The variability of seismic impacts: towards hazard agnostic capacity building in the Greater Wellington Region

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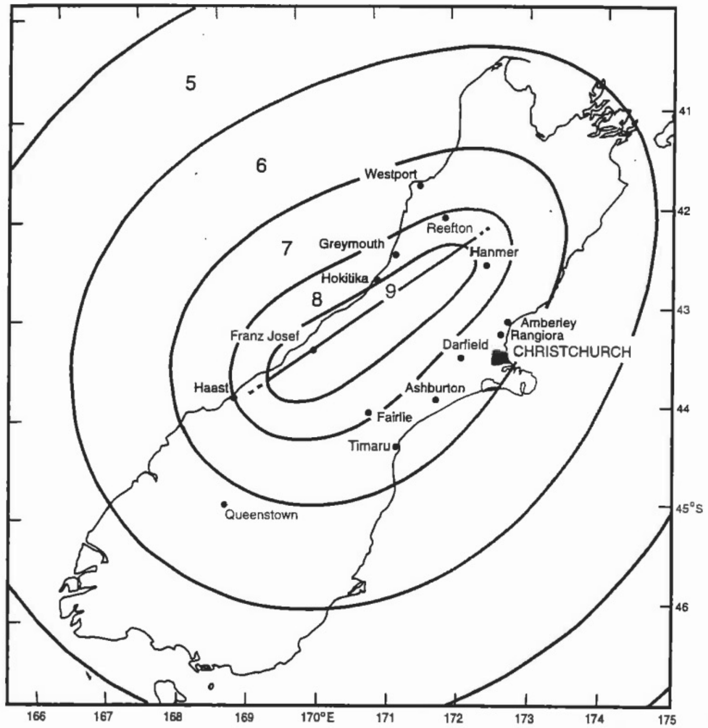
QuakeCoRE NZ Centre for Earthquake Resilience Te Hiranga Rū

November 2025

SEISMIC COMPLEXITY IN AOTEAROA NZ



THE PROBABILITY AND CONSEQUENCES
OF THE NEXT
ALPINE FAULT EARTHQUAKE

Research undertaken by:

Mark D. Yetton

Geotech Consulting Ltd

with

Andrew Wells

Nick J. Traylen

March 1998

2nd Printing July 1998

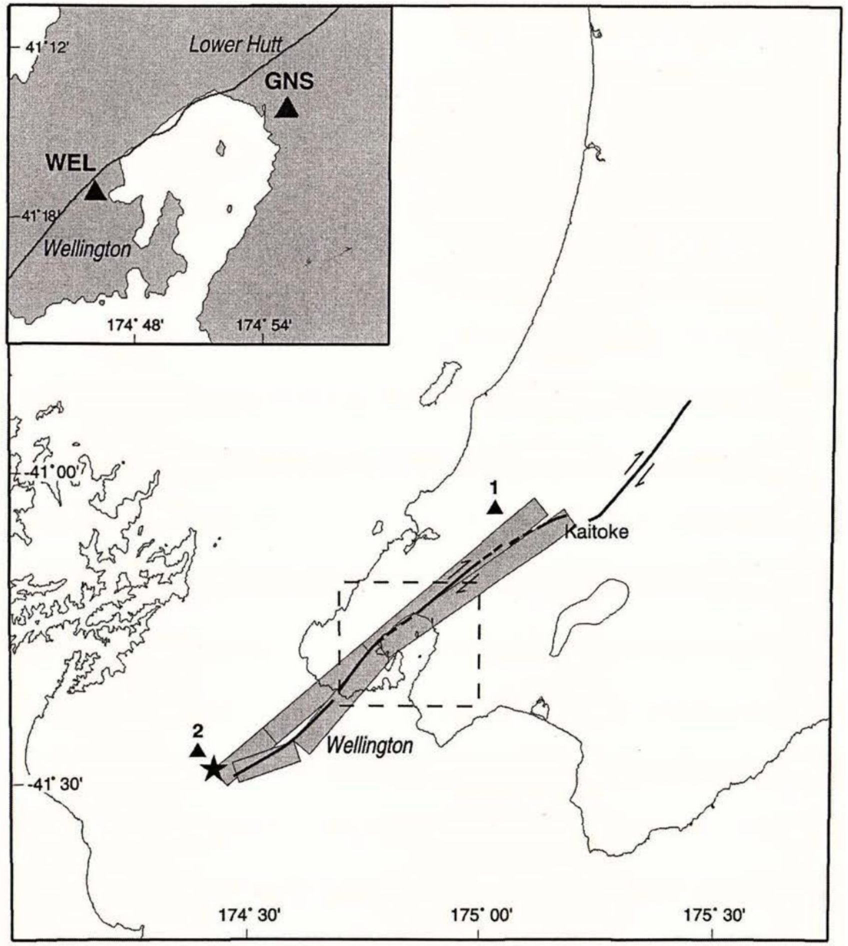
Modelling realistic ruptures on the Wellington fault

