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Future Direction For The Seismic Design Of Bridges In NZ

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NZ TRANSPORT AGENCY
WAKA KOTAHI

Te Kāwanatanga o Aotearoa
New Zealand Government

OUTLINE

- Introduction
- Bridge Design in NZ
- NZ Conditions & Challenges
- Next Steps & Future Direction
- Conclusions

INTRODUCTION
NZTA

NZ Transport Agency

- SH: Approx. 11,000km
  - Local roads: 83,000km
- SH: Approx. 5,000 SH bridges
  - Approx. 15,000 local road bridges
  - Approx. 1,700 KiwiRail bridges

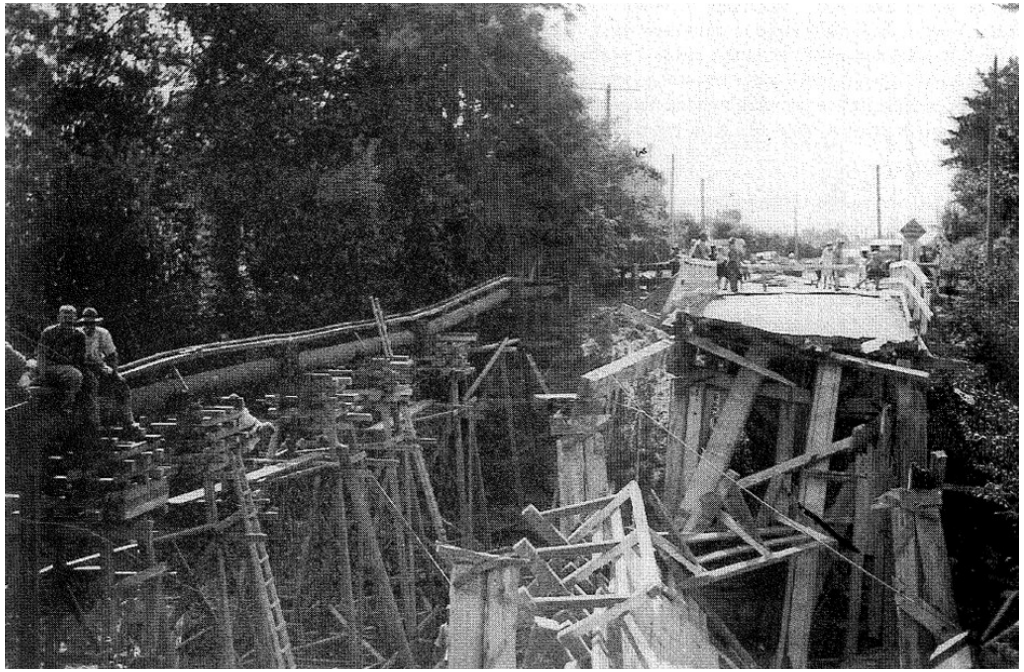
NZ BRIDGE DESIGN
History

1931 Hawke's Bay Earthquake

- M_w7.8, 2.5mins, 525 aftershocks
- 256 casualties, extensive damage to bridges & buildings
- Coastal areas around Napier lifted by around two metres. "uplifting of some 40km^2 (10,000acres) of sea-bed to become dry land."
- General Earthquake Building By-Law

*Photos courtesy of Alexander Turnbull library

NZ BRIDGE DESIGN
History

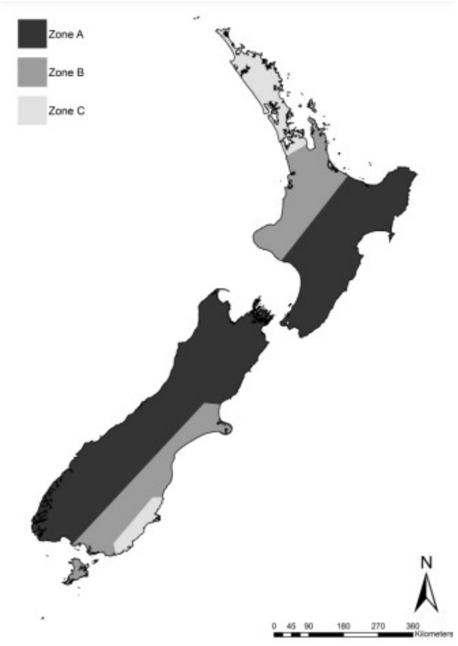


*Photos courtesy of the New Zealand Herald

NZ BRIDGE DESIGN History

Evolution of Seismic Design

- NZ Standard Model Building By-Law of 1935:
  - 0.08g - 0.1g, max of 0.15g
- NZ Loadings Code of 1965:
  - Seismic zones, ductility introduced
- 1972 Highway Bridge Design Brief:
  - “Importance factor” introduced in 1972 based on traffic volumes
  - Seismic design of earth retaining structures & piles
- 1987 Highway Bridge Design Brief:
  - Three different levels of loading (SLS, DCLS, CALS) with associated performance criteria



NZTA Bridge Manual
(3rd Edition, Amendment 4)

- For use in design of SH bridges but…
  - … is used for almost all bridges in NZ, as well as some non-bridge structures!
  - … is used for a design of soil structures as well.
- Refers to a number of national and international standards:
  - NZS3101, NZS3404, AS/NZS1170, etc
  - AS5100
  - AASHTO
  - British Standards & EuroCode
- **Seismic design almost completely standalone and independent of other NZ Standards**

Seismic Design – Key Features

- Probabilistic seismic hazard.
- 3 design levels ("Limit States"):
  - SLS: "No damage to primary structural elements"
  - DCLS: "Damage may be significant, but repairable" (=ULS)
  - CALS: "Extensive damage, collapse prevents" (=MCE)

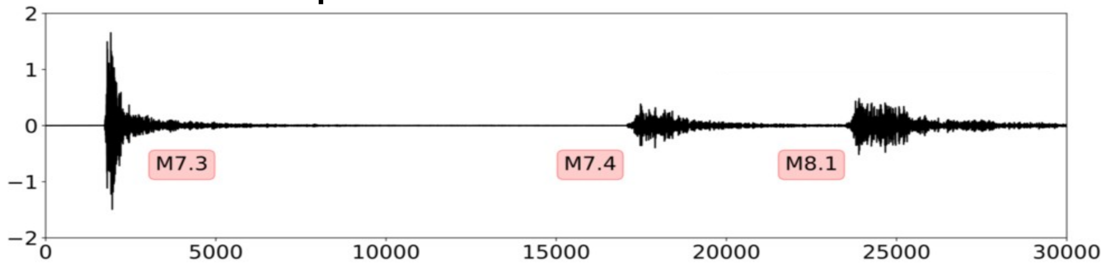
Primarily based on traffic volumes

Importance Level	SLS	DCLS	CALS
IL4	1/250	1/2500	Not checked
IL3+	1/150	1/1500	Lesser of: 1.5xDCLS or 1/2500
IL3	1/100	1/1000	Lesser of: 1.5xDCLS or 1/2500
IL2	1/80	1/500	Lesser of: 1.5xDCLS or 1/2500
IL1	1/50	1/250	Not checked

NZ BRIDGE DESIGN
Current Practice

Multiple events

- Two consecutive DCLS events, checked for CALS performance
- To allow for significant aftershocks

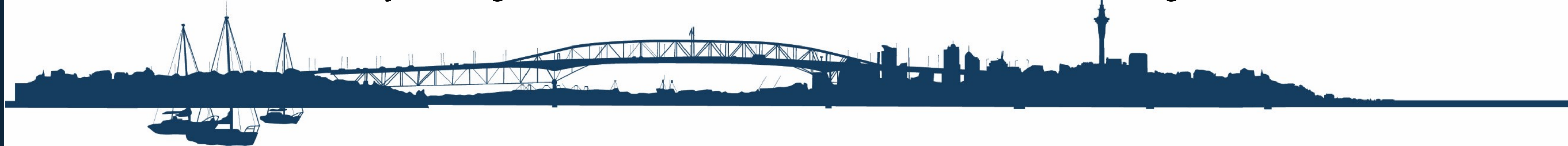


Kinematic effects

- Three design scenarios:
  - i) Full inertia and ground movements preceding liquefaction
  - ii) 80% of inertia (based on liquefied response) plus 100% of liquefaction-induced cyclic kinematic effects and other ground movements
  - iii) Full lateral spreading plus PH forces or 25% of intertia

