Transportation Resilience Research in Aotearoa New Zealand:

What are we doing and where are we heading?

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Transport Knowledge Hub

24 September 2021

Transport Knowledge Hub

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

Te Hiranga Rū | QuakeCoRE
Aotearoa New Zealand Centre for Earthquake Resilience

Acknowledgements

- Contribution from a wide range of institutions:
  - University of Auckland
  - University of Canterbury
  - University of Waikato
  - University of Otago
  - Lincoln University
  - NIWA
  - GNS Science
  - Market Economics
  - Resilient Organisations
  - Manaaki Whenua Landcare Research
  - etc

- We acknowledge the wide range of stakeholders partners involved across these projects

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Overview

- Wide range of research underway across the country with a focus on natural hazard and transport resilience
  - Efforts within research to align efforts across the country
  - Good awareness of activities across wider infrastructure research

- Strong partnership between research and industry
  - Interest in further expanding the breadth and depth of this

- This presentation will provide a snap-shot of a range of activities
  - **Contact us if you want to continue the conversation in any areas**

- Real world data, real world scale, real world complexity

Some terminology

Hazard

Vulnerability

Exposed Elements

Impact/Risk

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Topic Areas

- Hazards and multi-hazards
- Transport network components
- Network models
- Network dependencies
- Community expectations
- System users
- Economic implications
- Resilience metrics and criticality
- Transport decision making

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Programmes/Groups

- Resilience to Nature's Challenges NSC
- Te Hiranga Rū QuakeCoRE
- Deep South NSC
- A More Flood Resilient Aotearoa NZ
- Volcanic Programmes
- EQC
- Transportation Research Centre

- Opportunities for collaboration and co-creation of ongoing research

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RNC

- Phase 2

Resilience in Practice

Multihazard Risk

These Models will harness research from eight specialist **Programmes** outlined below.

Rural

Urban

Māori

Built

Earthquake Tsunami

Coastal

Volcano

Weather

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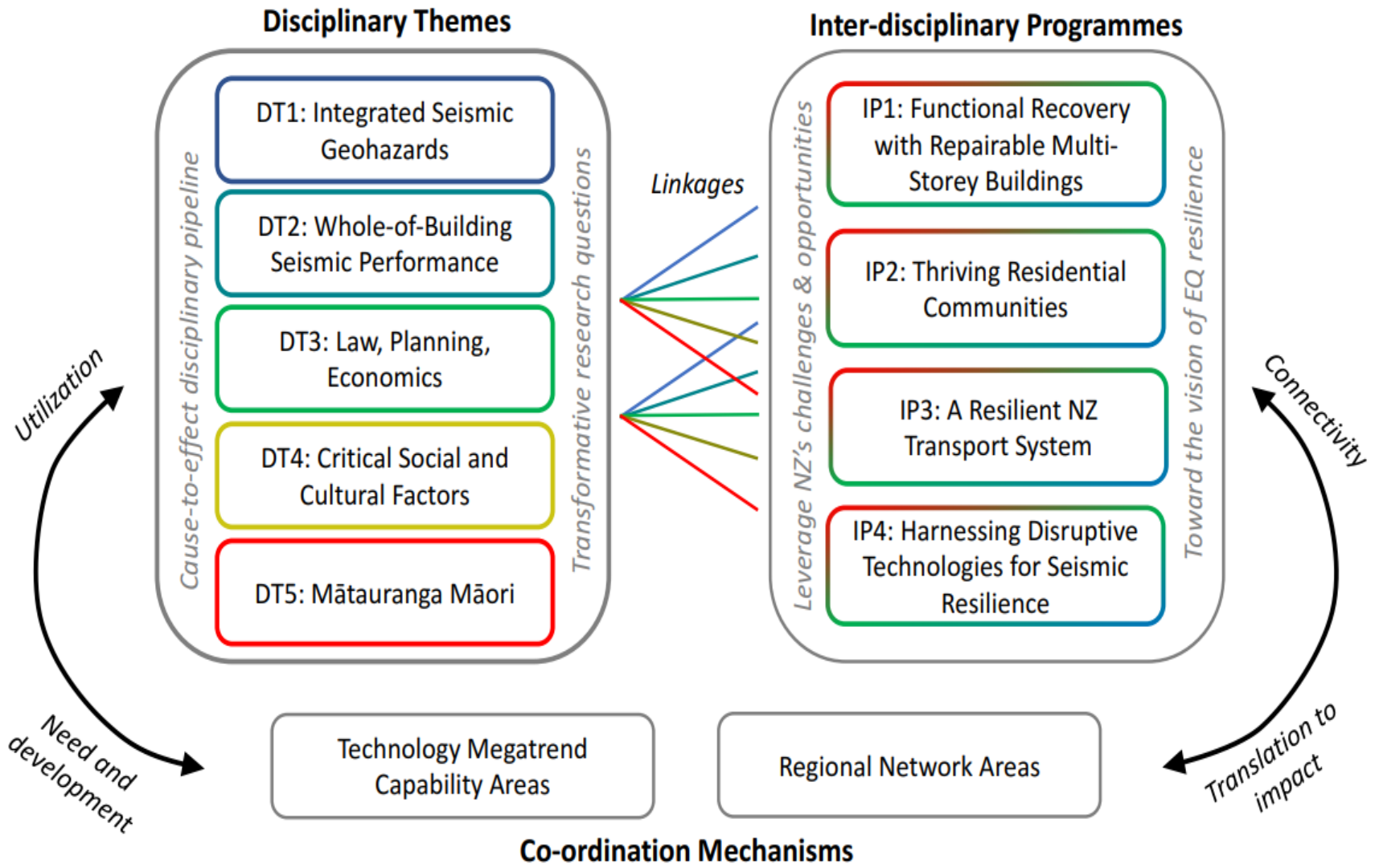
Te Hiranga Rū QuakeCoRE



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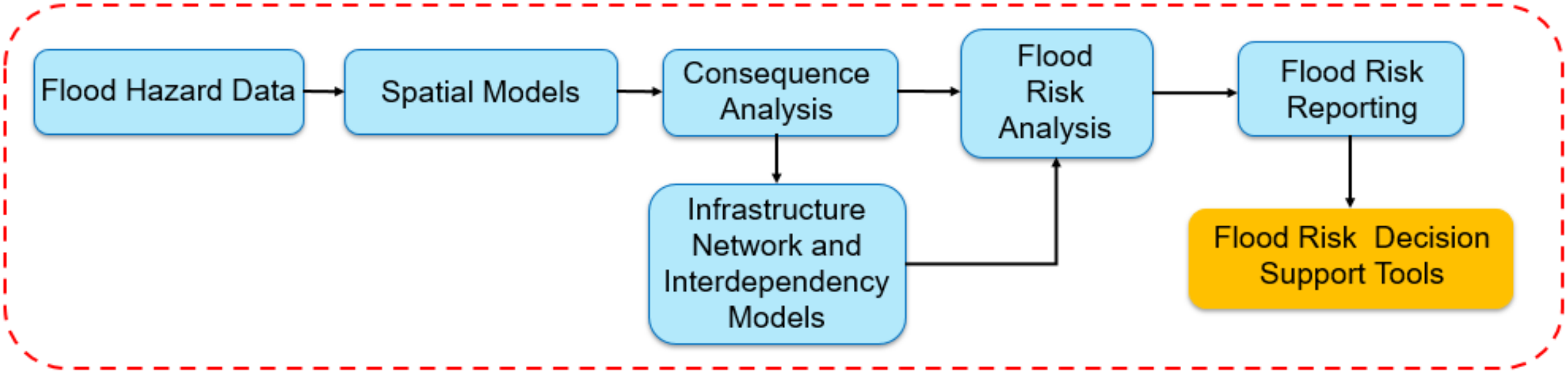
A more Flood-Resilient Aotearoa-NZ

- Nationally consistent flood inundation hazard and risk assessment
  - Flood mapping and risk to built environment
  - Social vulnerability
  - Risk reduction and adaptation



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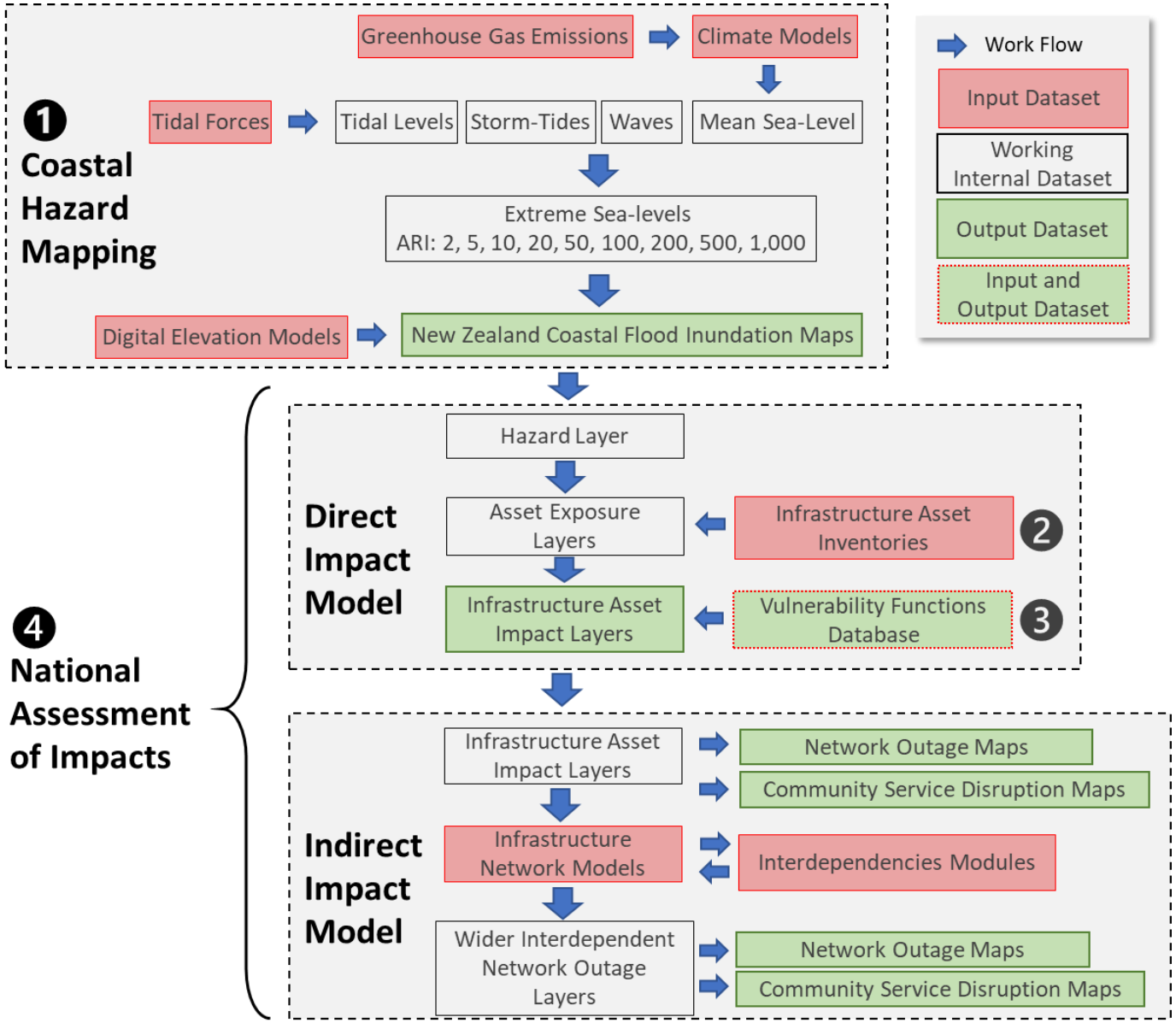
Infrastructure Disruption from Coastal Flooding

- Deep South NSC



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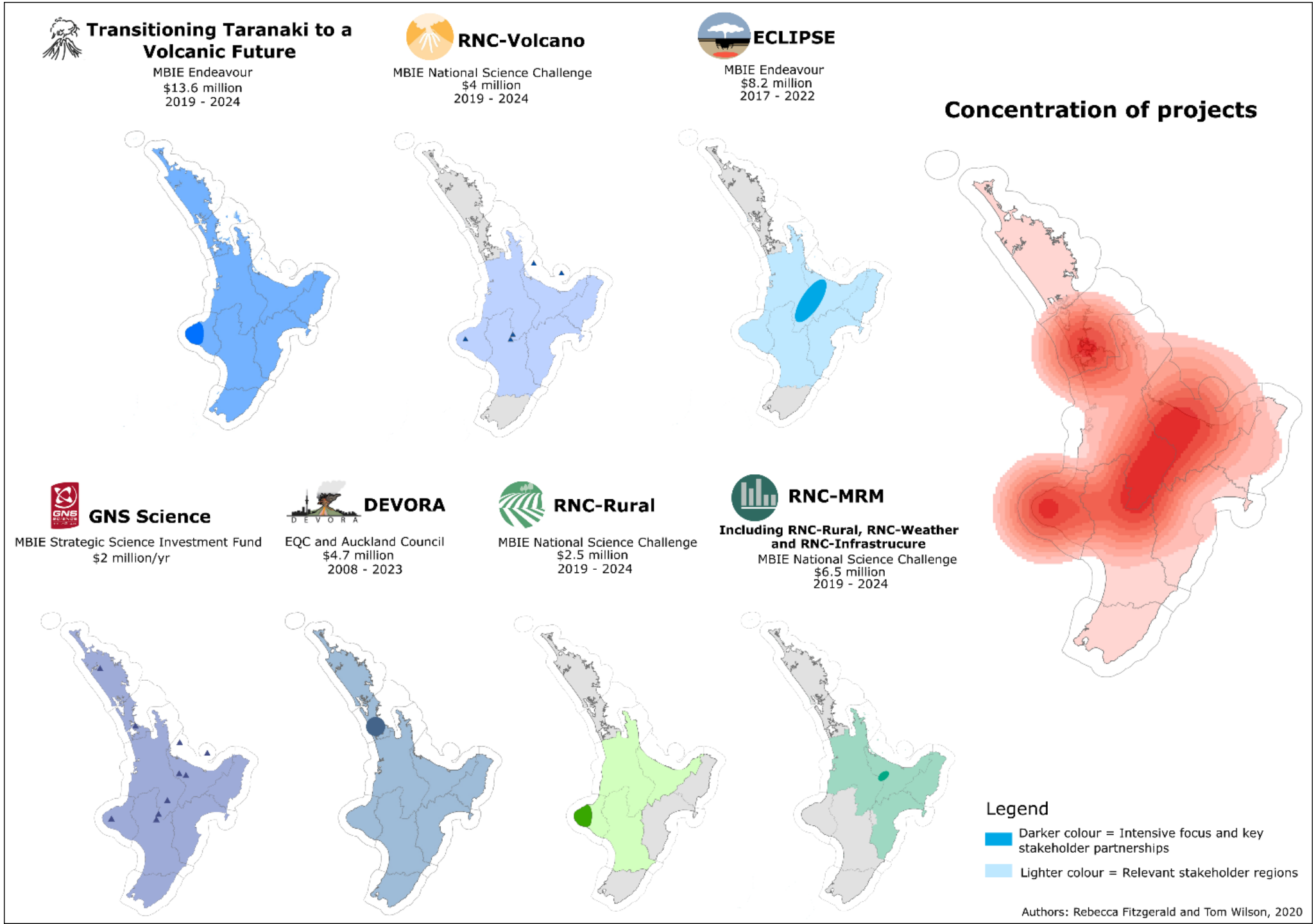
Volcanic Programmes



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Hazard Exposure

- Improve spatial and temporal representation of hazard exposure
  - Single and coincident/cascading hazards

  - Seismic and Co-seismic
  - Tsunami
  - Coastal Flooding
  - Pluvial and Fluvial Flooding
  - Volcanic