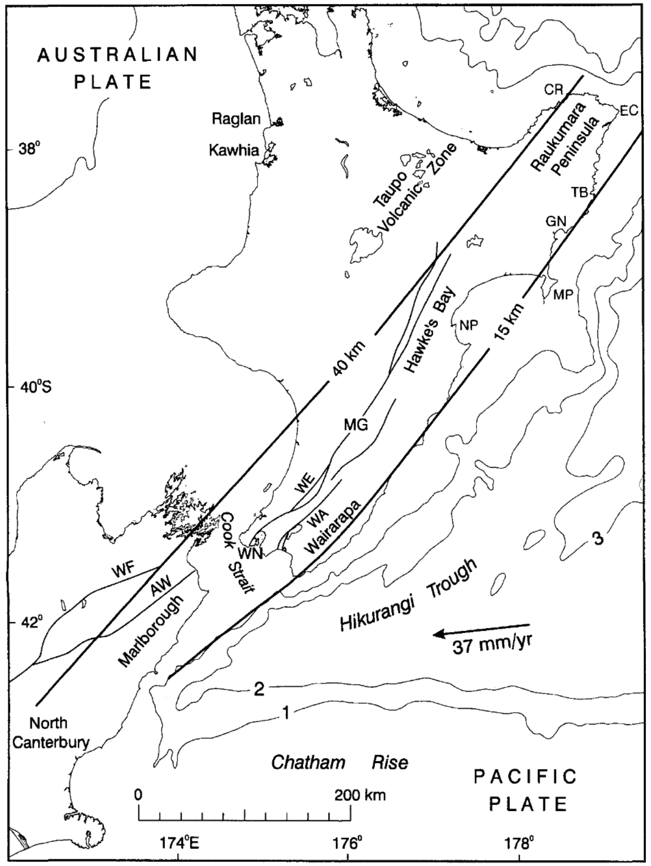
by Rafael Benites, Russell Robinson, Terry Webb, Peter McGinty

Confidential

Client Report 2002/85

November 2003





New Zealand Journal of Geology & Geophysics, 1998, Vol. 41: 343–354
0028–8306/98/4104–0343 $7.00/0

Plate coupling and the hazard of large subduction thrust earthquakes at the Hikurangi subduction zone, New Zealand

