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Estimating National-Scale Losses to Infrastructure from Natural Hazards: Phase 2 – Future Climate Scenarios, Regional Disaggregation and Flooding Impacts on Buildings

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Earth Sciences
New Zealand

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PURPOSE

This report provides an assessment of national-scale losses to infrastructure from natural hazards and future climate scenarios from 2025 to 2075. The report is accompanied by *.csv* data files containing the results. The information in these data deliverables and the report is intended to be used by the New Zealand Infrastructure Commission Te Waihanga for strategic decision-making on infrastructure investment in New Zealand. This report follows a previous report that estimated national-scale losses to infrastructure from natural hazards. The focus of this present report is providing climate-change related losses for future years and results disaggregated by region.

USE OF DATA

Date that Earth Sciences New Zealand can use associated data:
February 2026

BIBLIOGRAPHIC REFERENCE

Horspool NA, Paulik R, Griffiths N. 2026. Estimating national-scale losses to infrastructure from natural hazards: phase 2 – future climate scenarios, regional disaggregation and flooding impacts on buildings. Lower Hutt (NZ): Earth Sciences New Zealand. 46 p. GNS Science Consultancy Report 2026/07. Prepared for the New Zealand Infrastructure Commission Te Waihanga.

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EXECUTIVE SUMMARY

The New Zealand Infrastructure Commission Te Waihanga engaged Earth Sciences New Zealand to undertake national-scale analysis of natural hazard and future climate scenario-related losses to infrastructure. The purpose of the study is to inform national and sub-national strategic investment in infrastructure. Losses were calculated for inland flooding (fluvial and pluvial) and coastal flooding (extreme sea levels) under present-day and future climate scenarios, providing results disaggregated by territorial authority and infrastructure sector.

The current study extends a previous study for the New Zealand Infrastructure Commission Te Waihanga, undertaken by GNS Science in 2025 (prior to becoming part of Earth Sciences New Zealand), that estimated present-day losses for multiple natural hazards on horizontal and vertical infrastructure by estimating losses from future climate scenarios for flooding and coastal flooding and presenting the results at the sub-national level.

The loss assessment estimates the annual average loss (AAL), which is the estimated loss per year averaged over the long term. AAL is presented at the national and sub-national levels (per territorial authority). Future losses are estimated in response to mean sea-level rise (coastal flooding) and temperature (inland flooding) for Shared Socioeconomic Pathway (SSP) scenarios 2-4.5, 3-7.0 and 5-8.5 for the years 2025, 2035, 2045, 2055 and 2075.

The results can be used to understand the potential losses expected at a national and sub-national scale for major infrastructure sectors for both present-day and future climate conditions, as well as to prioritise and rank the risk to each sector across New Zealand's territorial authorities.

1.0 Introduction

Earth Sciences New Zealand has been engaged by the New Zealand Infrastructure Commission Te Waihanga to undertake a national-scale loss assessment from flooding and coastal flooding on infrastructure. The purpose of this study is to provide national and sub-national estimates of losses on horizontal and vertical infrastructure from flooding-related hazards under present-day conditions, as well as throughout this century under different climate scenarios.

The current study extends a previous study for the New Zealand Infrastructure Commission Te Waihanga undertaken by GNS Science in 2025 (prior to becoming part of Earth Sciences New Zealand) that estimated multi-hazard losses for horizontal and vertical infrastructure for present-day conditions at the national-scale (Horspool et al. 2025).

The scope of hazards includes fluvial and pluvial flooding (hereafter referred to only as flooding) and coastal flooding (extreme sea levels). For each hazard, losses are presented as average annual loss (AAL), the loss per year averaged over the long term. Loss in the context of this study refers to direct tangible (monetary) damage and repair costs to infrastructure. Infrastructure valuations from the New Zealand Infrastructure Commission Te Waihanga were used as input into the loss calculations, and the climate-driven changes in loss are assessed for inland and coastal-flooding hazards using median projections of temperature and relative sea-level rise under Shared Socioeconomic Pathway (SSP) global emissions scenarios (Riahi et al. 2017) for future years.

This study extends the loss-assessment methodology from Horspool et al. (2025) by modifying the inland and coastal-flooding hazard modelling to incorporate changes in mean sea level and temperature and considers the impact across the years from 2025 to 2075. Results are presented at the national level and disaggregated by territorial authority and infrastructure sector.

The results of the study are delivered in data files in comma-separated variable (*.csv*) format. This report presents the methodology used to estimate future climate-scenario-related losses and presents the high-level results.

1.1 Summary of Loss-Modelling Outputs Produced

A number of results were generated upon request by the New Zealand Infrastructure Commission Te Waihanga (Appendix 1). These include:

- Vertical infrastructure (i.e. hospitals, schools, other government buildings) losses (AAL) disaggregated by:
  - use category, and
  - territorial authority.

  for the years 2025, 2035, 2045, 2055 and 2075 and SSPs 2-4.5, 3-7.0 and 5-8.5.
- Horizontal infrastructure (i.e. state highways, local roads, rail, water, telecommunications and electricity) losses (AAL) disaggregated by:
  - infrastructure sector, and
  - territorial authority.

  for the years 2025, 2035, 2045, 2055 and 2075 and SSPs 2-4.5, 3-7.0 and 5-8.5.

1.2 Glossary of Terms

This glossary provides a definition and explanation of technical terms used in this report.

(AAL) Average Annual Loss: The expected loss that is estimated to occur each year, averaged over many years.

(AEP) Annual Exceedance Probability: The probability of a hazard of a certain intensity occurring in a single year. A 1% AEP hazard map shows the hazard intensity that has a 1% (or 1 in a 100) chance of being exceeded in a given year.

Asset: An element at risk that has certain attributes (e.g. location, value, characteristics). Also see *exposure*.

Damage Ratio: The ratio of the cost to repair an asset to the cost to replace it.

Exposure: An asset exposed to a hazard that has certain attributes (e.g. location, value, characteristics).

Footprint: A polygon that shows the physical extent of a building when viewed from above.

Hazard Intensity: The intensity of a given hazard expressed as defined units. For example, depth in metres for flood or volcanic ash thickness in millimetres.

Hazard Map: A spatial map that shows the hazard intensity for a certain *AEP*.

Hazard Model: A mathematical and computational model that estimates the intensity of hazards across an area.

Hazard Curve: A curve that represents *AEP* against *hazard intensity*.

Line Segment: A geospatial representation of a linear exposure or *asset* (e.g. a road) that is split into lengths of equal or unequal length.

Loss: The magnitude of loss from a natural hazard; in this study, this is financial monetary loss.

Loss Curve: A curve that represents *AEP* against *loss*.

Probabilistic Hazard or Loss: A model that estimates both the likelihood (*AEP*) and *hazard intensity* or *loss* for a given hazard.

Return Period: The average return time for a *hazard intensity* or *loss* of a given level. A 1-in-100-year return period is equivalent to a 1% *AEP*.

Spatial Resolution: The horizontal distance between points in a dataset or map.

(SSP) Shared Socio-economic Pathway: Scenarios modelling future social, economic and technological changes to forecast climate-change impact.

Vulnerability Curve: A curve that represents the *damage ratio* against *hazard intensity*.

2.0 Loss-Assessment Methodology

2.1 Multi-Hazard-Loss Model Framework

The loss-model framework to estimate losses for natural hazards is developed in RiskScape, an open-source software for multi-hazard risk modelling (Paulik et al. 2023a). RiskScape is a modular and configurable system designed to support customised model pipelines that evaluate hazard exposure and impacts for different elements at risk to multiple natural-hazard types.

The model pipelines used in this study are the same as those used in the previous study (Horspool et al. 2025) and are presented again here for completeness of this report. Following the overview of the generalised loss-modelling methodology for horizontal infrastructure networks, vertical infrastructure and private buildings, this section explains how future climate scenarios were integrated into the loss-modelling methodology.

2.2 RiskScape

Risk modelling for this project was undertaken using the RiskScape multi-hazard loss-modelling tool (Paulik et al. 2023b). RiskScape is a software suite for multi-hazard risk analysis developed in partnership between GNS Science, the National Institute of Water & Atmospheric Research (NIWA)[1], Catalyst IT and the Natural Hazards Commission Toka Tū Ake. RiskScape is open-source software with a flexible modelling engine that processes user-customised risk-analysis workflows. RiskScape is one of few open-source software specifically designed for multi-hazard risk analysis that is globally available.

RiskScape implements a risk-model design centred on an established conceptual framework for risk quantification:

$$R = f_c(H_i, E, V_i) \qquad \text{Equation 2.1}$$

where risk (R) is a function (f_c) of the consequences from a hazard event (H) impacting an exposure (E) (i.e. element at risk). Consequences are determined from the exposure vulnerability (V) to an impact type and magnitude in response to either single or multiple hazard events (i). Risk-quantification principles are often similar between modelling software; however, implementation of model workflows and functions may differ. Modelling software practised for single or multi-hazard risk quantification often operate standard model workflows or ‘calculators’ using prescribed data classifications or standards. RiskScape operates models and input data as independent entities, enabling risk quantification for any hazard and exposure type combination, including spatio-temporal interactions. This flexibility in the modelling system overcomes the major challenges of implementing highly variable methodologies for single or multi-hazard risk analysis in a software system.

A RiskScape model requires four key components:

- **Hazard data** in the form of geospatial files that represent the hazard intensity for a single scenario event or a probabilistic hazard map for a given AEP.
- **Exposure data**, which are geospatial data represented as a point, line or polygon that represent the asset at risk and any associated attributes relevant for the risk model (e.g. building construction type).
- **Risk function**, which is a mathematical expression of the vulnerability of the asset when exposed to the hazard. This is typically expressed as a vulnerability curve that relates the damage ratio (ratio of repair cost to replacement cost) to the hazard intensity, which may vary based on the attributes of an asset.

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[1] NIWA is now also part of Earth Sciences New Zealand, merged with GNS Science on 1 July 2025.

- **RiskScape pipeline**, which is a customised and flexible risk-analysis workflow that executes the RiskScape engine. A RiskScape pipeline allows the user to define steps to undertake in the risk-model workflow, such as geoprocessing input hazard or exposure data, geospatial sampling, consequence analysis steps and post-processing of risk results (Figure 2.1).

