HISTORIC PERFORMANCE AND SEISMIC EXPOSURE OF NEW ZEALAND STATE HIGHWAYS

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BACKGROUND

Recent earthquakes in New Zealand have demonstrated the significant impact that they can have on national infrastructure networks. The State Highway network is exposed to seismic and co-seismic hazards from a number of sources across the country, and an improved understanding of the potential network performance is a key part of the wider understanding of national seismic resilience. The research focuses on two areas:

1. Assessment of the historic seismic performance of state highway bridges in New Zealand. To assess the performance, case history database and comparison of the peak ground acceleration of the bridges with the peak ground acceleration from seismic screening was performed.

2. Analysis of the exposure of New Zealand state highways to earthquake-induced liquefaction and landslides. Using the geospatial model of Zhu et al. (2017) and Jessee et al. (2018), national-scale susceptibility maps have been developed and applied to the state highway network. The output will help to identify areas of potential exposure and to estimate the extent of exposure for future earthquake events.

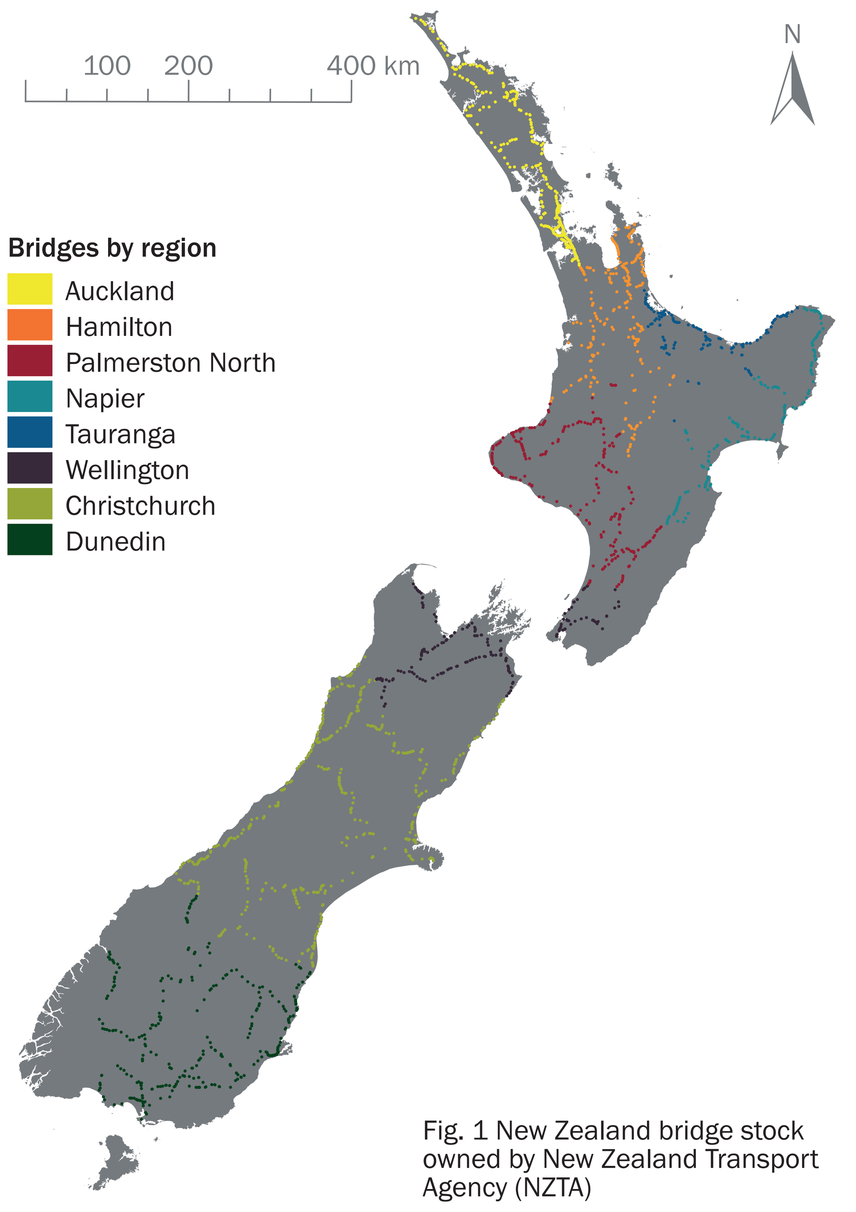

Fig. 1 New Zealand bridge stock owned by New Zealand Transport Agency (NZTA)