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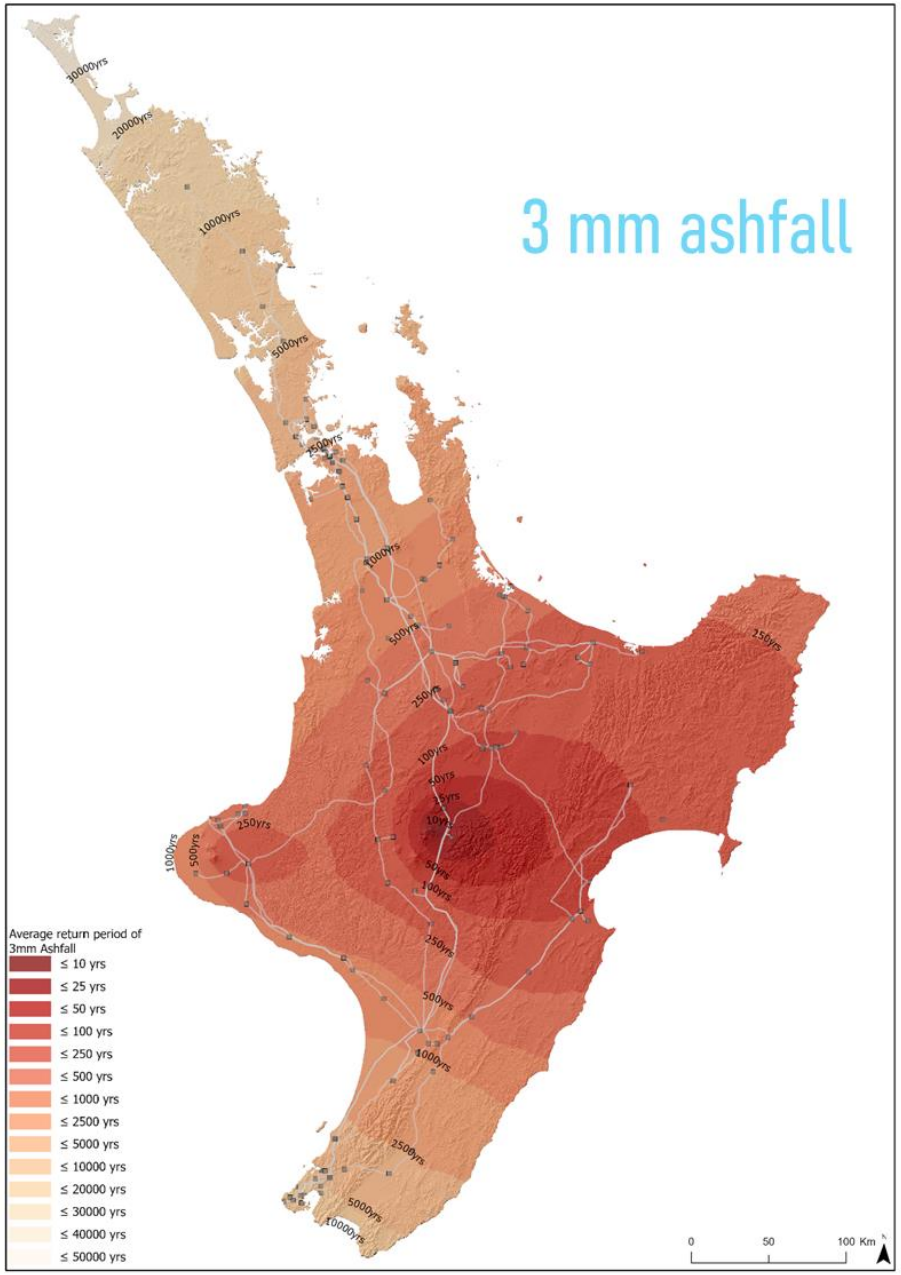
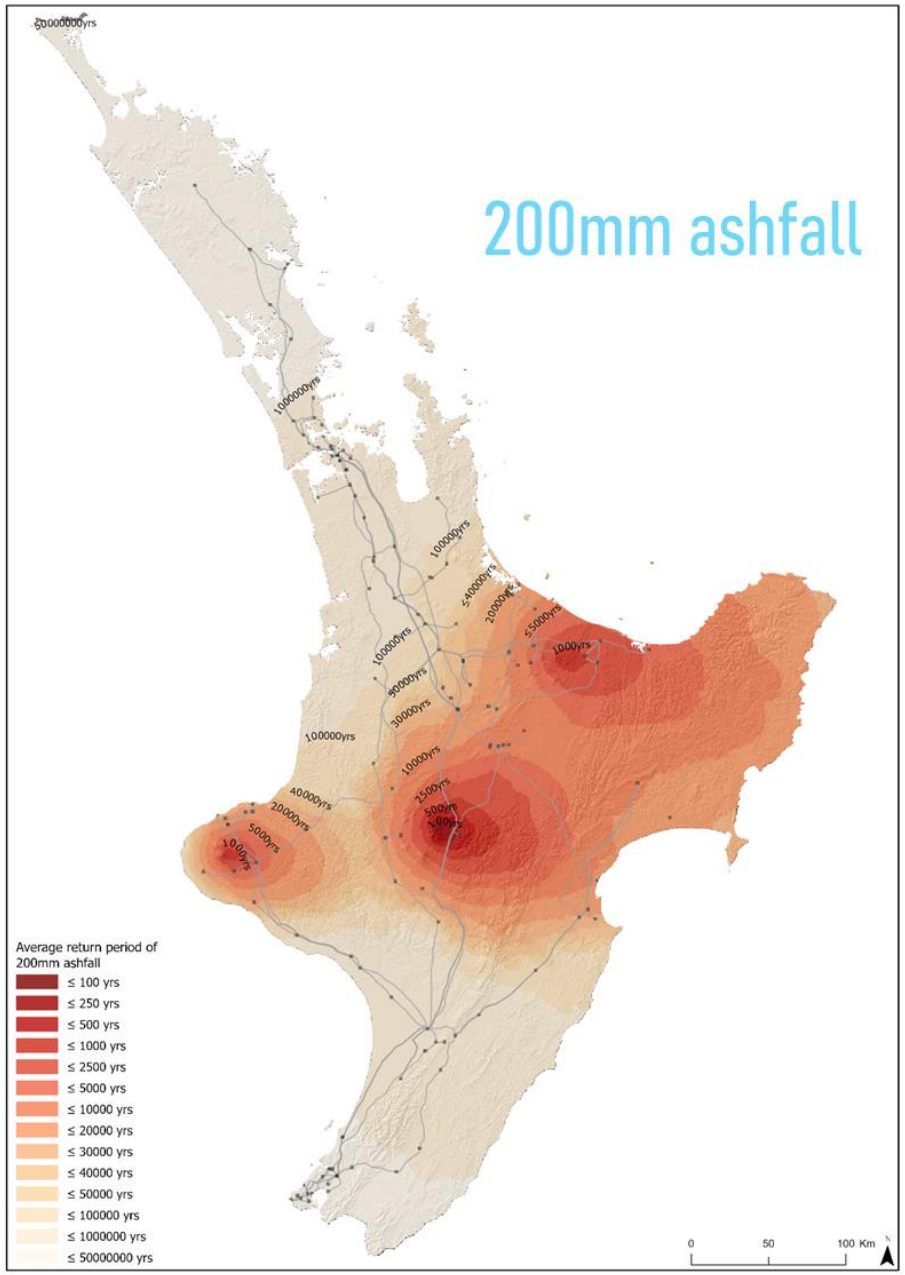
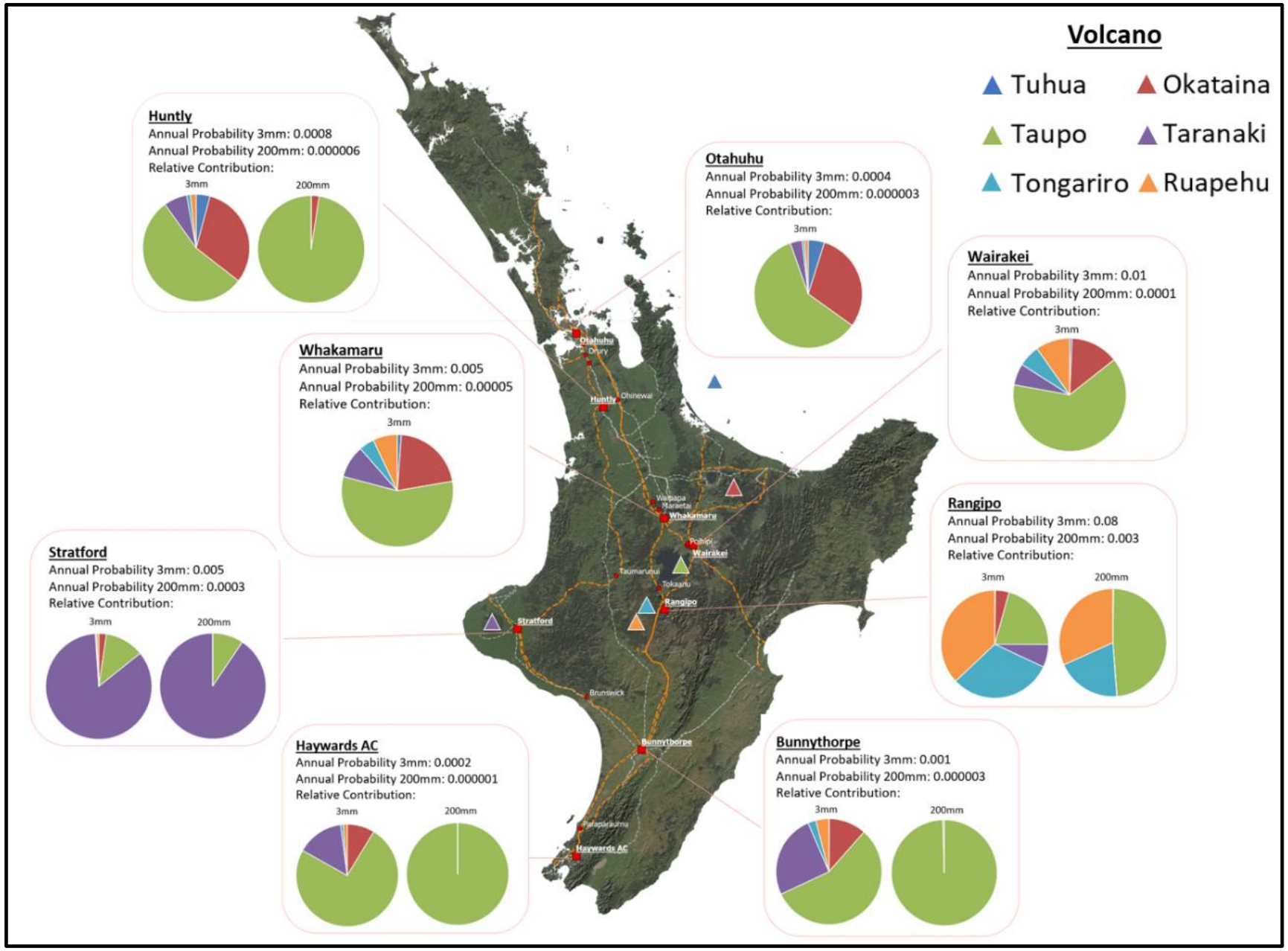
Probabilistic Ashfall Scenarios

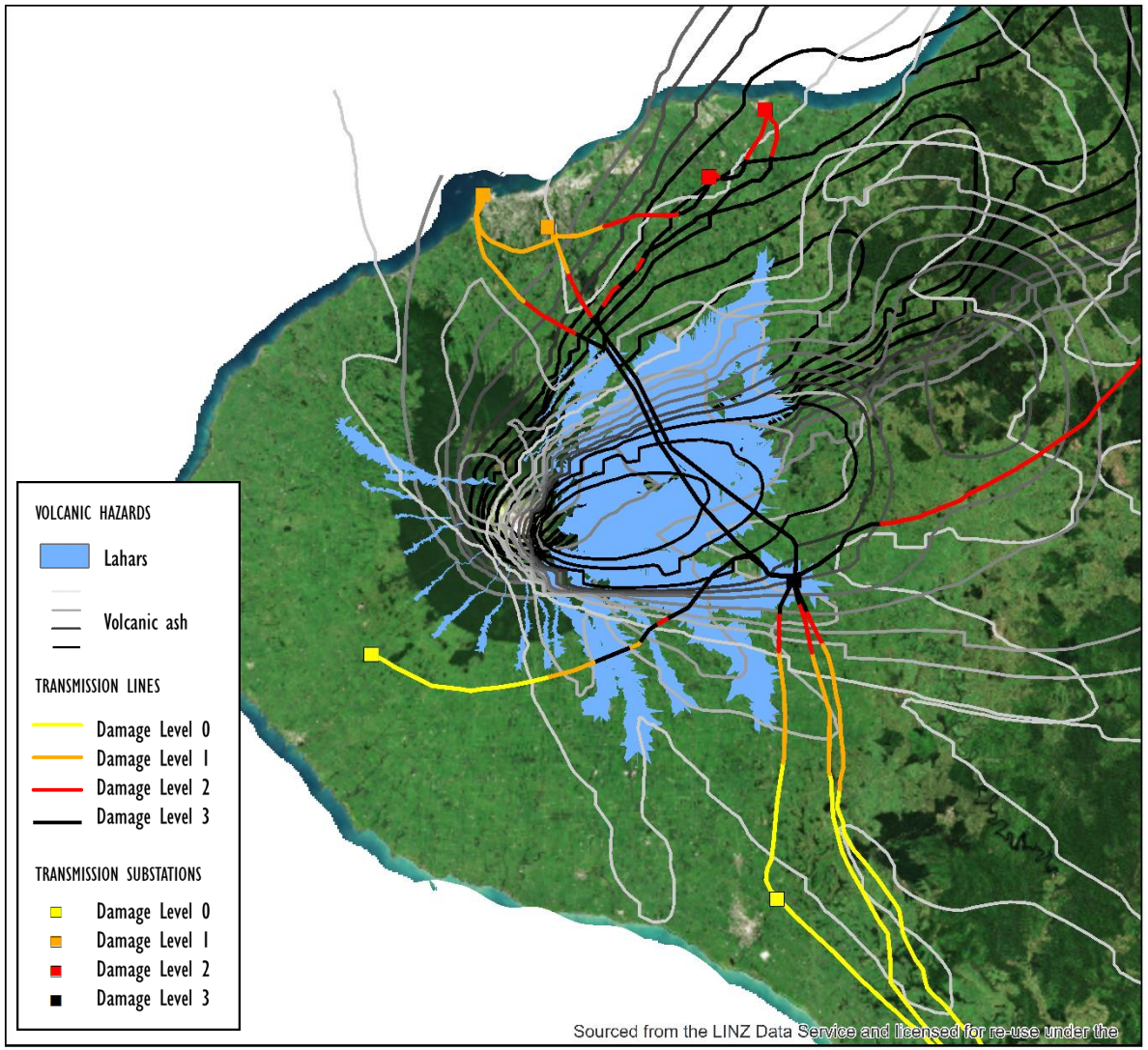




Ashfall Hazard Source for Key Sites



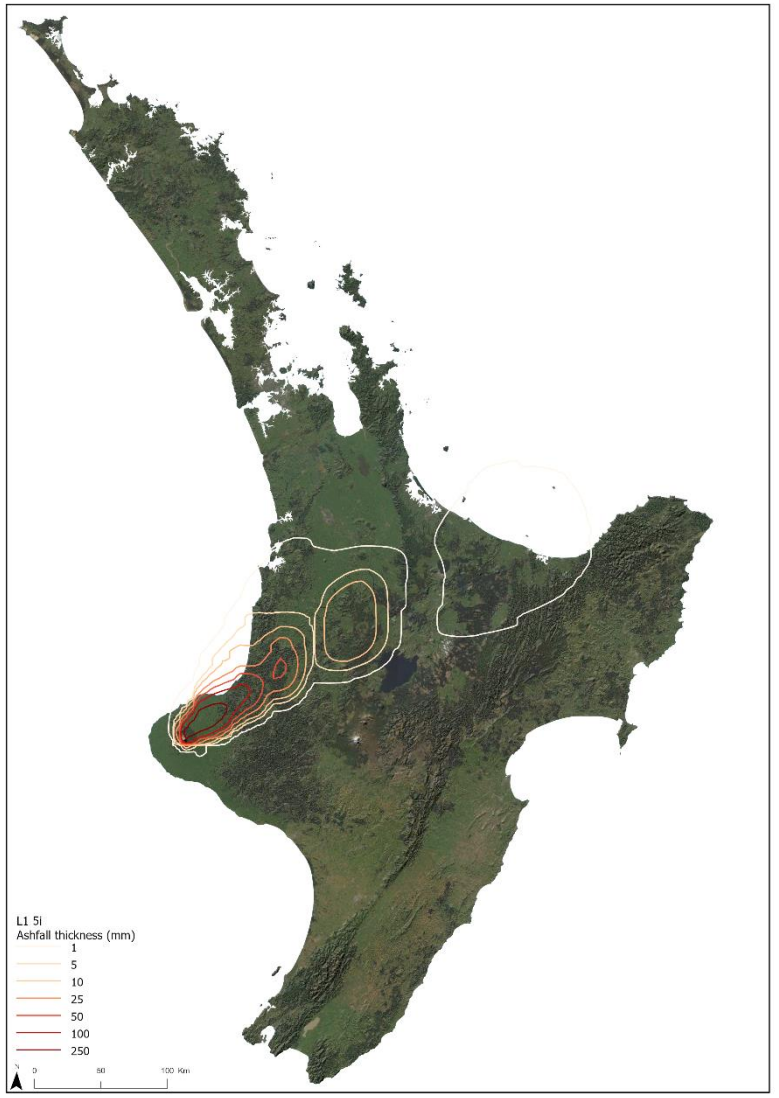
*NB: pie chart is not proportional in size to annual probability of ash hazard



SCENARIO LI:

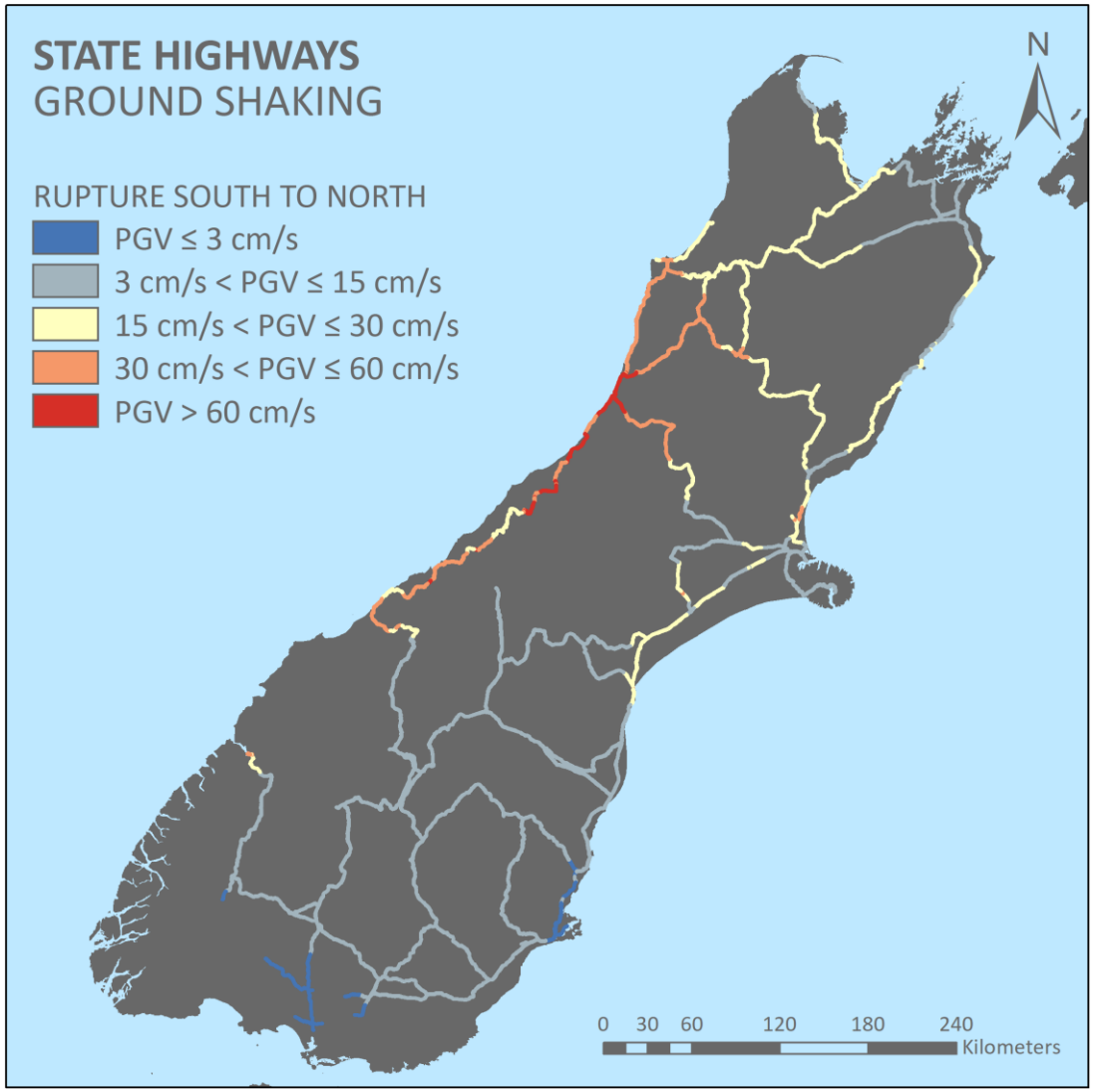
PHASE 4

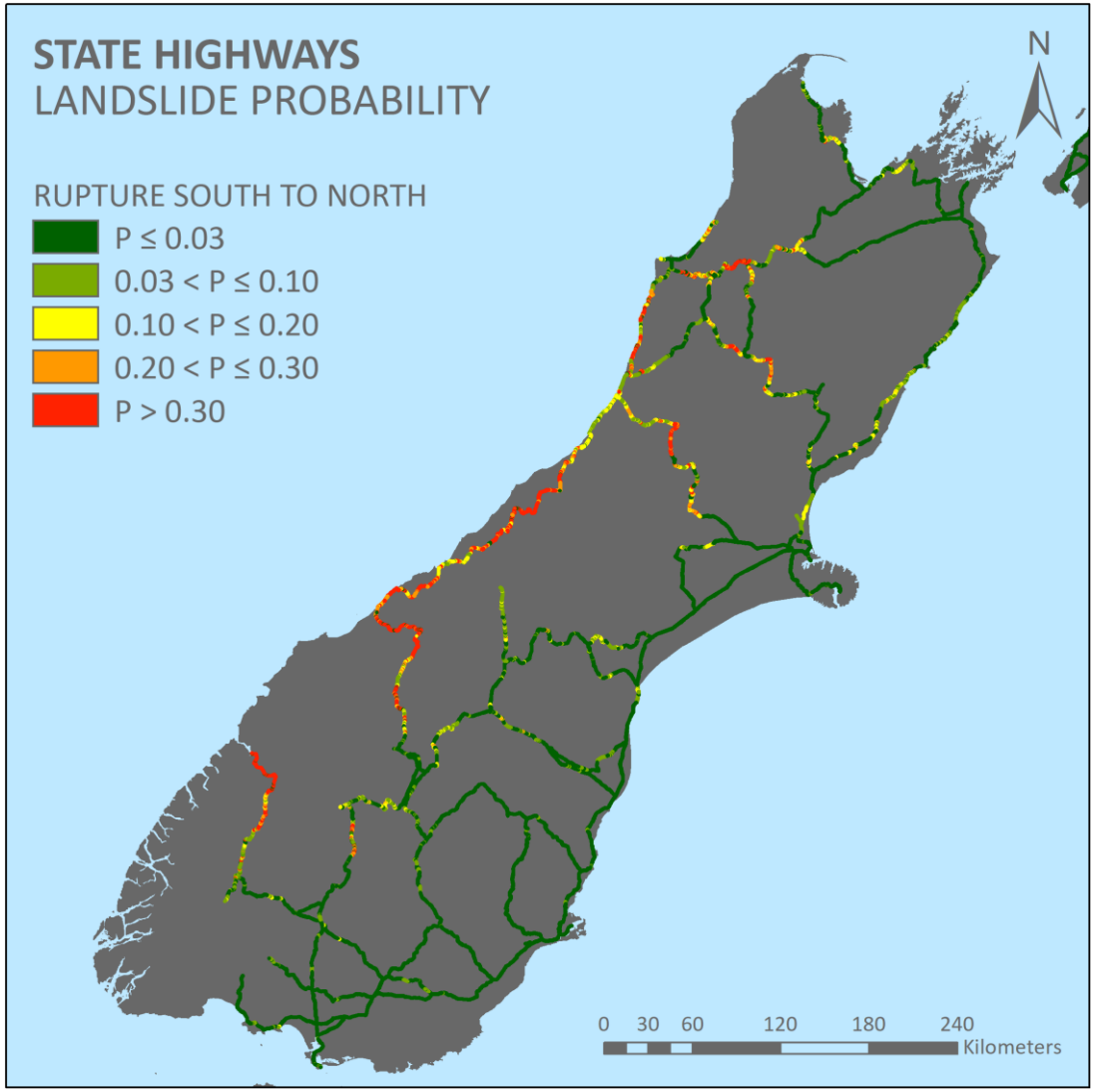
LARGE EXPLOSIVE ERUPTION



Seismic & Co-seismic

Lin et al.