2010/2011 Canterbury Earthquake Sequence

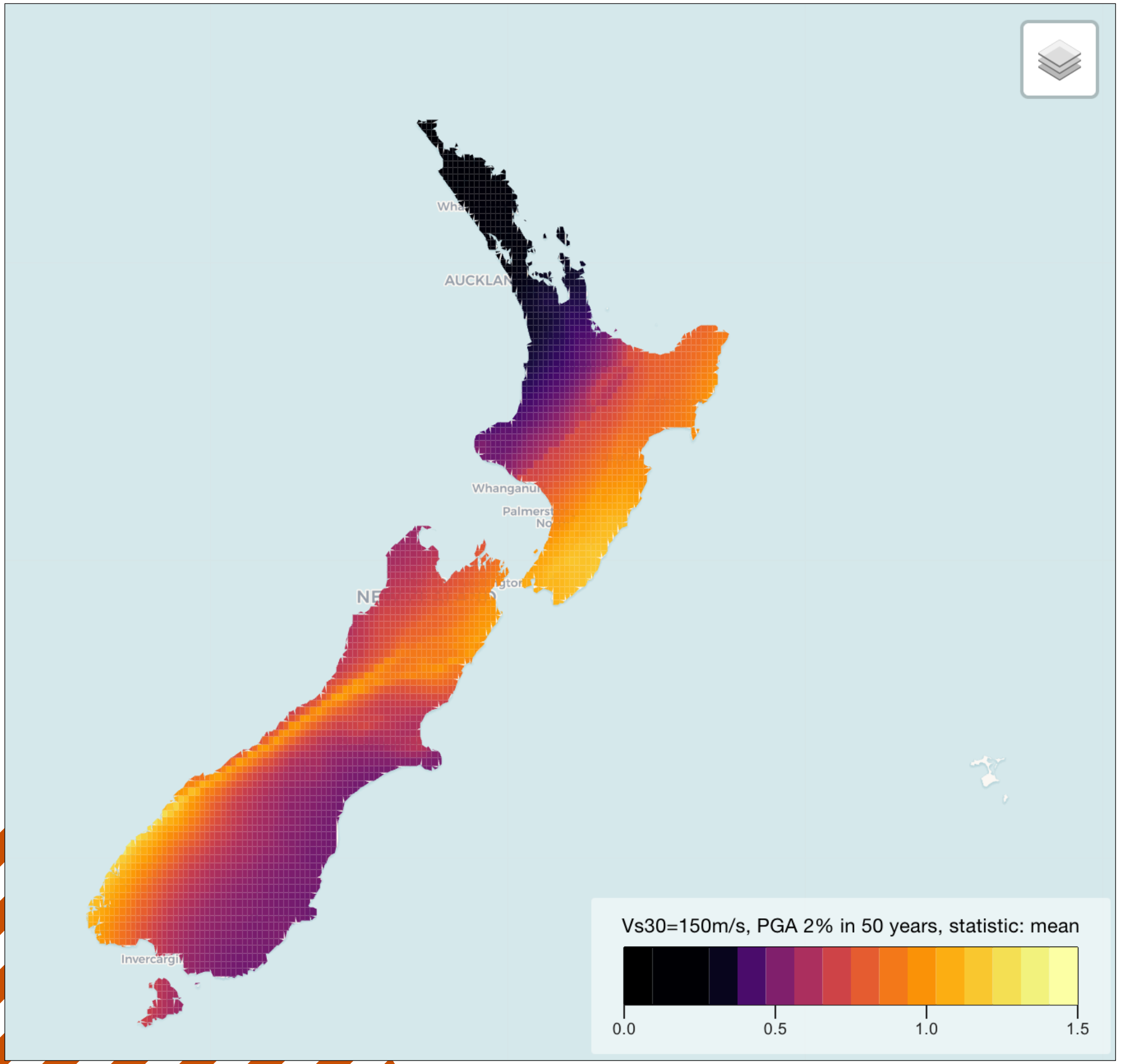
2016 Kaikōura Earthquake

LESSONS FROM THE UNEXPECTED

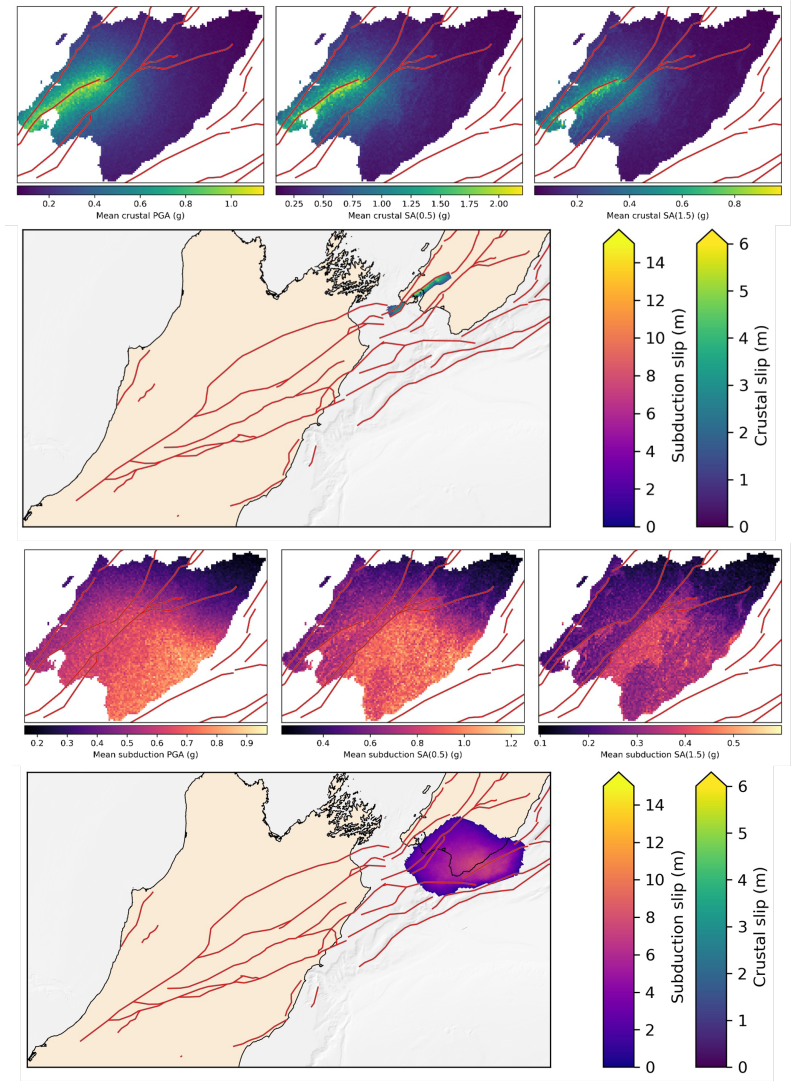
1. The most anticipated and well understood events ≠ the next major earthquake