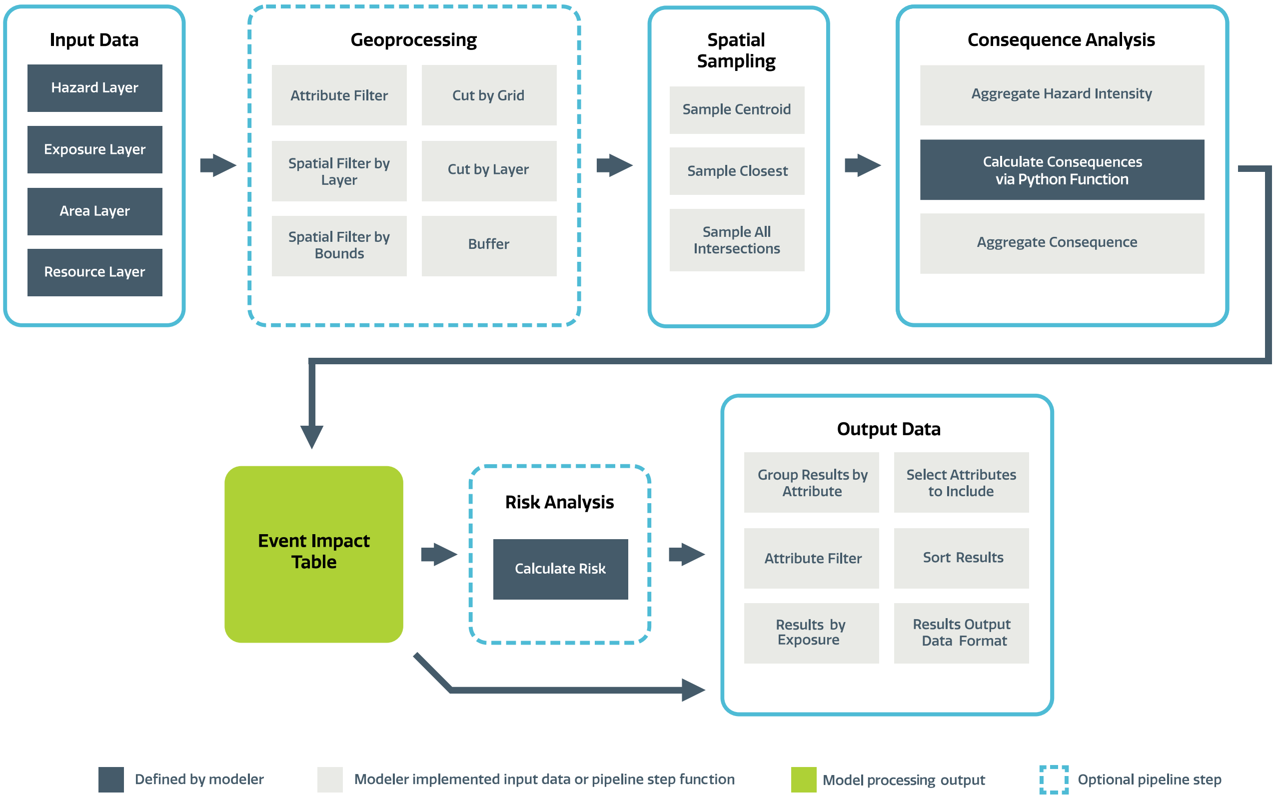

Figure 2.1 A schematic representation of the steps and functions of a RiskScape model pipeline.

The RiskScape software engine is distributed under AGPLv3 and is available for download.[2] Detailed information on the engine design, along with user guidance and tutorials, is available. A further description of the RiskScape engine design is presented by Paulik et al. (2023b).

2.3 Risk-Modelling Methodology

The risk-model pipeline developed for this study estimates losses using a probabilistic methodology, in that a range of hazard events across the probability (AEP) and hazard-intensity spectrum are considered. This differs from scenario-based analysis where only a single scenario event is used. Probabilistic risk assessment allows estimates of annualised loss to be calculated considering all possible events that may occur for a given hazard.

To estimate AAL for this study, a risk model was developed based on the hazard-based probabilistic risk model framework.[3] In a hazard-based probabilistic risk model, the hazard data is in the form of probabilistic hazard maps that represent the hazard intensity for a range of AEPs. A minimum of five AEPs are recommended for this type of analysis, based on sensitivity testing, in order to represent the full spectrum of event probabilities and hazard intensities.

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[2] https://riskscape.org.nz/

[3] https://riskscape.org.nz/docs/advanced/probabilistic/hazard-based.html

The hazard-based probabilistic risk analysis adopted for this study has been applied in other similar studies internationally. This includes estimates of seismic risk at a national scale by the Global Earthquake Model (Silva et al. 2020), a global multi-hazard risk assessment for road and rail assets (Koks et al. 2019) and a study on seismic risk to buildings in the United States of America (USA) based on their National Seismic Hazard Model (FEMA 2023).

The following steps are undertaken in the hazard-based probabilistic risk model:

1. For each infrastructure exposure element (e.g. grid cell, building footprint, line segment), the hazard value is sampled for each hazard map (corresponding to a given AEP) to create a hazard curve (Figure 2.2).
2. For each AEP in the hazard curve, the hazard-intensity value is used to sample the vulnerability model for that sector to calculate the damage ratio, defined as the ratio of repair cost to replacement cost. The damage ratio is multiplied by the replacement cost of the asset to estimate the loss (in NZD$) for that AEP.
3. This is repeated for each AEP to create a loss curve (Figure 2.3).
4. The area under the loss curve is integrated using numerical integration (trapezoid function, shown in Figure 2.3) to estimate the AAL. The AAL is divided by the total value of that sector to calculate the AAL as percentage of total value (Figure 2.3).

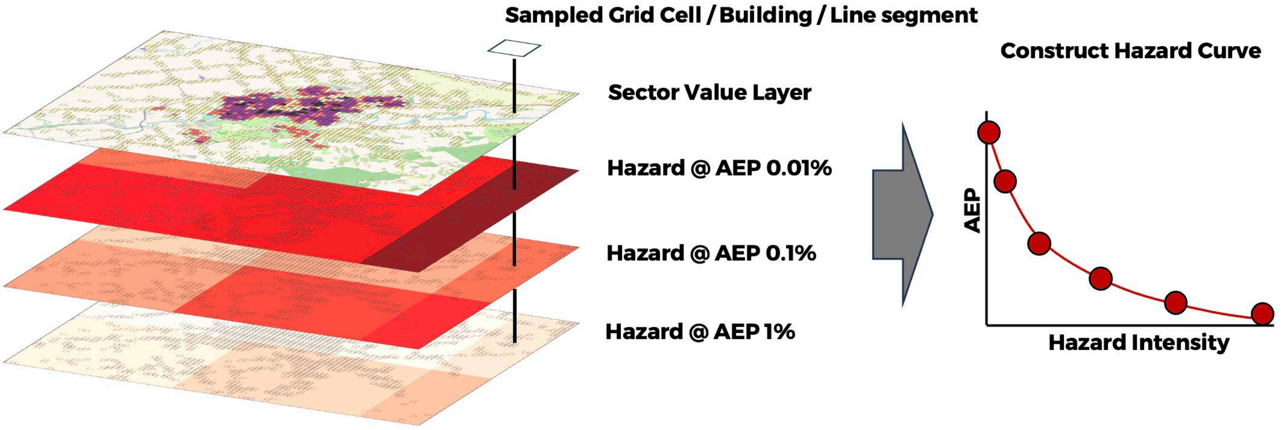

Figure 2.2 Schematic showing how a hazard curve is constructed for an exposure by sampling the hazard intensity at the geospatial location of the exposure for a set of probabilistic hazard maps.

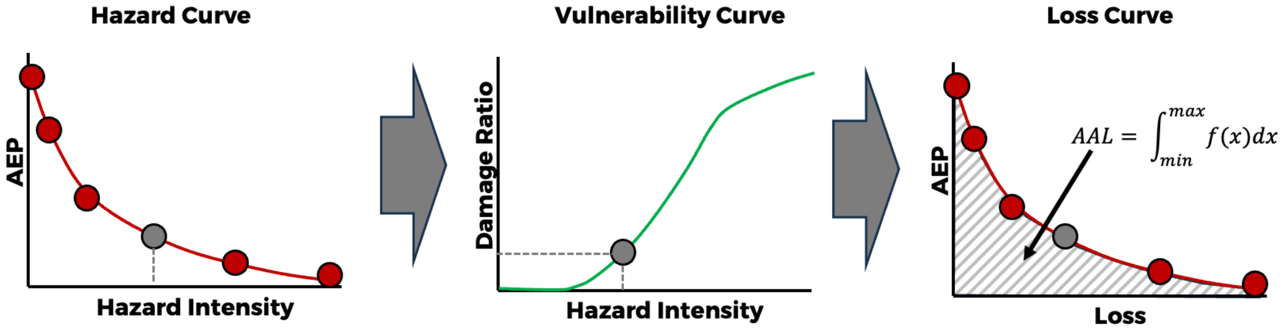

Figure 2.3 Processing steps to convert a hazard curve into a loss curve. For each AEP point that defines the hazard curve, a vulnerability curve that represents that infrastructure sector is used to calculate the damage ratio for that AEP. The damage ratio is multiplied by the exposure value to calculate the loss. When repeated for each AEP, the AEP-Loss points define the loss curve. The area under the curve is calculated through numerical integration to calculate the AAL.

While the risk-modelling workflow was the same for each infrastructure sector and hazard, the input data varied by hazard type and infrastructure sector. Hazard data that are available vary due to inconsistencies in the hazard models, such as different AEPs available ‘off the shelf’, and varying spatial resolution of the hazard models. Infrastructure-asset information is even more variable than hazard data. Some infrastructure-asset information required for risk modelling is available with national coverage via publicly accessible web services (e.g. national state-highway networks, national rail networks), some is only available from regional networks (e.g. council-owned roads) and others are not available at all (e.g. privately owned electricity or telecommunications networks). In order to address these inconsistencies in the asset information available for each infrastructure sector, three different risk models were developed that were used for certain infrastructure sectors. The overall risk and loss calculation as described above is consistent across the three models. but the way that the exposure data are processed varies.

2.3.1 Infrastructure Valuations

One of the key pieces of information for the risk model is the replacement cost of the infrastructure sectors. As noted above, this is required to estimate the loss when the damage ratio from the vulnerability function is multiplied by the replacement cost to estimate the loss. To maintain consistency with New Zealand Infrastructure Commission Te Waihanga reports, we used infrastructure-sector book valuations from the *Build or Maintain* report published in 2022 for horizontal infrastructure networks and vertical infrastructure (NZIC 2024). The report published national book valuations for each of the infrastructure sectors analysed in this study. This means that the loss estimates are based on 2022 book valuations, not full replacement valuations.

Valuations for private buildings were from the National Building Exposure model developed by GNS Science (Scheele et al. 2023) and do represent replacement value.

If book valuations are under-valued in relation to replacement cost, then the loss estimates will also be under-estimated. Loss estimates can be scaled to post-hoc to correct for this under-valuation.

2.3.2 Model 1: Horizontal Infrastructure

This model was used for infrastructure sectors where national-scale linear networks were available. This includes the state-highway and rail networks. For this model, the data were sourced from the Toitū Te Whenua Land Information New Zealand (LINZ) geospatial data service.[4] Each network was represented as line geometry. The line network was separated (cut) into segments of length equal to the resolution of the hazard being analysed. For example, the coastal-flooding hazard model had a spatial resolution of 20 m, so the line segments of the state-highway and rail networks were cut into 20 m segments.

The value of each segment was calculated by dividing the total infrastructure-sector valuation by the total length of the network to calculate the value per kilometres; this was then multiplied by the length (in kilometres) of each segment. This approach assumes equal valuation across the network (i.e. the Auckland Harbour bridge has a per-kilometre valuation the same as a rural state highway), as no valuation information was available to assign these in a more detailed manner. This simplified approach results in a ‘smearing’ of valuations across the country. In areas of high asset value (e.g. bridges), the losses are likely to be lower than expected, while, in areas of low asset value (e.g. rural state highways), the losses are likely over-estimated. However, it is assumed that this will average out across the country.

As described above, each line segment is iterated through the risk model to calculate the AAL for that segment. The AAL for each segment is then summed to calculate the national AAL for that network.

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[4] https://data.linz.govt.nz/data/

2.3.3 Model 2: Aggregated Infrastructure

Some infrastructure sectors have no national-scale information available, so a method was developed to address this. This includes the three waters, telecommunications, electricity and local roads sectors. This information is held by either individual councils or private operators and was not available. However, the total valuation of each sector is available in the NZIC (2024) report.