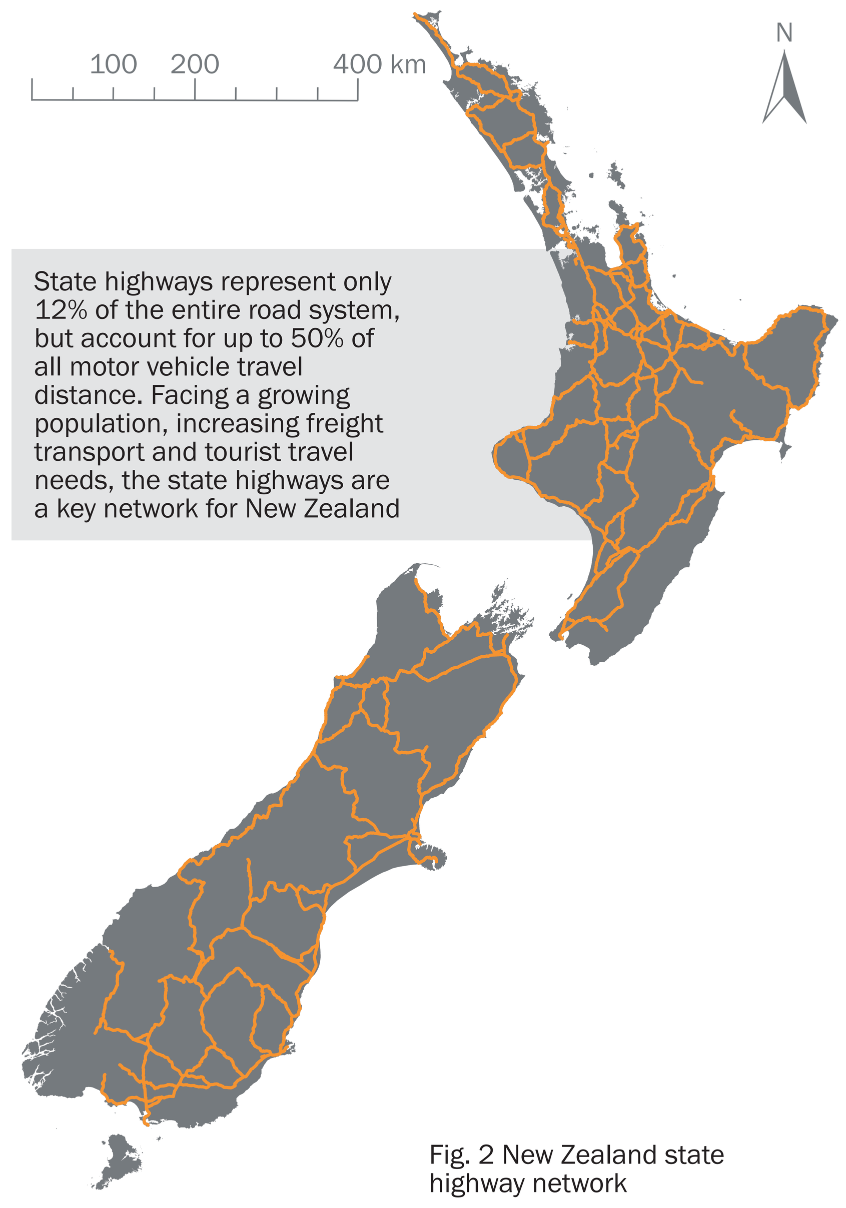

Fig. 2 New Zealand state highway network

CHARACTERISTICS OF STATE HIGHWAY BRIDGES

The age and construction characteristics of State Highway bridges are summarised in Figure 1. Cast in situ reinforced concrete bridges were common before the mid-1950's, and the use of precast concrete superstructures started to become popular after mid-1950's. These characteristics can be used to help understand the factors affecting the performance of the bridges in historic earthquakes.