2. Cascading hazards are a critical consideration for planning and recovery

SEISMIC RISK IN AOTEAROA



(Gerstenberger et al., 2023)



(Howell et al., 2023)

- 2022 National Seismic Hazard Model
- Physics-based earthquake simulators

= thousands of plausible earthquake events

SEISMIC HAZARD ANALYSIS

PROBABILISTIC

All known EQ scenarios
Exceedance probability over time
Recurrence intervals

THE GAP

DETERMINISTIC

Maximum credible event
"Worst case scenario" planning
~~Temporal element~~

ENSEMBLE MODELLING

Climate, weather, ground motion
Scenario ensemble
Variability of **impacts**

PROJECT OBJECTIVES

Assess impact variability across multiple earthquakes from various faults and fault zones

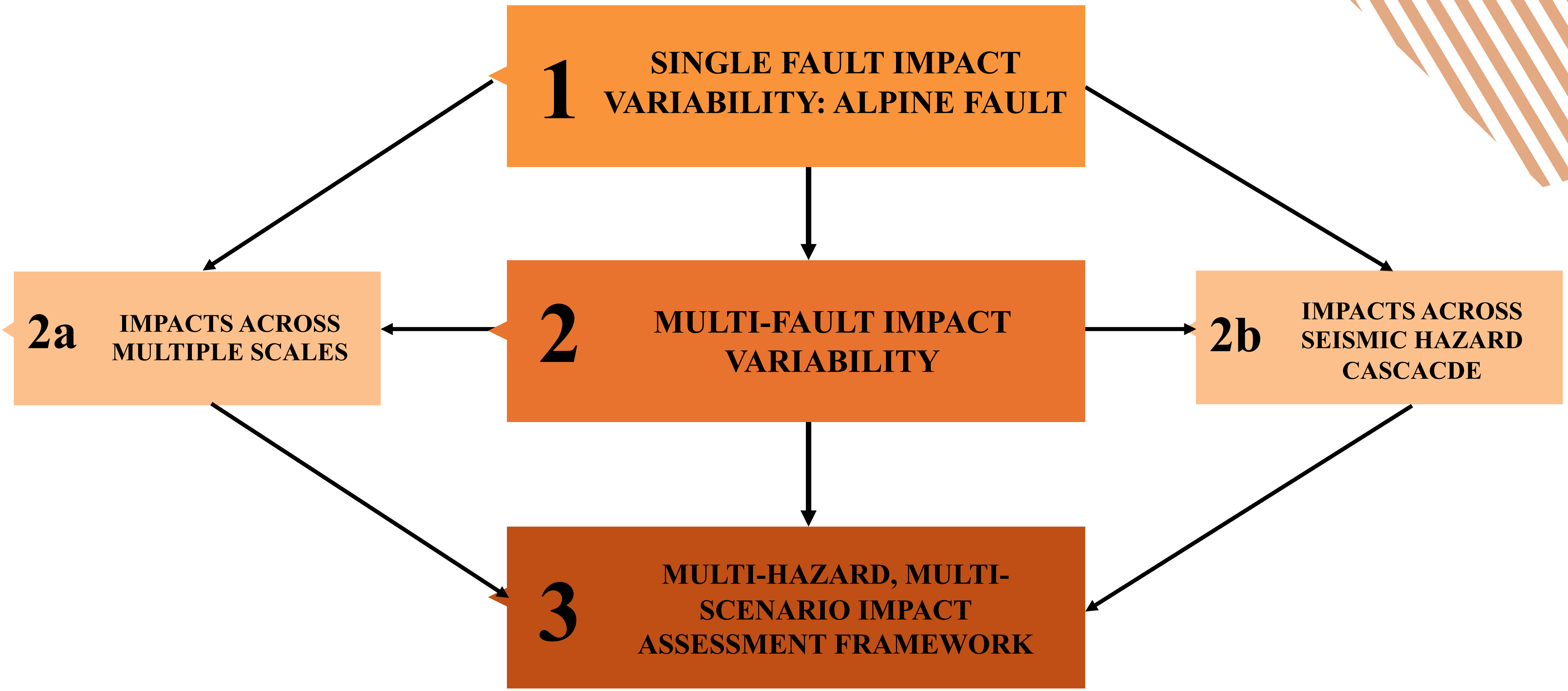
Evaluate the contribution of cascading hazards to impact severity (surface deformation, landslides, liquefaction, tsunami)

