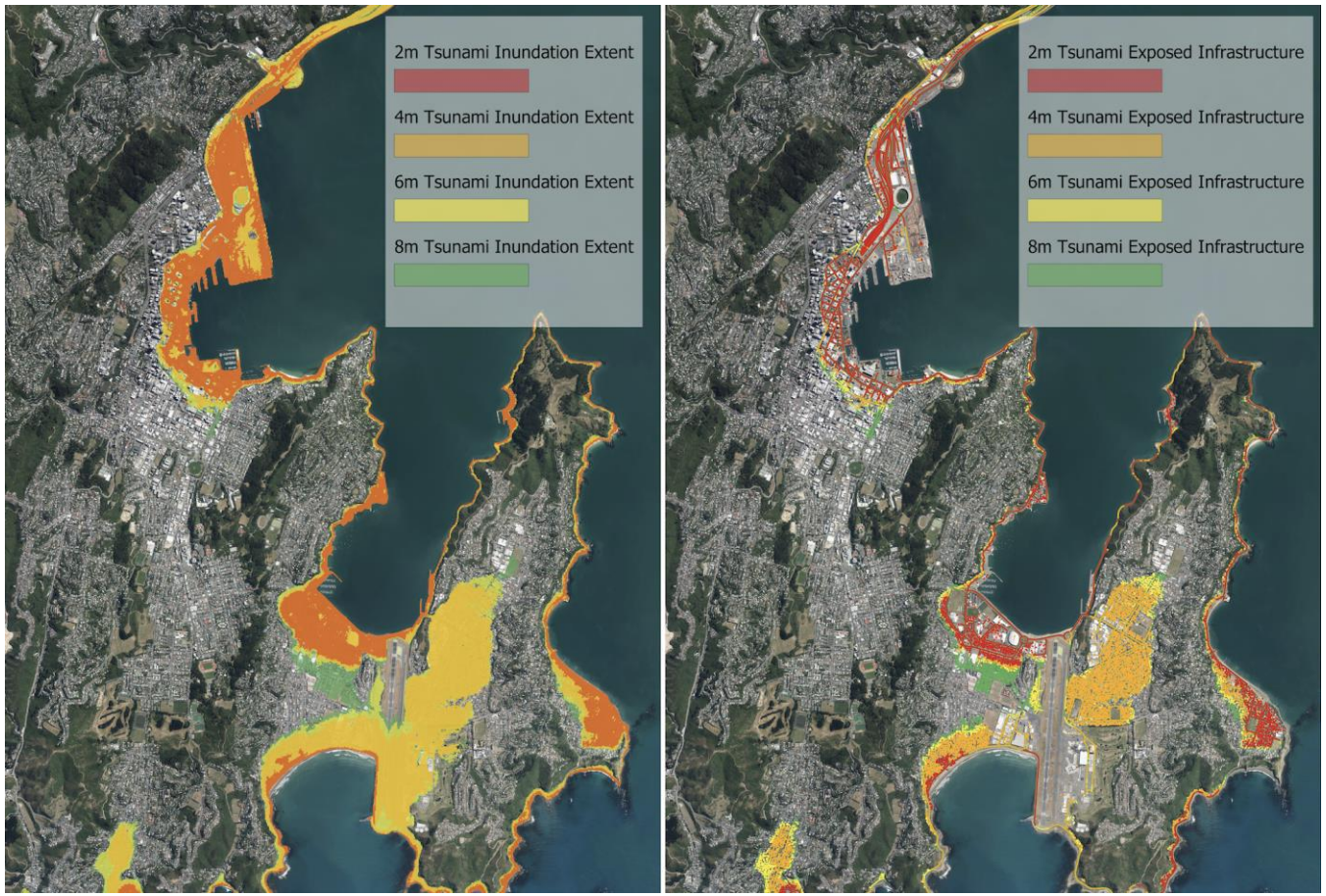
- Simplified modelling approach based on hydraulic principles
- Three important equation variables – slope, roughness, and wave height
- Land classification data used to characterize roughness
- Very efficient – requires approximately 10 minutes to run scenario for 20km of coastline
- The approach has been validated using inundation data from detailed hydrodynamic model