Spatial variation in ground motion

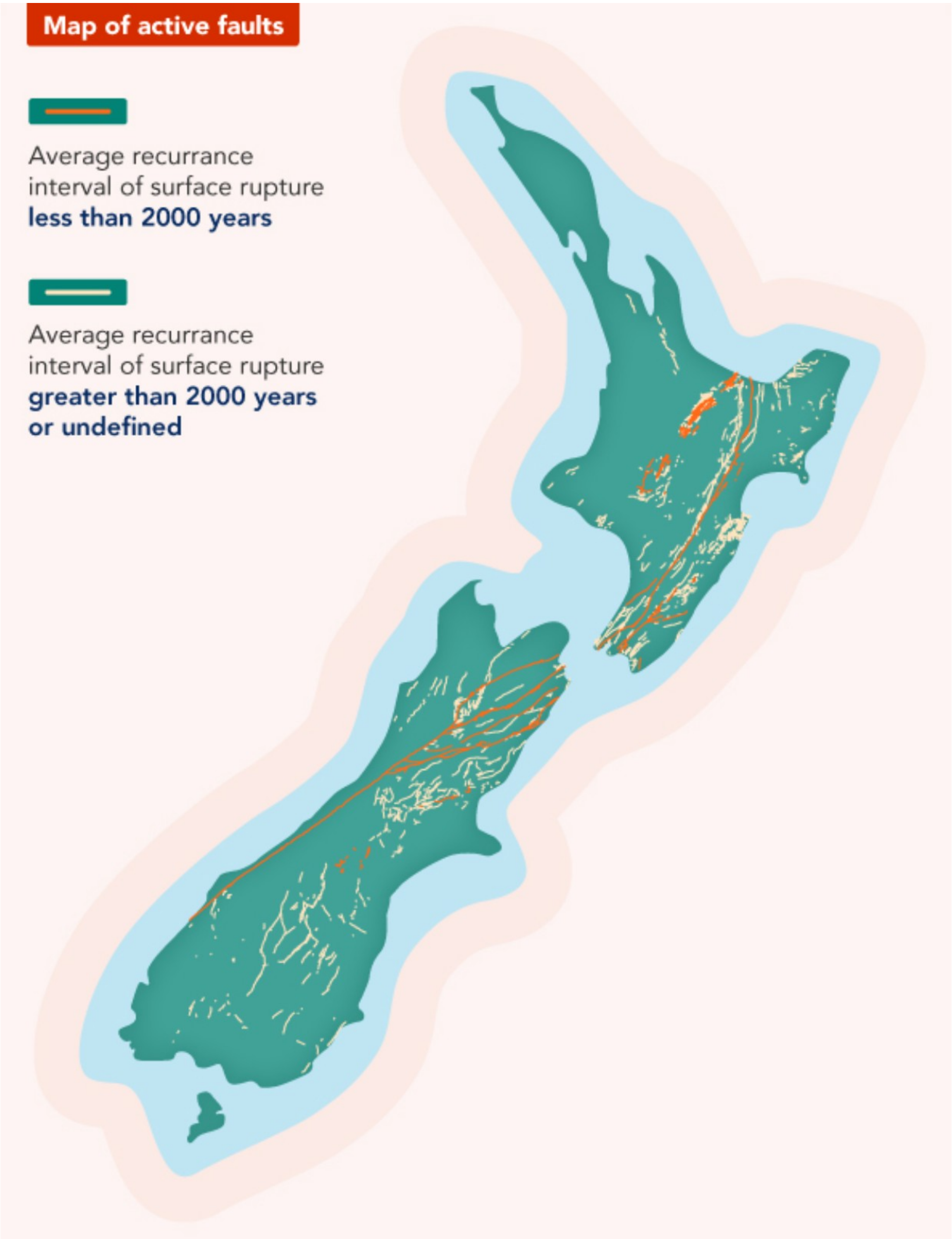
- “*For bridges longer than 200m in length the effects of spatially varying ground motion may be significant and should be considered in design.*”