To distribute the asset value of each sector geospatially across the country, a proxy for infrastructure density (and therefore asset value) was adopted. This approach has been applied in global studies to estimate infrastructure distribution and value to develop exposure models for natural-hazard risk assessments (Nirandjan et al. 2022, 2024). In this approach, a proxy available across the area of interest, in this case, New Zealand, is used to approximate the distribution of infrastructure.

It is assumed that population density is a good approximation of where infrastructure is distributed, as has been used in the studies by Nirandjan et al. (2022, 2024). The Statistics New Zealand gridded population dataset is used as the proxy for infrastructure density across New Zealand. The population grid has a resolution of 250 m x 250 m and provides the resident population in each grid cell.[5] An example of the population grid is shown in Figure 2.4.

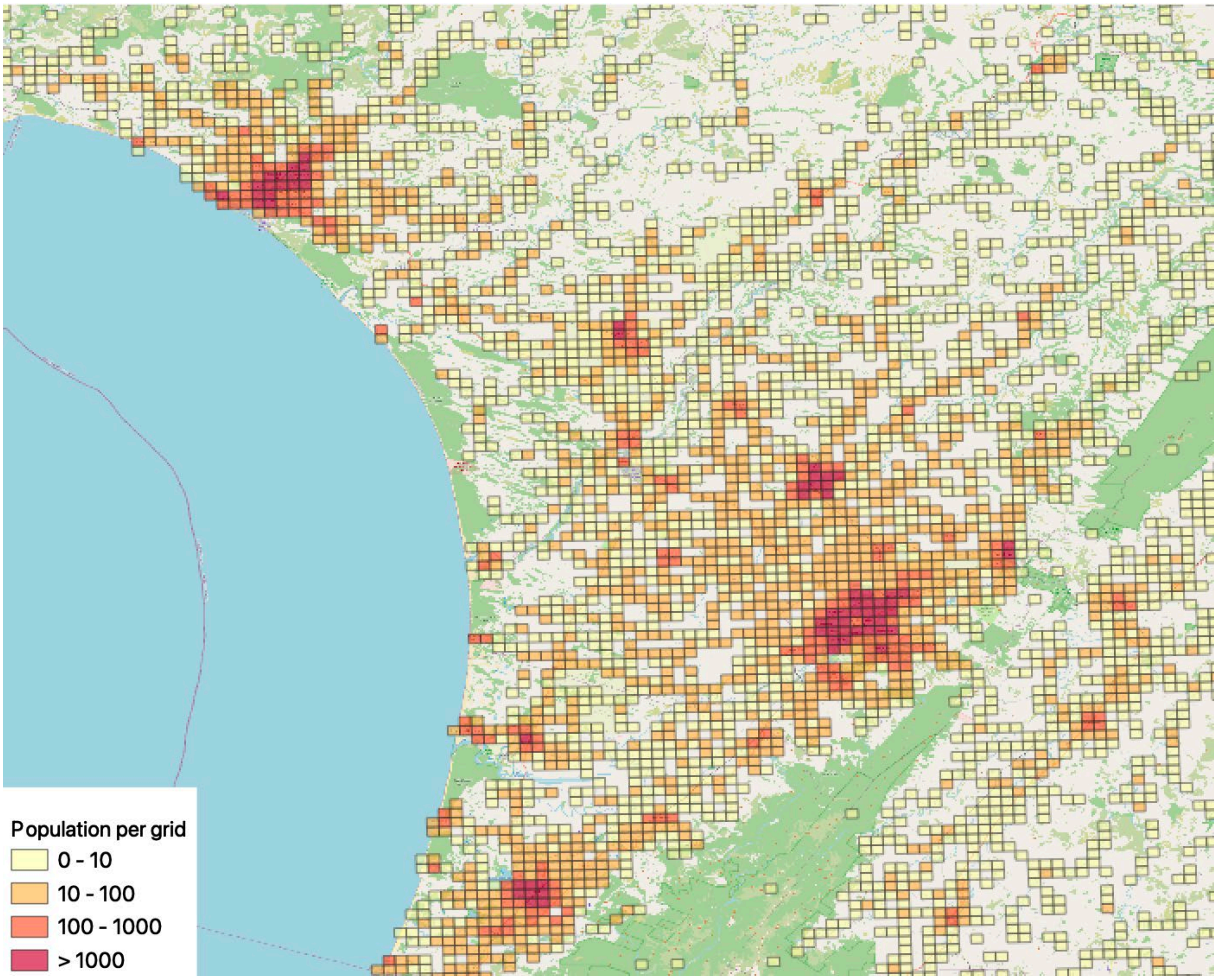

Figure 2.4 Example of the Statistics New Zealand population grid for the lower North Island.

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[5] https://datafinder.stats.govt.nz/layer/119709-new-zealand-estimated-resident-population-grid-250-metre/

To calculate the asset value of each infrastructure sector per grid cell, the sector book valuation per capita in NZIC (2024) is used and multiplied by the resident population per grid cell. This approach assumes that infrastructure is located where people live. There are some cases where this is not the case, for example, an electricity transmission line that traverses over farmland or a local road in a remote region. However, for the majority of the infrastructure value, this is located in populated areas.

In addition to an unknown replacement value, the components of the infrastructure network required to assign vulnerability functions is also unknown. For example, for water networks, how much of the asset value is from pump stations compared to pipes; and whether the water pipes are made of brittle or ductile material. To address this gap in information, regional infrastructure networks used for previous studies by GNS Science (that are not publicly available) were used to calculate the relative proportion of important components and their relative vulnerabilities. This information was used to create a single composite vulnerability curve that represents the entire network instead of multiple component-based vulnerability curves that are traditionally used for detailed infrastructure-network risk assessment.

Table 2.1 Example of how the average proportion of each component is calculated.

	Brittle Pipe Value Proportion	Ductile Pipe Value Proportion
Grid 1	0.4	0.6
Grid 2	0.5	0.5
Grid 3	0.3	0.7
Average Proportion	**0.4**	**0.6**

An example of how a single composite vulnerability curve is created for each hazard-sector combination is shown here using the example of the Auckland water network and earthquake vulnerability curves.

First the asset value per grid cell of each of the key components was calculated. This is shown for Auckland in Figure 2.5, where the replacement value of ductile and brittle pipes is calculated for each grid cell from regional-scale infrastructure network data from previous studies. For each grid cell, the proportion of asset value for brittle and ductile pipes is then calculated. The average value of this proportion is calculated for the region as a whole.

This average value of the proportions (per grid) provides the weight applied to each of the vulnerability functions for brittle and ductile pipes. Figure 2.5 shows how the vulnerability functions for brittle (red) and ductile (green) pipes are weighted by the average proportion to calculate a single composite vulnerability curve (black). The single composite vulnerability curve is used to represent that entire sector.

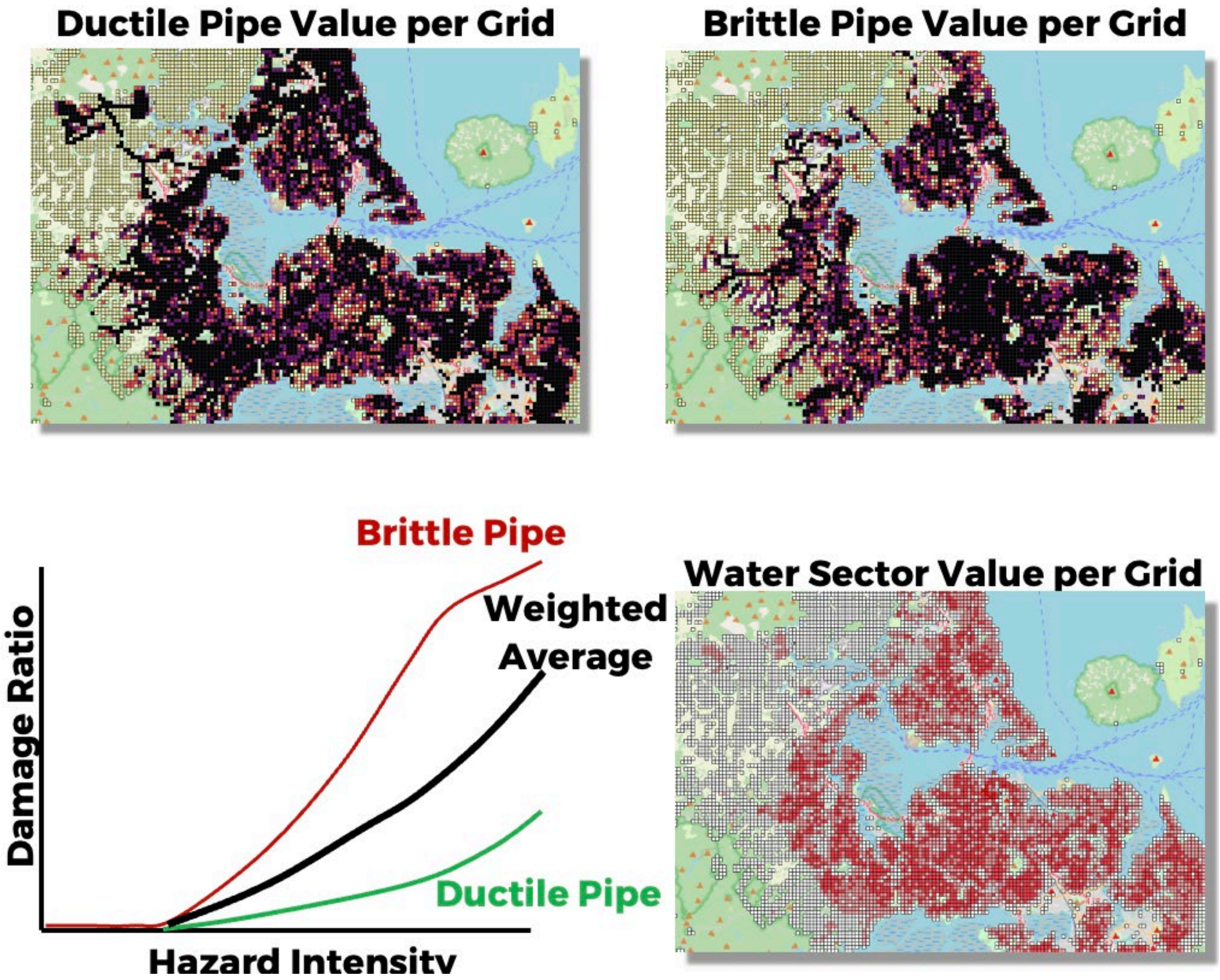

Figure 2.5 The value of each component (i.e. ductile pipes and brittle pipes) is calculated by summing the value of these assets per grid cell. The proportion of value per grid is then calculated. The average proportion of each component across the region is calculated to provide an average weighting of each component across the region. This is then used to calculate a weighted average vulnerability function that represents the vulnerability for the entire sector.

Once the composite vulnerability curve is developed for each infrastructure sector used in this model, it is applied through the common hazard-based probabilistic risk framework described above. This is done on a grid-by-grid basis, where the AAL is estimated for each grid cell for a given hazard. This results in a dataset of AAL per grid for each sector and hazard. The AAL across all grid cells for a given sector-hazard combination are summed to calculate the AAL at a national scale.