Compare local and regional impact patterns to assess scale dependency within impact variation

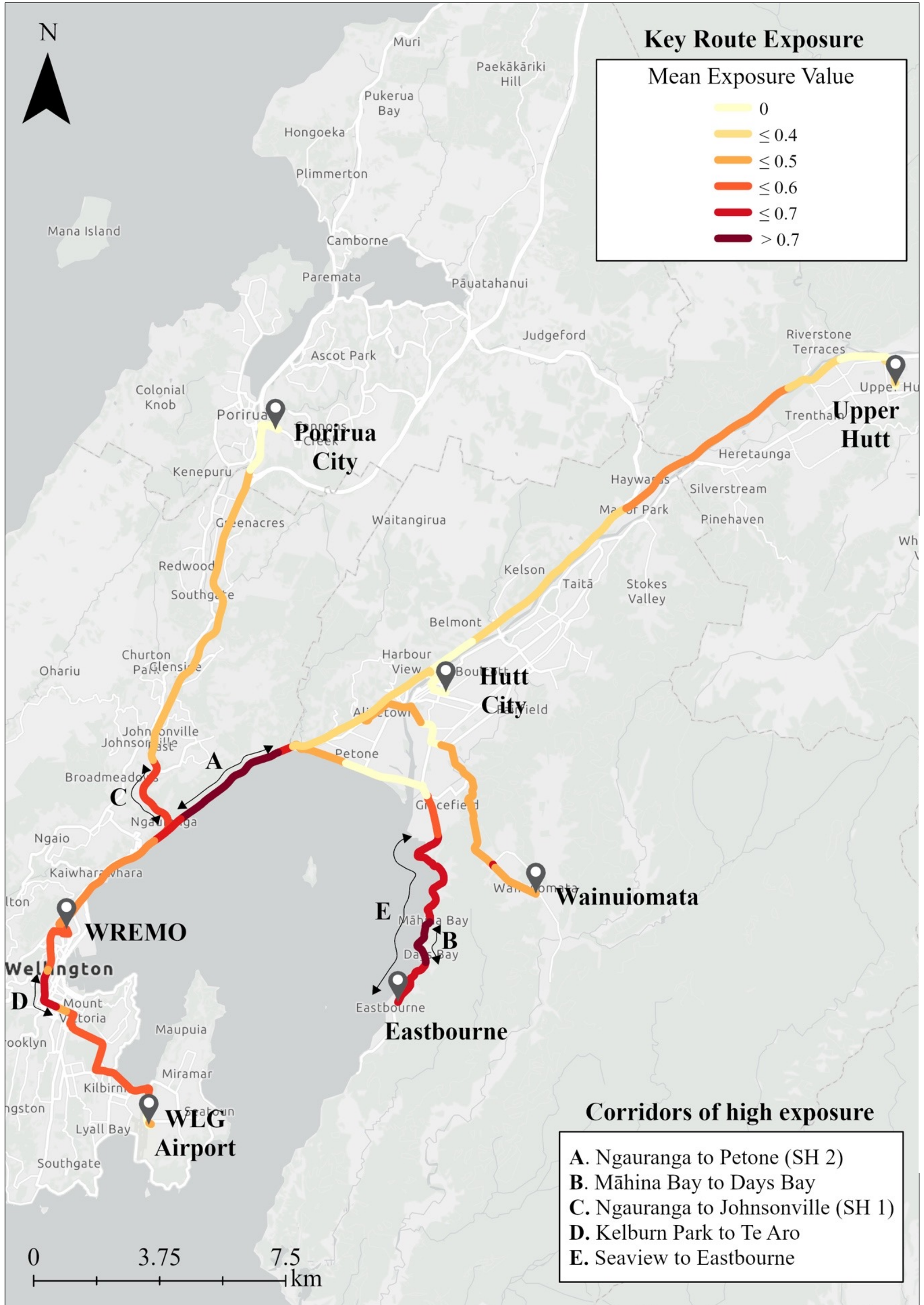
Create a multi-scenario impact modelling approach that integrates cascading hazards and identifies recurrent impact patterns