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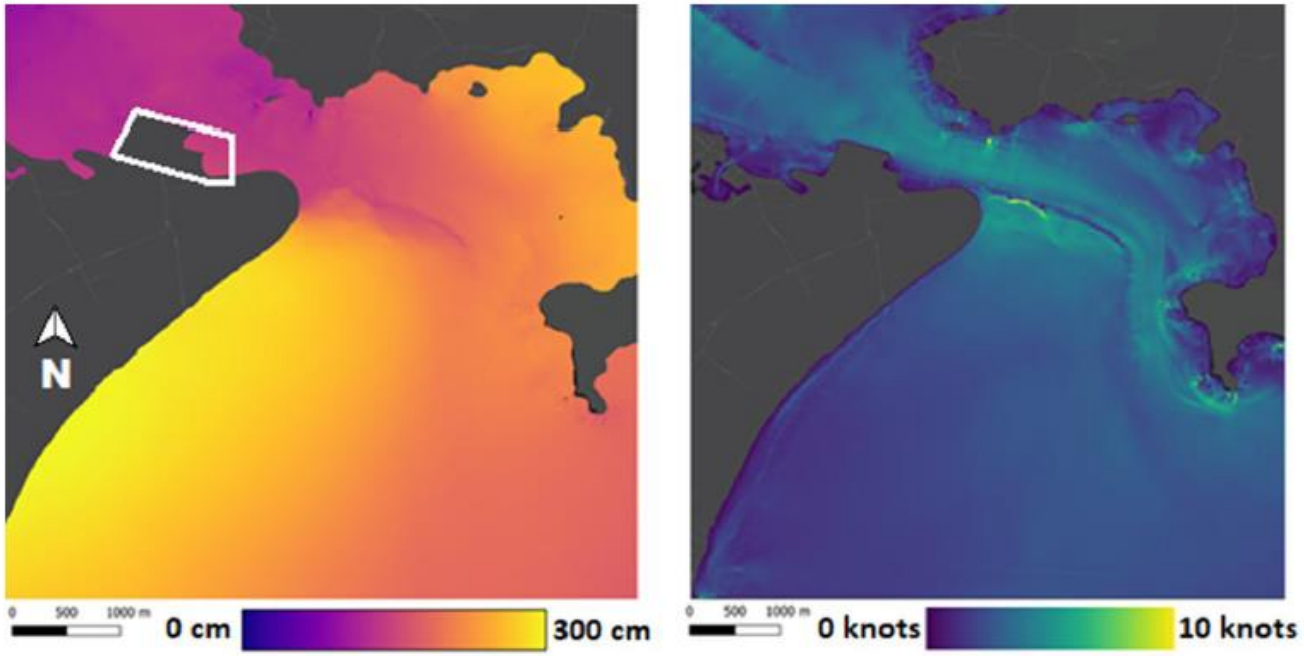
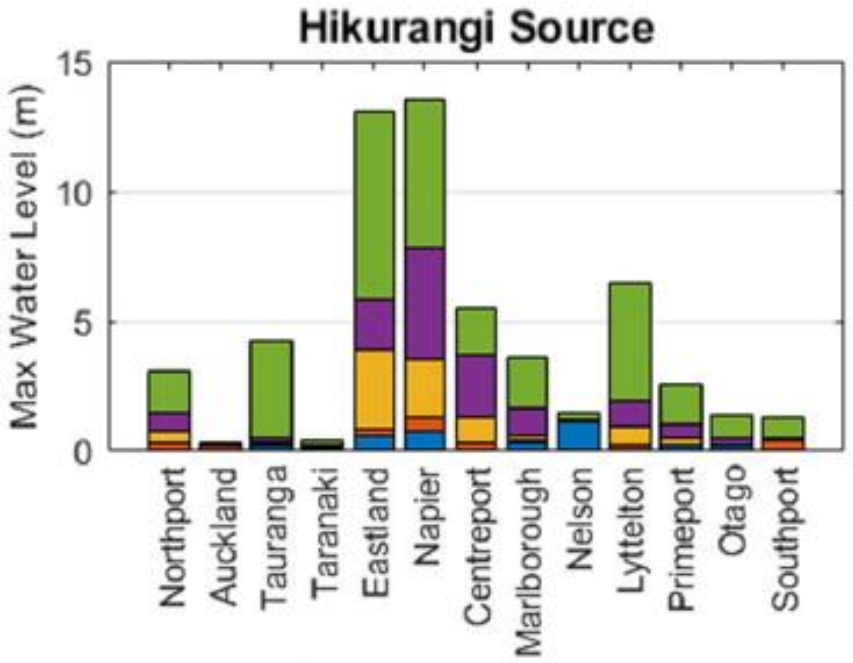
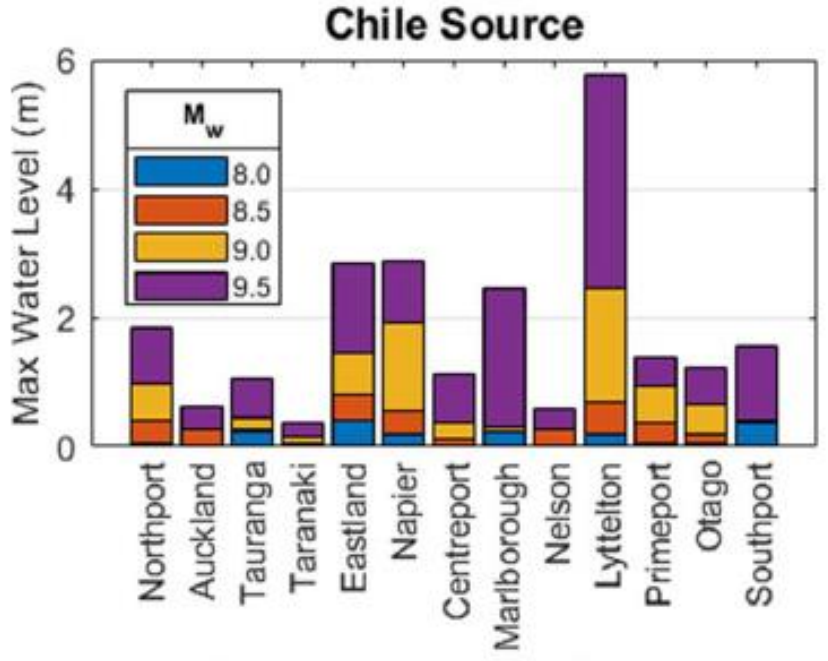
Tsunami & Ports

- Assessment of water levels and current speed across ports for key tsunami scenarios
- Number of scenarios with likely damage and disruption across multiple ports
- Need to view ports as key linked components



Popovich et al.





Transport Network Components

- Improve our understanding of how transport network components will perform when exposed to various hazards
  - Damage, downtime, reduction in service provision

- Bridges
  - Seismic
  - Tsunami
  - Flooding
- Roads
  - Flooding
  - Volcanic

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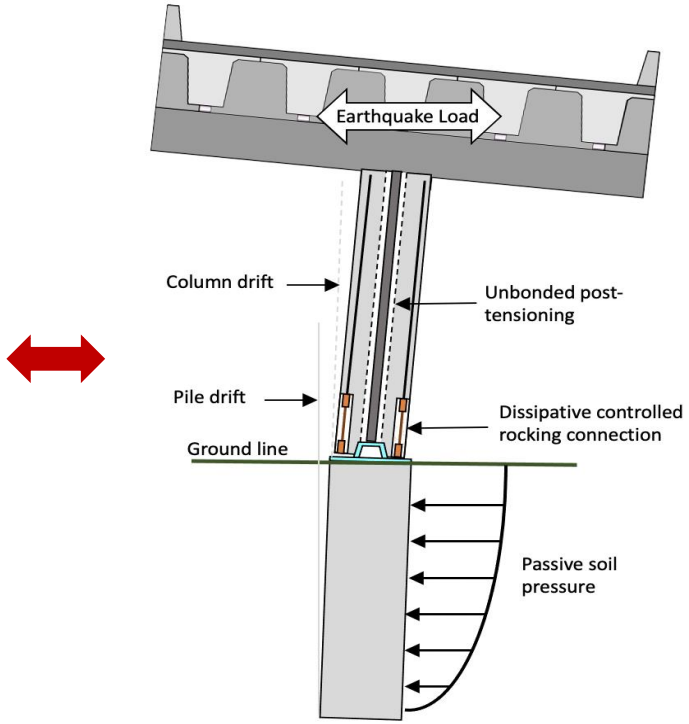
Bridge Field Testing

- Unique dataset quantifying lateral response of typical NZ bridge piles to inform seismic assessments

Palermo et al.

Bridge Laboratory Testing

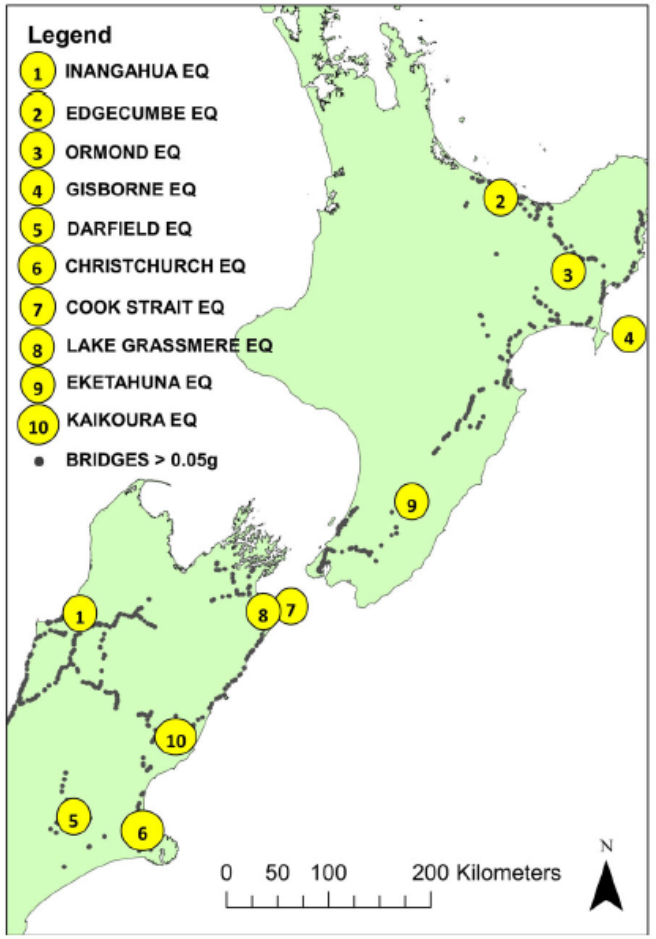
- Accelerated Bridge Construction
- Use of durable materials
- Impact of corrosion and degradation on performance

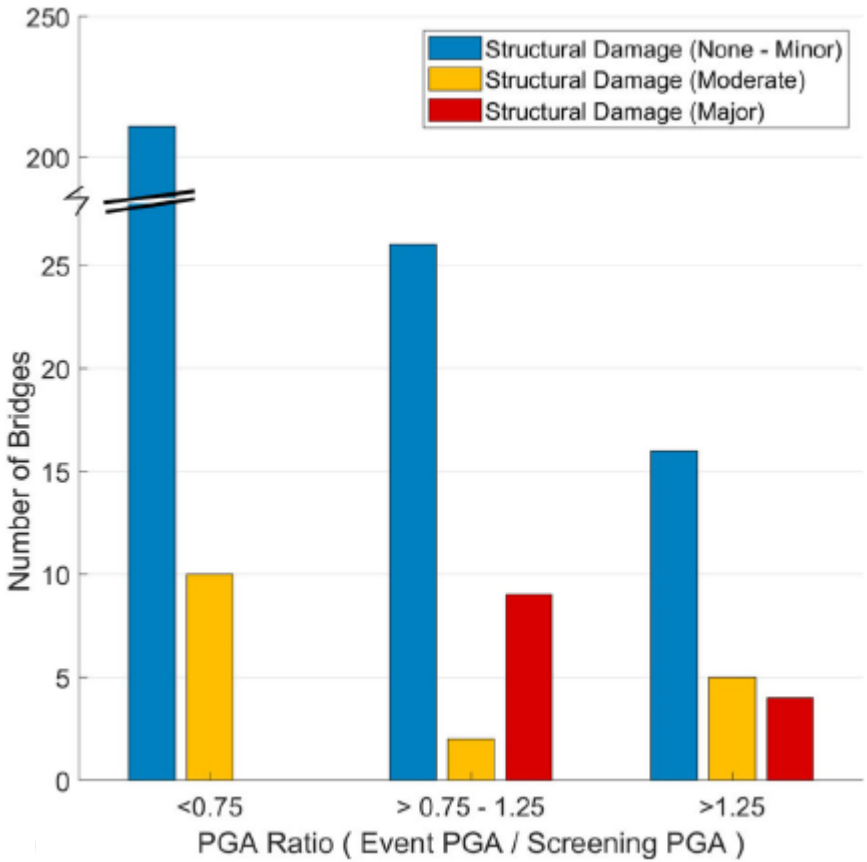


Lew et al.

Bridge Stock Seismic Exposure

- Database of all NZ bridges experiencing PGA>0.05g in past EQ
- Generally good performance of the bridge stock in past events,

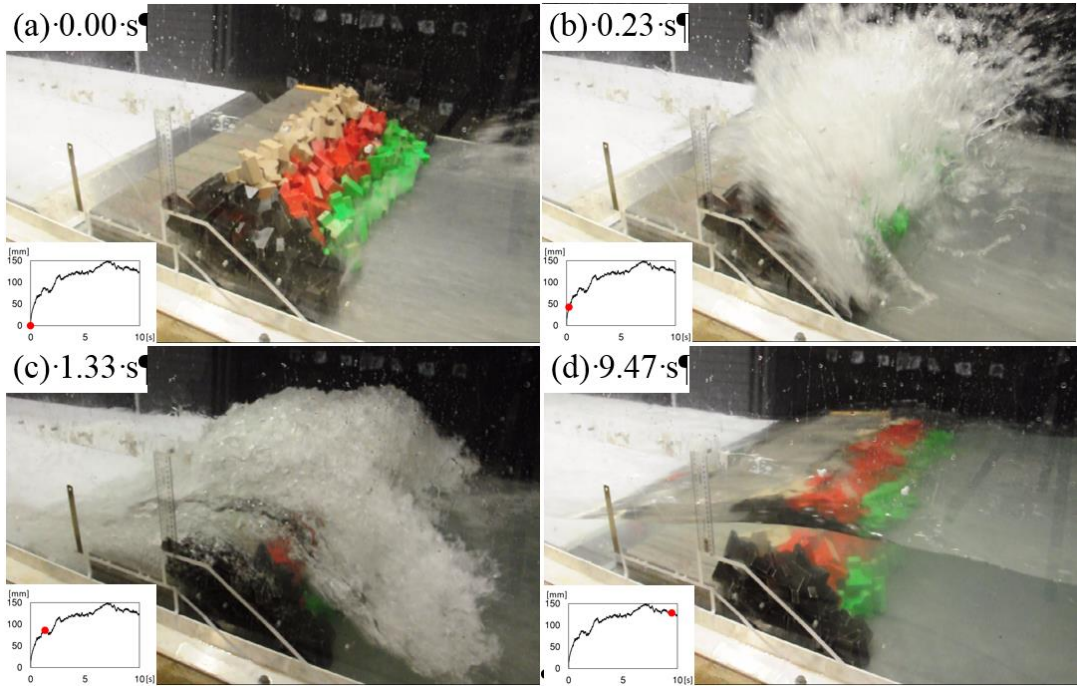


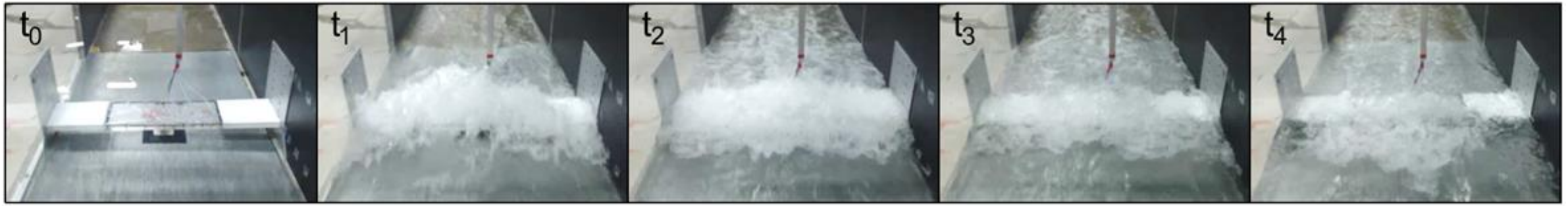


Whittaker et al.

Tsunami Experimental Modelling

- Scale modelling of infrastructure components
  - Bridges
  - Breakwater
  - Validate computational models
  - Improve damage assessments





Network Modelling

- Integration of transport network modelling approaches into resilience applications
  - Connectivity-based modelling
  - Flow-based modelling

  - Regional/National Transport Models
  - Urban Transport Models
  - Commuter, freight and tourism flows
  - Evacuation modelling and planning

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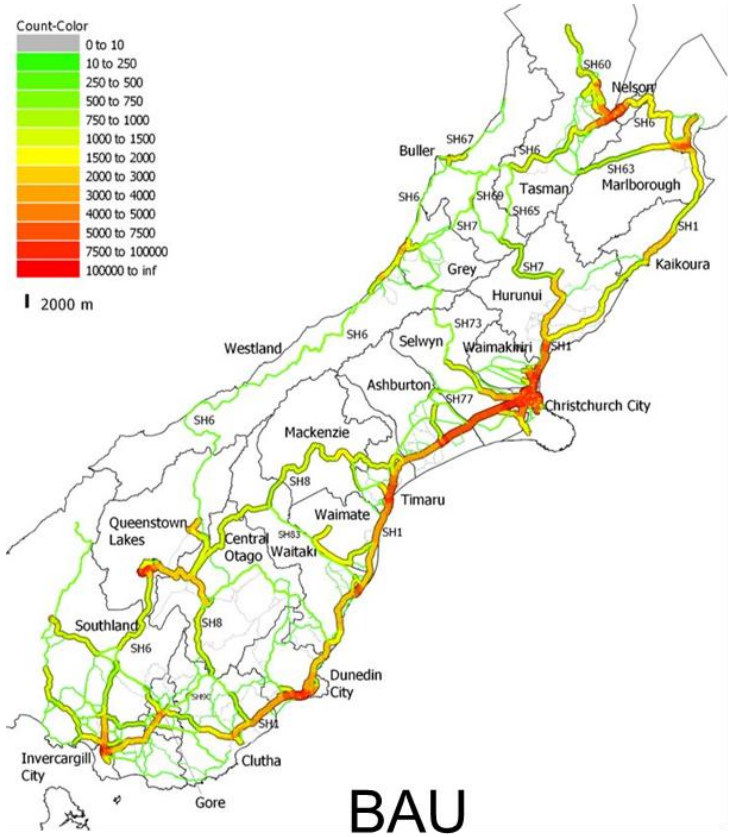
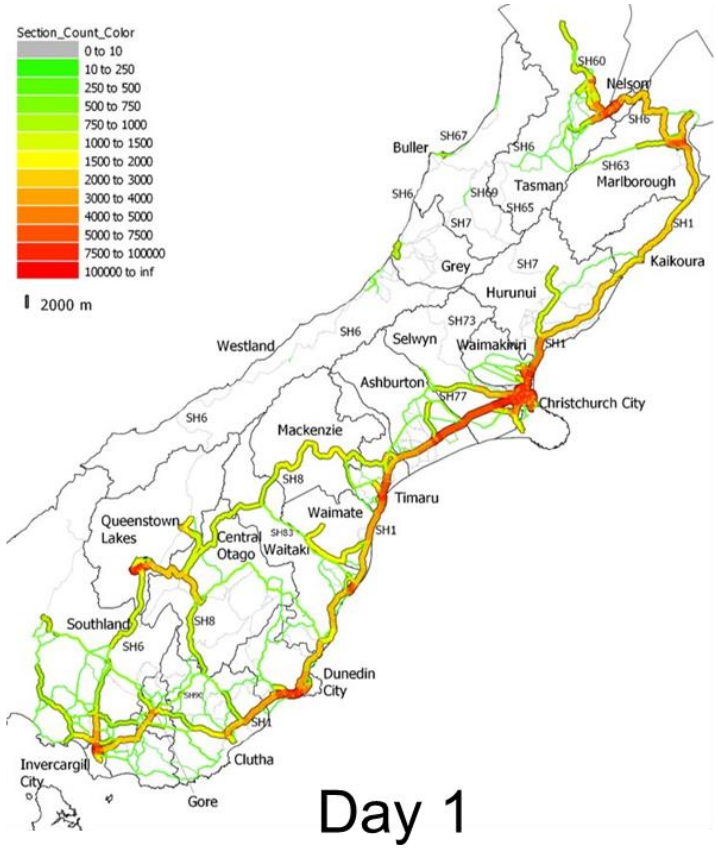
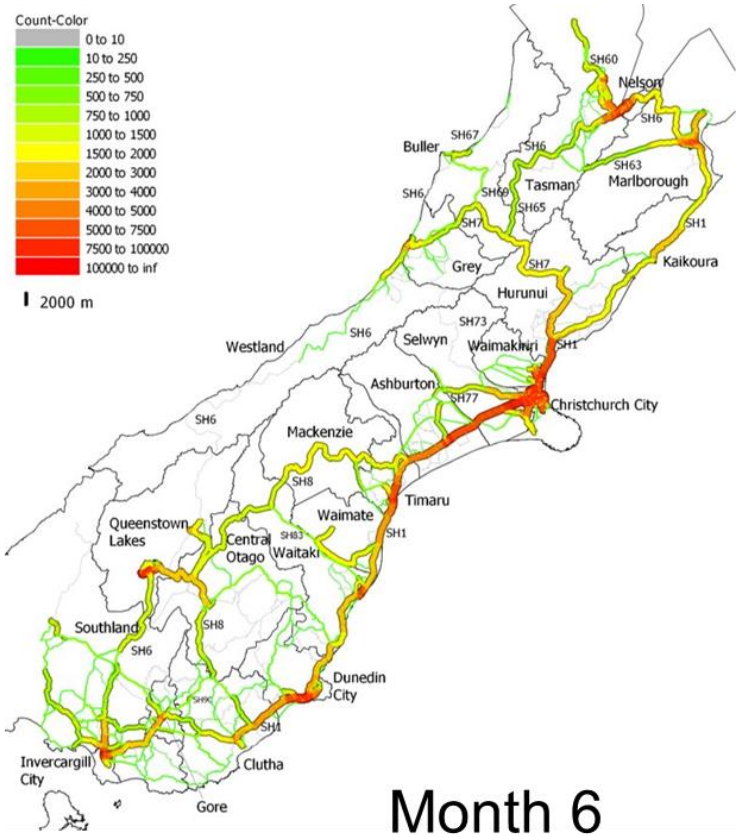
Aghababaei et al.