Due to the simplification steps in both distributing the asset value across grid cells and using a composite vulnerability model, the grid-cell results (an example is shown in Figure 2.6) are not recommended to be used at local scales. For local-scale studies, the damage and loss should be calculated using component-level analysis that is typically done for local authorities.

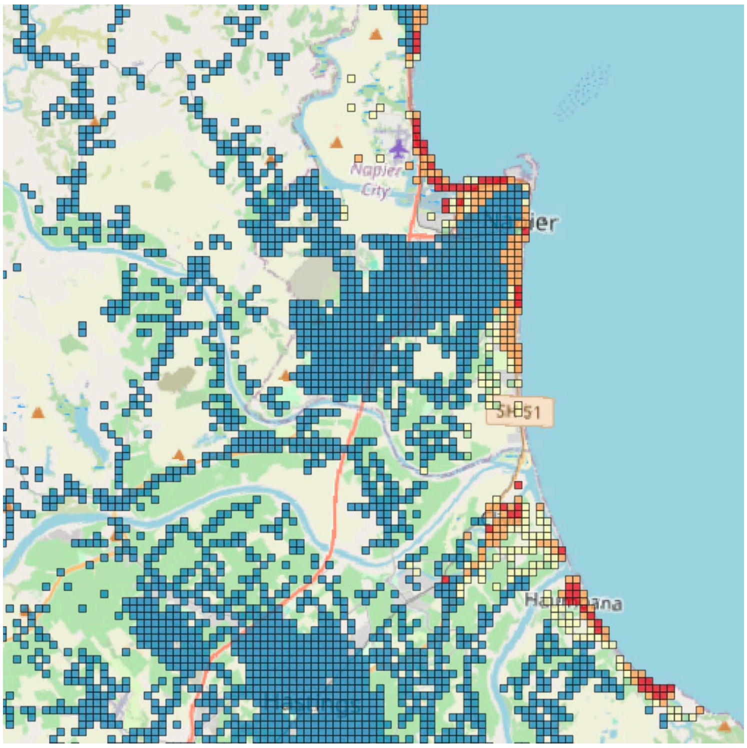

Figure 2.6 Example of estimated average annual loss (AAL) per grid cell. Red colours are higher AAL and blue colours are lower AAL.

2.3.4 Model 3: Vertical Infrastructure and Private Buildings

Modelling damage and losses to portfolios of vertical infrastructure (i.e. buildings) is common practise in New Zealand for insurance and re-insurance purposes. The risk models used for buildings are mature due to numerous events that have generated damage and loss, which vulnerability models can then be based on. Further, New Zealand has national-scale building-exposure data that represent each building in New Zealand in terms of its geospatial footprint and attributes (e.g. construction type, age, floor area), primarily based on the capital valuation data for rating purposes by local authorities, with the national dataset obtained from Cotality (formerly CoreLogic).

In this project, ‘vertical infrastructure’ refers to Government-owned buildings and ‘private buildings’ refers to privately owned buildings. GNS Science previously used the Cotality dataset to develop a nationwide building-exposure dataset for risk-modelling purposes (Scheele et al. 2023). This dataset contains every building in New Zealand and is updated every 2–3 years. The latest update occurred in 2024. The building-exposure dataset represents buildings geospatially by their footprint (polygon), sourced from the LINZ Building Footprint dataset.[6] Attributes of the building are assigned based on either the Cotality attribute information (e.g. floor area, use category) or by applying statistical distributions based on previous regional surveys by GNS Science and NIWA.

For vertical infrastructure in this application, the New Zealand Building Exposure dataset is first filtered by use category to only include use categories that are within scope of the study as defined by the New Zealand Infrastructure Commission Te Waihanga. These are also the categories defined in NZIC (2024). This includes education, hospitals and local and central government.

Once the target buildings are filtered, the replacement value from the building-exposure dataset is adjusted to ensure the sum of each use category is equal to that of the book values in the NZIC (2024) report for that sector. This is achieved through normalisation, where a scale factor is calculated by

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[6] https://data.linz.govt.nz/layer/101292-nz-building-outlines-all-sources/

dividing the value for a specific sector in the report by the total value of buildings in that sector (e.g. education) from the New Zealand Building Exposure dataset. This scale factor is then applied to each building value in the dataset, ensuring that the total value of all buildings in that sector matches with the value reported in NZIC (2024). For private buildings, the replacement cost value from the Earth Sciences New Zealand building exposure dataset is used and is not scaled.

The vulnerability model for each building is applied based on building attributes, such as age (related to building code), construction type, number of stories and, for flood-related hazards, floor height.

For both vertical infrastructure and private buildings, the valuation reflects the replacement value of the building and does not include contents or land.

In this model, the AAL is estimated for each building following the hazard-based probabilistic risk framework described above. The results for each building are then aggregated up to the territorial authority, regional or national scale for reporting.

2.4 Future Climate-Scenario Projection

Unlike the previous study (Horspool et al. 2025) which only estimated present-day losses under current climate conditions, this study also estimates losses for future years under different climate scenarios represented by SSPs (Riahi et al. 2017). Each SSP has a different forecast of temperature and mean sea-level changes that influence flooding and coastal-flooding hazards. Mean sea-level changes vary around the country for each SSP. These can be visualised in the NZ SeaRise web viewer.[7] The following sections describe the hazard data for each hazard and how future climate-scenario projections are incorporated into the analysis.

2.4.1 Coastal Flooding

Coastal flooding was represented by extreme sea-level-driven flooding in this study. Coastal-flood hazard scenarios were sourced from Paulik et al. (2023b) and represent seven AEPs: 10, 20, 50, 100, 200, 500 and 1000 years. The hazard layers represent inundation extent and water depth at 10 m and 30 m grid resolutions, based on a composite digital elevation model (DEM) of airborne lidar (10 m grid) and bias-corrected Shuttle Radar Topography Mission (SRTM) data (30 m grid). Coastal-flooding protection from stopbanks was represented using a national stopbank inventory, with land protection uniformly applied for a 100-year annual recurrence interval extreme sea-level elevation. Present-day and future flood regime changes in response to mean sea-level rise were represented by simulating extreme sea-level inundation under 0.1 m increments from 0 m to 2 m.

Future coastal-flooding frequency and magnitude will be influenced by global sea-level change. In this study, future rates and timing of mean sea-level rise around New Zealand's coastline for five SSP (1–5) global emissions scenarios were based on probabilistic relative sea-level-rise projections developed for 7435 coastal sites by the NZ SeaRise programme (Levy et al. 2024; Naish et al. 2024). For each SSP scenario, relative sea-level projections to 2100 (17th, 50th and 83rd percentiles) were used for medium confidence climatic processes. Relative sea-level projection sites were represented as point geometries that were converted to Voronoi polygons, then spatially joined to road corridors to evaluate the future timing and uncertainty of projected road exposure and loss from coastal flooding.

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[7] https://searise.nz/maps/

2.4.2 Inland Flooding

Inland flooding was represented by fluvial- and pluvial-driven inundation. Inland flood-hazard scenarios were sourced from Harang et al. (2024) and represented seven AEPs: 10, 20, 50, 100, 200, 500 and 1000 years. The hazard layers represent inundation extent and water depth at 8 m grid resolution, based on a lidar DEM. Like coastal flooding, inland flood protections (i.e. stopbanks) were also considered in the model. The inland flood-hazard model domain represented ~73% (197,415 km^2) of New Zealand's mainland area. Future flood-regime changes in response to changing climatic conditions were represented by simulating inundation under 0°C, 1°C , 2°C and 3°C of temperature warming.

The future rates and timing of temperature change on the mainland area were based on probabilistic temperature projections developed at ~12 km^2 for New Zealand by downscaling six global climate models from the Coupled Model Intercomparison Project (CMIP6) (Gibson et al. 2024). Rolling multi-model annual mean temperature change (17th, 50th and 83rd percentiles) across all climate models for SSP1–5 global emissions scenarios (medium confidence) were calculated for each ~12 km^2 grid, starting at 2015–2034 (i.e. centred on 2024) and ending at 2080–2100. Temperature projections were spatially joined to each exposure location to evaluate the future timing and uncertainty of projected hazard exposure and loss from inland flooding.

2.4.3 Climate-Scenario-Loss Projection

Losses were projected in response to temperature or sea-level change under medium confidence SSP2-4.5 (medium greenhouse gas emissions), SSP3-7.0 (high greenhouse gas emissions) and SSP5-8.5 (very high greenhouse gas emissions) scenarios. All SSP scenarios in this study used the median (50th percentile) projection.

The future projected climate variables are related to infrastructure loss (AAL) as follows for coastal flooding:

$$AAL(t) = f\big(SLR(t)\big) \qquad \text{Equation 2.2}$$

where $SLR(t)$ is projected mean sea-level rise in metres (Levy et al. 2024; Naish et al. 2024) at decade t. The approach is similar for inland flooding:

$$AAL(t) = f\big(\Delta T(t)\big) \qquad \text{Equation 2.3}$$

where $\Delta T(t)$ is the projected temperature change in degrees Celsius (Gibson et al. 2024) at decade t. In this study, t represents each decade between 2020 and 2090 (e.g. 2020, 2030, ..., 2090).

This flexible approach enables computation of loss (AAL) for any projected mean sea-level- or temperature-change scenario, avoiding the need to simulate numerous projected coastal and inland flood-hazard scenarios using expensive and time-consuming numerical models.

For each exposure location, a piecewise linear function was fitted to the relationship between the independent climate variable and loss-dependant variables:

$$f(x) = \begin{cases} b_0 + m_1(x - x_0),\ x_0 < x < x_1 \\ b_1 + m_2(x - x_1), x_1 < x < x_2 \\ \vdots \\ b_{n-1} + m_n(x - x_{n-1}), x_{n-1} < x < x_{n-1} \end{cases} \qquad \text{Equation 2.4}$$

where x is the climate variable (i.e. mean sea level, temperature), x_n is the maximum value of the climate variable, $f(x)$ is the function for infrastructure loss (AAL) loss, m_i is the slope between points and b_i the point intercepts. The slope for individual exposures (m_i) is computed as:

$$m_i = \frac{y_i - y_{i-1}}{x_i - x_{i-1}}$$ Equation 2.5

where x_i is the mean sea-level or temperature value and y_i is infrastructure loss (AAL) corresponding to x_i. The continuity between point segments is enforced by recursively defining the point intercepts (b_i):

$$b_i = b_{i-1} + m_i(x_{i-1})$$ Equation 2.6

Here, the piecewise linear function minimises the residual error between modelled and interpolated loss metric.

2.5 Model Confidence

Each of the hazard-sector risk models has varying levels of confidence due to the various model components that make up that model (e.g. the hazard model, vulnerability model and exposure model). In order to communicate the confidence in the results, each hazard-sector model has been evaluated and categorised into having low, moderate or high confidence (Table 2.2). The level of confidence is related to the suitability of the model for the study purposes and these categorisations are explained below:

- **Low confidence:** Vulnerability models based on international studies with no validation to New Zealand data. Models have been simplified or upscaled, and there are significant assumptions for this study. This also includes vulnerability models based on expert judgement. The exposure model is based on generalisation of asset types and valuations spatially.
- **Moderate confidence:** Vulnerability models based on international events and validated in New Zealand. Moderate levels of model simplification, or assumptions. The exposure model is based on some simplification but with actual spatial distribution of assets.
- **High confidence:** Vulnerability models based on damage and loss data from New Zealand events. Models have been used for a variety of New-Zealand-based projects and have been improved over time. The exposure model is based on asset-level typology and valuations.