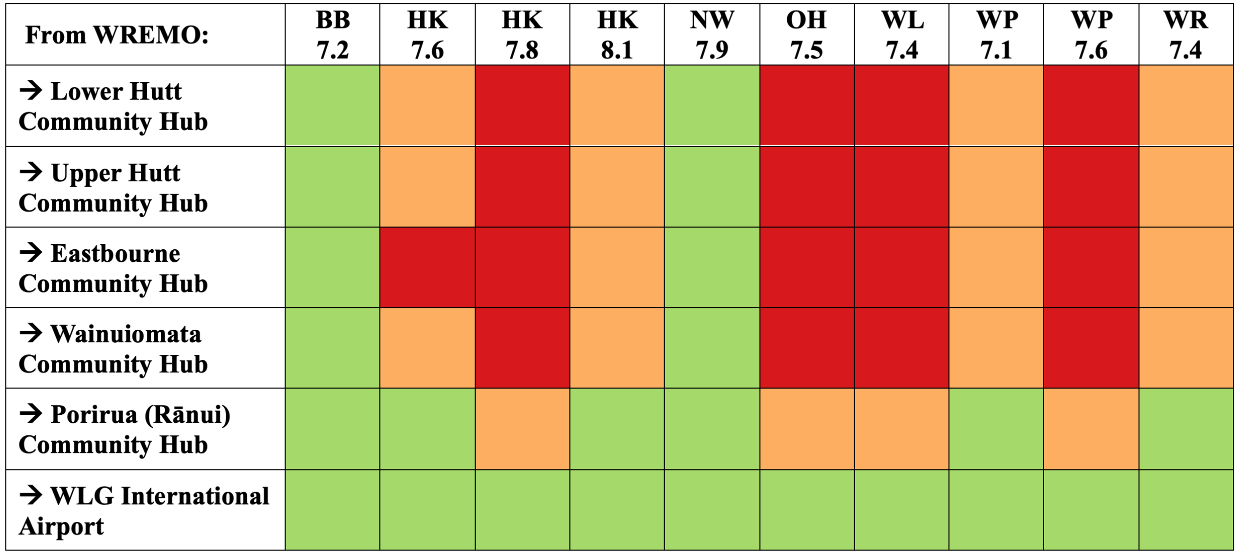
So that **low-specificity impacts** can be prepared for even when the next major earthquake is unknown.