South Island – Alpine Fault EQ

- South Island Transport Model
  - Commuters, Tourism, Freight
- Kaikoura EQ case history and Alpine Fault EQ scenario

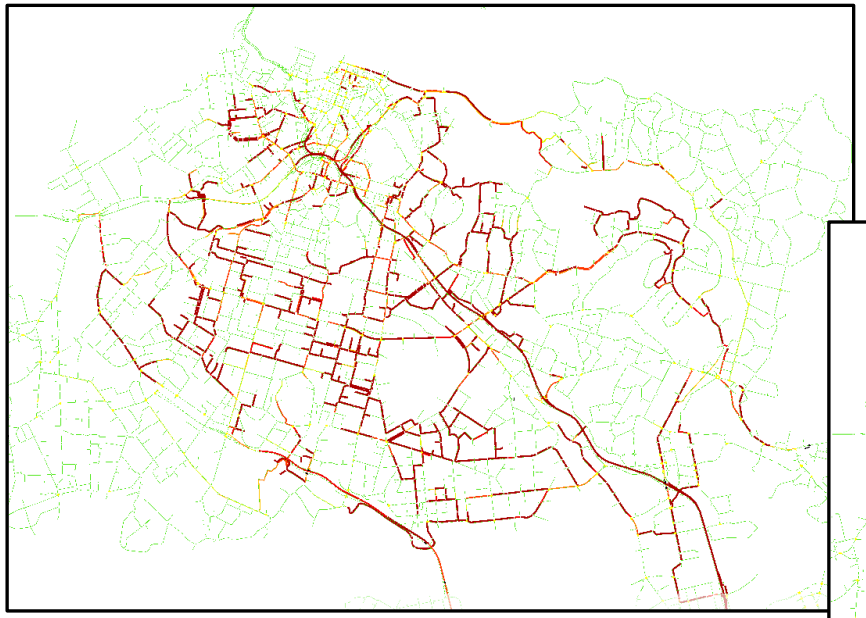


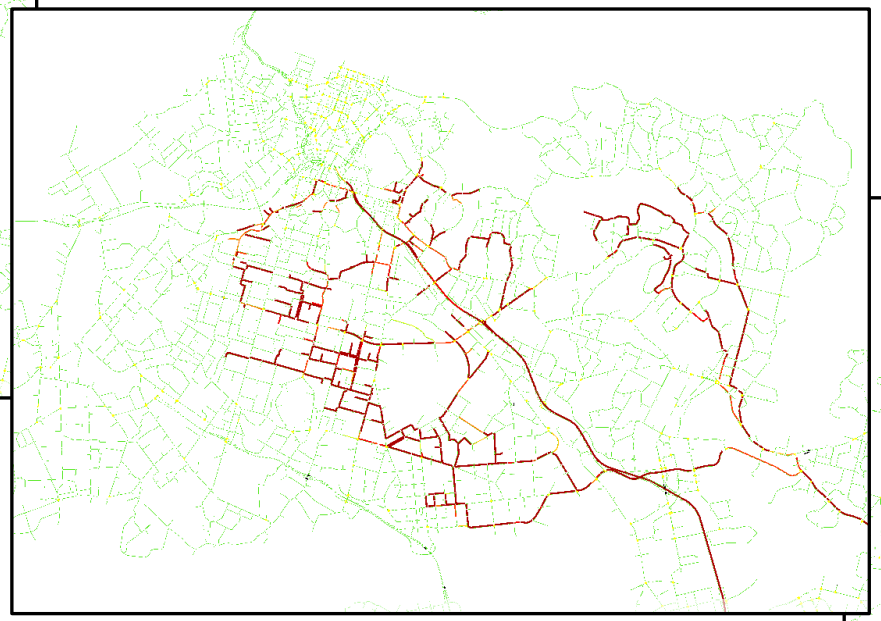


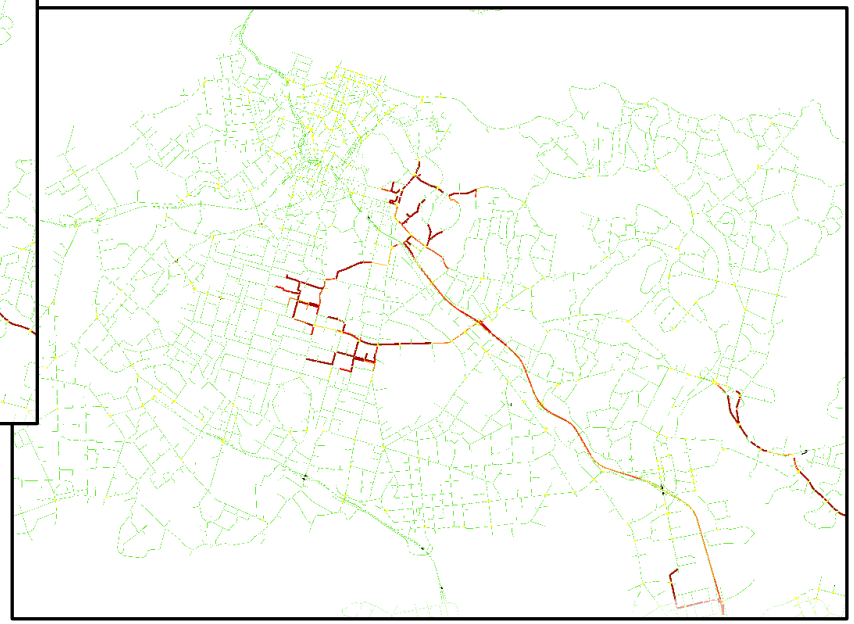


Auckland Evacuation Travel

1. Time taken to decide to call an evacuation
2. Public notification time
3. Evacuee's time to prepare
4. Evacuee's travel time to beyond the evacuation zone

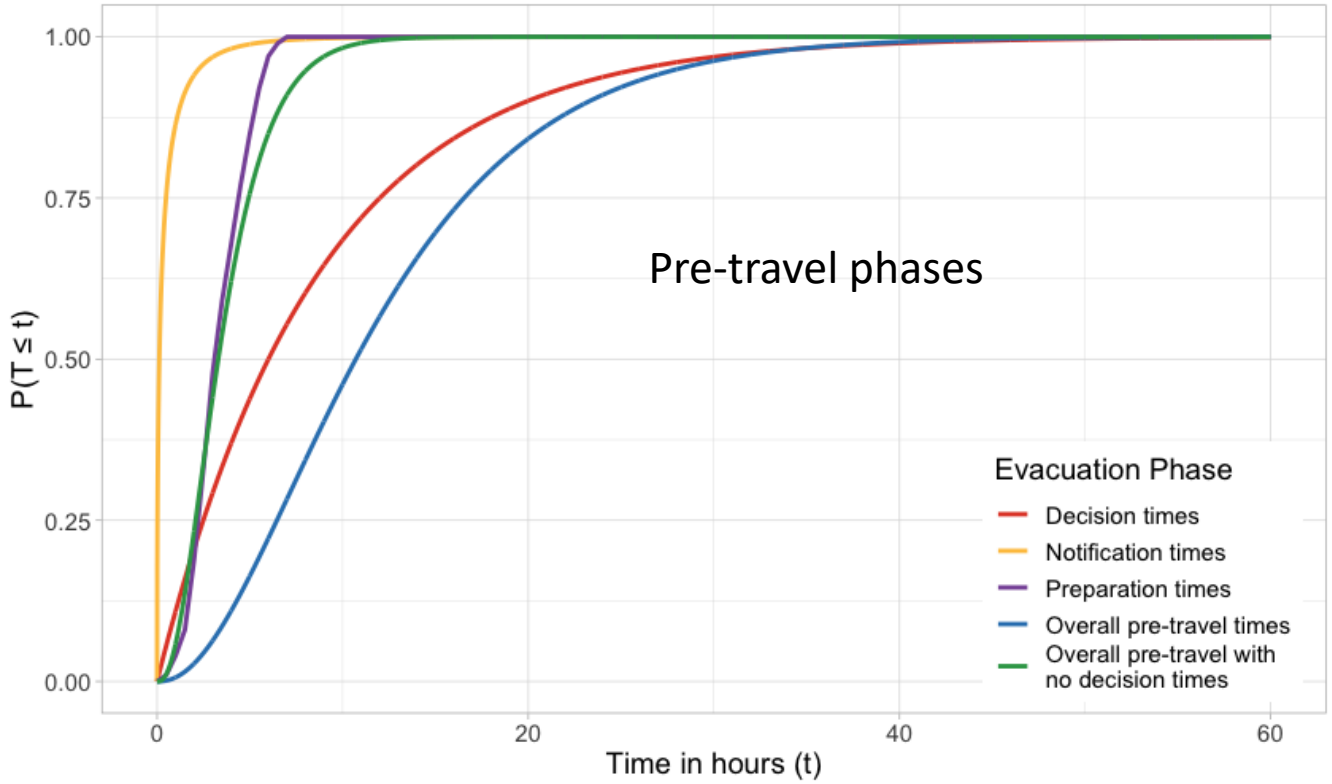




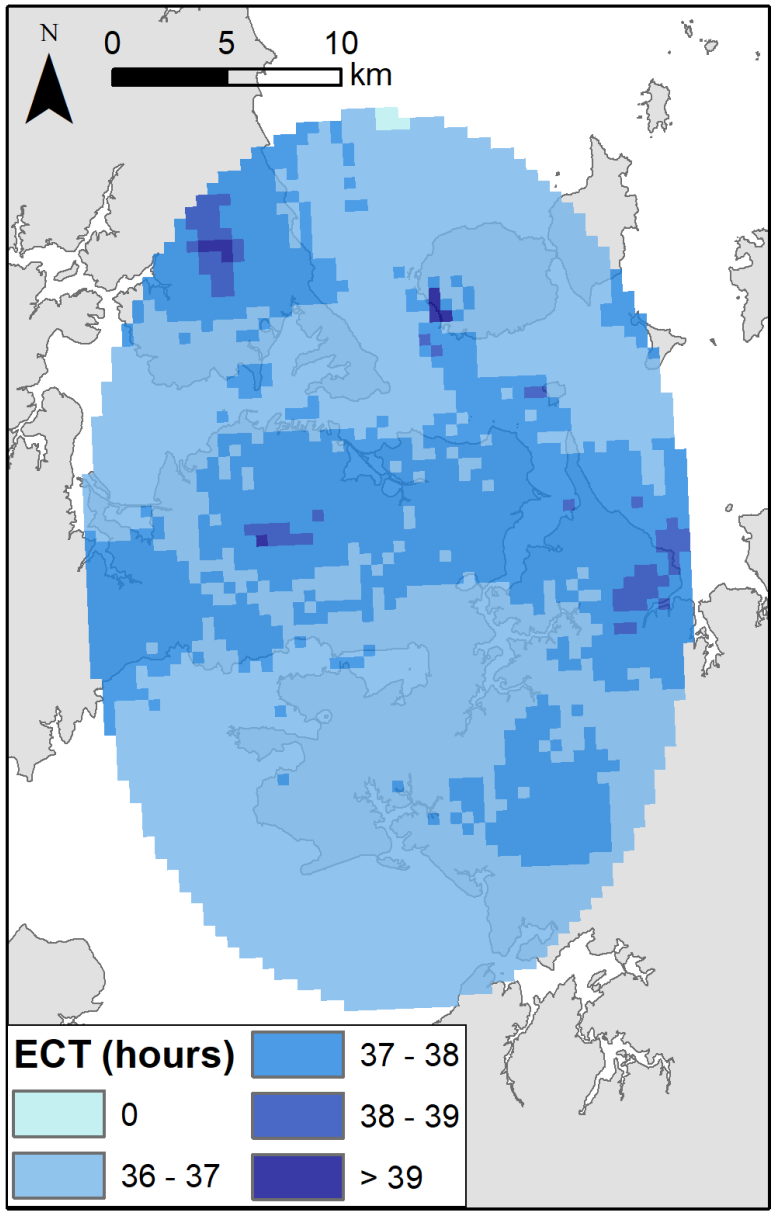


Evacuation Clearance Times

- Likely a need to evacuate before the exact location of volcanic vent is known
- Clearance times comprises of pre-travel (independent of vent location) and travel phases (spatially variable across the AVF)



Wild et al.



Median clearance time with no vent uncertainty

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Tsunami Impacts

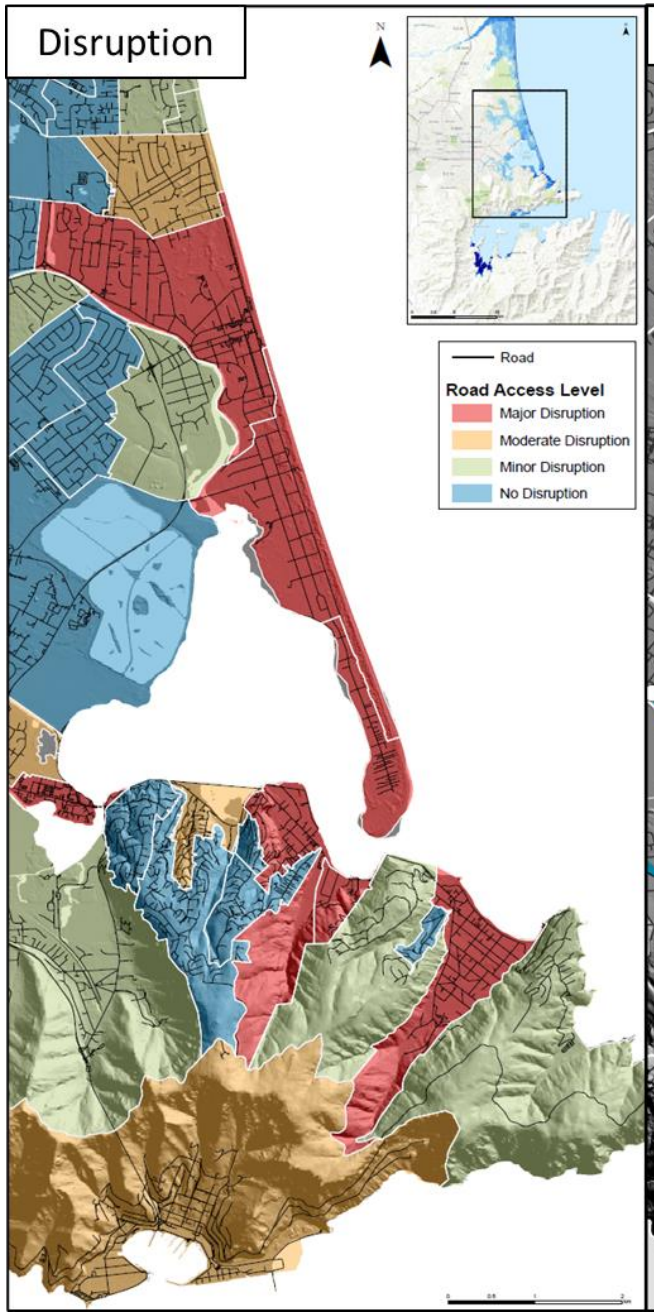
Williams et al.