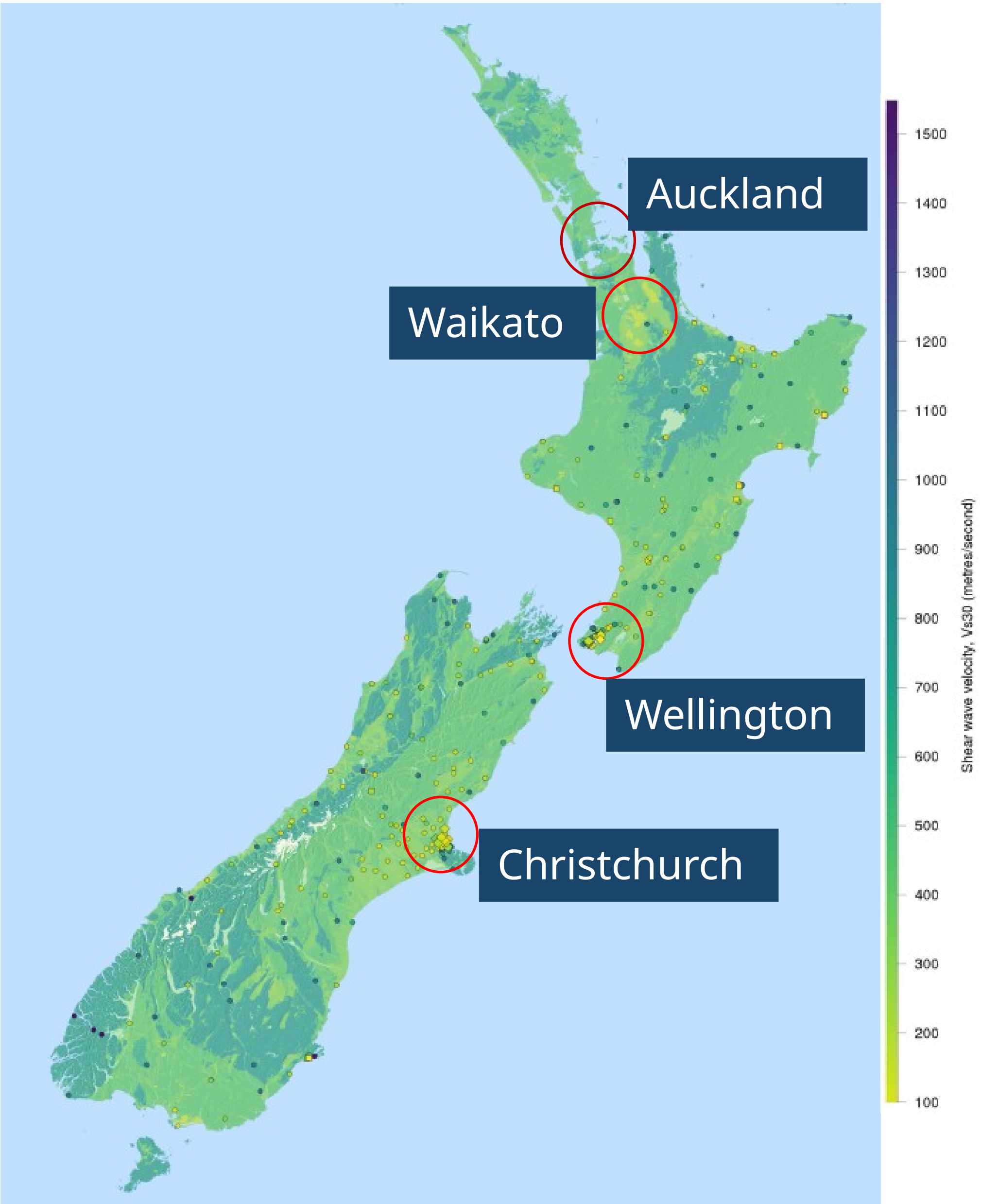


NZ CONDITIONS
Geography

NZ CONDITIONS
Geography

NZ CONDITIONS
Hazards





NZ CONDITIONS
Hazards

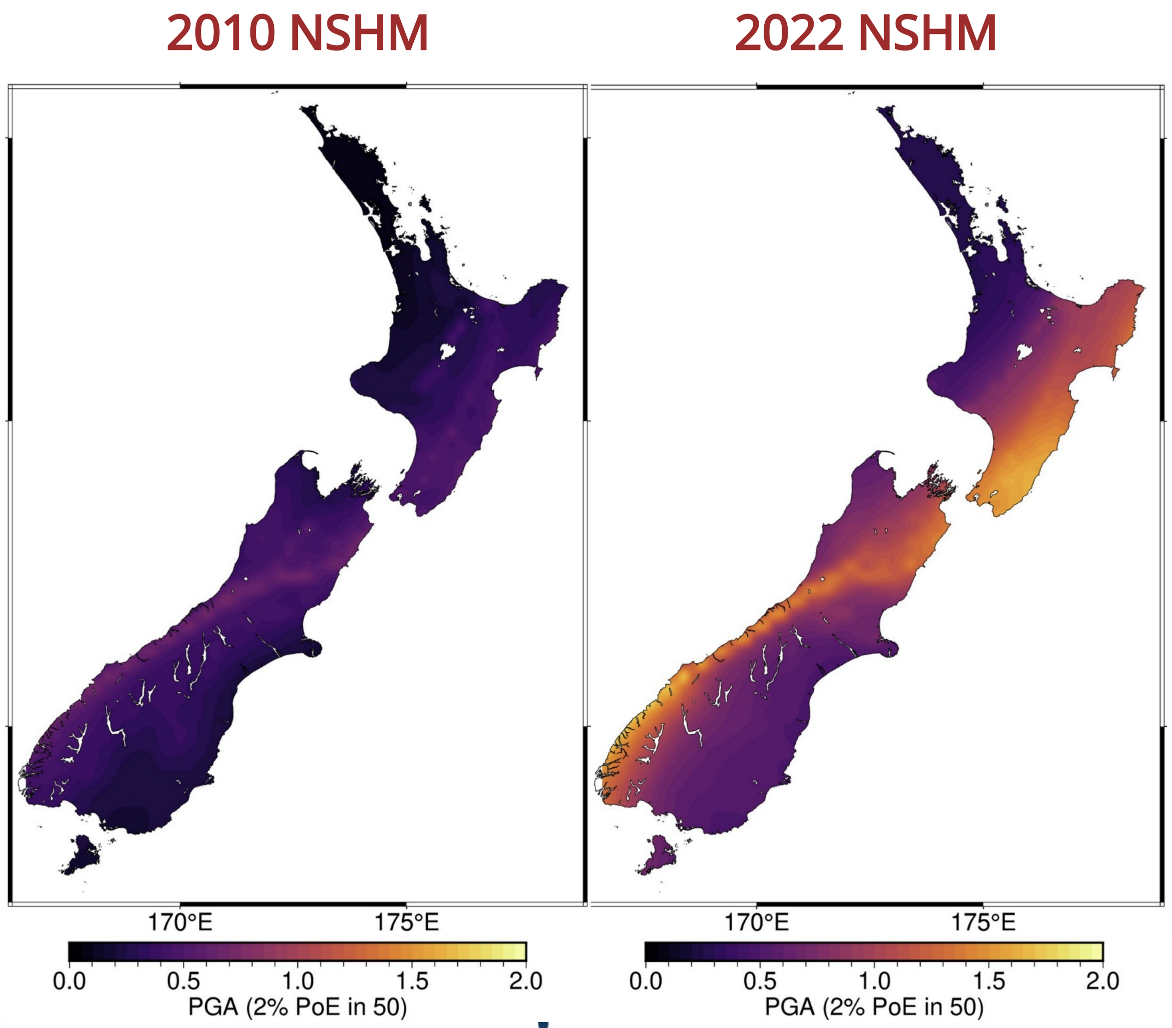
NZ Highway Geohazards

- Approx. 6000 geohazard sites identified on the NZ state highway network

NZ CONDITIONS
Hazards

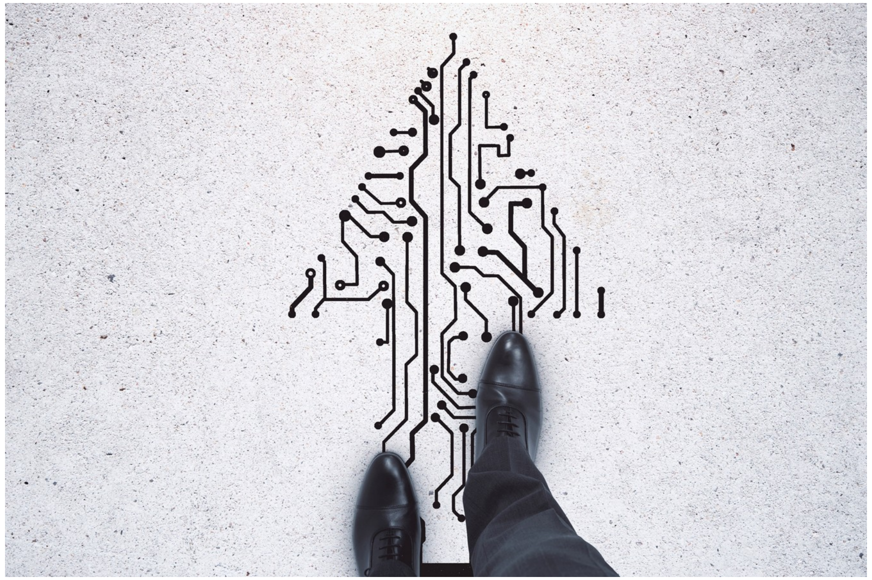
Evolving understanding of hazard

- Previous National Seismic Hazard Model published early 2000's, minor update in 2010
- New National Seismic Hazard Model released in 2022
- Significant increase in hazard across a lot of NZ



FUTURE DIRECTION
Where to?

How do we tackle these challenges?