Table 2.2 Overall confidence in hazard-sector models in this study.

	Water	Electricity	Telecommunications	Road and Rail	Vertical	Private Buildings
Coastal Flooding	Moderate	Moderate	Low	High	High	High
Inland Flooding	Moderate	Moderate	Low	High	High	High

For infrastructure sectors, vertical infrastructure has the highest confidence due to the maturity of the vulnerability functions that are based on New Zealand damage and loss data. Further, modelling losses to buildings is common for insurance and re-insurance purposes in New Zealand, which has led to development of high-quality models. The electricity and water sectors have similar levels of moderate confidence, as many of these sectors were studied following New Zealand hazard events, with New-Zealand-based vulnerability models developed. Telecommunications is the sector with the lowest confidence, which is due to the low availability of data for risk assessments. This has resulted in few studies investigating the vulnerability of the sector, therefore resulting in risk-assessment models based mostly from international studies.

2.6 Limitations

Natural hazards cause a wide range of direct and indirect, tangible and intangible impacts on infrastructure. However, this study focuses on direct damage and repair costs to infrastructure. This focus is suitable for disaster-risk management and climate-adaptation planning, especially for risk profiling or hot-spot mapping. Such analyses provide information baselines for monitoring loss changes over time due to factors such as climate scenarios, hazard mitigation or land-use change. While limited in terms of impact metrics, loss to infrastructure does produce important baseline information for prioritising more detailed, location-specific risk assessments.

Limitations specific to the model-input datasets include:

Hazard Layer: Coastal Flooding (Extreme Sea Levels)

- The coastal-flood hazard layers are generated using a static inundation model, which does not account for dynamic hydrodynamic processes such as wave action, storm-surge timing or interactions with tides. This simplification may under- or over-estimate the extent and depth of inundation in some locations.
- The input elevation data are a composite DEM combining high-resolution lidar (10 m grid), where available, and coarser SRTM (30 m grid) data elsewhere. While bias correction is applied, this merging of datasets introduces spatial inconsistencies in terrain representation, especially in areas lacking lidar coverage.
- Stopbank protection is represented by a uniform 1% extreme sea-level elevation threshold that assumes consistent protection standards across all defended areas. In reality, stopbank design, maintenance and performance varies widely, meaning that actual levels of protection could be higher or lower than assumed.

Hazard Layer: Inland Flooding (Fluvial–Pluvial)

- Inland flood-hazard layers are derived from hydrological modelling at a 4 m grid resolution using lidar DEMs. This provides relatively high spatial detail but remains limited in representing small-scale features (e.g. culverts, drains) that influence the intensity of water flows. Not modelling these small-scale drainage features may lead to small over-estimation of losses in some urban areas.
- Model coverage extends over 73% of the New Zealand mainland (197,415 km^2) where lidar is available. The 27% gap means that areas outside lidar coverage are not represented, potentially under-estimating exposure in rural or remote regions. See the LINZ website for information about lidar coverage.[8]
- The hazard layers are not yet directly comparable with finer-scale, locally developed flood models. Variability in modelling approaches, input parameters and calibration may lead to inconsistencies, reducing the reliability of comparisons between national- and local-scale results.

Exposure Data: Infrastructure Valuation

- As discussed in Horspool et al. (2025), exposure data are not available for most infrastructure sectors, so the spatial distribution of asset locations and valuation were distributed based on either know locations (e.g. national state highways and rail) or using population density as a proxy (for the water, telecommunications, electricity and local roads sectors). Infrastructure book valuations were sourced from the New Zealand Infrastructure Commission Te Waihanga and were assumed to represent the replacement cost of assets when calculating loss. If the valuations are under-estimated, as is often the case when using book value, then the loss results

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[8] https://www.linz.govt.nz/products-services/data/types-linz-data/elevation-data/lidar-data-coverage

will subsequently be lower. Due to the use of damage ratios (repair cost divided by replacement cost) in estimating losses in RiskScape, loss results can be scaled proportionately to infrastructure replacement value to account for this. As the infrastructure valuations likely reflect the book value, not the replacement value, the losses should be scaled if full replacement cost losses are required.

- Valuations for private buildings are estimated replacement values, so losses for private buildings do not need to be scaled.
- The modelling here does not include some important infrastructure types, such as gas networks, ports, airports and waste management.
- Asset values used in this study reflect 2024 values. Asset-valuation changes or different network configurations in future years (beyond 2025) are not considered.

Modelling Methodology: Simplified Distribution of Asset Values

- Two of the simplifications used in the 'aggregated risk model (Model 2)' to represent the infrastructure exposure are worthy of further discussion. These include the way that asset values are distributed by population density and how infrastructure exposure is assumed to be located within population grid cells. Both of these steps were necessary due to the limitation of having no knowledge on the infrastructure networks at a national scale.
- By using population as a proxy for infrastructure locations, the model will be missing locations where infrastructure is located outside of populated areas. In this case, any infrastructure located further than ~250 m from a residential property will not be modelled at its correct location. It is thought that this simplification will have negligible effect on the estimated losses. This is due to a very small proportion of infrastructure value lying outside of populated areas; the exception for this is dams, power-generation facilities, water-treatment facilities and large substations. From a calculation of known network-exposure data, these facilities typically make up less than 1% of the total network value, so not modelling their correct location is likely to have no material effect at the national scale.
- Further, the apportionment of asset types within a sector is assumed based on expert judgement. For example, in the electricity sector, a proportion of asset valuations are assigned to above- and below-ground infrastructure. If these differ locally to what is actually present, this will have some impact on the loss estimates.
- Using population density as a proxy for distributing the asset value of each infrastructure sector is also a simplifying and averaging effect. This means that high-value assets are 'smeared' across the rest of the country, and low-value assets may have their asset value increased in the model. The New Zealand Infrastructure Commission Te Waihanga found that urban areas have less infrastructure per person and rural areas more infrastructure per person.[9] This means that the infrastructure value may be over-estimated in urban areas and under-estimated in rural areas.
- Combined, these two limitations are thought to change the national-scale AAL by only a few percent compared to using a precise geospatial model of asset-value apportionment due to the averaging effect of the over- and under-estimation of both asset locations and asset valuations. However, the change in sub-national (i.e. Territorial Authority) -level losses may vary more.

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[9] https://tewaihanga.govt.nz/our-work/research-insights/auckland-s-infrastructure-the-cost-to-serve-a-city-that-s-growing-upwards

3.0 Results

3.1 National Losses by Infrastructure Sector and Climate Scenario

Table 3.1 presents modelled infrastructure and private building losses (in millions of NZD$) disaggregated by infrastructure sector for both flooding and coastal-flooding hazards under current (2025) conditions and future climate scenarios (SSP2-4.5, SSP3-7.0 and SSP5-8.5) for 2075. The results highlight substantial increases in losses across all infrastructure categories, with particularly increased losses observed in horizontal network assets and private buildings.

3.1.1 Estimated Losses

3.1.1.1 Flooding

Under baseline (2025) conditions for flooding, total losses are estimated at NZD $471.89 million, with the largest contributions from private buildings (NZD $190.78 million), electricity (NZD $90.10 million) and water infrastructure (NZD $68.42 million). Local roads (NZD $46.85 million) and central roads (NZD $25.29 million) also represent significant components of total losses.

By 2075, losses increase across all emissions scenarios. Under SSP2-4.5, total losses rise to NZD $682.07 million, representing an increase of approximately 45% relative to 2025. Under SSP3-7.0, losses increase to NZD $707.22 million (~50% increase), and, under SSP5-8.5, total losses reach NZD $721.35 million (~53% increase).

The largest absolute increases are observed in:

- Private buildings, increasing from NZD $190.78 million to NZD $248.21 million under SSP5-8.5 (+NZD $57.43 million).
- Electricity infrastructure, increasing from NZD $90.10 million to NZD $155.79 million (+NZD $65.69 million).
- Water infrastructure, increasing from NZD $68.42 million to NZD $118.26 million (+NZD $49.84 million).
- Local roads, increasing from NZD $46.85 million to NZD $78.24 million (+NZD $31.39 million).

The rail, telecommunications and vertical infrastructure (government, hospitals, education) sectors also show consistent increases, although their contributions to total losses remain comparatively smaller. Overall, network infrastructure (water, electricity, transport) dominates total losses and drives much of the increase under future scenarios.

3.1.1.2 Coastal Flooding

Coastal-flooding losses are lower than fluvial flooding under current conditions but show a greater proportional increase over time. In 2025, total coastal-flooding losses are estimated at NZD $242.70 million, approximately half of inland-flooding losses.

By 2075, total losses increase to:

- NZD $461.72 million under SSP2-4.5 (~90% increase).
- NZD $503.62 million under SSP3-7.0 (~107% increase).
- NZD $542.77 million under SSP5-8.5 (~124% increase).

This indicates that coastal-flooding risk is highly sensitive to emissions pathways and associated sea-level rise.

The largest contributors to coastal-flooding losses are:

- Private buildings, increasing from NZD $77.13 million to NZD $193.80 million under SSP5-8.5.
- Electricity infrastructure, increasing from NZD $54.72 million to NZD $113.71 million.
- Water infrastructure, increasing from NZD $40.26 million to NZD $83.34 million.
- Local roads, increasing from NZD $34.11 million to NZD $70.74 million.

Private building losses more than double under all future scenarios, reflecting increased exposure of built assets in coastal zones.

Rail and telecommunications infrastructure, while smaller in absolute terms, also show significant proportional increases. Vertical infrastructure (government, hospitals, education) exhibits steady but more moderate increases.

3.1.2 Estimated Losses as a Percentage

3.1.2.1 Flooding

Table 3.2 presents infrastructure losses expressed as a percentage of total asset value for both inland- and coastal-flooding hazards under current (2025) conditions and future climate scenarios (SSP2-4.5, SSP3-7.0 and SSP5-8.5) for 2075. This normalised representation provides insight into the relative risk of different asset classes, independent of their absolute value.

Under baseline (2025) conditions, relative losses from flooding are generally low across all asset classes, with total losses equivalent to 0.027% of asset value. The highest relative impacts are observed in:

- Rail infrastructure (0.31%).
- Water (0.21%) and electricity (0.20%).
- Local roads (0.16%).

Other asset classes, including vertical infrastructure (government, hospitals, education) and private buildings, exhibit relatively low proportional losses (≤0.04%).

By 2075, relative losses increase across all scenarios. Under SSP2-4.5, total losses rise to 0.039%, increasing further to 0.040% under SSP3-7.0 and to 0.041% under SSP5-8.5, indicating a modest increase in nation-wide proportional losses.

At the sector level, the following increases are observed:

- Rail infrastructure increases from 0.31% to 0.55%, representing the highest relative vulnerability across all asset classes.
- The water and electricity networks increase to approximately 0.36% and 0.34%, respectively, under SSP5-8.5.
- Local roads increase to 0.27%, while central roads increase more modestly to 0.11%.
- Vertical infrastructure categories (government, hospitals, education) and private buildings show relatively small increases in percentage terms, generally remaining below 0.07% even under higher emissions scenarios.

3.1.2.2 Coastal Flooding

Under baseline (2025) conditions, relative losses from coastal flooding are generally low across all sectors, with total losses equivalent to 0.014% of asset value, approximately half of that of flooding. The highest relative impacts are observed in:

- Local roads, water and electricity networks (0.12%).
- Rail infrastructure (0.06%).
- Central government roads (0.05%).