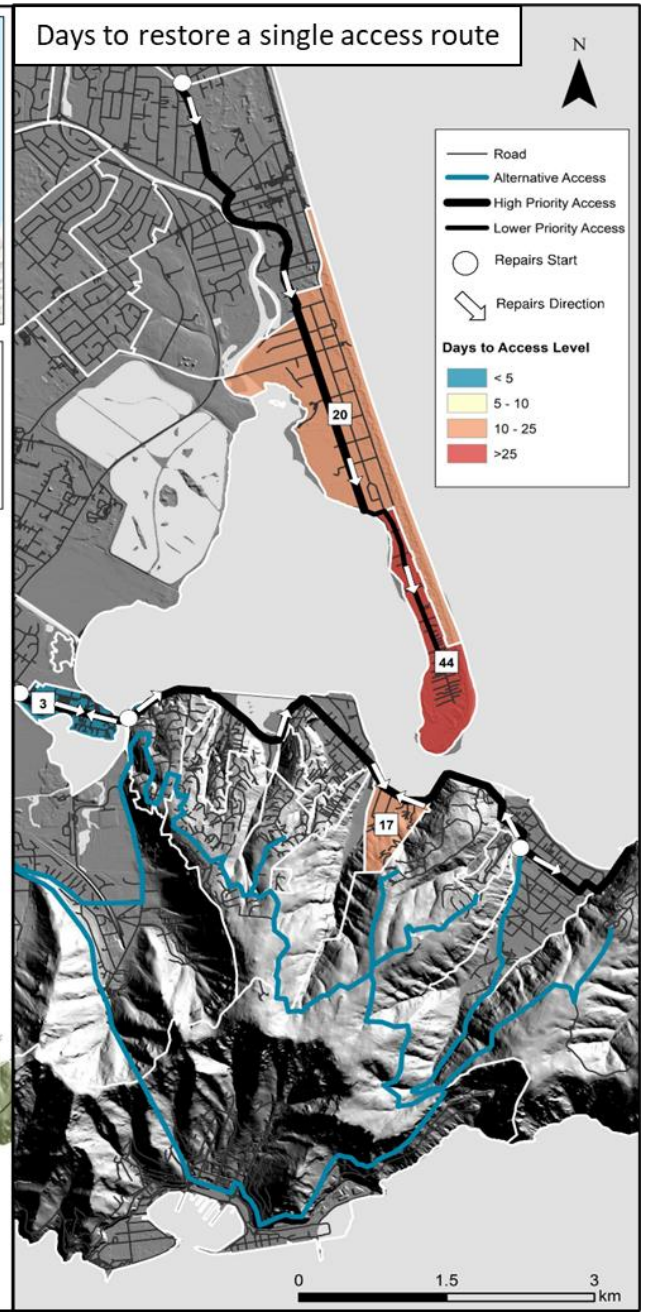
Post-event Field Surveys

Fragility Functions

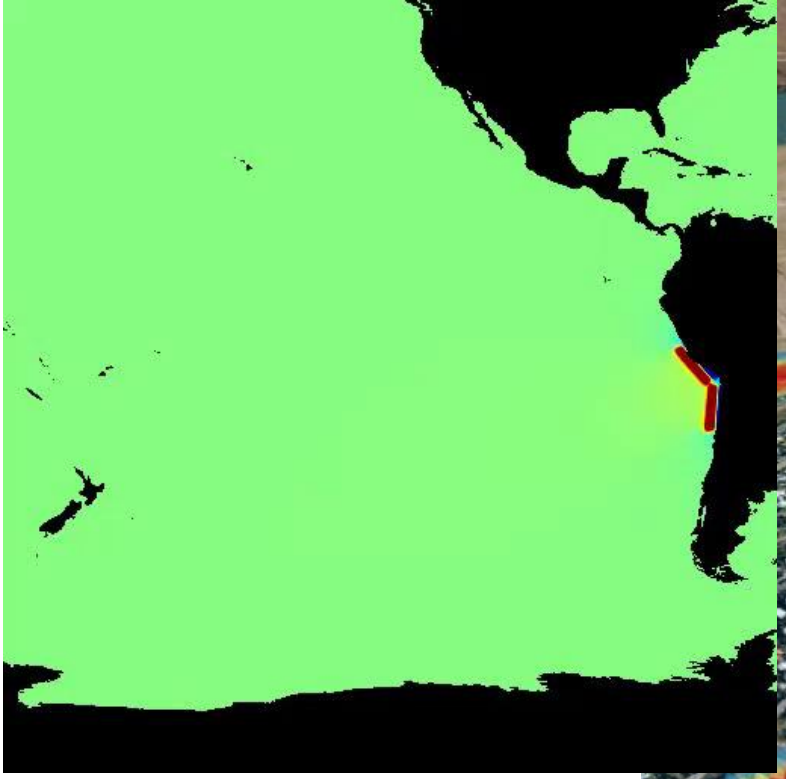
Direct Damage Assessment

Service Level Assessment



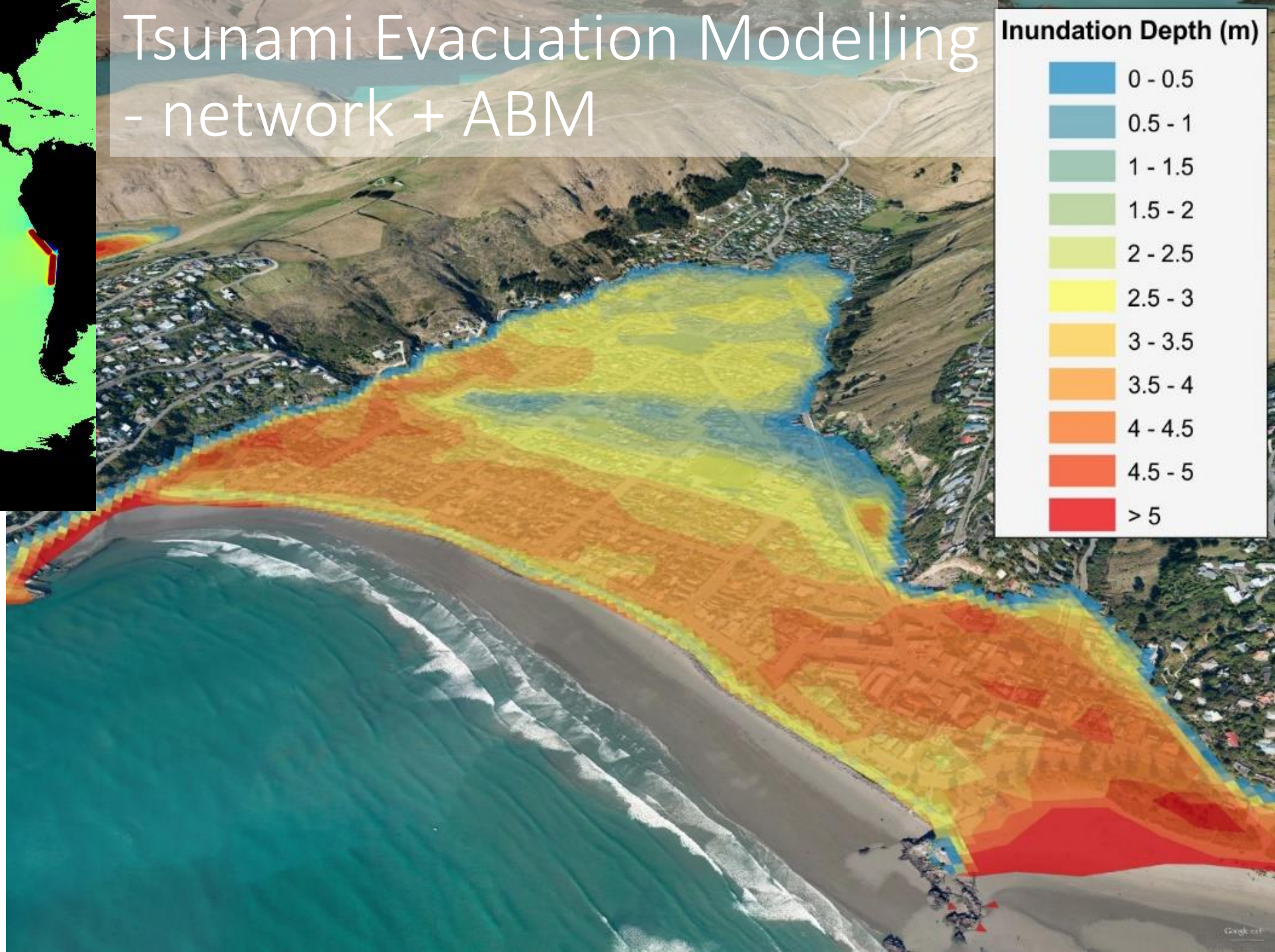


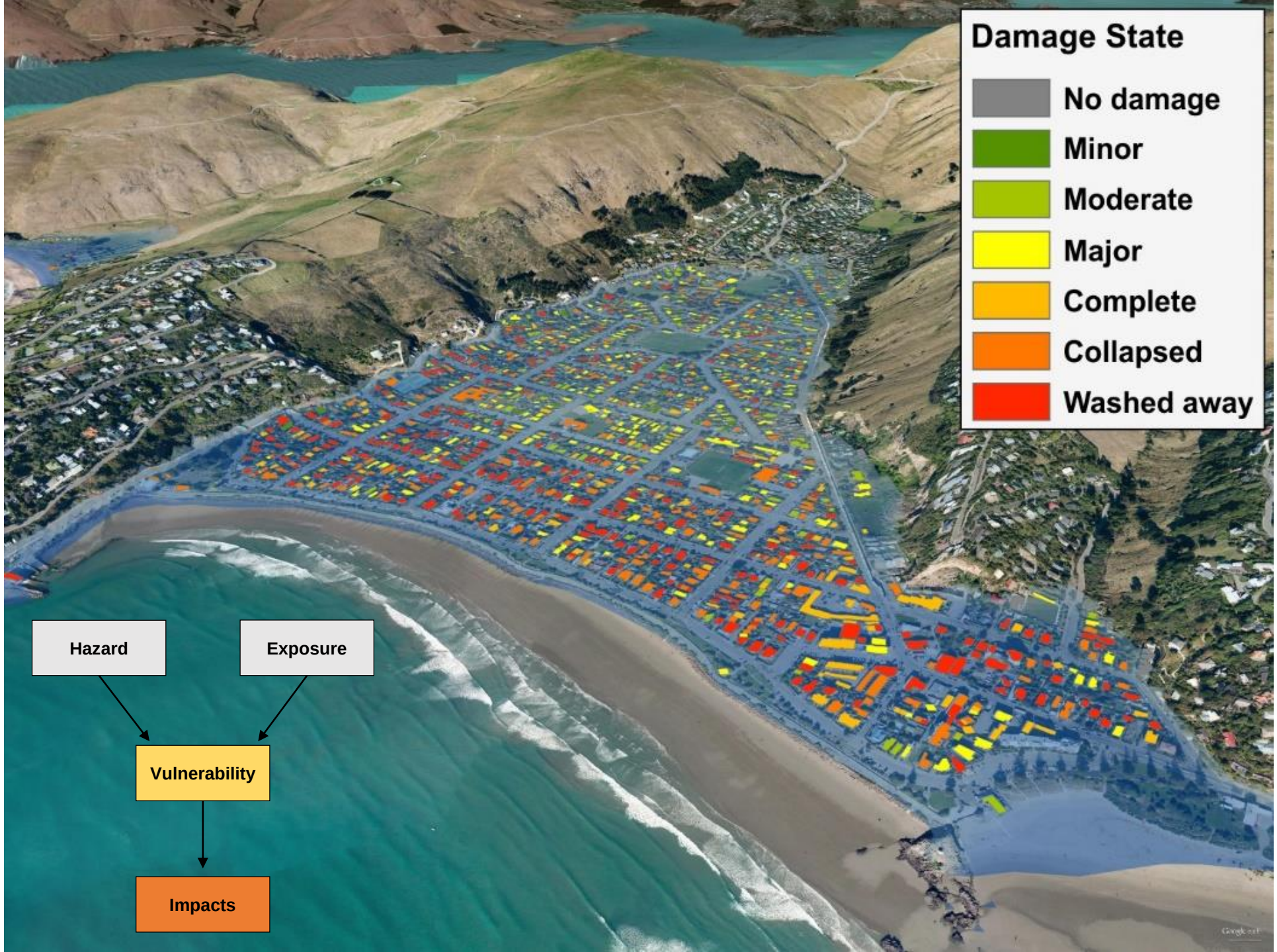
Tsunami Evacuation Modelling - network + ABM



- Occur approximately every 100-300 years
- Historical events in 1604, 1868, 1877, 1960
- ~12 hours official warning
- Waves 4-6m above tide at Christchurch

Lane et al.
Scheele et al.





Lane et al.
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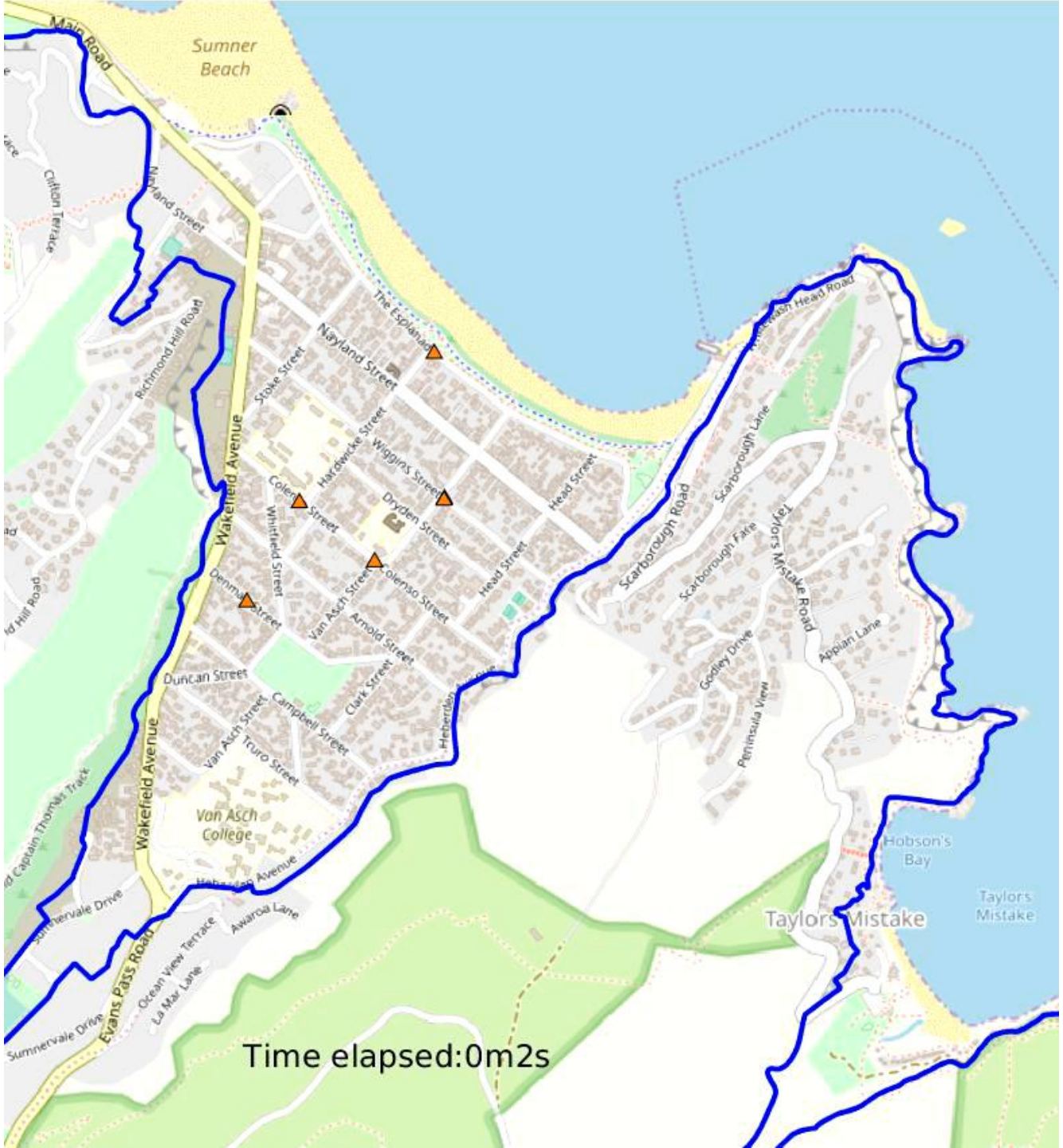

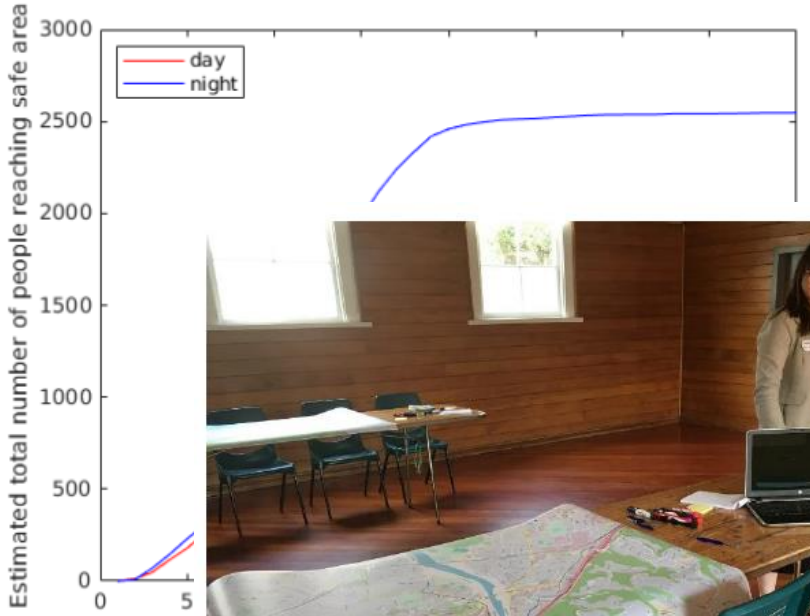

NB: animation is a simulation not a recommendation.

Power et al, 2019

Interdependencies

- Improve the representation of the interaction and dependencies across transport and wider infrastructure networks
  - How does damage in one network affect the functionality of other networks
  - Systems of Systems modelling

  - Direct and Indirect outages across networks
  - Influence of model resolution and complexity

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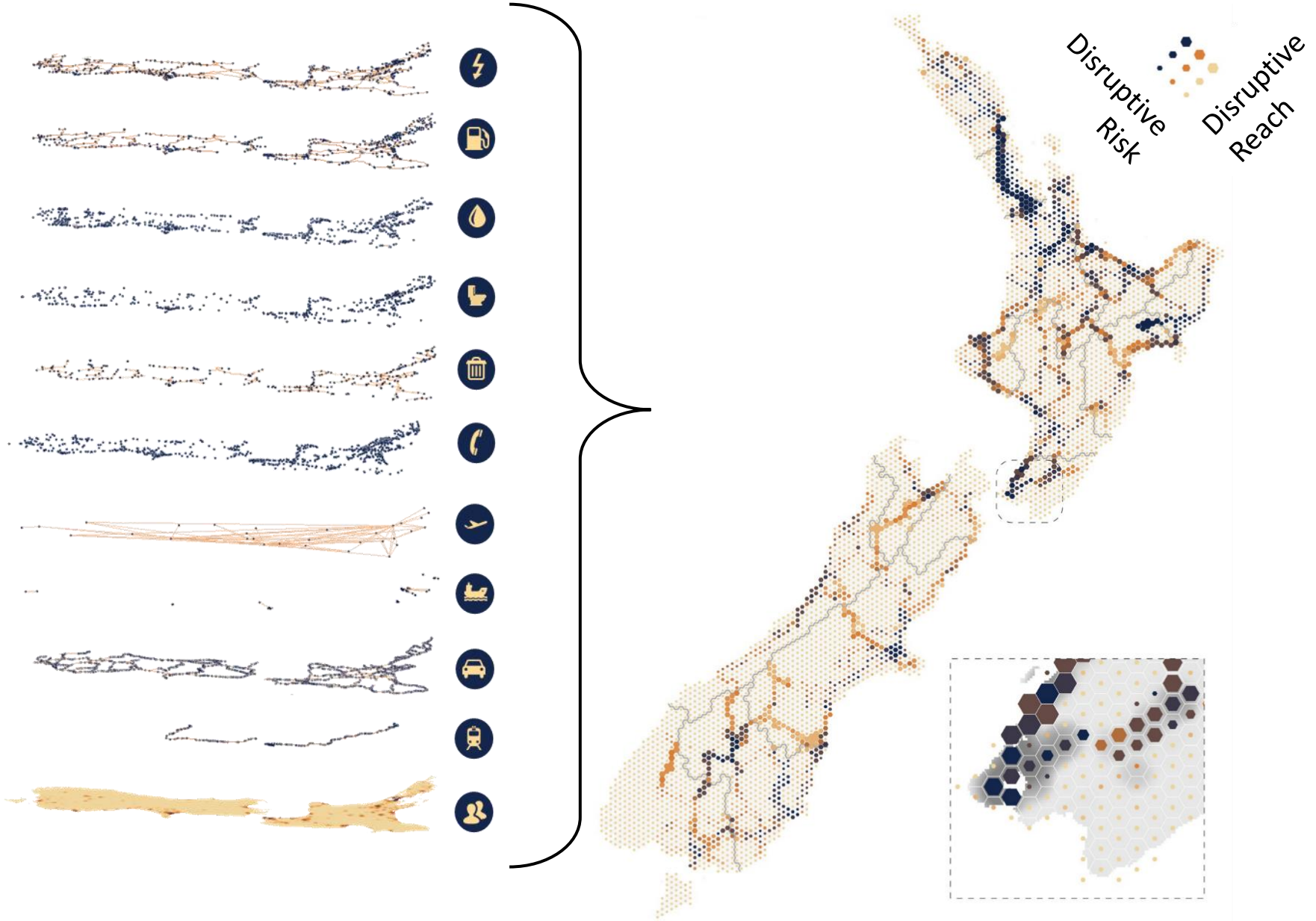
Zorn et al.