Inundation extent in Wellington using simplified model



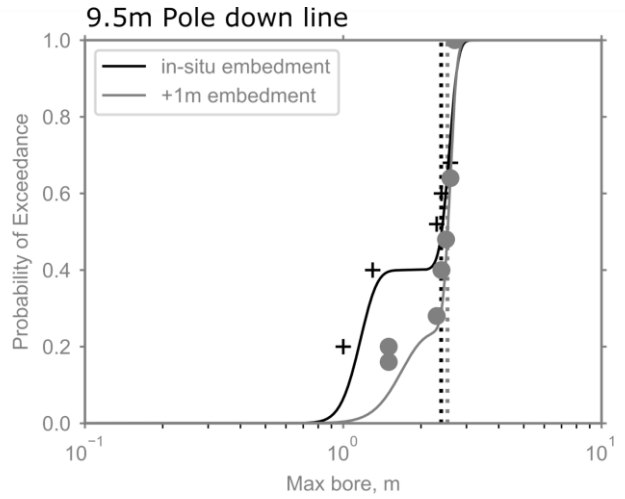
Whittaker, Kimpton, and Wotherspoon

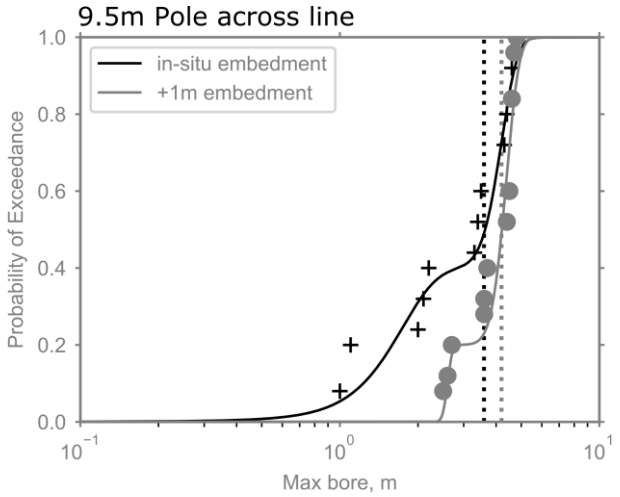
Tsunami impacts on horizontal infrastructure

- Building on previous work investigating impacts on bridges and simple structures.
- Physical experiments of tsunami bore impacts on infrastructure.
- Fragility curve development by inputting experimentally measured forces and moments into a structural model

Impacts on bridges

Probablistic tools





Tsunami impacts on vertical infrastructure

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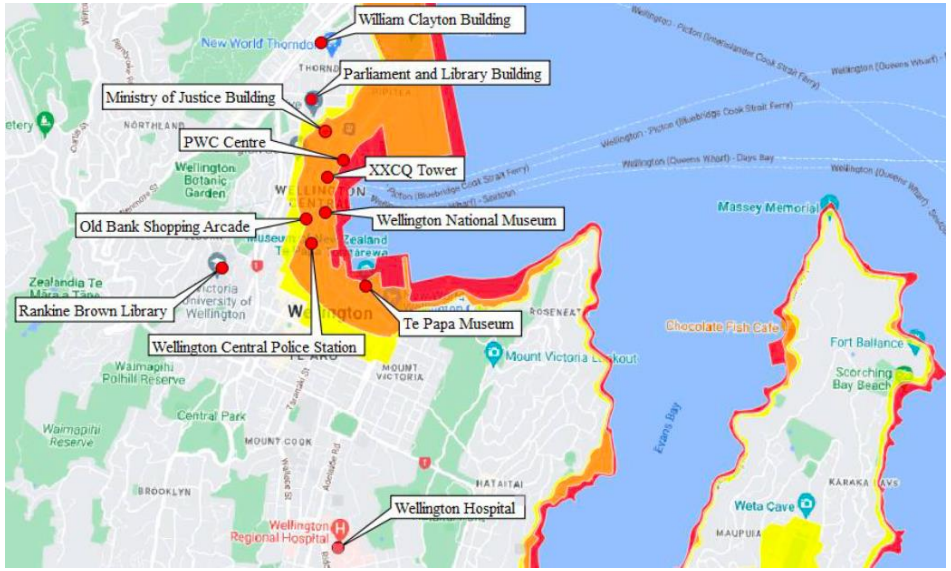
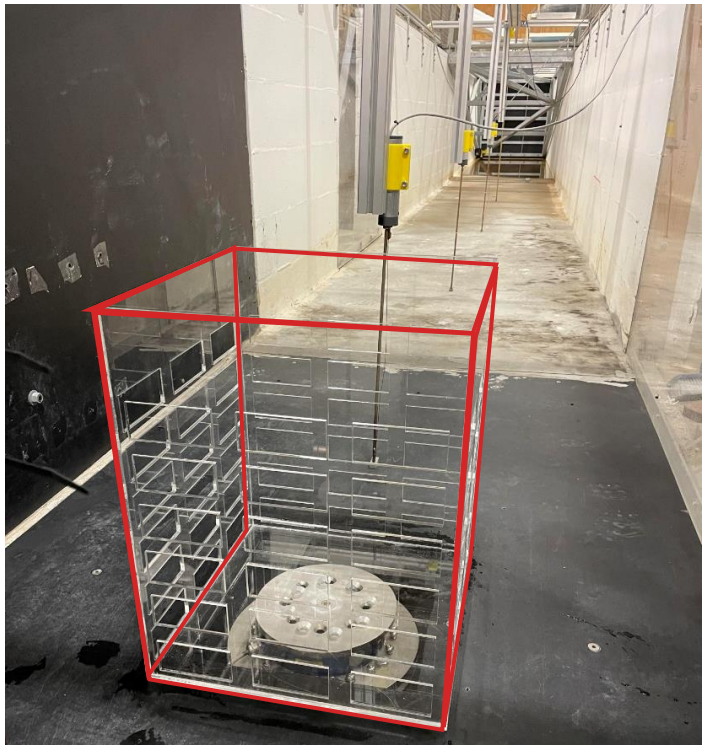
- Physical experiments of tsunami bore impacts on buildings extended using advanced numerical methods
- Evaluating loading standards for new buildings
- Developing analysis procedures for existing buildings