Other asset classes, including government, hospitals, education and private buildings, exhibit relatively low proportional losses (≤0.02%).

By 2075, relative losses increase across all scenarios. Under SSP2-4.5, total losses rise to 0.026%, increasing further to 0.028% under SSP3-7.0 and to 0.031% under SSP5-8.5, indicating a moderate increase in nation-wide proportional losses. Total losses increase under each SSP for coastal flooding at a higher rate than that of flooding, indicating a higher sensitivity of coastal-flooding losses to climate scenarios.

At the asset level, more increases are observed:

- Rail infrastructure triples in losses, with increases from 0.06% to 0.18%, representing the highest relative vulnerability across all asset classes.
- The water and electricity networks increase in losses by double to approximately 0.25% under SSP5-8.5.
- Local roads and central government roads double in losses to increase to 0.24% and 0.10%, respectively.
- Vertical infrastructure categories (government, hospitals, education) and private buildings show relatively small increases in percentage terms, generally remaining below 0.06% even under higher emissions scenarios.

Overall, while absolute losses increase substantially, relative losses as a percentage of asset value remain comparatively small but exhibit consistent upwards trends across all sectors.

Table 3.1 Summary of average annual loss (in million NZD$) per infrastructure sector for flood and coastal flooding in 2025 and 2075 under the three different climate scenarios.

Climate Scenario		Networks						Vertical				Total
		Water	Electricity	Telecommunications	Local Roads	Central Roads	Rail	Government	Hospitals	Education	Private Buildings	
Flood	2025	68.42	90.10	1.15	46.85	25.29	14.60	17.37	3.62	13.71	190.78	471.89
	SSP2-4.5 in 2075	111.79	147.24	1.91	74.71	39.83	23.99	24.70	4.90	19.54	233.46	682.07
	SSP3-7.0 in 2075	115.95	152.73	1.99	76.98	41.28	25.00	25.09	4.98	20.34	242.88	707.22
	SSP5-8.5 in 2075	118.26	155.79	2.03	78.24	42.05	25.59	25.31	5.03	20.84	248.21	721.35
Coastal Flooding	2025	40.26	54.72	0.52	34.11	19.84	3.00	9.49	0.68	2.95	77.13	242.70
	SSP2-4.5 in 2075	71.70	97.77	1.39	60.85	32.81	6.79	22.29	1.22	4.60	162.30	461.72
	SSP3-7.0 in 2075	77.71	106.01	1.55	65.95	35.23	7.53	24.78	1.33	4.94	178.59	503.62
	SSP5-8.5 in 2075	83.34	113.71	1.71	70.74	37.60	8.20	27.03	1.42	5.22	193.80	542.77

Table 3.2 Summary of average annual loss per infrastructure sector as a percentage (%) of total value of each sector for flood and coastal flooding in 2025 and 2075 under the three different climate scenarios.

Climate Scenario		Networks						Vertical				Total
		Water	Electricity	Telecommunications	Local Roads	Central Roads	Rail	Government	Hospitals	Education	Private Buildings	
Flood	2025	0.21	0.20	0.01	0.16	0.07	0.31	0.04	0.03	0.04	0.01	0.027
	SSP2-4.5 in 2075	0.34	0.32	0.01	0.25	0.11	0.52	0.06	0.03	0.06	0.02	0.039
	SSP3-7.0 in 2075	0.35	0.33	0.01	0.26	0.11	0.54	0.06	0.04	0.06	0.02	0.040
	SSP5-8.5 in 2075	0.36	0.34	0.01	0.27	0.11	0.55	0.06	0.04	0.07	0.02	0.041
Coastal Flooding	2025	0.12	0.12	0.00	0.12	0.05	0.06	0.02	0.00	0.01	0.01	0.014
	SSP2-4.5 in 2075	0.22	0.21	0.01	0.21	0.09	0.15	0.05	0.01	0.01	0.01	0.026
	SSP3-7.0 in 2075	0.24	0.23	0.01	0.22	0.09	0.16	0.06	0.01	0.02	0.01	0.028
	SSP5-8.5 in 2075	0.25	0.25	0.01	0.24	0.10	0.18	0.06	0.01	0.02	0.01	0.031

3.2 Sub-National Losses by Territorial Authority for 2025

Table 3.3 summarises the AAL in 2025, expressed in NZD$ millions, across key sectors for the 10 territorial authorities with the highest losses. The results highlight both the geographic concentration of risk and the relative contribution of different infrastructure classes to total losses.

Across the top 10 territorial authorities, total losses range from NZD $20.44 million to NZD $101.72 million per annum, indicating substantial variation in exposure and vulnerability.

Auckland records the highest total losses at NZD $101.72 million, significantly exceeding all other territorial authorities. Christchurch City follows with NZD $65.17 million, while Palmerston North City (NZD $39.53 million) and Napier City (NZD $34.36 million) also show elevated losses.

The remaining territorial authorities, including Waikato District, Whakatāne District, Thames-Coromandel District, Kaipara District, Tauranga City and Lower Hutt City, exhibit total losses in the range of approximately NZD $20–26 million.

This distribution reflects both the value of infrastructure assets (particularly in Auckland and Christchurch) and differing hazard-exposure profiles.

Across all regions, network infrastructure – particularly water, electricity and transport – accounts for a substantial share of total losses:

- The water and electricity networks are consistently among the largest contributors. For example, in Auckland, water (NZD $21.41 million) and electricity (NZD $20.28 million) together account for over 40% of total losses.
- Local roads also represent a significant component, particularly in Christchurch City (NZD $8.86 million) and Napier City (NZD $5.96 million).
- Central roads and rail contributions vary more significantly by region, with notably high central government road losses in Kaipara District (NZD $5.67 million) and Thames-Coromandel District (NZD $3.06 million), suggesting concentrated exposure of roads in high-hazard areas.
- Telecommunications losses are minimal across all authorities, generally contributing less than NZD $0.30 million, indicating relatively lower vulnerability within this sector.

Vertical infrastructure and private buildings show a different pattern, with private buildings consistently dominating this category:

- Private buildings represent the single largest contributor to total losses in most regions, including Auckland (NZD $36.82 million), Christchurch City (NZD $29.13 million) and Tauranga City (NZD $10.63 million).
- Education infrastructure is particularly significant in Palmerston North City (NZD $6.34 million), standing out relative to other regions.
- Government and hospital assets contribute comparatively smaller amounts, although Palmerston North City shows elevated losses in both government (NZD $3.69 million) and hospitals (NZD $0.76 million).

Overall, vertical infrastructure and private buildings contribute a substantial share of total losses, but its composition varies more across regions than network infrastructure.

The data highlight notable differences in the composition of losses between territorial authorities:

- Urban centres (e.g. Auckland, Christchurch) are characterised by high absolute losses across both the network and private-building sectors, reflecting large asset exposures.

- Provincial and coastal districts (e.g. Thames-Coromandel, Kaipara, Whakatāne) show relatively higher loss contributions from transport infrastructure, particularly central government roads, indicating potential vulnerability of critical access routes.
- Palmerston North City stands out for its relatively high losses in education and government infrastructure, suggesting a concentration of public assets in hazard areas.

Table 3.4 summarises AAL as a percentage of total asset value for flood and coastal-flooding hazards in 2025 for the 10 most relatively exposed territorial authorities. This normalised view highlights areas where infrastructure is most vulnerable relative to its total value, rather than in absolute monetary terms.

Total relative losses across the top 10 territorial authorities range from 0.11% to 0.20% of total asset value.

Wairoa District exhibits the highest relative losses at 0.20%, indicating the greatest proportional exposure despite not appearing among the highest in absolute loss terms. Kaipara District and Whakatāne District follow at 0.18%, with several other districts – Hauraki, Napier and Ōpōtiki – at 0.17%. Buller District (0.15%) and Thames-Coromandel District (0.14%) show moderately high relative losses, while Palmerston North City (0.12%) and Kawerau District (0.11%) represent the lower end of the top 10.

This distribution contrasts with the absolute loss results, highlighting that smaller or less-urbanised districts often experience higher proportional impacts.

As with absolute losses, network infrastructure dominates relative losses, particularly water, electricity and local roads:

- Water infrastructure consistently shows the highest proportional losses, reaching 2.76% in Wairoa District and exceeding 1.5% in most regions.
- Electricity networks also exhibit high relative losses, with values up to 2.42% (Wairoa District) and generally above 1% across most authorities.
- Local roads are another key contributor, with losses exceeding 1% in many districts, including Wairoa (1.74%), Kaipara (1.55%) and Napier (1.55%).
- Central Government roads and rail show more variability:
    - Central Government roads are particularly significant in Kaipara District (0.99%) and Thames-Coromandel District (0.40%).
    - Rail losses are notably high in Hauraki District (2.21%), indicating concentrated exposure of rail infrastructure in that region.
- Telecommunications losses remain minimal across all regions (≤0.08%), suggesting comparatively lower relative vulnerability.

Relative losses for vertical infrastructure and private buildings are generally lower than for network assets but show important regional variation:

- Government asset losses are significant in some districts, particularly Palmerston North City (0.73%) and Buller District (0.66%).
- Hospitals show elevated relative losses in Buller District (0.38%) and Ōpōtiki District (0.23%), indicating potential sensitivity of critical health infrastructure in these areas.
- Education infrastructure is most prominent in Palmerston North City (0.37%), reflecting the concentration of educational assets.

- Private buildings exhibit relatively low proportional losses across all regions (generally ≤0.09%), despite being a major contributor in absolute terms.

The results highlight distinct regional patterns:

- Highly exposed districts (e.g. Wairoa, Kaipara, Ōpōtiki) show consistently high losses across multiple network sectors.
- Transport-driven risk is evident in regions such as Hauraki (rail) and Kaipara (central roads).
- Mixed infrastructure exposure is observed in Palmerston North City, where vertical infrastructure (government and education) contributes a larger share of relative losses compared to other regions.
- Overall, the data indicate that relative risk is not solely driven by asset values but by the intersection of exposure and hazard.

Table 3.3 Summary of average annual loss (in million NZD$) per infrastructure sector for flood and coastal flooding in 2025. The top 10 territorial authorities are shown in terms of total.

Territorial Authority	**Networks**						**Vertical**				**Total**
	Water	**Electricity**	**Telecommunications**	**Local Roads**	**Central Roads**	**Rail**	**Government**	**Hospitals**	**Education**	**Private Buildings**	
Auckland	21.41	20.28	0.30	13.43	3.59	1.46	3.40	0.22	0.80	36.82	101.72
Christchurch City	11.09	11.39	0.14	8.86	1.18	0.35	1.15	0.22	1.67	29.13	65.17
Palmerston North City	5.63	7.29	0.10	3.29	0.28	0.22	3.69	0.76	6.34	11.92	39.53
Napier City	8.36	8.82	0.11	5.96	0.50	0.22	0.39	0.03	0.42	9.55	34.36
Waikato District	4.81	5.91	0.09	2.72	1.65	1.78	0.52	0.00	0.29	8.16	25.95
Whakatane District	4.60	4.99	0.07	2.86	1.27	0.65	0.31	0.02	0.32	10.24	25.32
Thames-Coromandel District	3.51	2.96	0.05	2.18	3.06	0.00	0.88	0.03	0.41	9.41	22.48
Kaipara District	4.03	3.13	0.05	2.46	5.67	0.47	0.49	0.01	0.56	5.50	22.36
Tauranga City	3.11	3.34	0.04	2.28	0.75	0.21	0.71	1.05	0.06	10.63	22.17
Lower Hutt City	3.15	3.97	0.05	2.25	0.06	0.17	0.39	0.03	0.29	10.09	20.44

Table 3.4 Summary of average annual loss as percentage (%) of total value per infrastructure sector for flood and coastal flooding in 2025. The top 10 territorial authorities are shown in terms of total.