National Networks

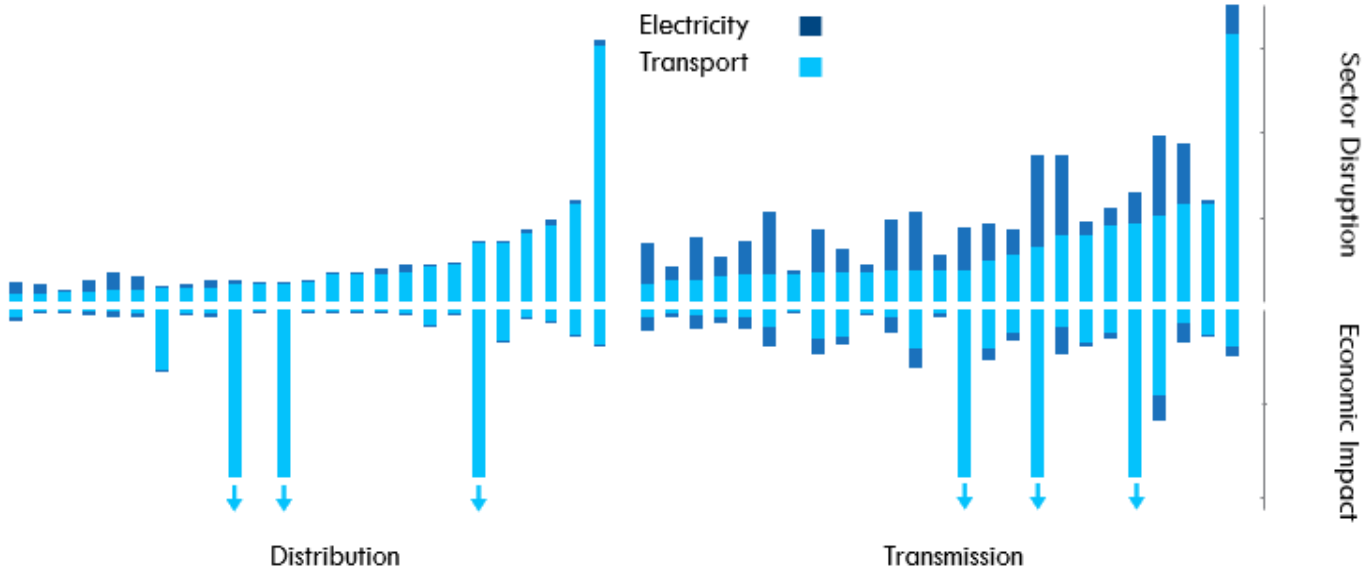
- Collate 10 infrastructure sector models with varying interconnectivity
- No single infrastructure is indicative of the cascading impacts
- 55% of failures are attributed to the **direct damage** to a network
- 45% being due to **indirect impacts** – such as a loss in electricity/waster supply/road connectivity/etc.

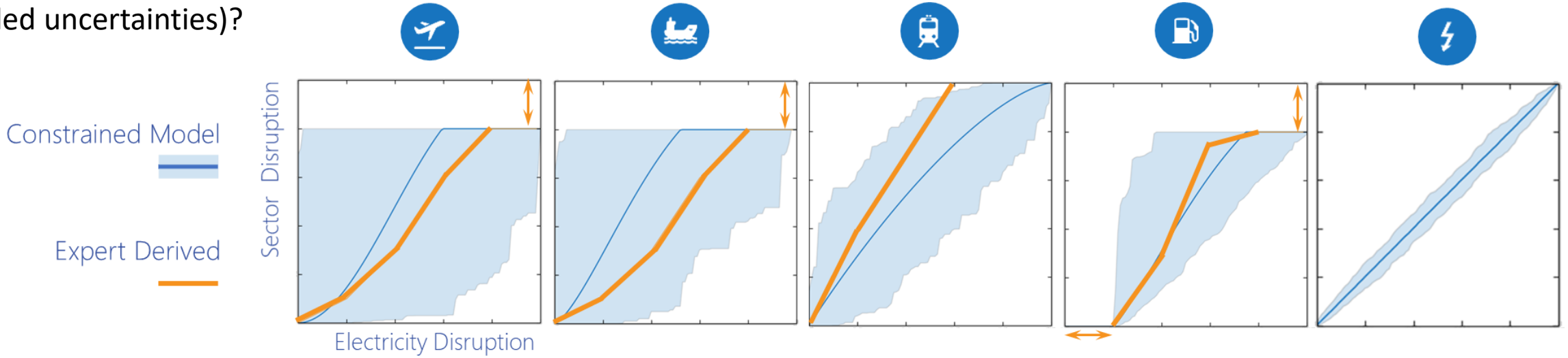


Transport-Electricity Dependencies

Zorn et al.

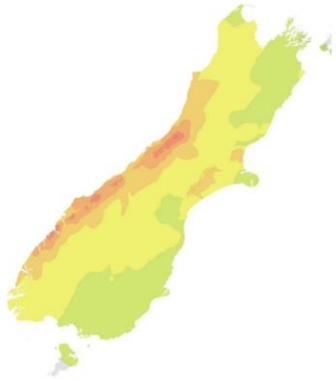
- Co-location ≠ User Dependence
- Not all assets are created equal
- Electricity demand ≠ criticality
- What if you are dependent on electricity from a non-priority asset following an event?
- How well does expert-elicitation capture dependencies (versus simulation and modelled uncertainties)?



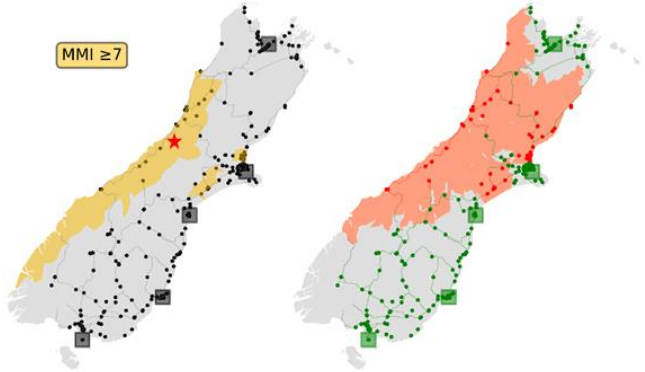


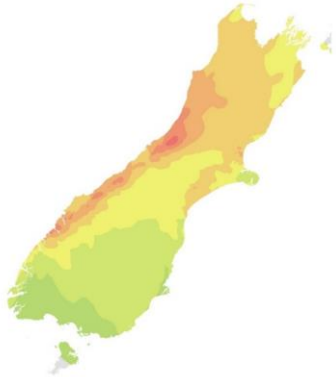
Liu et al.

Alpine Fault EQ

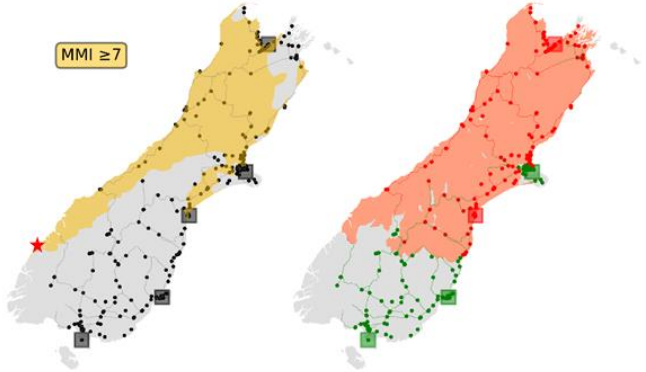


North-to-South Scenario





South-to-North Scenario

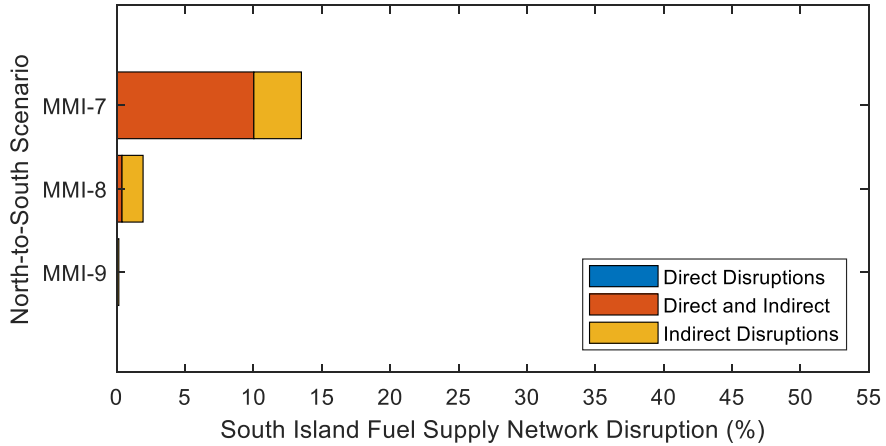


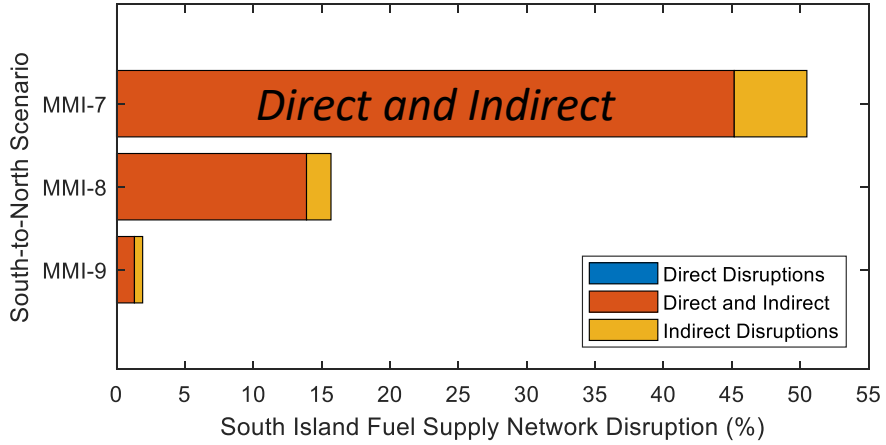
Fuel Supply Asset Exposure

Extent of Supply Disruption

AF Scenarios

Geospatial outages

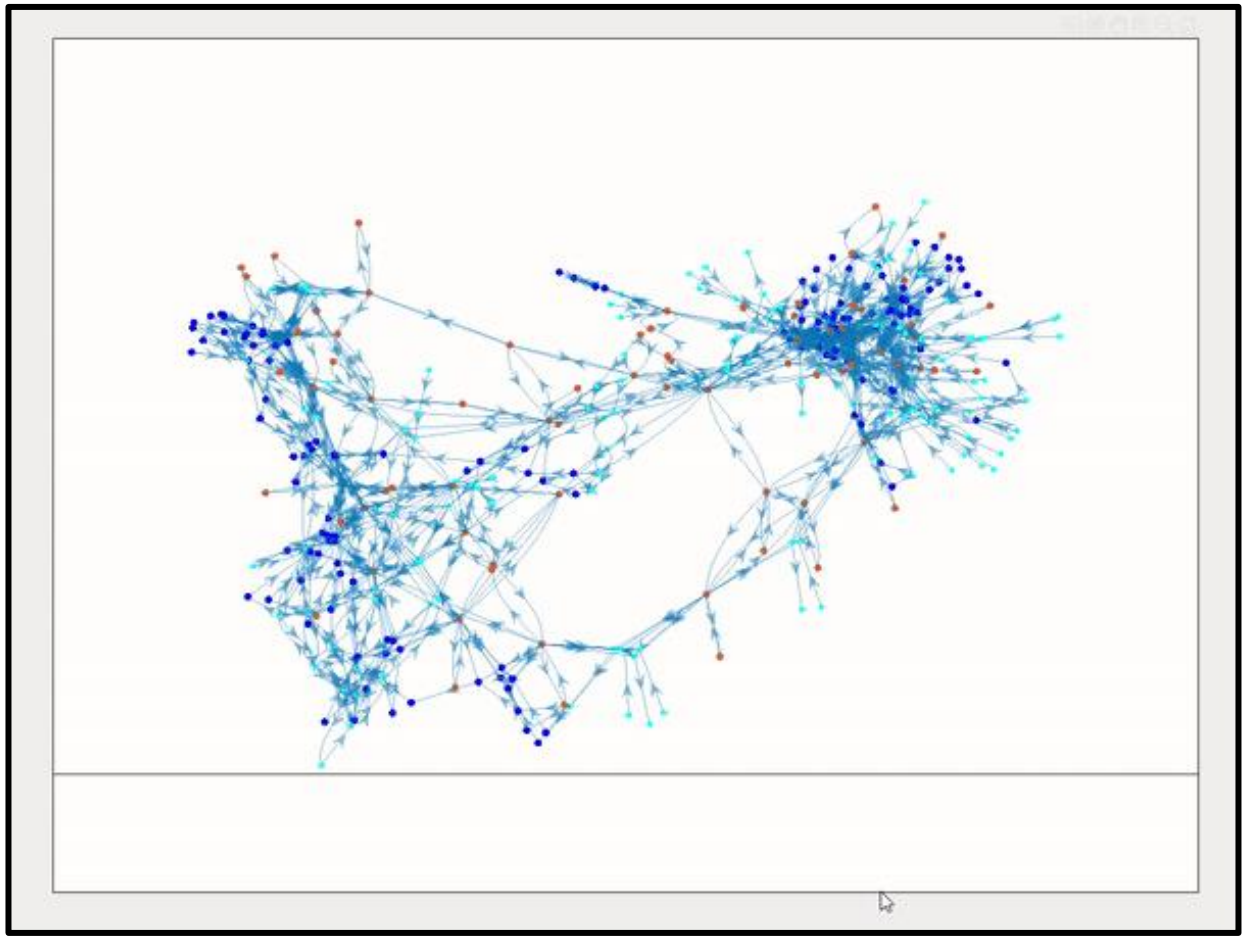




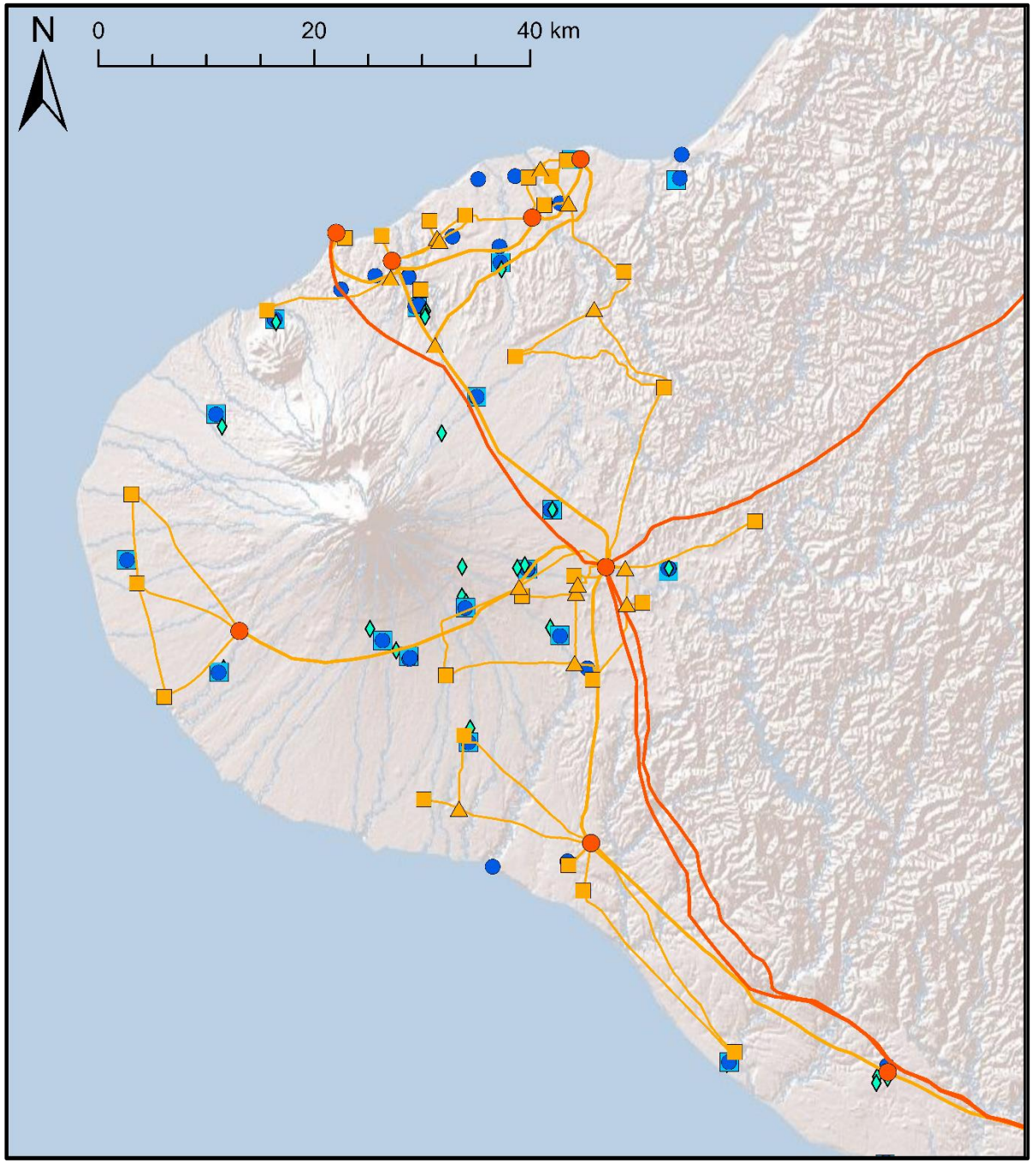
Quantification of extent of indirect outages and importance of redundancies

Mt Taranaki Eruption

- Exposure of critical infrastructure



Weir et al.



Systems Users and Community

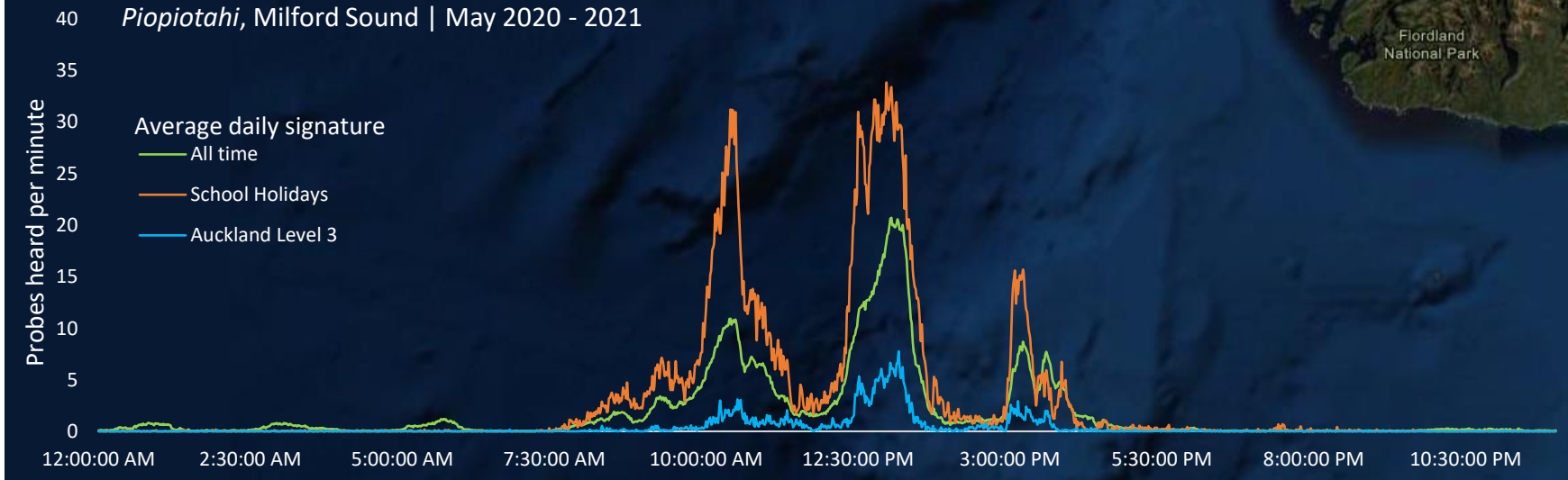
- Improve our representation of users of the transport system and how they will they be impacted?