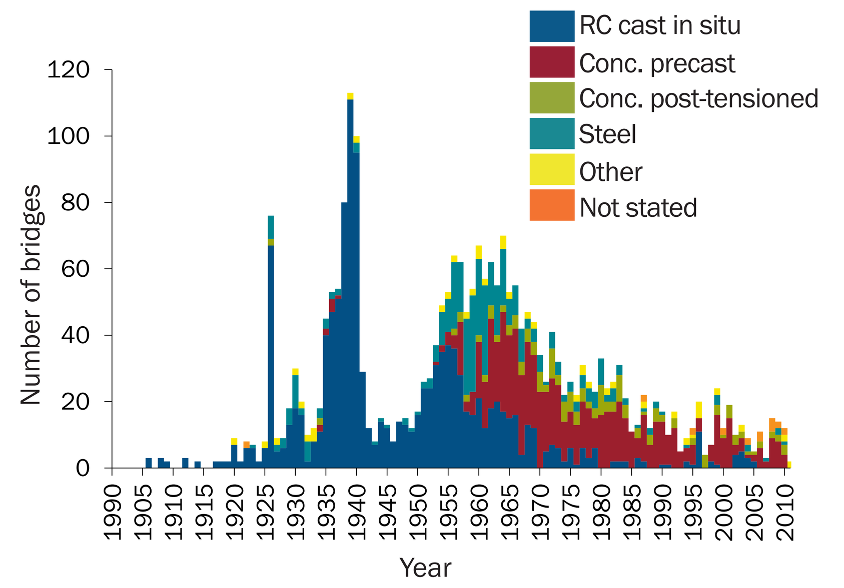

Fig. 3 Distribution of year of construction and superstructure types for state highway bridges built after 1900

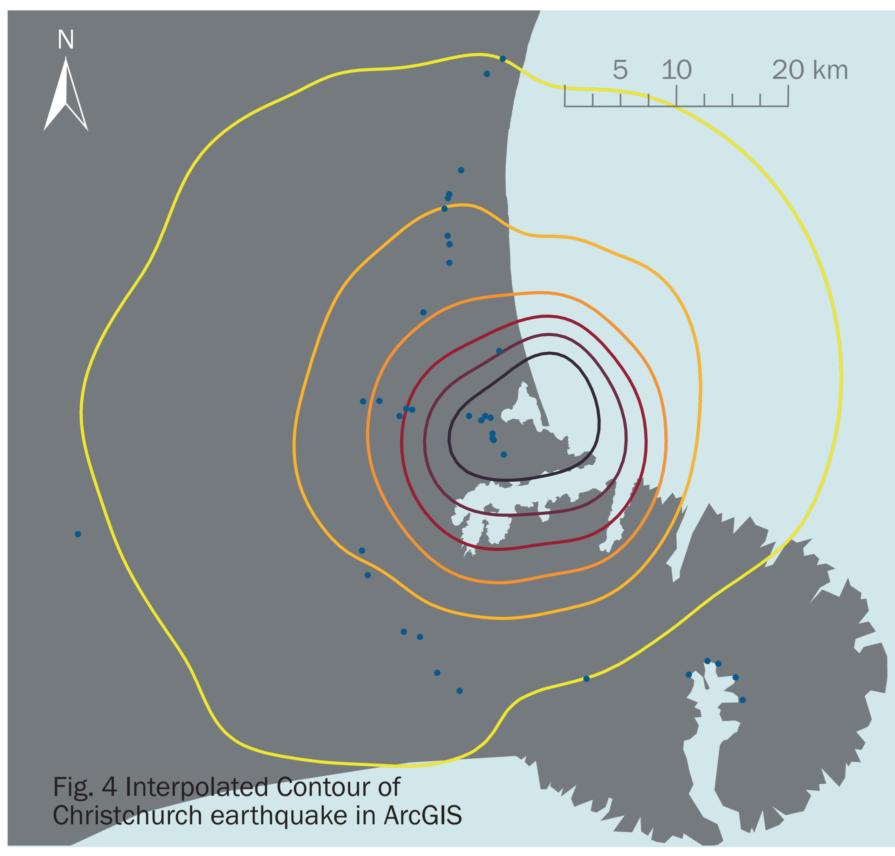

Fig. 4 Interpolated Contour of Christchurch earthquake in ArcGIS

BRIDGE HISTORIC PERFORMANCE

Estimates of the ground motion intensity for 10 earthquakes, from the 1968 Inangahua earthquake through to the 2016 Kaikoura earthquake were produced in this study. The ground motion intensity, using peak ground acceleration (PGA), for the case history events was defined using contours defined from recorded and felt events. PGA at each bridge location for these events were approximated using kriging tools in ArcGIS. An example of the results of the interpolation for the Christchurch earthquake is shown in Figure 4.