FUTURE DIRECTION
4Rs

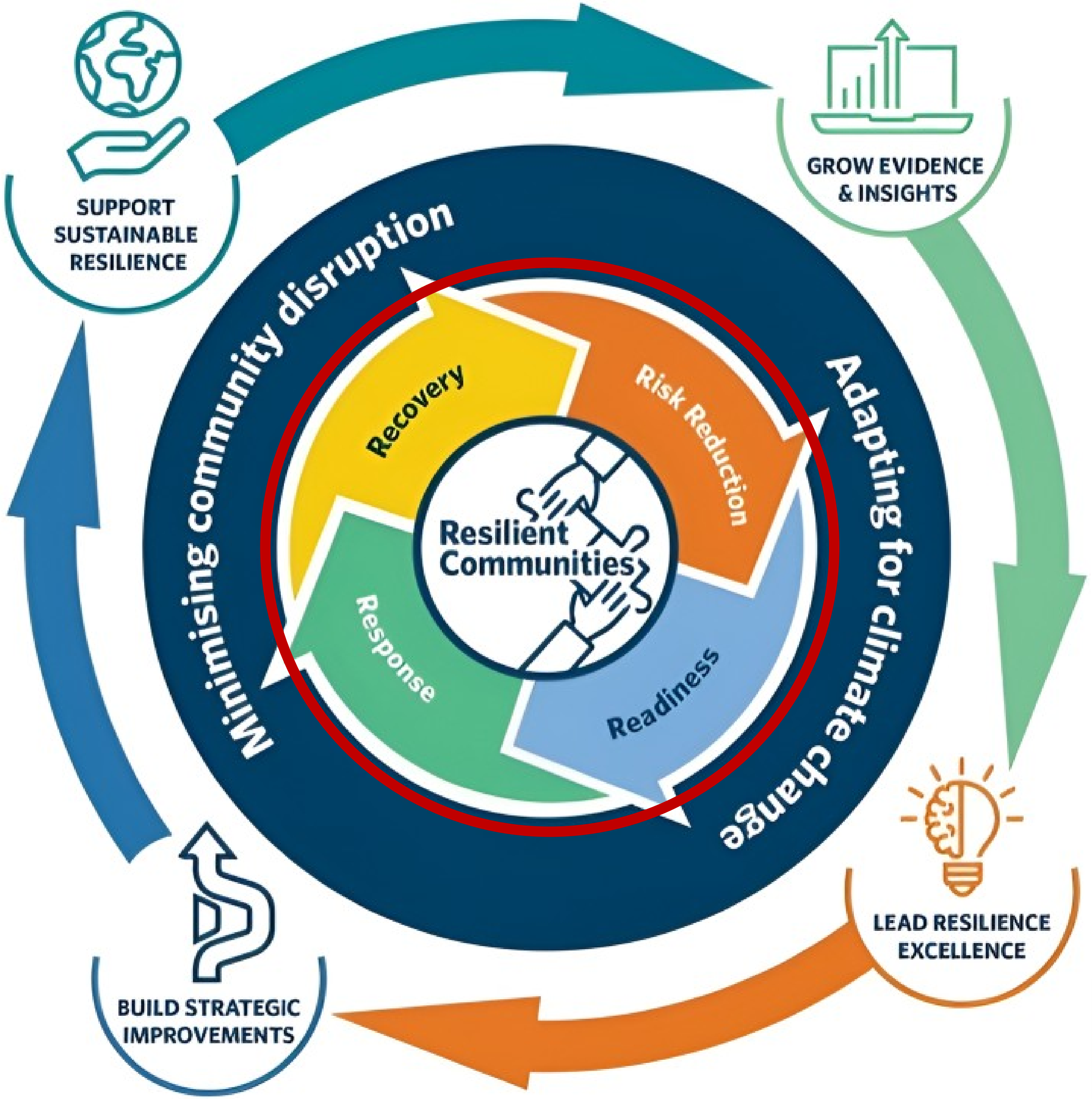
The 4Rs of Resilience

Risk Reduction

Readiness

Response

Recovery



RISK REDUCTION
Seismic Screening

Seismic Screening Programme

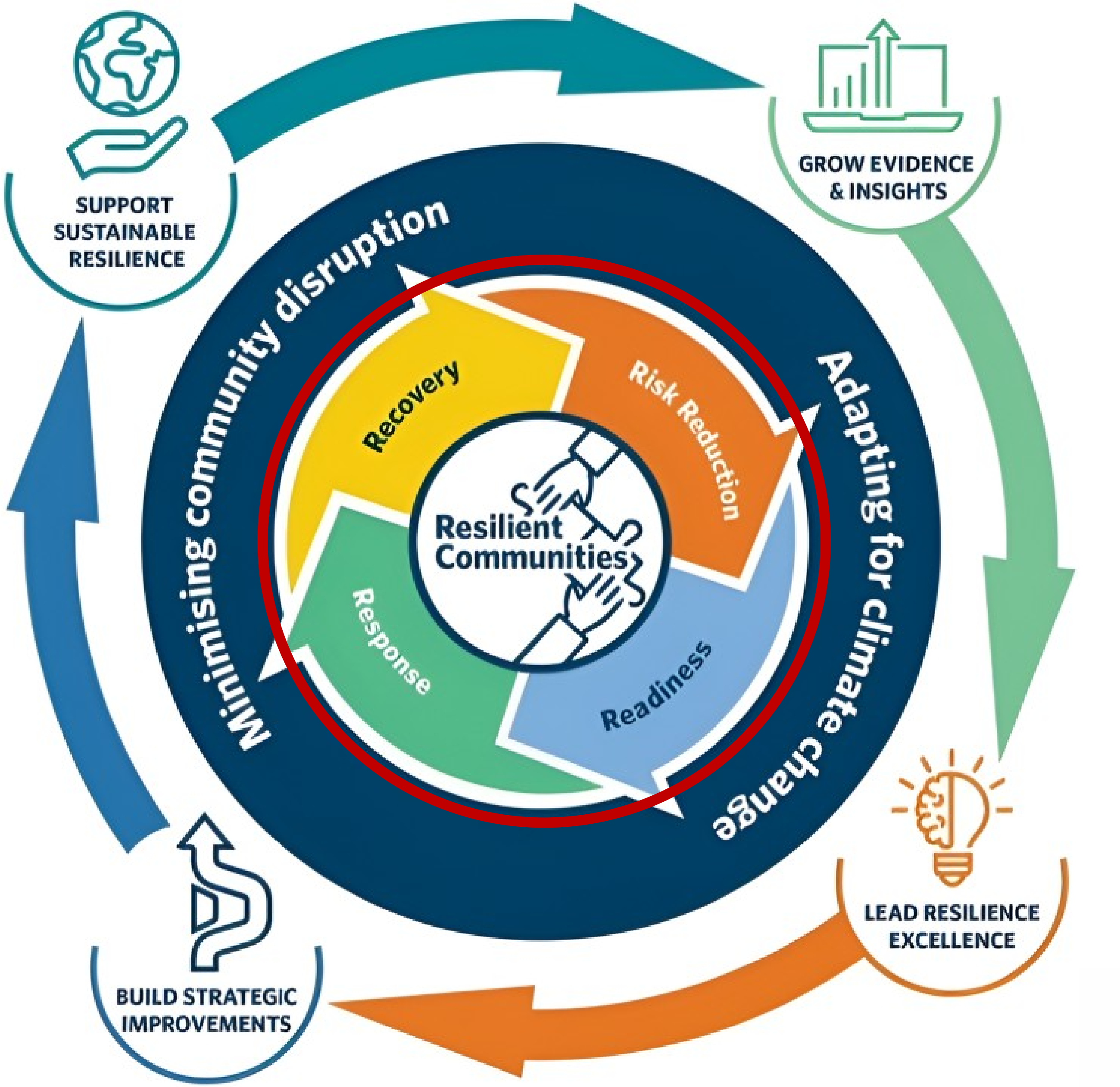
- Screening of existing SH bridges in 1990’s & early 2000’s
- Seismic assessment of bridges with significant risk
- Retrofit programme:
    - Strengthening (FRP wrapping, steel jacketing)
    - Linkage bars & shear keys

FUTURE DIRECTION
4Rs

The 4Rs of Resilience

Risk Reduction:

- At a corridor & network level, not just individual assets
- Targeted investment to optimise network resilience

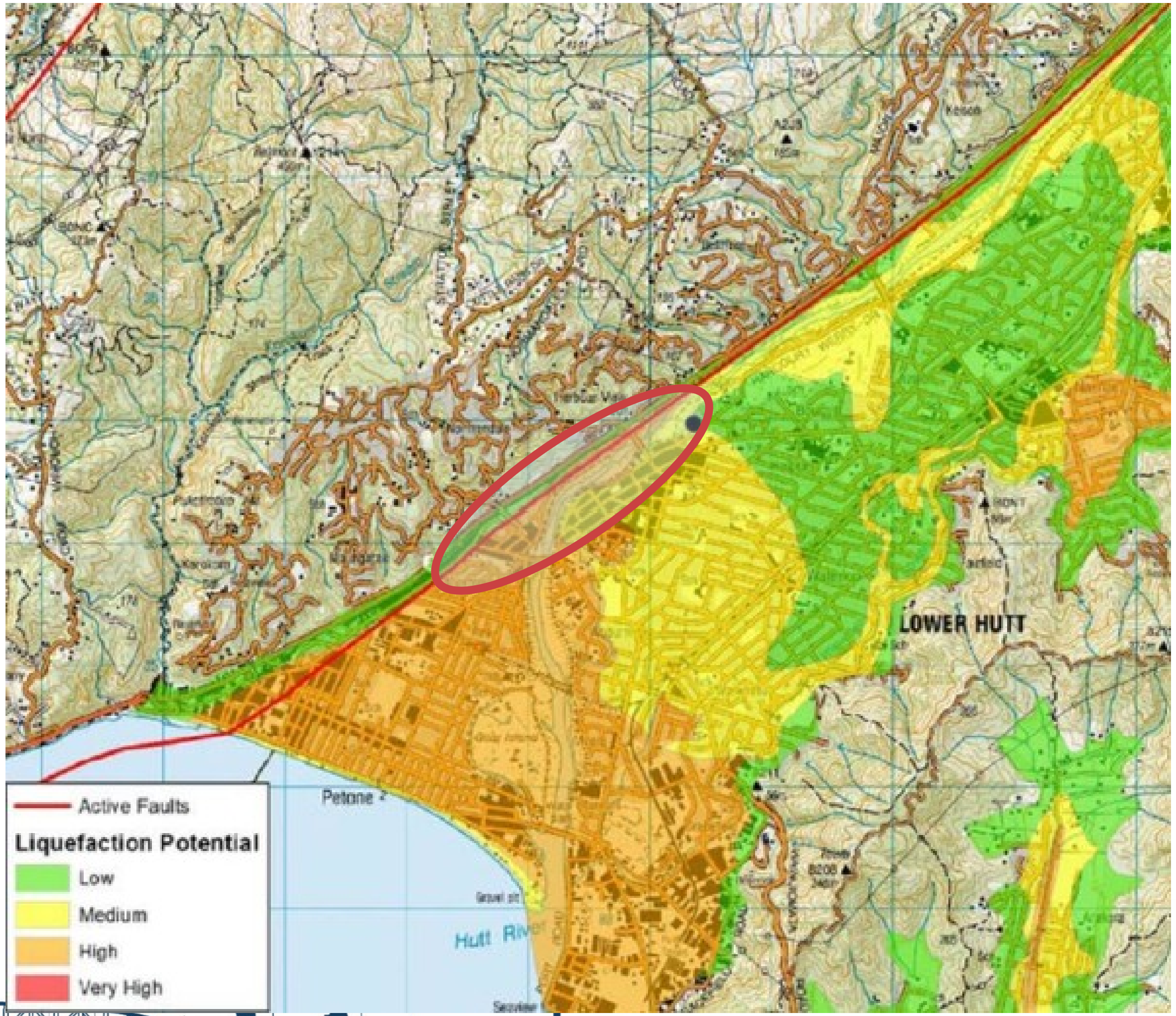


FUTURE DIRECTION
4Rs – an example

Risk Reduction – an example

New project:

- High seismicity: >2g (@ APoE of 1/1000)
- Soft soils: $V_{s,30} \leq 300$m/s
- Active fault: movements of 8-10m horizontal, ~5m vertical
- Adjacent to large, unstable slope
- Large areas of liquefiable soils



FUTURE DIRECTION
4Rs – an example

Risk Reduction – an example

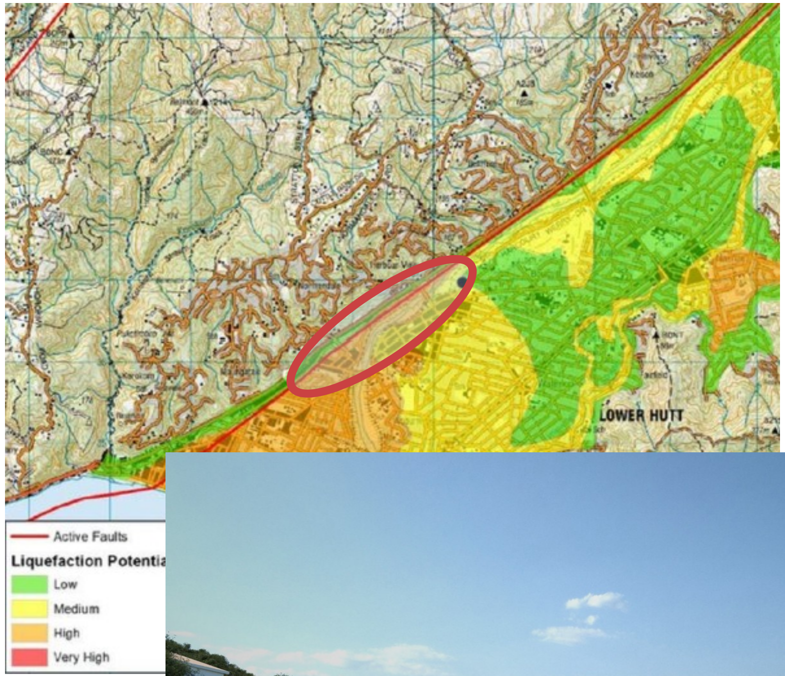
New project:

Re-direct investment from:

- ground improvements

…to…

- stabilising adjacent slopes

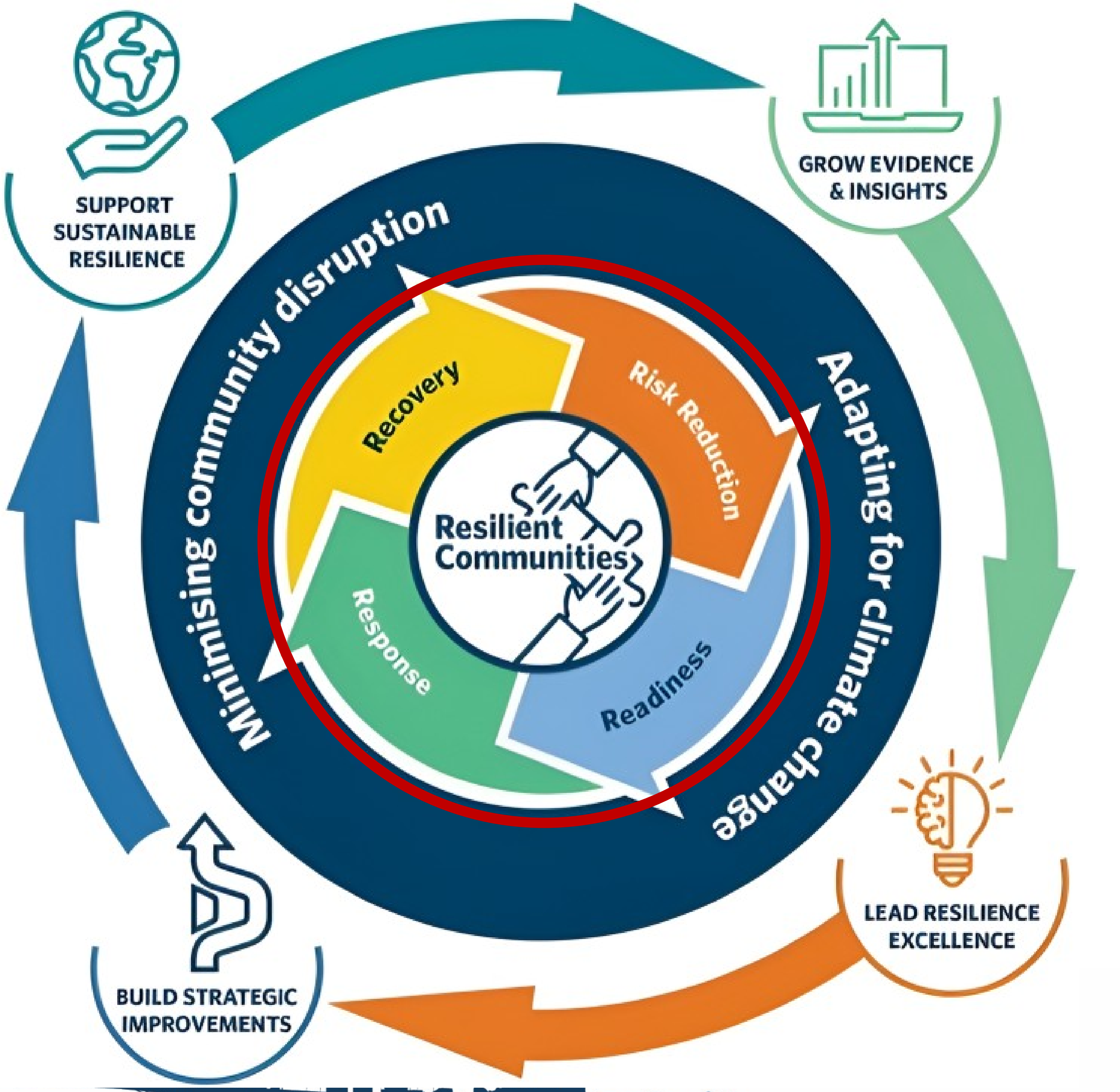


FUTURE DIRECTION
4Rs

The 4Rs of Resilience

Readiness:

- Plan ahead
- Put in good systems



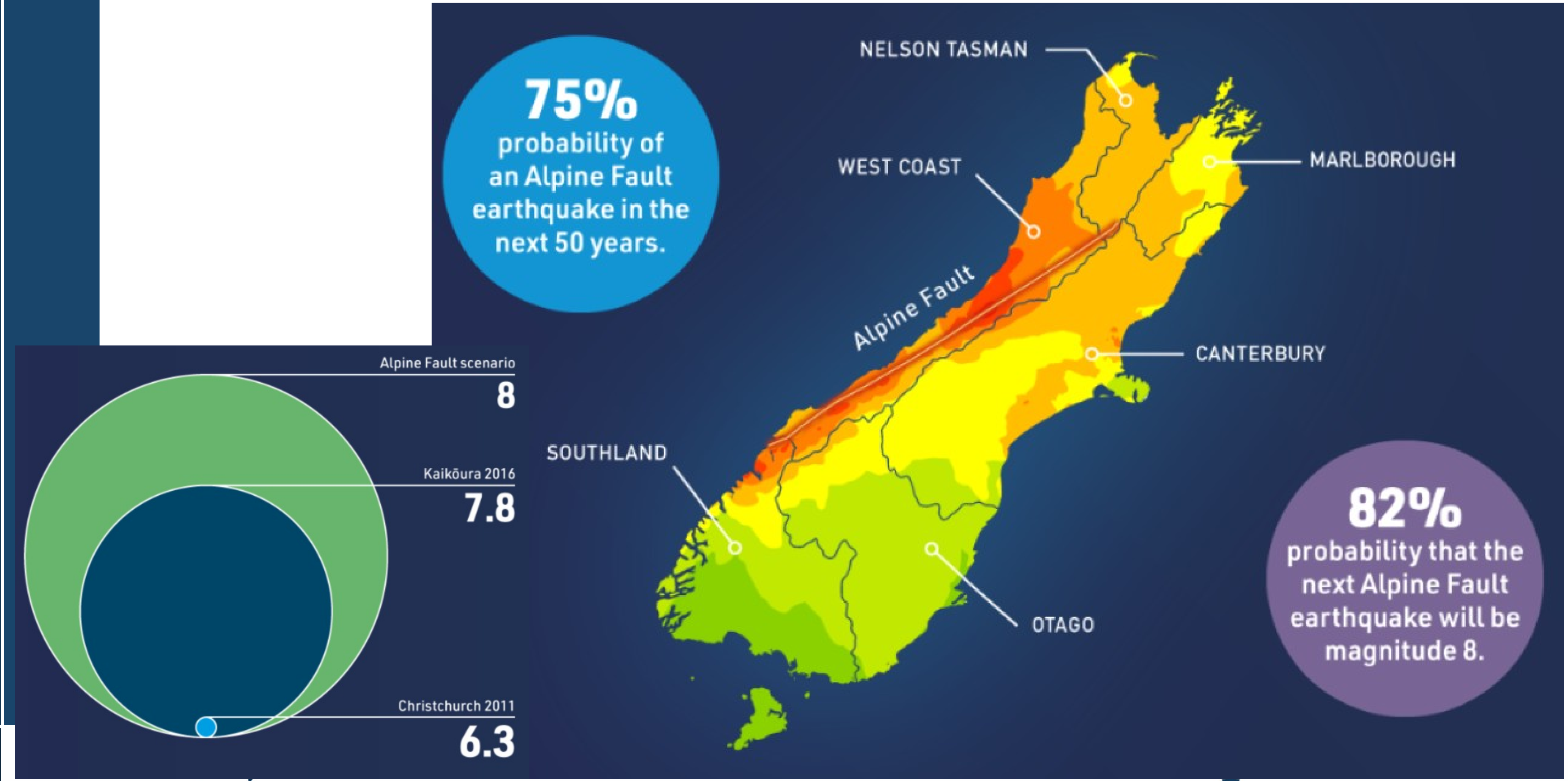
Readiness – an example

Readiness:

- Plan ahead.
- An example: AF8

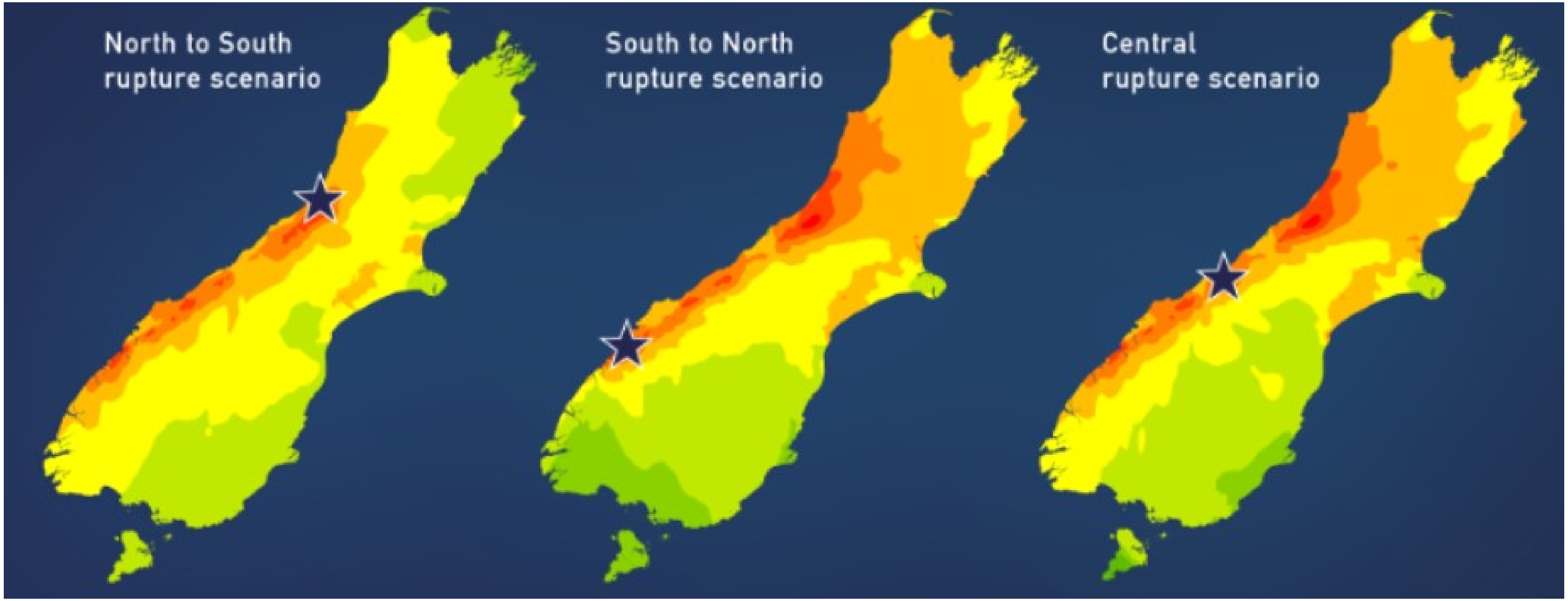
FUTURE DIRECTION
4Rs – an example

Scenario Planning – AF8



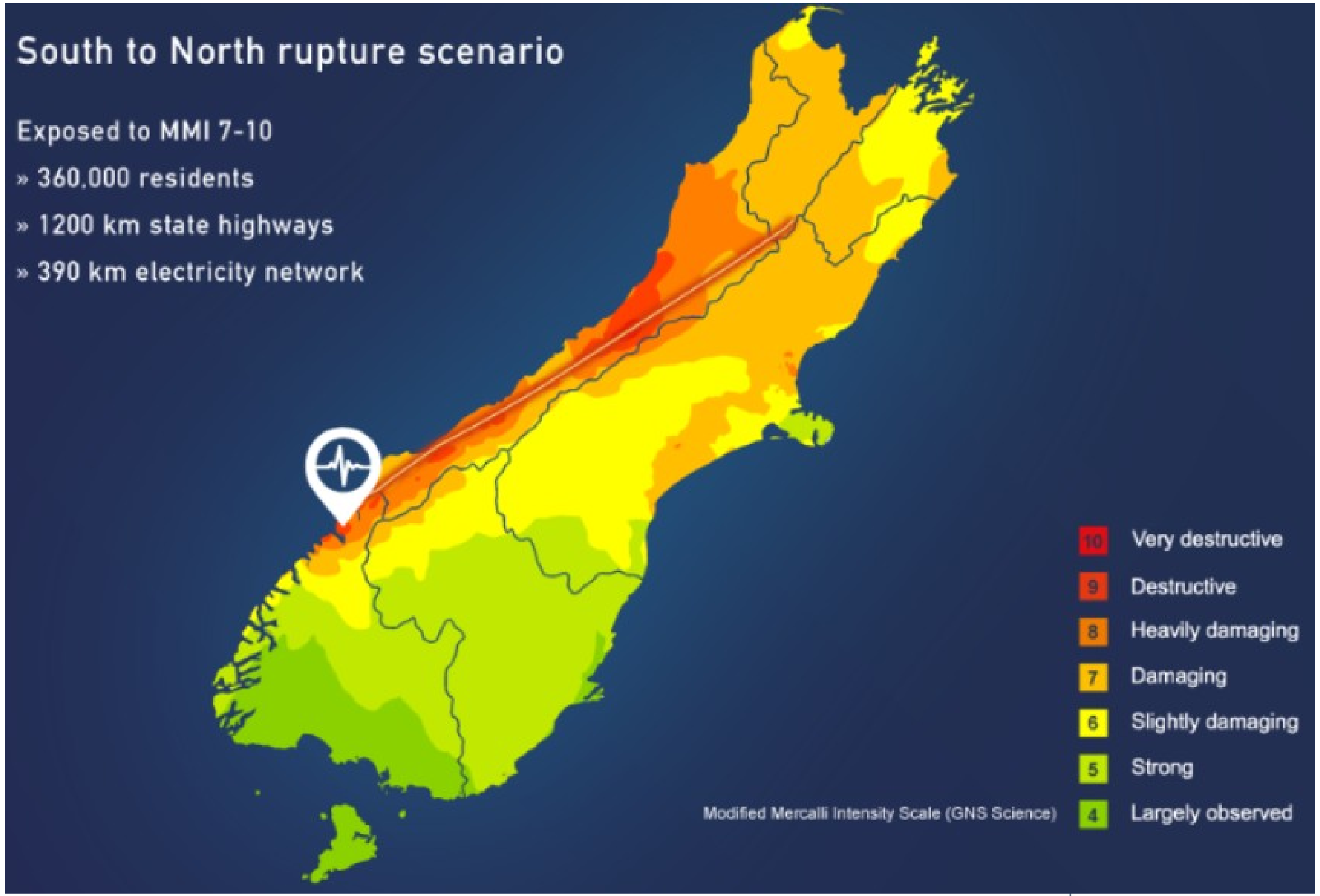
FUTURE DIRECTION
4Rs – an example

Scenario Planning – AF8



FUTURE DIRECTION
4Rs – an example

Scenario Planning – AF8

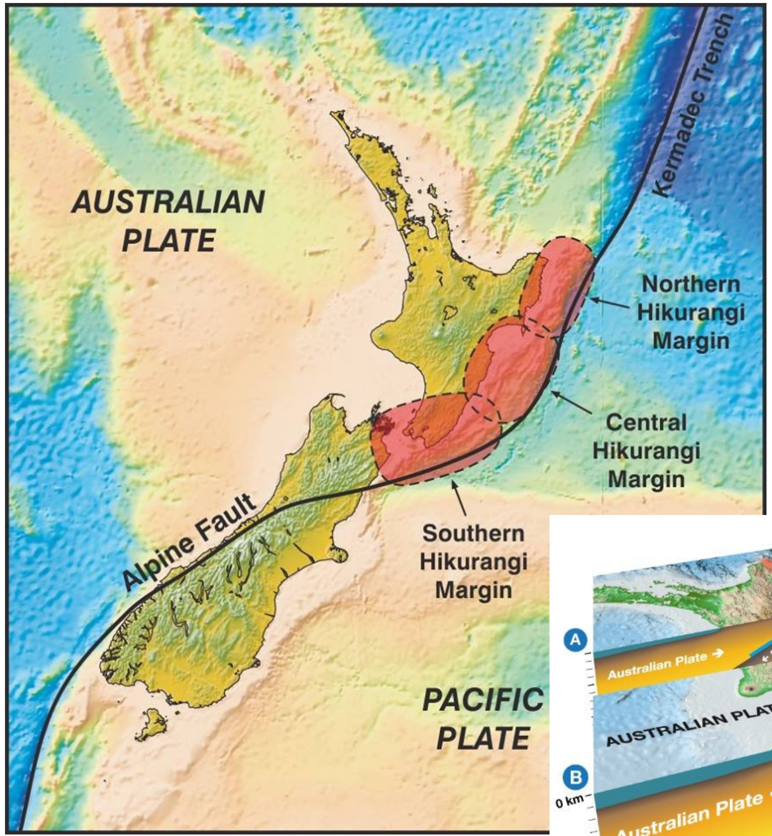


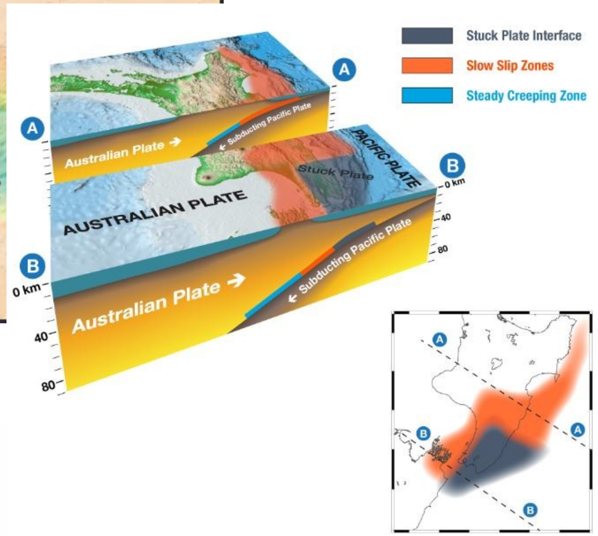
FUTURE DIRECTION

4Rs – an example

Scenario Planning – Hikurangi Subduction Zone

- 25% probability in next 50 years
- Capable of M9+
- Tsunami event likely





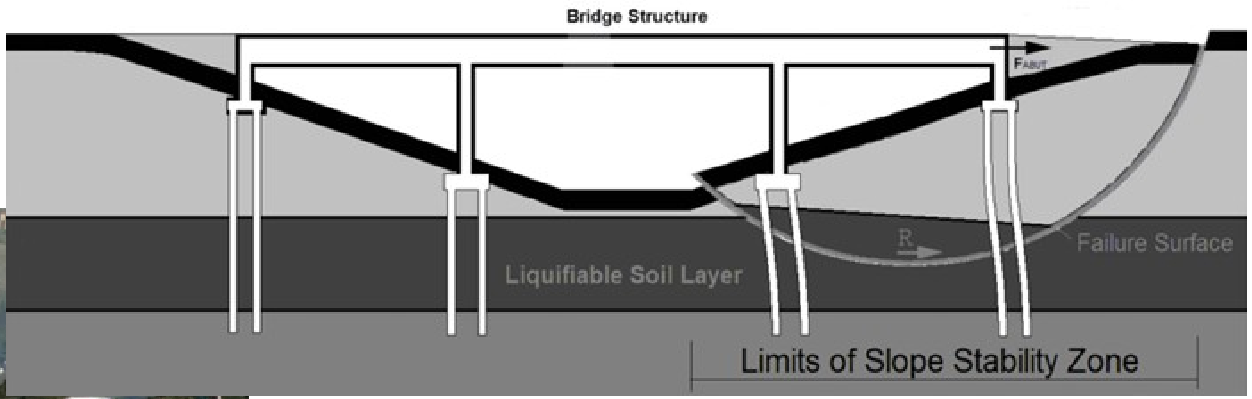
FUTURE DIRECTION

Next Steps

Where to next?

Evolve design framework to:

- Better address consequence.
  Not all “damage” is equal – can we accept increased soil movements without compromising (life) safety of bridge?



FUTURE DIRECTION
Next Steps

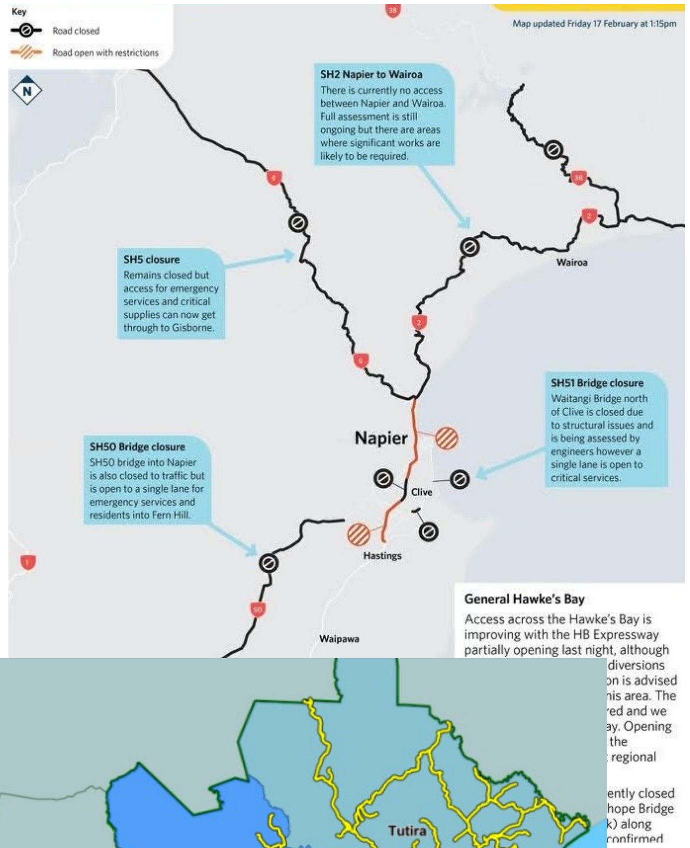
Where to next?

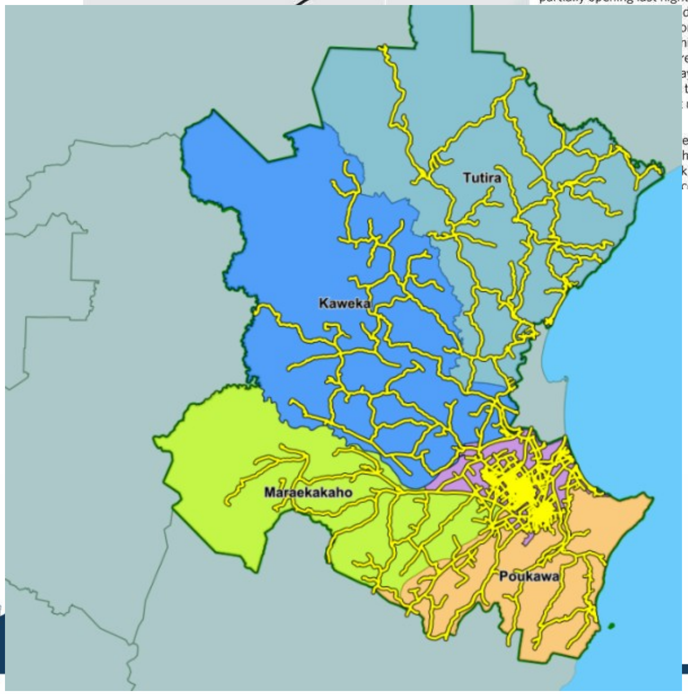
Evolve design framework to:

- Better address role of bridge in the network.