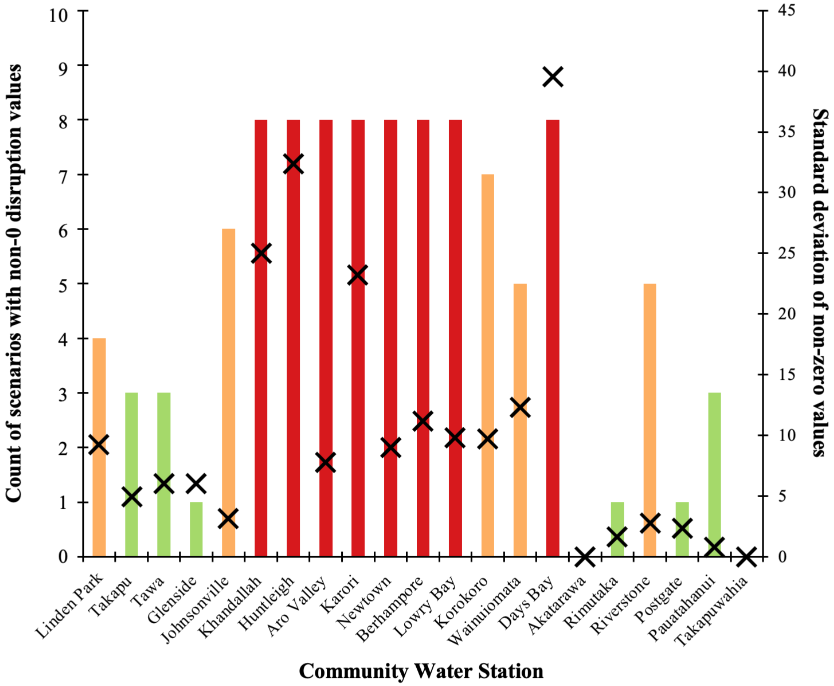
PROJECT STRUCTURE

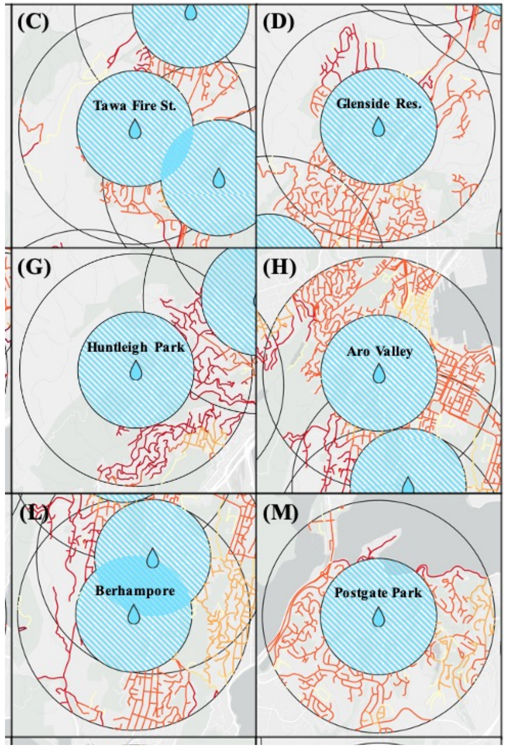


ENSEMBLE APPROACHES

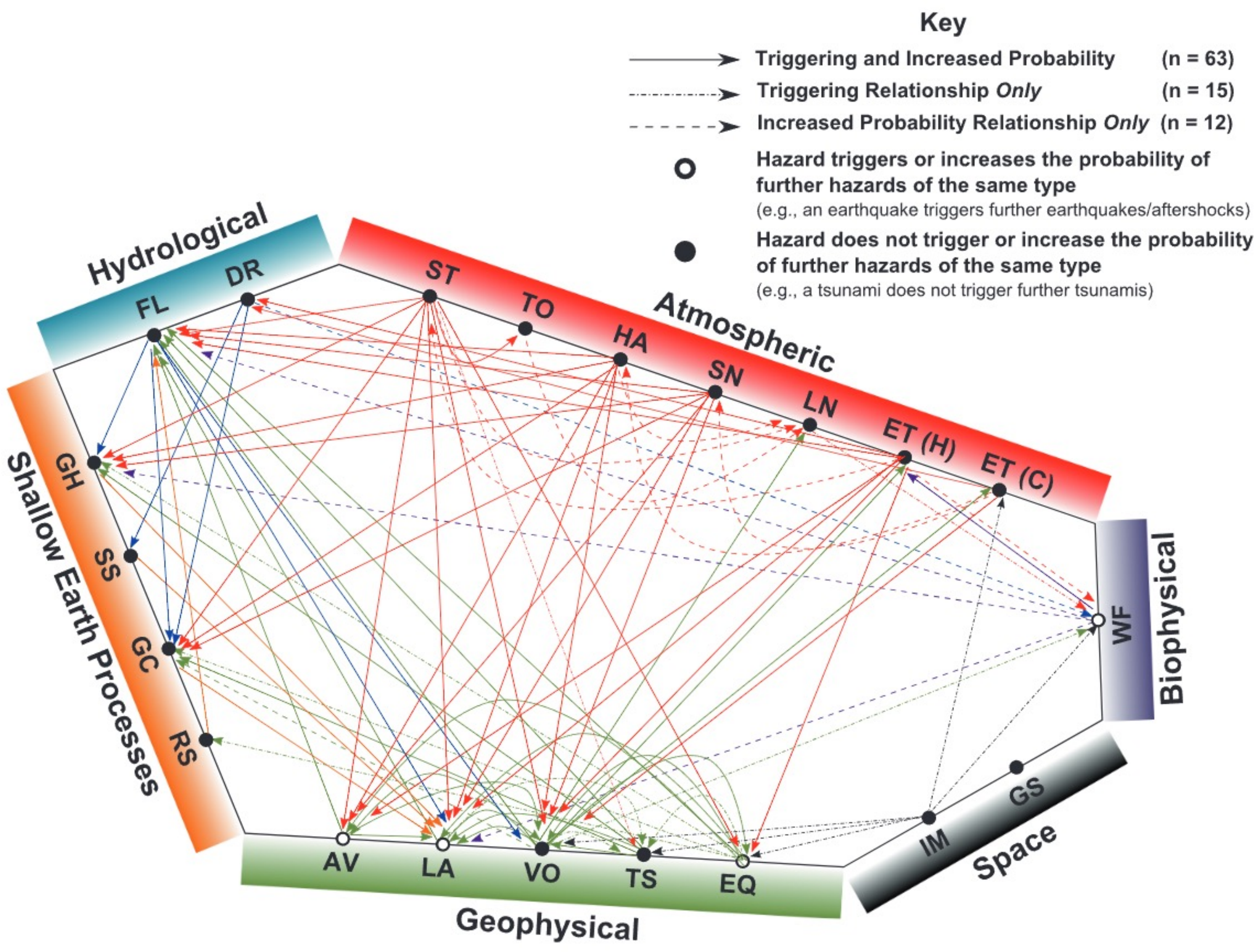








Harvey et al. (2024) – impacts to key routes and CWS access



Hazard type linkages. A network diagram showing the potential hazard type linkages between 21 natural hazards (Gill & Malamud, 2014): EQ = earthquake, TS = tsunami, VO = volcanic eruption, LA = landslide, AV = snow avalanche, RS = regional subsidence, GC = ground collapse, SS = soil (local) subsidence, GH = ground heave, FL = flood, DR = drought, ST = storm, TO = tornado, HA = hailstorm, SN = snowstorm, LN = lightning, ET (H) = extreme high temperatures, ET (C) = extreme cold temperatures, WF = wildfires, GS = geomagnetic storms, and IM = impact events.

EXISTING APPROACHES MAY:

Consider a *range of hazards* but for a *single earthquake event*

(e.g. Davies et al., 2021; Mowll et al., 2023; Sadashiva et al., 2021)

OR

Consider *numerous earthquake scenarios* but only for *individual hazards*

(e.g. Lin et al., 2024; 2025; Robinson et al., 2018; 2020)

BUT RARELY BOTH

CHAPTER 1

How does seismic hazard and impact vary within the GWR and upper S Island across a range of plausible Alpine Fault EQs?

ALPINE FAULT EARTHQUAKE ENSEMBLE

Composite scenarios – AF > MFS
Updated AF ground motion data (Bradley et al., PBES, 2022 NSHM)

SEISMIC HAZARD MODELLING

Landslides, liquefaction, surface deformation

TRANSPORT NETWORK IMPACTS

Road and rail network of GWR, Nelson, Tasman, Marlborough

EXPECTED OUTPUTS

- Assessment of impact variability across a range of plausible, composite AF/ MFS scenarios