Peak Ground Acceleration (PGA)
0.60g 0.30g
0.50g 0.20g
0.40g 0.10g
Bridges

Bridges affected by historic earthquakes are mostly distributed around the eastern and southern part of the North Island and the northern part of the South Island. A total of 694 bridges were estimated to have experienced a PGA above 0.05g. The PGA have been used to compare with the seismic screening PGA to assess their predicted performance. The ground motion intensity experienced by the bridges in historic earthquakes together with the damage characteristics collated from post-reconnaissance reports can be used to assess the accuracy of analytical models.

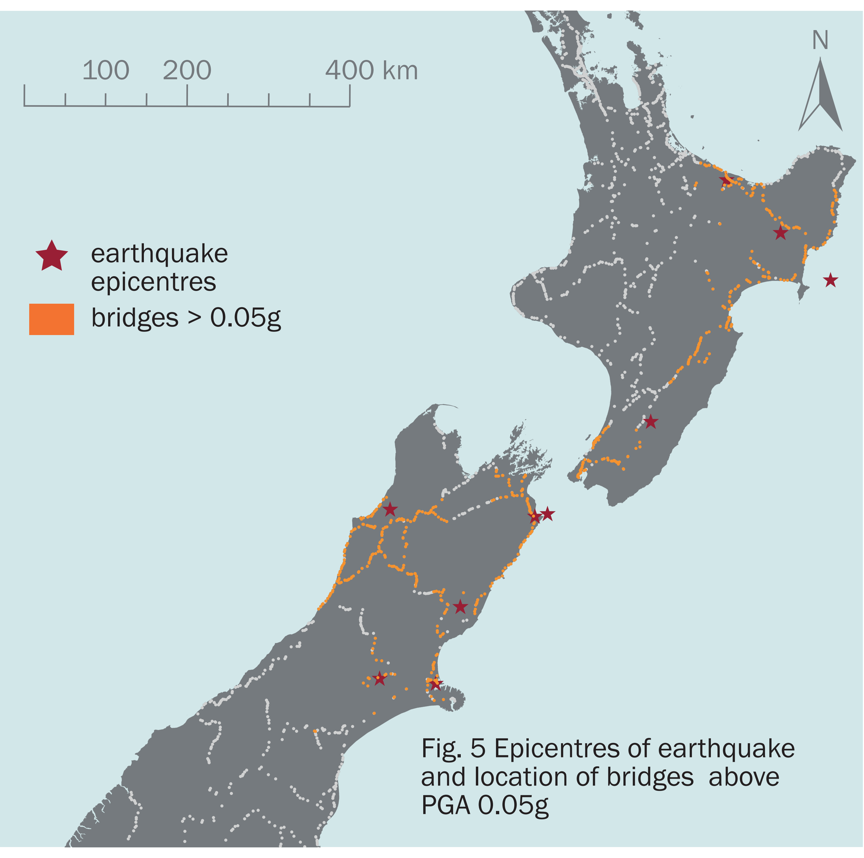

Fig. 5 Epicentres of earthquake and location of bridges above PGA 0.05g

EXPOSURE TO LIQUEFACTION

Liquefaction during seismic events can lead to significant damage to infrastructure, e.g. distortion of roads. Because of its young coastal sediments and its location along the Pacific Basin Ring of Fire, New Zealand is prone to liquefaction and lateral spreading.

Based on the geospatial model of Zhu et al. (2017), a liquefaction susceptibility map of New Zealand at a 100m grid spacing was created and applied to the state highway network. The evaluation of the map shows a relatively high susceptibility to liquefaction with around 75% of the network being considered susceptible to a moderate to very high degree. This is because a large proportion of state highways is located close to the coast and across alluvial plain areas.