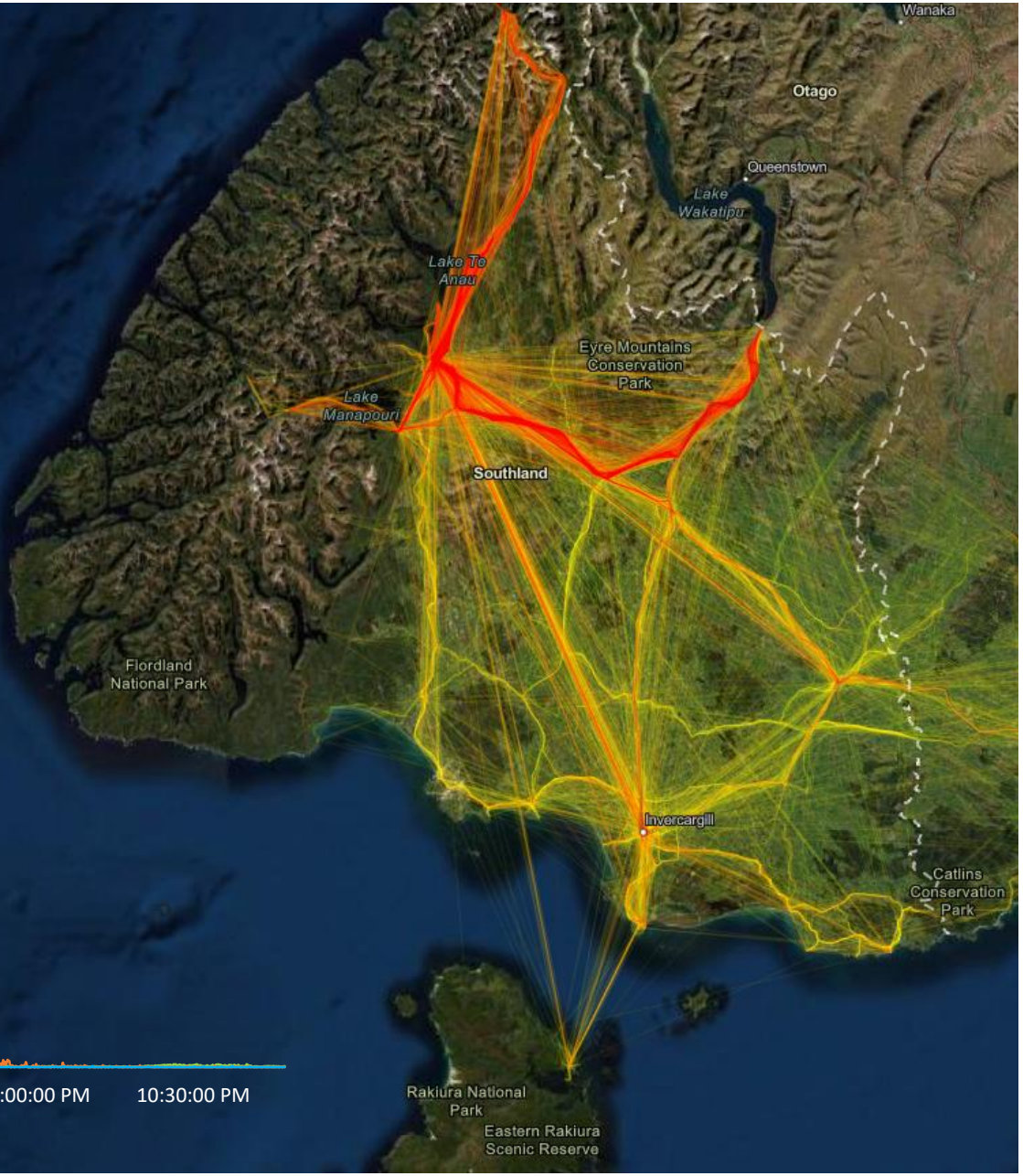
  - Transient populations
  - Dynamic exposure models
  - Agriculture Systems
  - Supply Chain and Logistics

Darling et al.

Dynamic risk exposure models

1. Fundamental to risk modelling is representative exposure data
2. Need to find ways to distribute people through space and time
3. To ultimate understand who is exposed to disaster risk when and how this changes through <u>time</u> and <u>space</u>

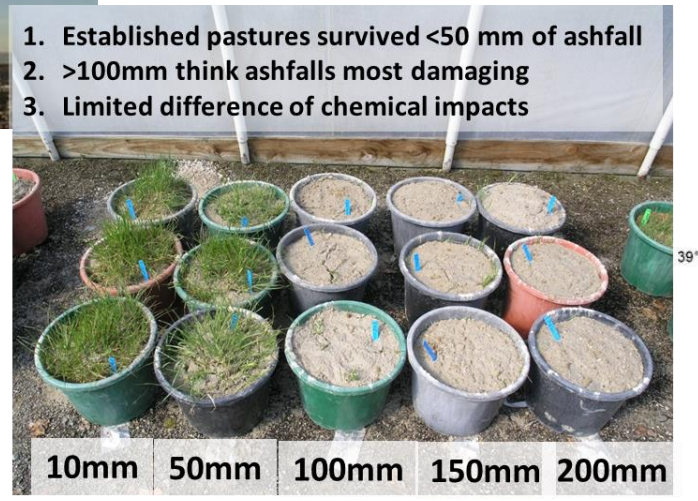


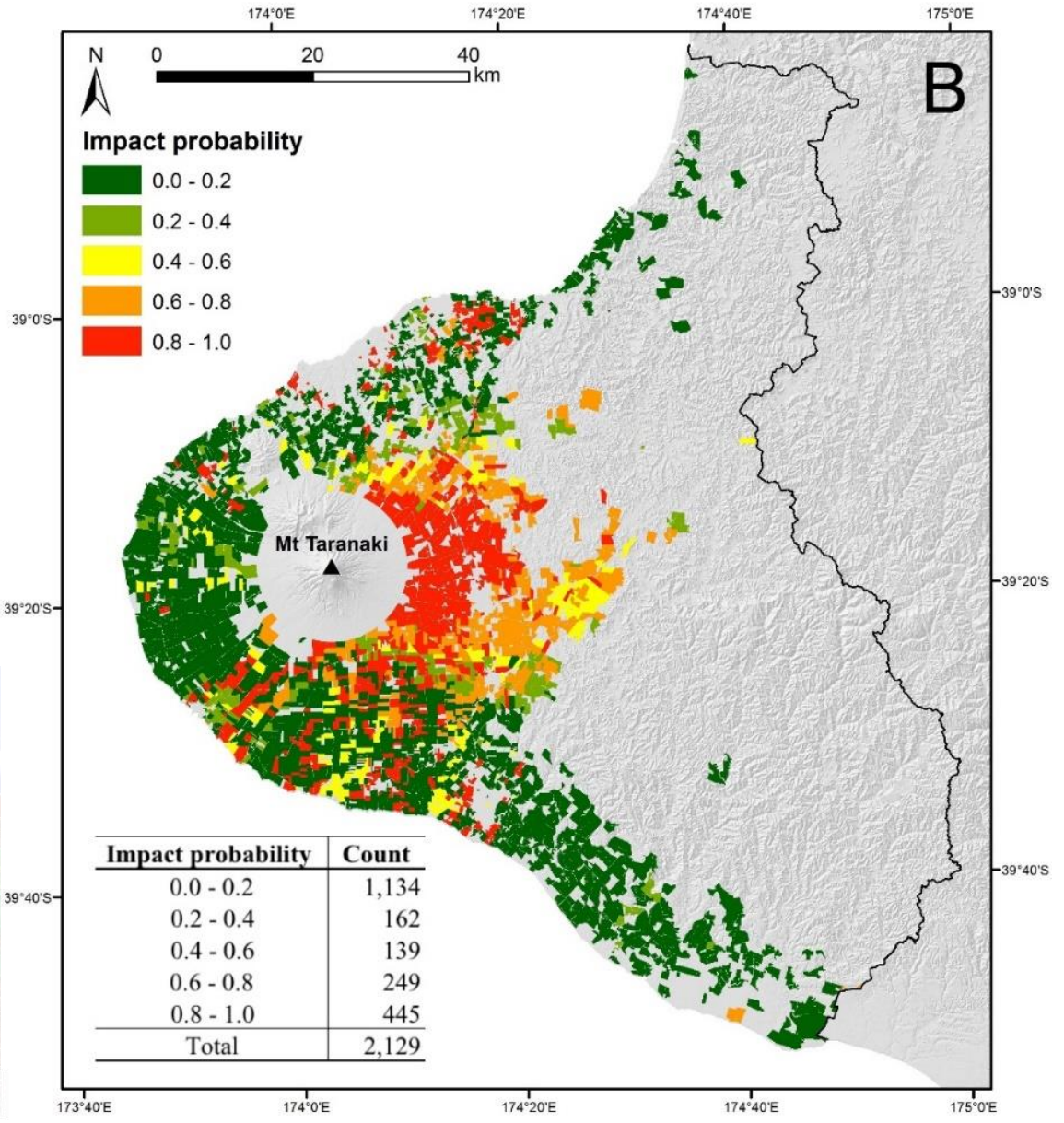


Agricultural Systems

Wild et al.

- Mt Taranaki scenario:
  - Disruption of critical infrastructure
  - Disruption of labour force (public health and transport)



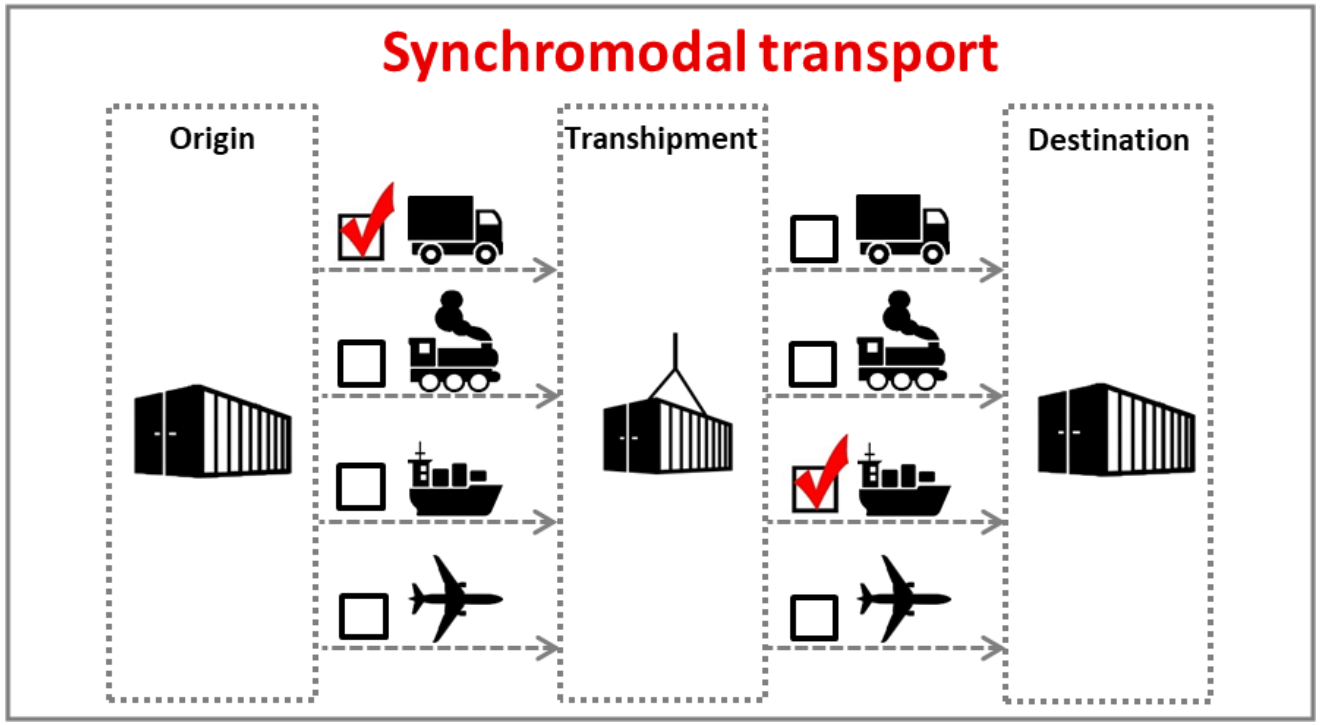


Impact probability	Count
0.0 - 0.2	1,134
0.2 - 0.4	162
0.4 - 0.6	139
0.6 - 0.8	249
0.8 - 1.0	445
Total	2,129

Keeping Goods Moving

- Identifying the factors influencing the rapid reconfiguration of freight operations across modes
  - 2016 Kaikoura EQ
  - Interviews across sector

- Identified 31 factors influencing rapid modal shifts

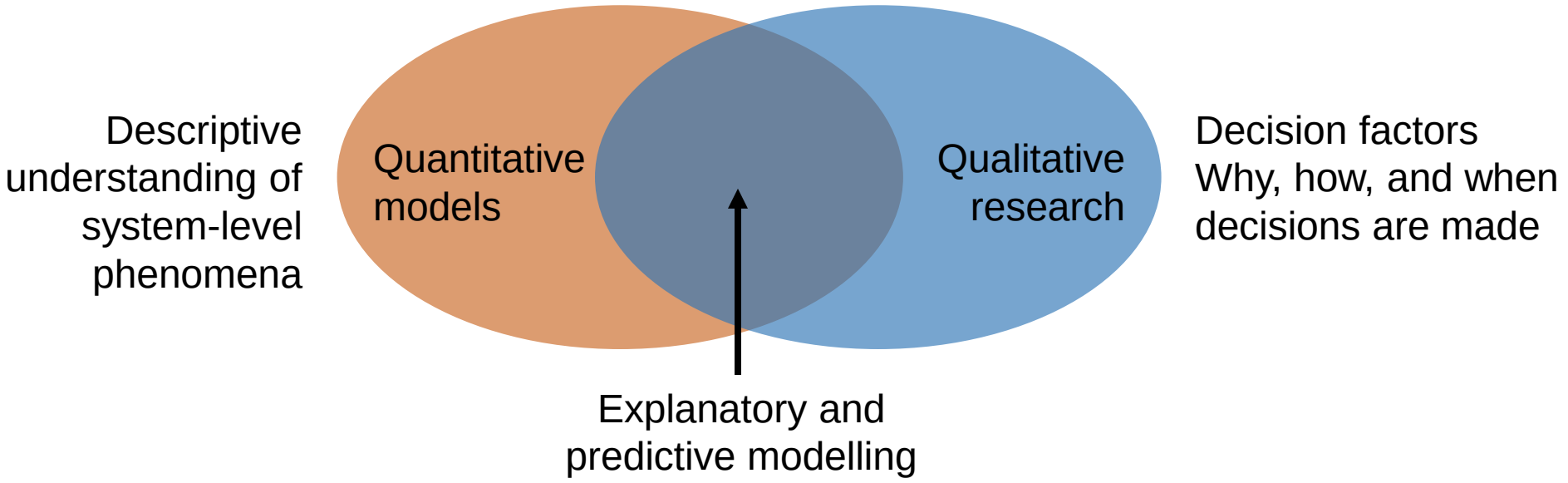


Findings: **Increased physical, digital and business integration**, as well as **redundancies** (routes, modes, port capacity, shipping containers) are needed to create a more flexible and adaptable freight system in NZ.

Supply Chain Behaviour

- To understand supply chain vulnerabilities and to create supply chain resilience, we need to have a handle on supply chain behaviour.

- Behaviour:
- How supply chains use and depend on transport networks.
- How supply chains are impacted by transport network disruptions.
- How supply chains will adapt.



Metrics & Economics

- How can we represent resilience in the context of transportation and how the wider impacts of service disruption?

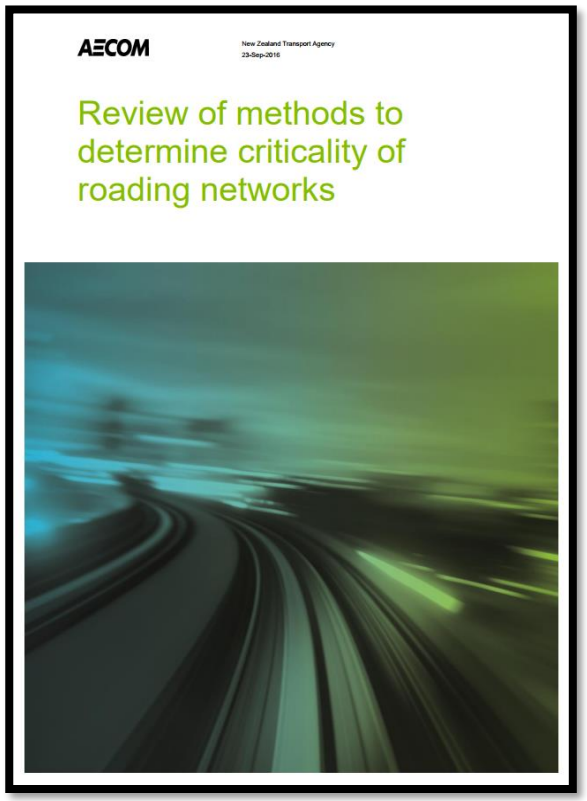
  - Criticality
  - Flow-based resilience metrics
  - Access to essential services
  - Minimum Levels of Service
  - Integration of land use and economic models
  - Economic impacts

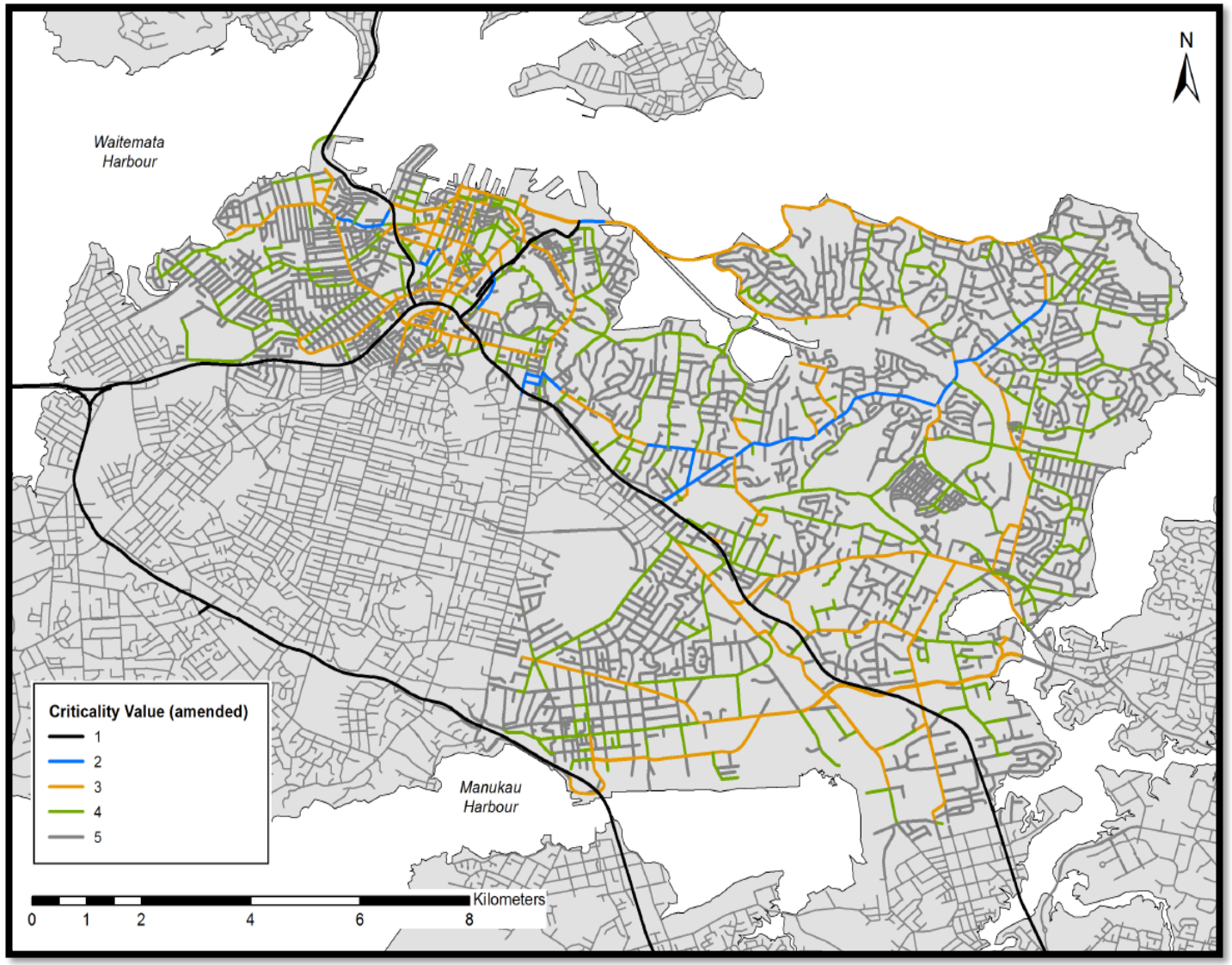
L

Rebello et al.