Base isolated buildings in inundation zones



1:60 scale building



National Science Challenges | RESILIENCE TO NATURE'S CHALLENGES | Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Tsunami impacts on ports

- NZ port system a critical part of the national infrastructure network
  - International trade
  - Regional recovery
  - Transport (particularly inter-island)

- Long coastline and distribution of ports means exposed to range of potential tsunami sources
  - Local + Distant subduction zones

- This study focussed on assessing tsunami hazard for range of sources and magnitudes
  - Hazard at single ports
  - Events where multiple ports are exposed
  - Importance and function of the ports exposed

Tsunami impacts on ports

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- Water Levels
  - Damage will be dependant on elevation of port infrastructure
- Current Speeds
  - Vessel damage and port functionality disruption
  - Damage to port infrastructure

Damage	Range of Current Speeds
No damage expected	< 3 knots
Minor/moderate damage possible	Between 3 and 6 knots
Major damage possible	Between 6 and 9 knots
Extreme damage possible	> 9 knots

Tsunami impacts on ports – Hikurangi south

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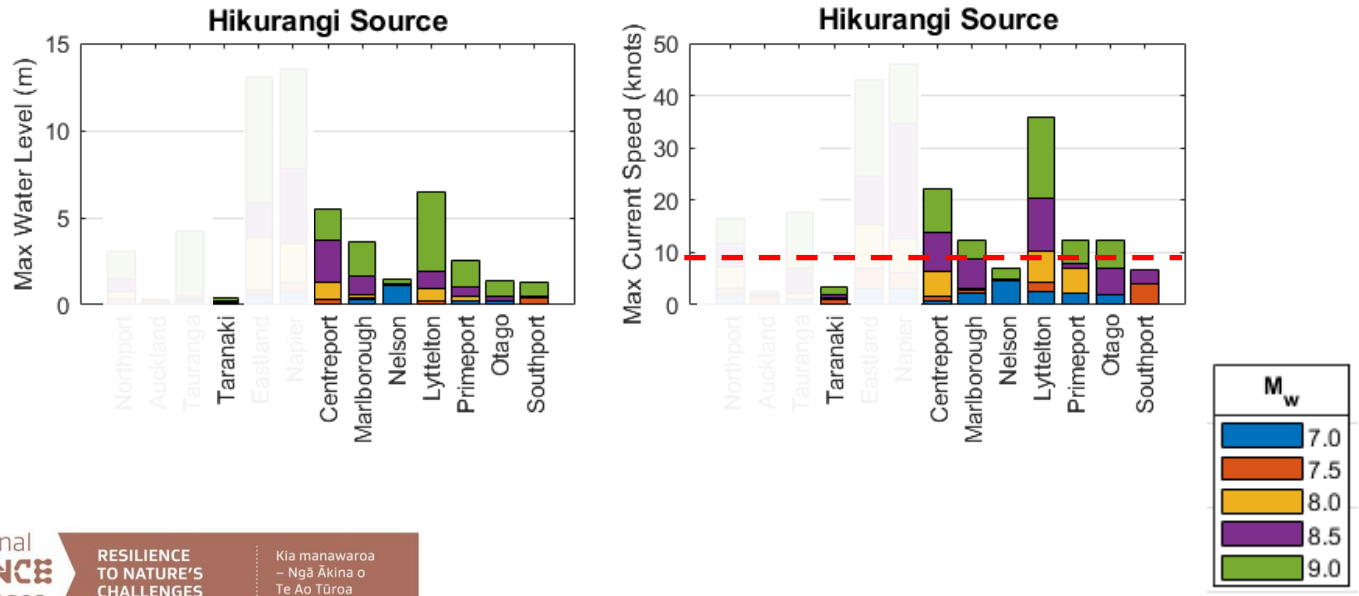
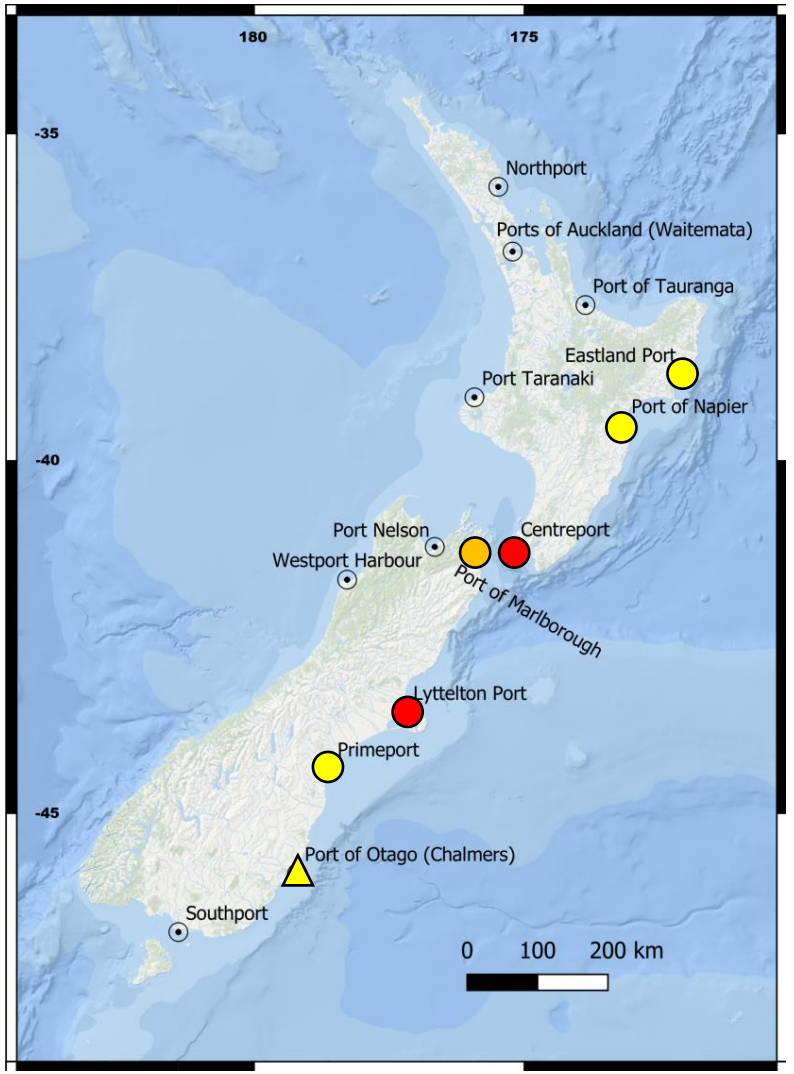
- Extends to Centreport, Marlborough, Lyttleton + Primeport
- Potential impacts at Eastland + Napier remain
- Impacts on both ends of interisland link
- Lyttelton key port in SI





Wotherspoon et al.

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Tsunami impacts on ports – Peru source