State highway bridges lead to even higher susceptibility results with 90% of the structures being assigned a "moderate" to "very high" category. Bridges often span rivers, where soil is alluvial and saturated, which are primary indicators for potential manifestation of liquefaction. However, given the variability of soil deposit characteristics in these locations, further investigation would be necessary to confirm these classifications.

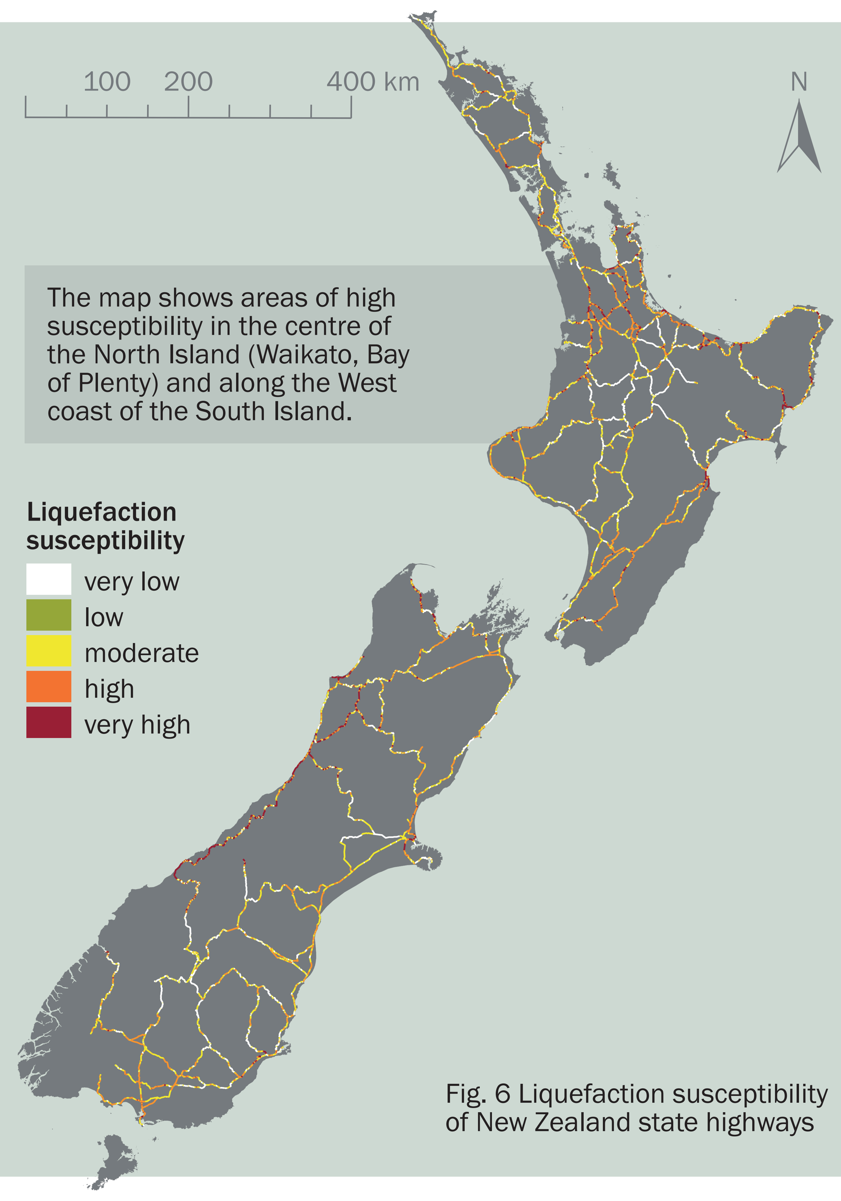

Fig. 6 Liquefaction susceptibility of New Zealand state highways

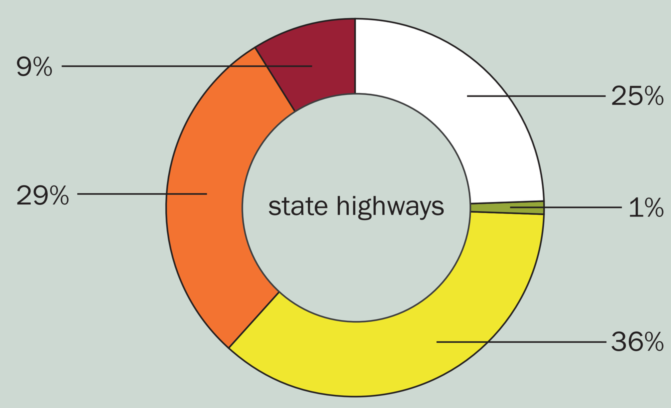

Fig. 7 Liquefaction susceptibility of state highways

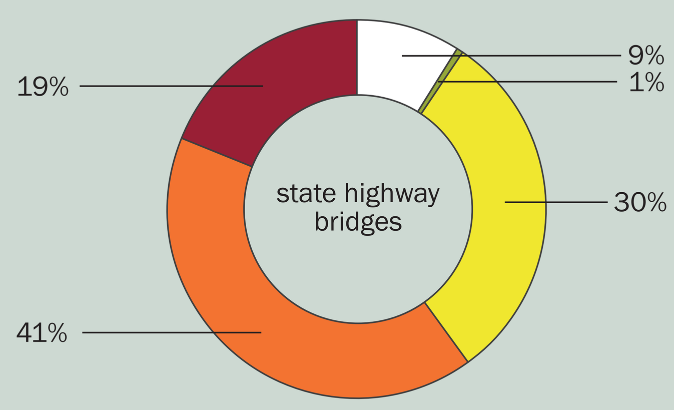

Fig. 8 Liquefaction susceptibility of state highway bridges

FUTURE RESEARCH

A large dataset of bridge performance case histories from historic New Zealand earthquakes have been collated. Further analysis of the bridge performance is underway, particularly in relation to bridges that performed well under high ground motions, and those that were damaged in low excitation levels. This will include assessment of characteristics such as age and geometry, and how this may have contributed to the severity of the damage. These findings may help inform future assessment methods and design, and provide input for the subsequent development of fragility functions for the bridges.

Geospatial methods suggest that state highways seem to be more susceptible to liquefaction than landslides. However, further research has to be undertaken regarding the extent of damage on the network. In addition, analysing liquefaction and landslide susceptibility is only the first step in an adequate hazard assessment. Ground shaking data for different earthquake scenarios and the consideration of infrastructure criticality (such as traffic volume, economic value, etc.) are required to fully understand the potential impacts of earthquakes on New Zealand State Highways.

EXPOSURE TO LANDSLIDES

Earthquake triggered landslides can cause severe damages to infrastructure, especially to roads in mountainous terrain. Compared to liquefaction induced damages, the repair and/or restoration of landslide damages often require more time and resources, such as the costs for removal of landslide debris. Large areas of New Zealand are exposed to landslides due to frequent ground shaking and soft rock Tertiary landscapes, consisting of clay layers with very low frictional resistance.

Based on the geospatial model of Jessee et al. (2018), a landslide susceptibility map of New Zealand at a 200m grid spacing was created and applied to the state highway network. In contrast to liquefaction, state highways appear to be less susceptible to landslides: Only one third of the network falls under the categories "moderate" to "very high". This also applies to state highway bridges: around 30% of the structures show "moderate" to "very high" susceptibilities.