Territorial Authority	**Networks**						**Vertical**				**Total**
	Water	**Electricity**	**Telecommunications**	**Local Roads**	**Central Roads**	**Rail**	**Government**	**Hospitals**	**Education**	**Private Buildings**	
Wairoa District	2.76	2.42	0.08	1.74	0.15	0.53	0.12	0.17	0.10	0.07	0.20
Kaipara District	2.28	1.26	0.05	1.55	0.99	0.49	0.27	0.02	0.25	0.05	0.18
Whakatāne District	1.84	1.43	0.05	1.28	0.25	0.50	0.08	0.02	0.07	0.09	0.18
Hauraki District	1.74	1.14	0.04	1.16	0.43	2.21	0.09	0.02	0.12	0.08	0.17
Napier City	1.95	1.47	0.04	1.55	0.36	0.61	0.14	0.09	0.06	0.06	0.17
Ōpōtiki District	1.90	1.60	0.05	1.21	0.14	0.00	0.10	0.23	0.09	0.07	0.17
Buller District	1.91	1.33	0.04	1.42	0.13	0.20	0.66	0.38	0.13	0.07	0.15
Thames-Coromandel District	1.60	0.96	0.03	1.11	0.40	0.00	0.48	0.03	0.18	0.07	0.14
Palmerston North City	0.97	0.90	0.03	0.63	0.14	0.46	0.73	0.15	0.37	0.04	0.12
Kawerau District	0.82	0.79	0.02	0.68	0.17	0.26	0.10	0.16	0.06	0.06	0.11

3.3 Sub-National Losses by Territorial Authority for 2075

Table 3.5 summarises modelled infrastructure losses for the top 10 territorial authorities by increase in loss between 2025 and 2075 under the SSP3-7.0 emissions scenario. Across all regions assessed, increases in expected infrastructure losses are observed, with the magnitude of change varying significantly by location.

Overall, the results indicate a consistent upwards trend in infrastructure risk, with all of the top 10 territorial authorities experiencing increases of at least 80% relative to 2025 baseline levels. The largest relative increase is observed in Hauraki District, where losses rise from NZD $14.73 to $50.70 million, representing a 244% increase. This suggests a more than threefold escalation in infrastructure risk under the future climate scenario.

Nelson City also exhibits a pronounced increase (166%), with losses increasing from NZD $10.55 to 28.03 million. Buller District and Whakatāne District show similar proportional increases of 117% and 116%, respectively, indicating a doubling or more of infrastructure losses by 2075. Napier City, while already having relatively high baseline losses (NZD $34.36 million), is projected to reach NZD $73.19 million, corresponding to a 113% increase.

Moderate increases are observed in Grey District and Waimakariri District, both at 95%, and Lower Hutt City at 93%. Although the proportional increases are slightly lower than in other regions, the absolute increases remain significant, particularly for Lower Hutt City, where losses nearly double from NZD $20.44 million to $39.47 million.

Table 3.5 Total average annual loss for all infrastructure sectors for flood and coastal flooding in 2025 and 2075 under SSP3-7.0. The top 10 territorial authorities are shown, ranked by percentage increase.

Territorial Authority	Total Infrastructure Losses in 2025 (NZD$ million)	Total Infrastructure Losses in 2075 under SSP3-7.0 (NZD$ million)	Increase (% of 2025)
Hauraki District	14.73	50.70	244
Nelson City	10.55	28.03	166
Buller District	9.39	20.39	117
Whakatāne District	25.32	54.78	116
Napier City	34.36	73.19	113
Grey District	4.50	8.79	95
Waimakariri District	19.78	38.54	95
Lower Hutt City	20.44	39.47	93
Horowhenua District	7.09	12.90	82
Tauranga City	22.17	39.90	80

4.0 Discussion

This study provides a national and sub-national assessment of current and future climate-driven losses to infrastructure from inland and coastal flooding across New Zealand. By extending the Phase 1 national-scale analysis (Horspool et al. 2025) to include future climate scenarios and territorial authority-level disaggregation, the results provide new insight into how infrastructure risk is likely to evolve over coming decades, where that risk is concentrated and which sectors are most exposed.

4.1 Observed Losses from Past Events

Observed losses from flooding and coastal inundation in New Zealand are typically derived from insurance-claims data, primarily compiled by the Insurance Council of New Zealand and analysed in subsequent studies. These data provide the most consistent long-term record of losses from natural-hazard events, although they represent only insured losses and therefore under-estimate total economic damages. Comparison of past losses can be used to benchmark the modelling undertaken in this study.

Long-term analyses of insured natural-hazard losses prior to 2022 indicate that New Zealand experiences AAL of approximately NZD $624–657 million across all hazards, with a high degree of variability driven by infrequent but catastrophic earthquake events. When earthquake losses are excluded to isolate weather-related hazards – of which flooding is the dominant component – the observed average annual insured loss reduces to approximately NZD $135 million. This figure is widely interpreted as a proxy for weather-driven hazards, including fluvial, pluvial and coastal flooding prior to 2022 (McAneney et al. 2022).

More recent insurance-industry reporting calculates slightly higher annualised losses when recent events are included, suggesting that typical storm-related annual insured losses of infrastructure are in the order of NZD $200–300 million, with recent years showing variability between NZD $200 and 400 million depending on event occurrence.[10]

However, these averages mask significant inter-annual variability. For example, major compound flood events, such as the 2023 Auckland Anniversary floods and Cyclone Gabrielle, each generated insured losses in the order of NZD $1.7–1.9 billion, illustrating the highly skewed annual loss distribution typical of natural-hazard events . Consequently, while annualised losses provide a useful long-term expectation, realised losses in any given year may deviate substantially from the mean, as observed in recent years.

These reported estimated losses are similar in magnitude, albeit slightly lower that those estimated in this study for the year 2025. Given that the observed reported losses documented above are only for insured losses, the total losses observed from the past decade may be more similar to the modelled estimates from this study. This gives confidence that the modelled estimates from this study are similar to those being reported for recent years.

4.2 National-Scale Trends and Climate Sensitivity

At the national level, the results from this study show a clear and consistent increase in AAL across all infrastructure sectors and private buildings under future climate scenarios. For flooding, total losses increase by approximately 45–53% between 2025 and 2075, depending on the emissions pathway. For coastal flooding, proportional increases are substantially larger, with total AAL more than doubling under higher emissions scenarios. This contrast highlights the strong sensitivity of coastal flooding risk to sea-level rise and reinforces the long-term significance of coastal exposure for New Zealand’s infrastructure.

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[10] https://www.bonded.co.nz/blog/post/145404/new-zealand-recorded-minimal-insured-losses-from-natural-disasters-in-2024/

While absolute losses from inland flooding remain higher than those from coastal flooding across all time horizons considered, the faster rate of increase in coastal-flooding losses suggests that coastal hazards will become an increasingly important contributor to national infrastructure risk in the second half of this century. This finding is consistent with the non-linear influence of mean sea-level rise on flood frequency and extent, whereby relatively small increases in sea level can result in large increases in exposure and damage.

Across both hazards, network infrastructure – particularly electricity, water and transport – dominates total losses and drives much of the projected increase over time. These sectors combine high asset values with widespread spatial exposure and sensitivity to flood-related hazards, making them key contributors to national-scale risk. In contrast, vertical-infrastructure categories such as hospitals, education and government buildings contribute smaller absolute losses, reflecting both their lower total asset value and, in many cases, lower exposure and vulnerability to flooding.

4.3 Relative Losses and Infrastructure Vulnerability

When losses are expressed as a percentage of total asset value, a different pattern emerges. Although total system-wide relative losses remain small (generally below 0.05% of asset value at the national scale), network infrastructure consistently shows higher proportional impacts than vertical infrastructure and private buildings. Rail, water, electricity and local roads exhibit the highest relative losses under both inland and coastal flooding, indicating that these assets are disproportionately vulnerable relative to their value.

The relatively low proportional losses for private buildings, despite their large contribution to absolute losses, reflect the very large total value of the building stock nationally. This distinction between absolute and relative loss metrics is important for interpretation: absolute losses are more relevant for understanding total financial impact, whereas relative losses provide insight into relative risk at the sector and regional level.

4.4 Regional Patterns and Sub-National Differentiation

Disaggregation of results by territorial authority reveals strong spatial variability in both absolute and relative losses. Large urban centres, such as Auckland and Christchurch, consistently rank highest in absolute AAL, reflecting the concentration of infrastructure assets and population. However, smaller and less-urbanised districts often experience higher relative losses as a percentage of total asset value. Districts such as Wairoa, Kaipara, Whakatāne and Ōpōtiki emerge as having higher risk in proportional terms, indicating that infrastructure in these areas is more exposed to flooding relative to its total value.

These findings highlight that infrastructure risk is not solely a function of asset concentration but also of location, hazard exposure and infrastructure composition. In some regions, losses are driven by extensive transport networks exposed to flooding (e.g. central government roads in Kaipara and Thames-Coromandel), while, in others, vulnerability is concentrated in specific sectors, such as rail or water infrastructure. Palmerston North City presents a contrasting case, with relatively high losses in education and government infrastructure, reflecting the concentration of public assets located in flood zones.

Projected changes between 2025 and 2075 further emphasise regional differences in climate sensitivity. Some districts experience increases in total losses exceeding 100% under SSP3-7.0, while others show more moderate growth. These differences are influenced by both the underlying hazard regime and the spatial distribution of assets, underscoring the importance of regionally specific adaptation and investment strategies.

4.5 Interpretation, Limitations and Use of Results

The results presented in this study are intended for strategic, national- and regional-scale decision-making rather than site-specific design or local planning and decision-making. The modelling approach necessarily incorporates a range of simplifications, particularly in the representation of infrastructure exposure and valuation for sectors where detailed national datasets are not available. The use of population density as a proxy for infrastructure distribution, as well as the application of composite vulnerability curves, introduce averaging effects that limit the suitability of the results for local-scale application.

Similarly, the hazard models used for both inland and coastal flooding are national in scope and do not capture all local-scale processes, such as detailed drainage networks, dynamic coastal processes or locally specific flood-protection performance. These limitations mean that losses may be over- or under-estimated in specific locations, although the effects are expected to average out at national and regional scales.

Despite these limitations, the consistency of trends across sectors, hazards and scenarios provides confidence in the overall conclusions. The results offer a robust baseline for comparing infrastructure risk across regions and sectors, assessing the influence of different emissions pathways and identifying priorities for more detailed analysis.

4.6 Implications for Infrastructure Investment

The findings have several implications for long-term infrastructure planning and investment in New Zealand.

- First, the projected increase in losses under all climate scenarios highlights the importance of integrating climate-change considerations into infrastructure decision-making, even under moderate emissions pathways.
- Second, the dominance of network infrastructure losses suggests that resilience investments in water, electricity and transport systems are likely to yield substantial risk-reduction benefits.
- Third, the strong regional variability in both absolute and relative losses across hazards, infrastructure types and regions, indicates targeted strategies that reflect that local hazard exposure, infrastructure composition and capacity are needed.