  Is there redundancy in the surrounding network? Or will loss of function lead to disconnecting a whole community or region?

  Is the bridge key for emergency response routes (to hospitals, airports & ports, etc) post-event?





FUTURE DIRECTION

Next Steps

Where to next?

Evolve design framework to:

- Consider the other functions of the bridge in response & recovery

  Most bridges carry more than just traffic – power, comms, water, etc.

  Does performance of bridge allow for these critical utilities for post-event response?

FUTURE DIRECTION
Next Steps

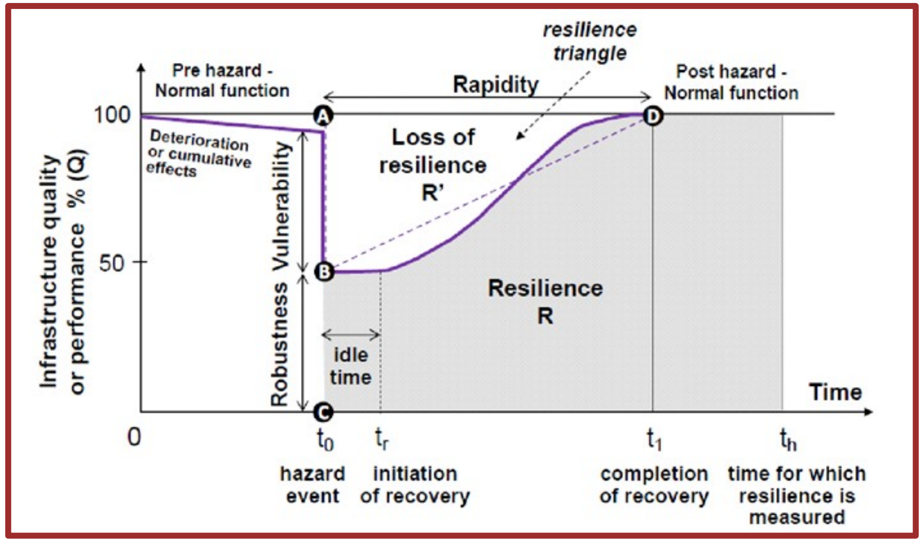
Where to next?

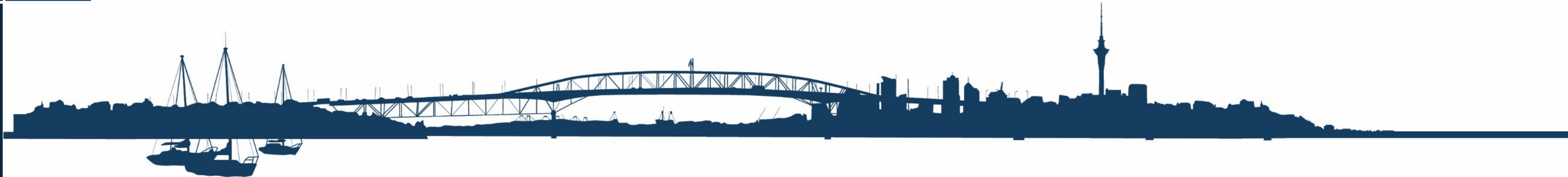
Evolve design framework to:

- Enable more uptake of low-damage and innovative solutions

  Does current design philosophy & requirements enable the use of innovative solutions?
  Does it allow them to be used 'economically'?

  Do the current Limit States and performance criteria make sense for 'non-traditional' solutions?

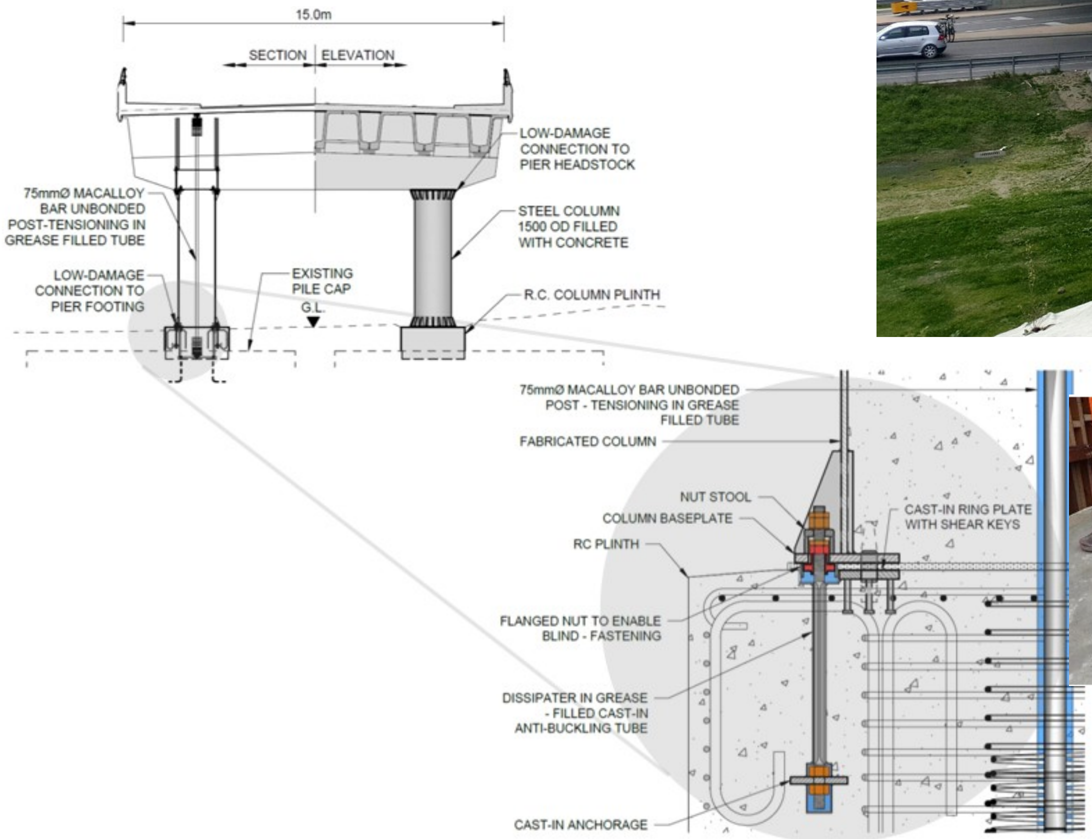




FUTURE DIRECTION
Next Steps

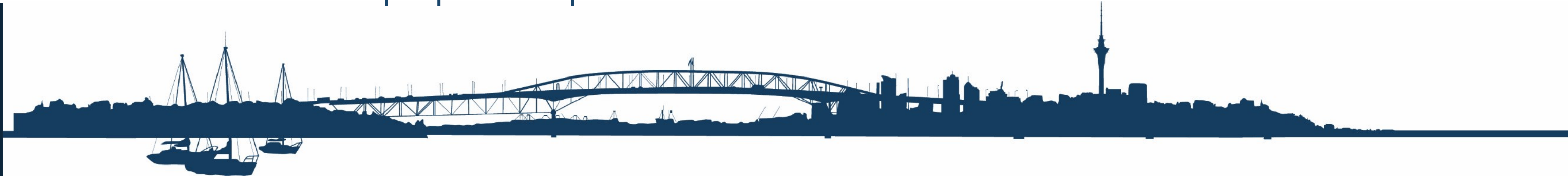
Wigram-Magdala Bridge

- PT rocking pier with dissipative connections



Conclusions

- Current seismic design framework has served us well, but…
- …it is time for an evolution for NZ seismic design.
- We need to consider the 4Rs of Resilience to better deliver a resilient transport network, not just stronger bridges.
- To enable that, our design framework needs to more directly consider:
    - Consequence
    - Corridor & network performance
    - Performance & response beyond transport, and
    - Fit-for-purpose requirements to enable non-traditional solutions



THANK YOU FOR YOUR TIME