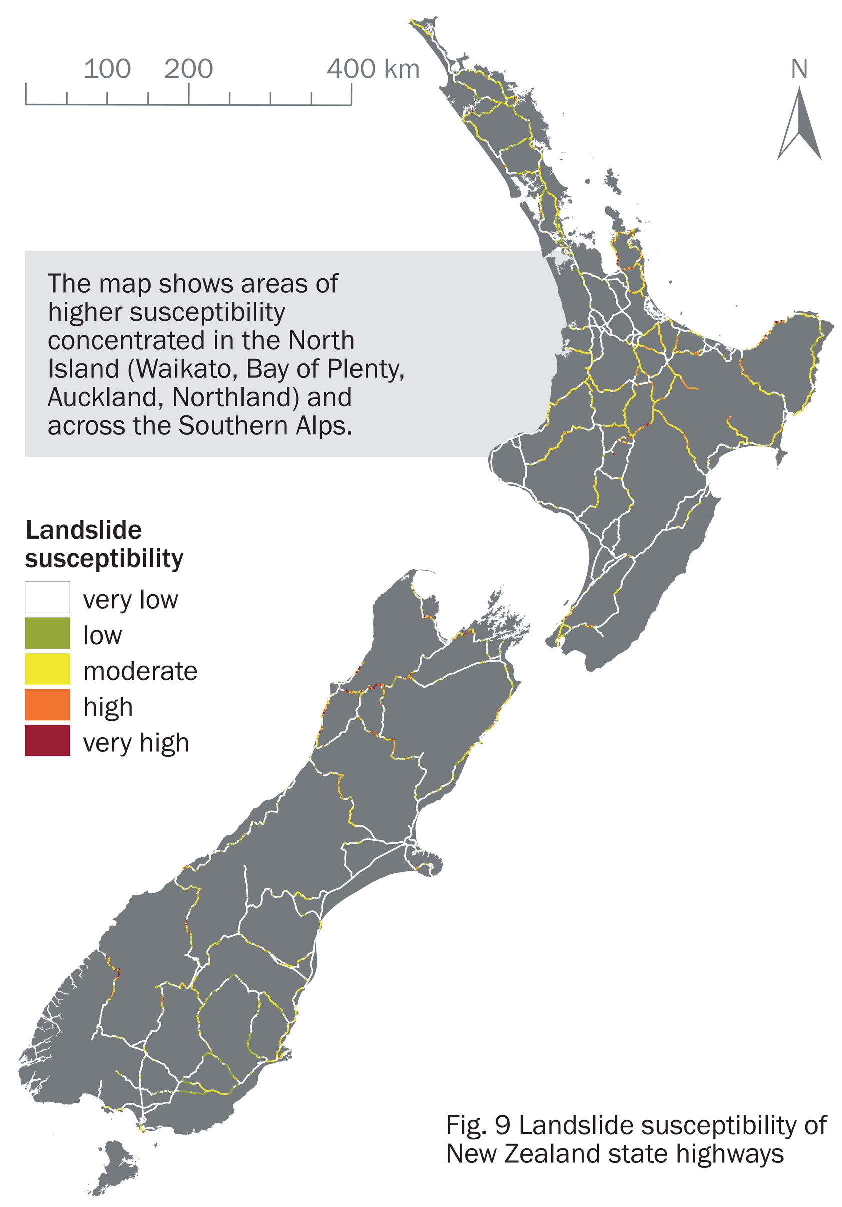

Fig. 9 Landslide susceptibility of New Zealand state highways

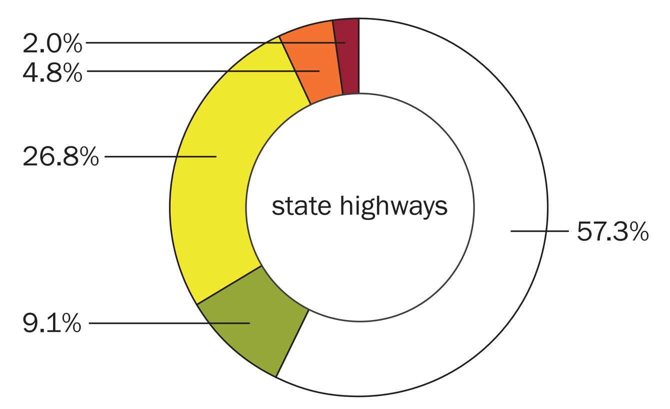

Fig. 10 Landslide susceptibility of state highways

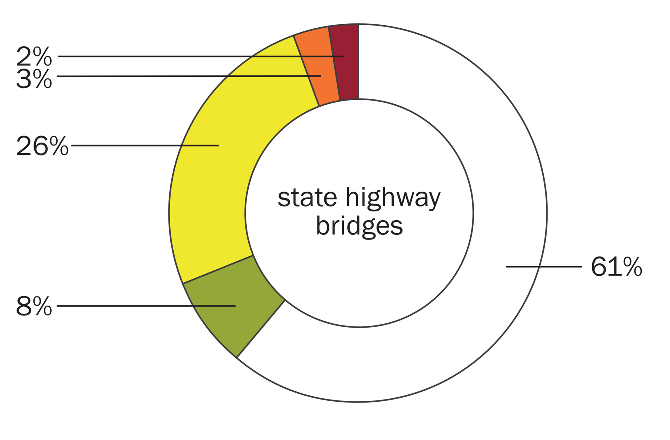

Fig. 11 Landslide susceptibility of state highway bridges

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