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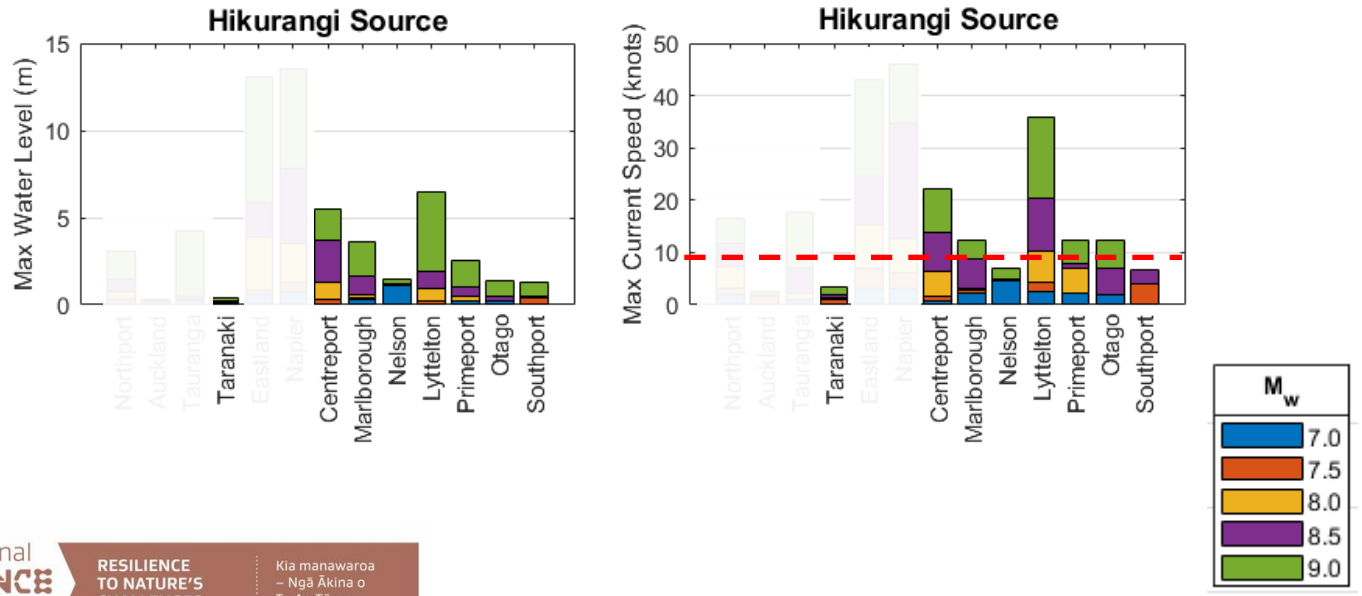

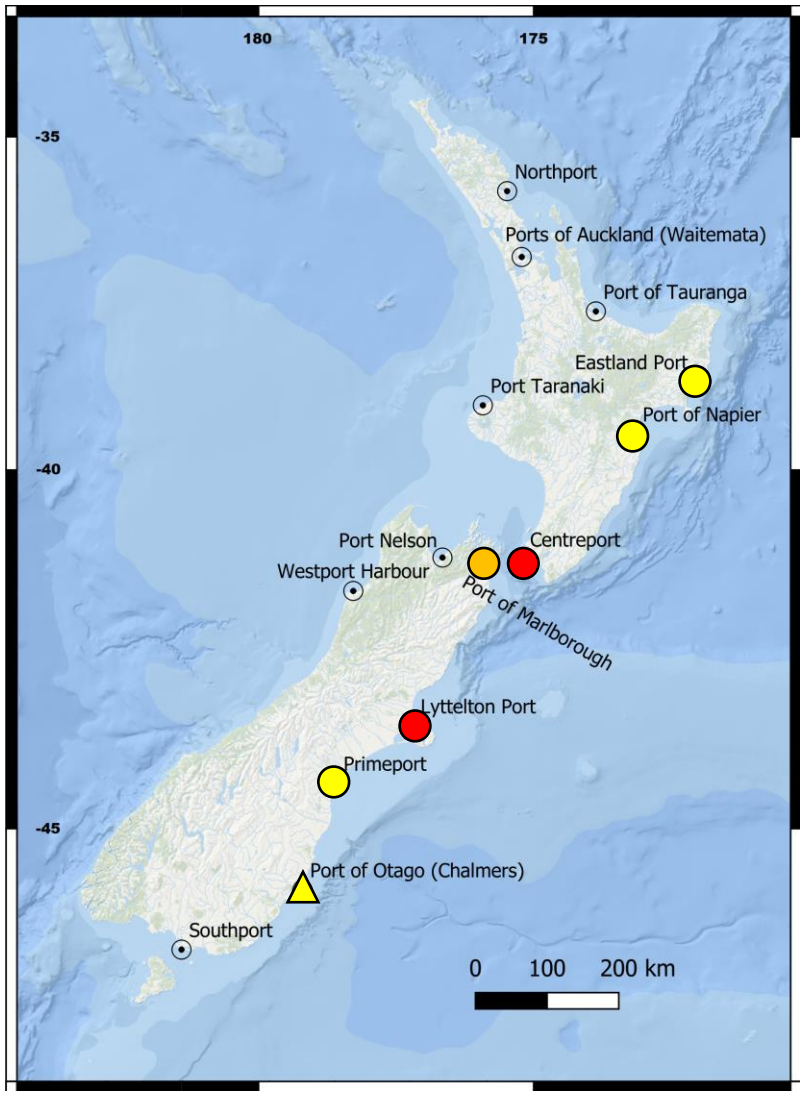

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