- Comparison of GM inputs from PBES, PBGMS & empirical methods

- Evaluation of various multi-hazard modelling approaches, and the applicability of existing approaches for seismic hazards
- Recommendations for future multi-hazard models

- High-resolution hazard and impact maps of ground shaking, surface deformation, landslides and liquefaction across the GWR and upper SI
- Identified transport network vulnerabilities / low-specificity impacts

- A preliminary approach to multi-hazard ensemble modelling for earthquakes generated by a single fault source

PLANNING IMPLICATIONS

- ✓ Low-specificity impacts; *where should we invest?*
- ✓ Multi-hazard integration; *what cascading effects should be prepared for?*
- ✓ Identifies vulnerabilities irrespective of the next major event
- ✓ Supports impact focused planning

PHD TIMELINE

MID-2026

- ✓ Preliminary multi-hazard ensemble approach for a composite rupture of the Alpine Fault and MFS
- ✓ Beginning to draft first manuscript

END OF 2026

- ✓ Manuscript complete for multi-hazard impact assessment for an ensemble of AF earthquakes
- ✓ Working on multi-fault multi-hazard ensemble model

MID-2027

- ✓ Multi-fault multi-hazard impact assessment completed w/ analysis of scale dependency
- ✓ Draft of second manuscript complete

END OF 2027

- ✓ Final stages of developing impact assessment framework for multi-hazard ensemble analysis
- ✓ Validation and robustness testing
- ✓ Draft of third manuscript underway

THESIS SUBMISSION EARLY 2028 (TBC)

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