Criticality

- Revised framework for criticality rating of road networks
  - Road function
  - Access to lifelines/evacuation route
  - Access to essential services

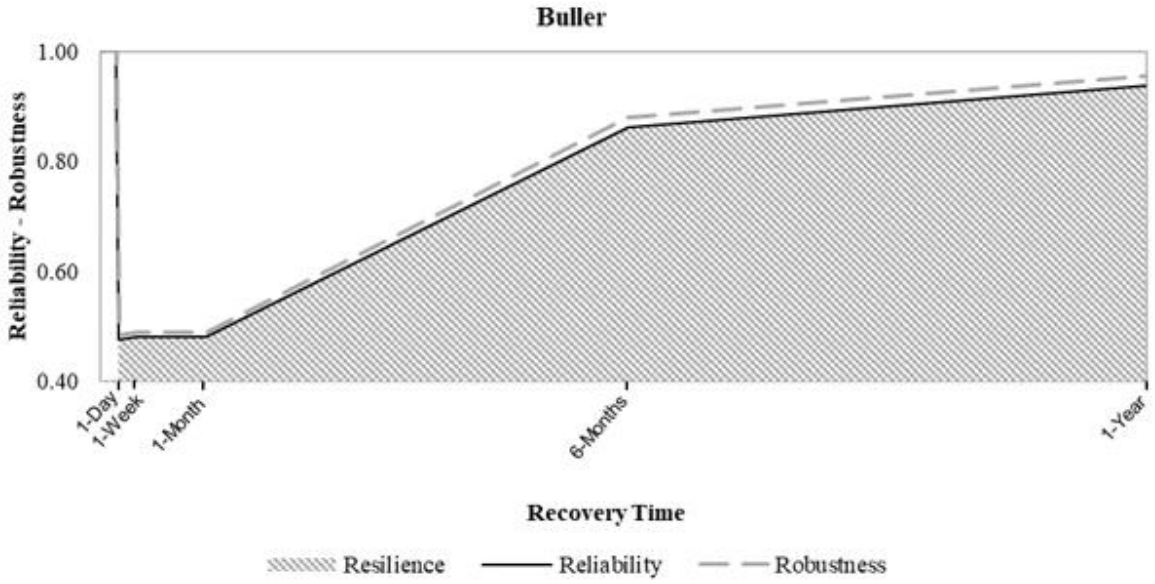


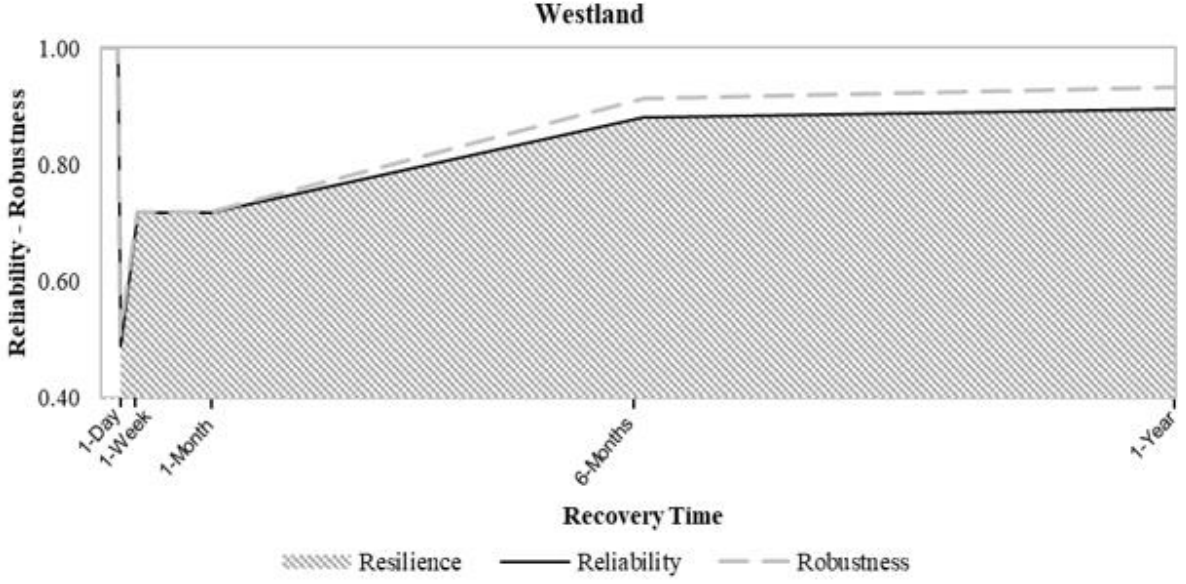


Aghababaei et al.

Post-Hazard Resilience Metrics

- Transport modelling-based resilience metrics
  - Eliminated trips (robustness) & increased travel time (redundancy)
- To support the increase of resilience in transport infrastructure,
  - Comparing recovery plans
  - Prioritisation of proposed resilience mitigation measures
  - Determine relative criticality of road links



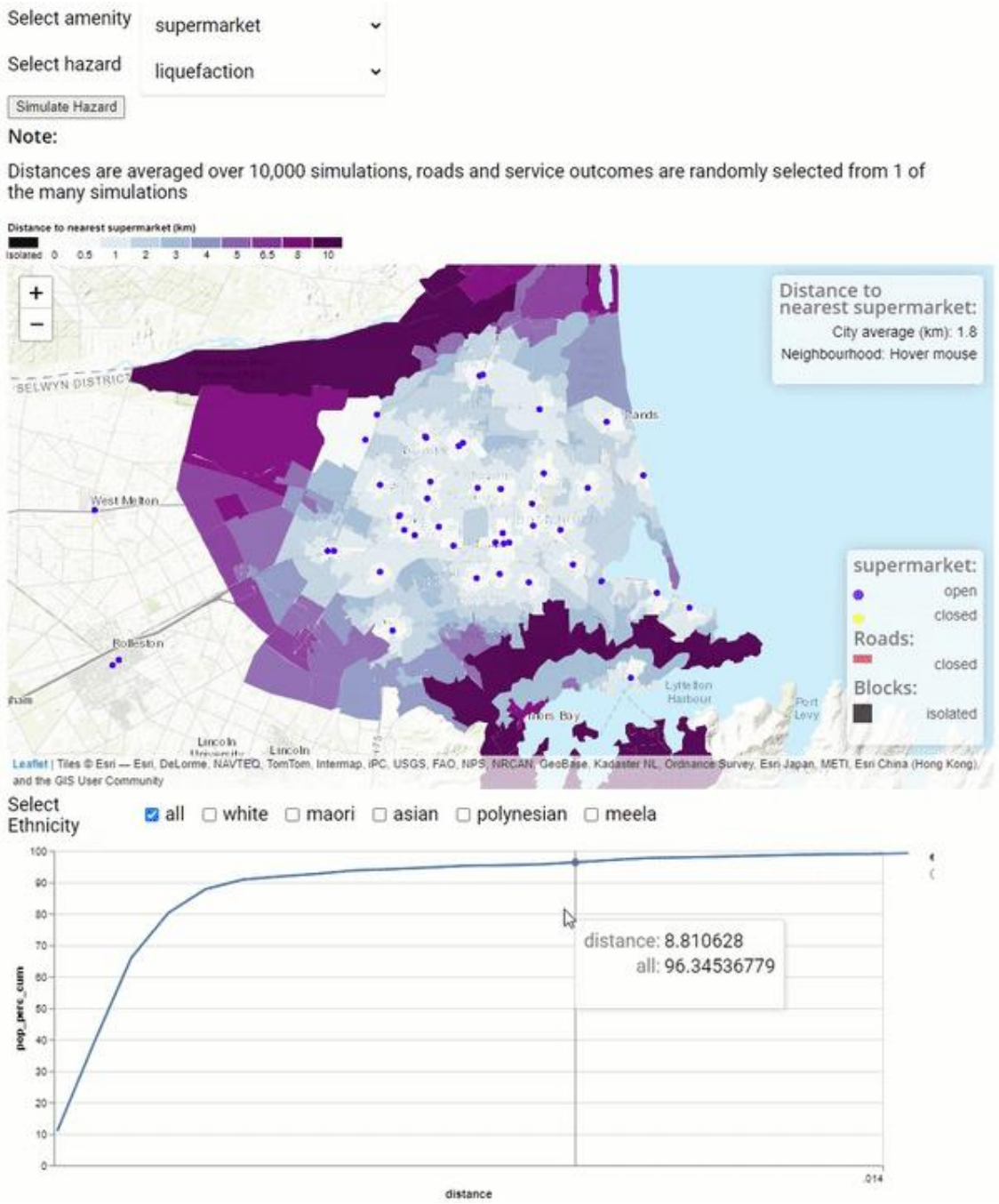


d)

Access to Essential Services

Logan et al.

- Network distance to any service (e.g., supermarket, healthcare…)
- Natural hazard scenario assessment
  - Road damage
  - Facility and dependent service failure
- Demographic group equity assessment



More information

Minimum Levels of Service

- Develop a framework to define and order emergency levels of service, that would allow interpretation by key stakeholders

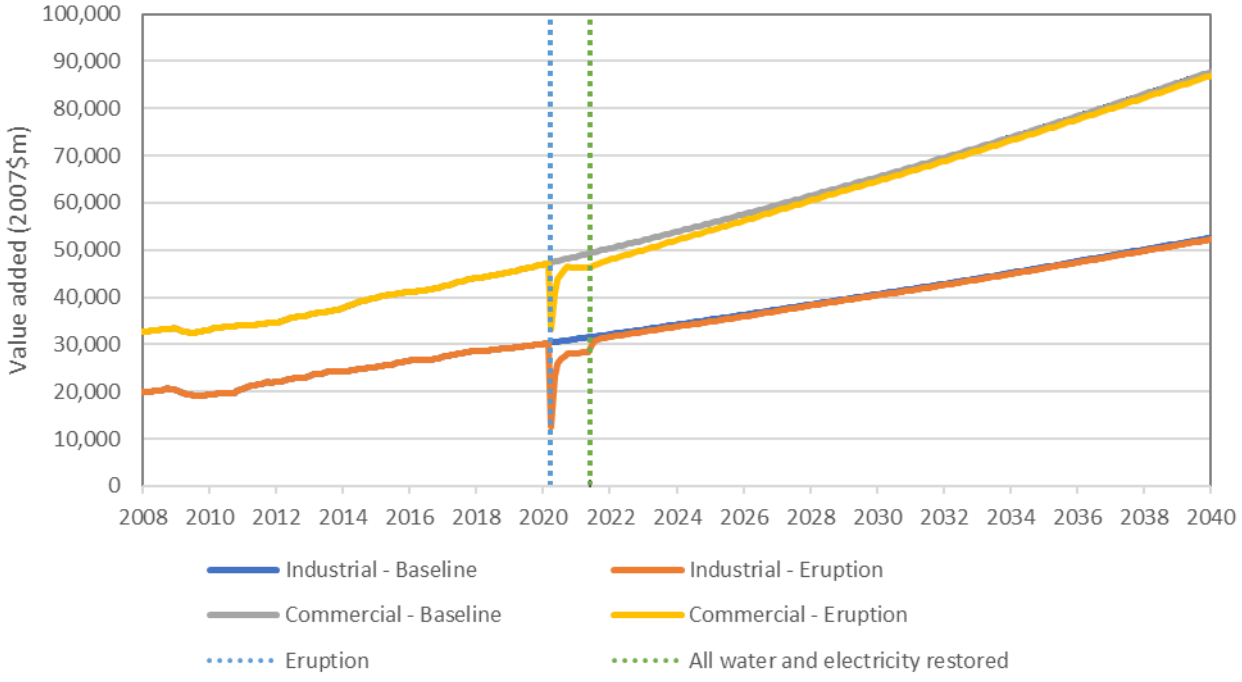
- What ‘emergency levels of service’ for each infrastructure sector could be defined

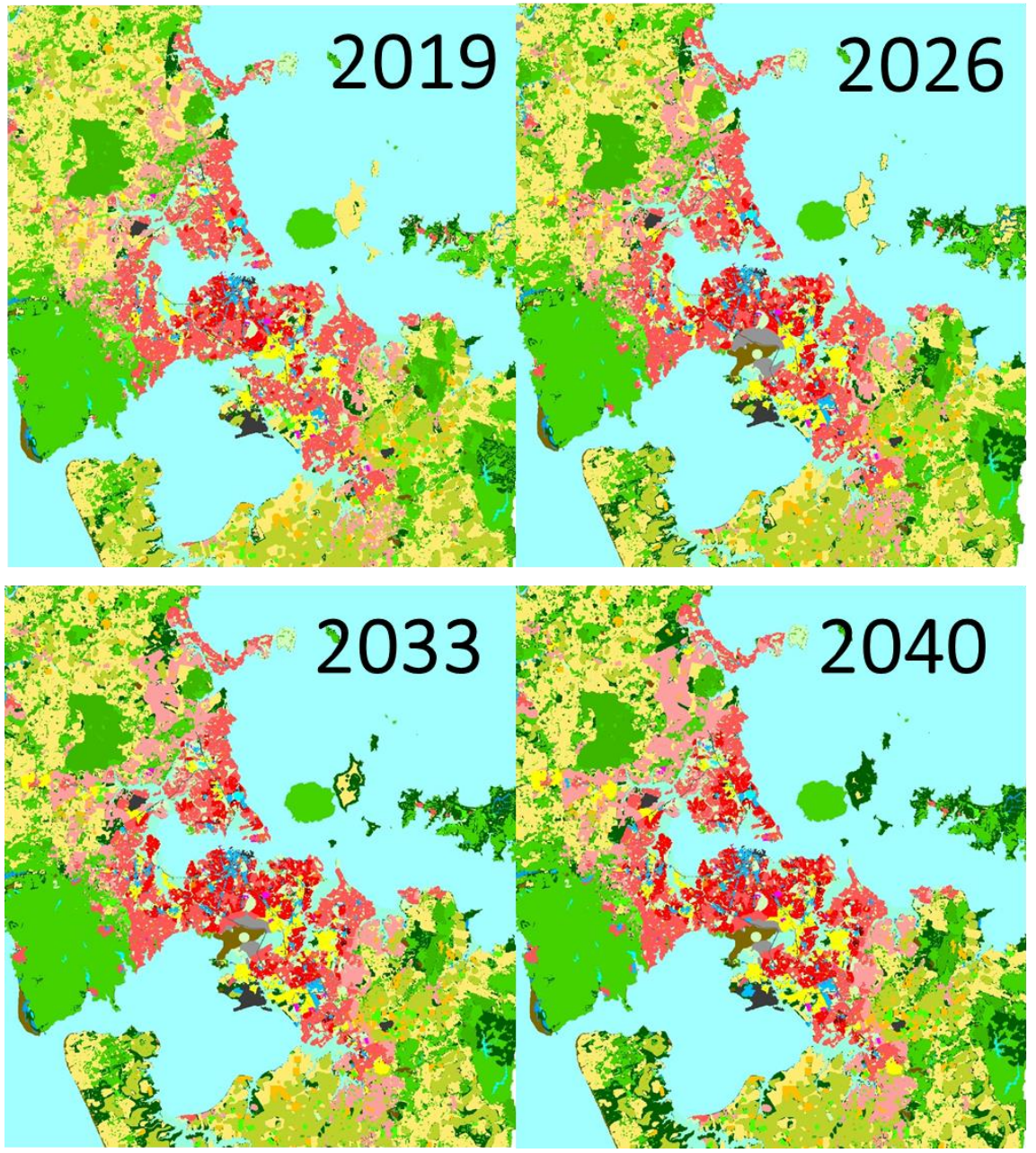
- Outputs are intended to inform:
  - Lifeline utilities of where there may be gaps in delivery
  - Emergency management – to inform planning
  - Community members – ‘what might I expect following a major event’

Cardwell et al.

Integrated Land Use/Economic Models

- Simulation of land use change and economic activity after volcanic eruption
- Future integration with improved and new infrastructure network models



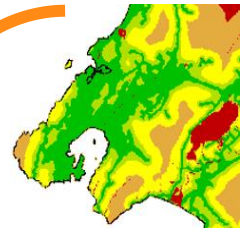


Economic Impacts (MERIT)

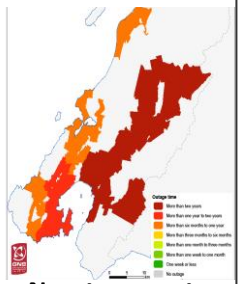
McDonald et al.

Event Occurs - Building and Infrastructure Damage

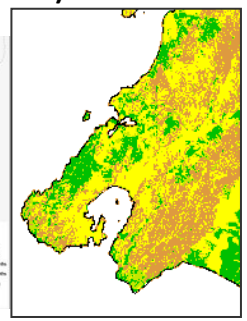
Direct Impact Maps (including interdependencies)



Transport – Fuel, Road, Rail, Water, Air, Ports

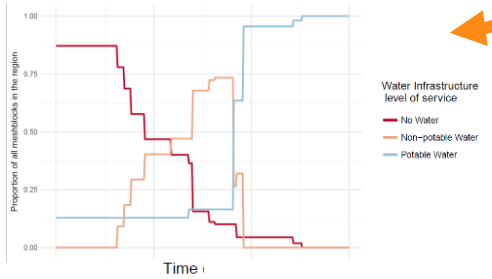


Non-transport Infrastructure



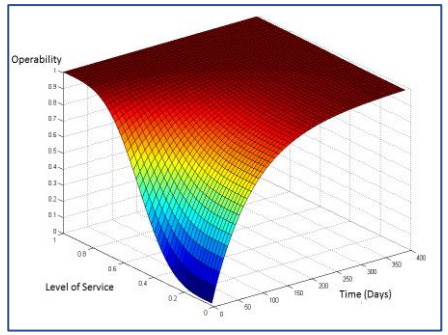
Buildings

Infrastructure Recovery through time

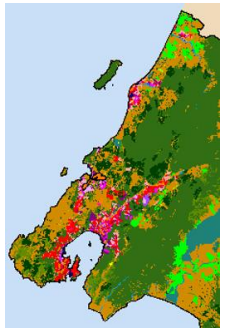


Direct Tourism impacts

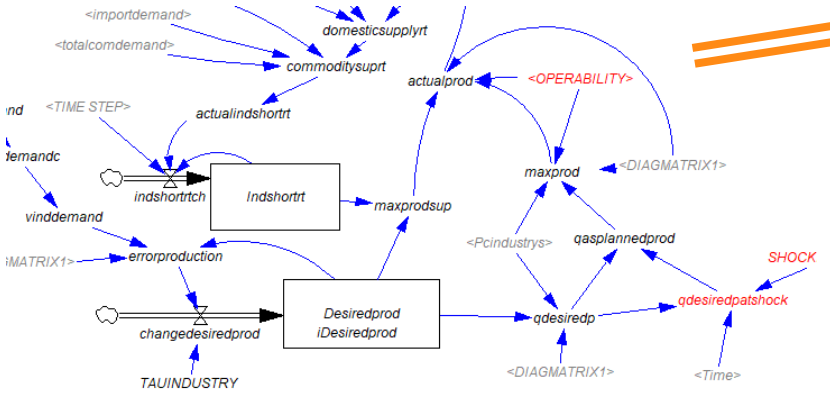
Business Operation



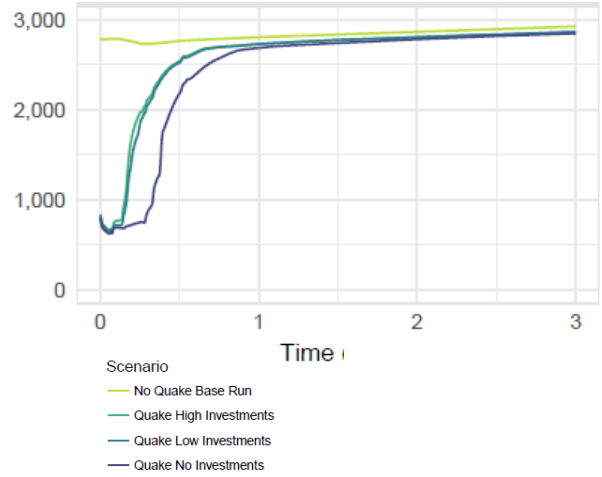
People & Business Relocation



Flow on Wider Economic Impacts using the Dynamic Economic Model



Results through time for Region, NZ – GRP, Income etc by industry



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Summary

- Broad range of research underway across the country
  - From hazard exposure through to decision making aspects
  - Improving specific areas with a view to incremental wider integration

- Good collaboration across the research environment
  - Working together to develop teams that will lead to the best outcomes
  - Improve efficiency of the engagement with industry

- Partnership with industry a key part to this success
  - Continued relationships with existing partners
  - **Any wider interest or engagement is welcomed so please reach out**

T

Questions?

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- Tom Wilson
  - thomas.wilson@canterbury.ac.nz

References

- **Research Programme Links:**
- Resilience to Natures Challenges National Science Challenge
- https://resiliencechallenge.nz/
- Te Hiranga Ru QuakeCoRE
- http://www.quakecore.nz/
- Increasing flood resilience across Aotearoa (Endeavour Programme)
- https://niwa.co.nz/natural-hazards/research-projects/m%C4%81-te-haumaru-%C5%8D-te-wai-increasing-flood-resilience-across-aotearoa-0
- Infrastructure Disruption from Coastal Flooding (Deep South National Science Challenge)
- https://deepsouthchallenge.co.nz/research-project/infrastructure-disruption-from-coastal-flooding/
- Transitioning Taranaki to a Volcanic Future
- https://www.volcanicfutures.co.nz/
- DEVORA: Determining Volcanic Risk in Auckland
- https://www.devora.org.nz/

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