Finally, the results reinforce the value of national-scale loss modelling as a screening tool to identify priority sectors and locations for more detailed, component-level risk assessments and adaptation planning.

5.0 Conclusion

This study provides a national-scale assessment of future climate-driven losses to infrastructure from inland and coastal flooding in New Zealand that is disaggregated by territorial authority and infrastructure sector. By integrating probabilistic hazard models with climate projections under multiple SSPs, the analysis offers a consistent framework for understanding how infrastructure risk is expected to evolve from 2025 to 2075.

The results show that average annual losses increase substantially across all infrastructure sectors and regions under future climate scenarios. Inland flooding remains the dominant contributor to total losses over the period considered, but coastal flooding exhibits much larger proportional increases, particularly under higher emissions pathways. Network infrastructure, especially electricity, water and transport, accounts for the majority of losses and displays the highest relative vulnerability, while private buildings dominate absolute losses due to their large asset value.

At the sub-national level, the analysis reveals significant regional variability. Large urban centres experience the highest absolute losses, whereas smaller and more rural districts often face higher proportional impacts. These findings demonstrate that infrastructure risk is shaped not only by asset scale, but also by exposure, hazard characteristics and infrastructure composition.

While the modelling approach includes necessary simplifications and is not intended for local-scale application, the results provide an evidence base for national and regional infrastructure planning. The outputs can be used to prioritise sectors and locations for further investigation, inform long-term investment strategies and support the development of targeted adaptation and resilience measures.

6.0 References

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APPENDICES

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APPENDIX 1 Description of Data Deliverables

The following table lists the electronic (*.csv* format) data files supplied to the New Zealand Infrastructure Commission Te Waihanga as deliverables of this project.

Table A1.1 List of digital deliverables.

Name	Description
Task 1 and 2	Loss results from this study disaggregated by territorial authority and building-use category. One file per year and Shared Socioeconomic Pathway (SSP) combination. One file for average annual loss (AAL) as absolute dollar losses (NZD$ million) and one file for AAL as a percentage of total value.
Task 3A	Loss results from Phase 1 (Horspool et al. 2025) disaggregated by regional council and infrastructure sector disaggregation.
Task 3B	Loss results from this study disaggregated by territorial authority and infrastructure sector. One file per year and SSP combination. One file for AAL as absolute dollar losses (NZD$ million) and one file for AAL as a percentage of total value.

APPENDIX 2 Results Disaggregated by Hazard and Infrastructure Type

Further results are summarised here than those in Section 3. These include the disaggregation of losses by hazard and infrastructure type for different Shared Socioeconomic Pathway (SSP) scenarios and years.

Loss results are reported at national and territorial authority levels for years 2025, 2035, 2045, 2055 and 2075 under the SSP2-4.5 (medium greenhouse gas emissions), SSP3-7.0 (high greenhouse gas emissions) and SSP5-8.5 (very high greenhouse gas emissions) scenarios.

For private buildings, results are also disaggregated by use category according to the classification in Scheele et al. (2023). For horizontal and vertical infrastructure (e.g. hospitals, education, government), results are disaggregated by infrastructure sector as per Horspool et al. (2025).

As the results have multiple variables, the results can be presented and interpreted in different ways. For a infrastructure-hazard combination (e.g. coastal flooding on vertical infrastructure), results for a single SSP across multiple years shows the change in loss over time for that climate scenario. If the losses for the same infrastructure-hazard combination are viewed for a given year (e.g. 2075) for different SSPs, these results can show the variation in future losses from different climate scenarios.

A2.1 Fluvial and Pluvial Flooding

Figure A2.1 and Table A2.1 show the national-level losses, as average annual loss (AAL) (NZD$ million), for the various infrastructure sectors.

At the national level, key observations of the results are:

- **Under SSP2-4.5:**
    - All sectors increase in AAL by 2075, with the highest increase occurring in telecommunications, rail, water and electricity. The smallest increase is for hospitals.
    - The largest increase in AAL across all sectors occurs primarily by 2045, with only slight increases in AAL between 2045 and 2075 reflecting the emissions pathway in this SSP.
    - The increase in AAL percentage is relatively consistent across all sectors (35–64% increase) between 2025 and 2075.
- **Under SSP3.7.5:**
    - All sectors increase in AAL by 2075, with the highest increase occurring in telecommunications, rail, water and electricity. The smallest increase is for hospitals.
    - The largest increase in AAL across all sectors occurs primarily by 2045, with moderate increases in AAL between 2045 and 2075. The increase between 2045 and 2075 is larger than that of SSP2-4.5.
    - The increase in AAL percentage is relatively consistent across all sectors (40–66% increase) between 2025 and 2075.
- **Under SSP5-8.5:**
    - All sectors increase in AAL by 2075, with the highest increase occurring in telecommunications, rail, water and electricity. The smallest increase is in hospitals and government.
    - SSP5-8.5 sees a steady increase in AAL by 2045 and a continued rise in AAL by 2075. The increase in AAL by 2075 is higher than that of both SSP2-4.5 and SSP5-8.5.

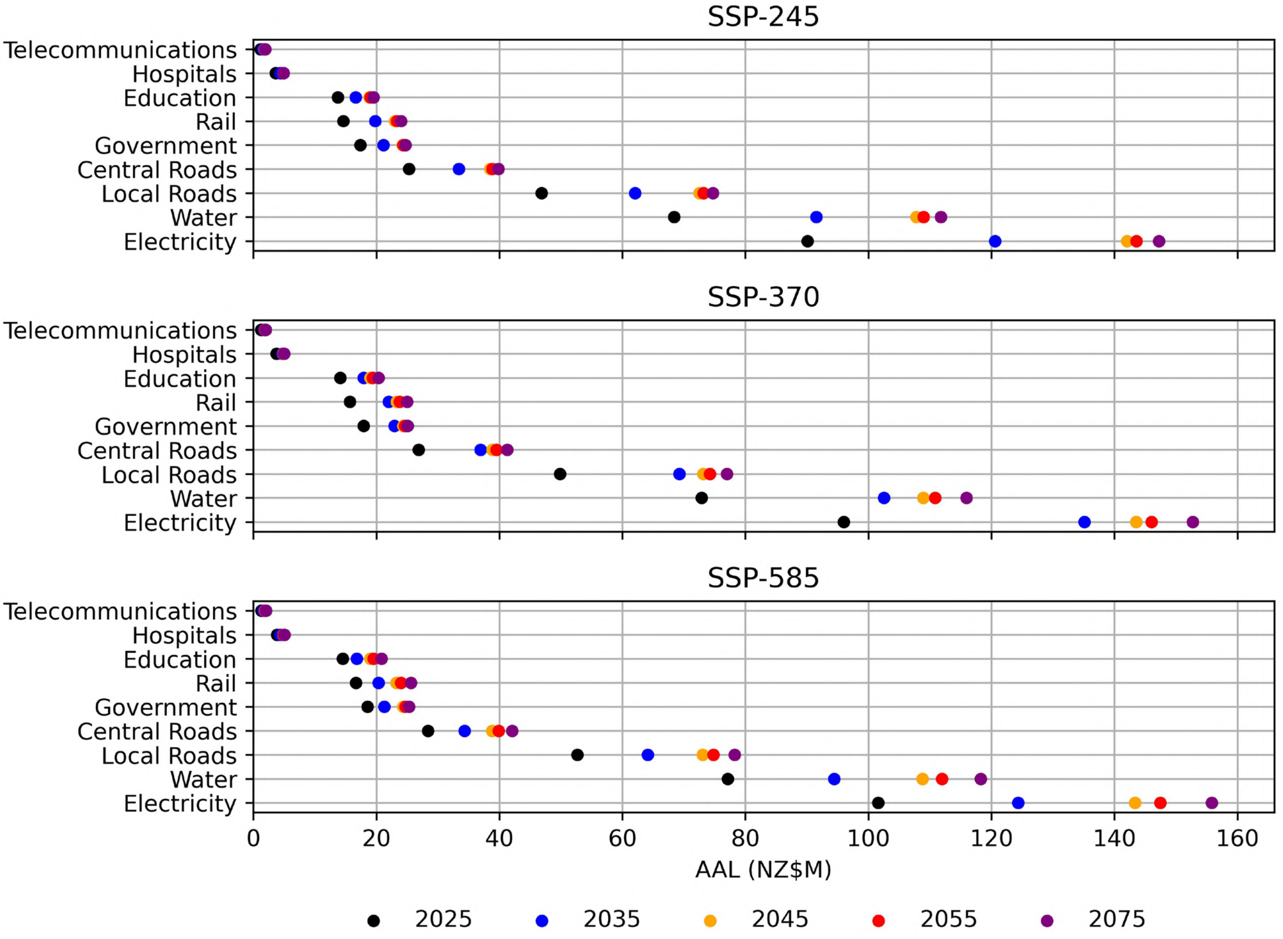

Figure A2.1 Infrastructure sector average annual losses (AAL) in NZD$ million at the national level for flooding under temperature-change scenarios.

Table A2.1 Infrastructure sector average annual losses (AAL) in NZD$ million at the national level for flooding under temperature-change scenarios.

Infrastructure Sector	2025	2035	2045	2055	2075
SSP2-4.5					
Electricity	90.10	120.56	142.03	143.56	147.24
Water	68.42	91.52	107.79	108.96	111.79
Local Roads	46.85	62.03	72.52	73.17	74.71
Central Roads	25.29	33.37	38.47	38.86	39.83
Government	17.37	21.15	24.25	24.38	24.70
Rail	14.60	19.79	23.03	23.31	23.99
Education	13.71	16.63	18.84	19.03	19.54
Hospitals	3.62	4.38	4.87	4.88	4.90
Telecommunications	1.15	1.55	1.83	1.85	1.91
SSP3-7.0					
Electricity	95.98	135.09	143.51	146.01	152.73
Water	72.89	102.53	108.92	110.83	115.95
Local Roads	49.86	69.23	73.14	74.19	76.98
Central Roads	26.88	36.94	38.86	39.51	41.28
Government	17.90	22.95	24.38	24.61	25.09
Rail	15.68	21.97	23.29	23.76	25.00
Education	14.13	17.93	19.01	19.38	20.34
Hospitals	3.76	4.69	4.88	4.89	4.98
Telecommunications	1.23	1.74	1.85	1.89	1.99
SSP5-8.5					
Electricity	101.57	124.32	143.33	147.45	155.79
Water	77.12	94.40	108.79	111.94	118.26
Local Roads	52.67	64.09	73.06	74.80	78.24
Central Roads	28.38	34.34	38.79	39.89	42.05
Government	18.54	21.28	24.37	24.70	25.31
Rail	16.65	20.34	23.25	24.01	25.59
Education	14.50	16.82	18.98	19.53	20.84
Hospitals	3.84	4.37	4.88	4.90	5.03
Telecommunications	1.30	1.59	1.85	1.91	2.03

Results for vertical infrastructure (buildings) at the territorial authority level are noted in Figure A2.2, showing the top 10 territorial authorities by AAL (in 2025). The results show that Auckland, Christchurch and Palmerston North have the highest estimated AAL from flooding. Palmerston North and Auckland are the most sensitive to climate-change effects, showing increases in AAL across all three SSPs between 2025 and 2075, while Christchurch sees only small change in AAL between 2025 and 2075.

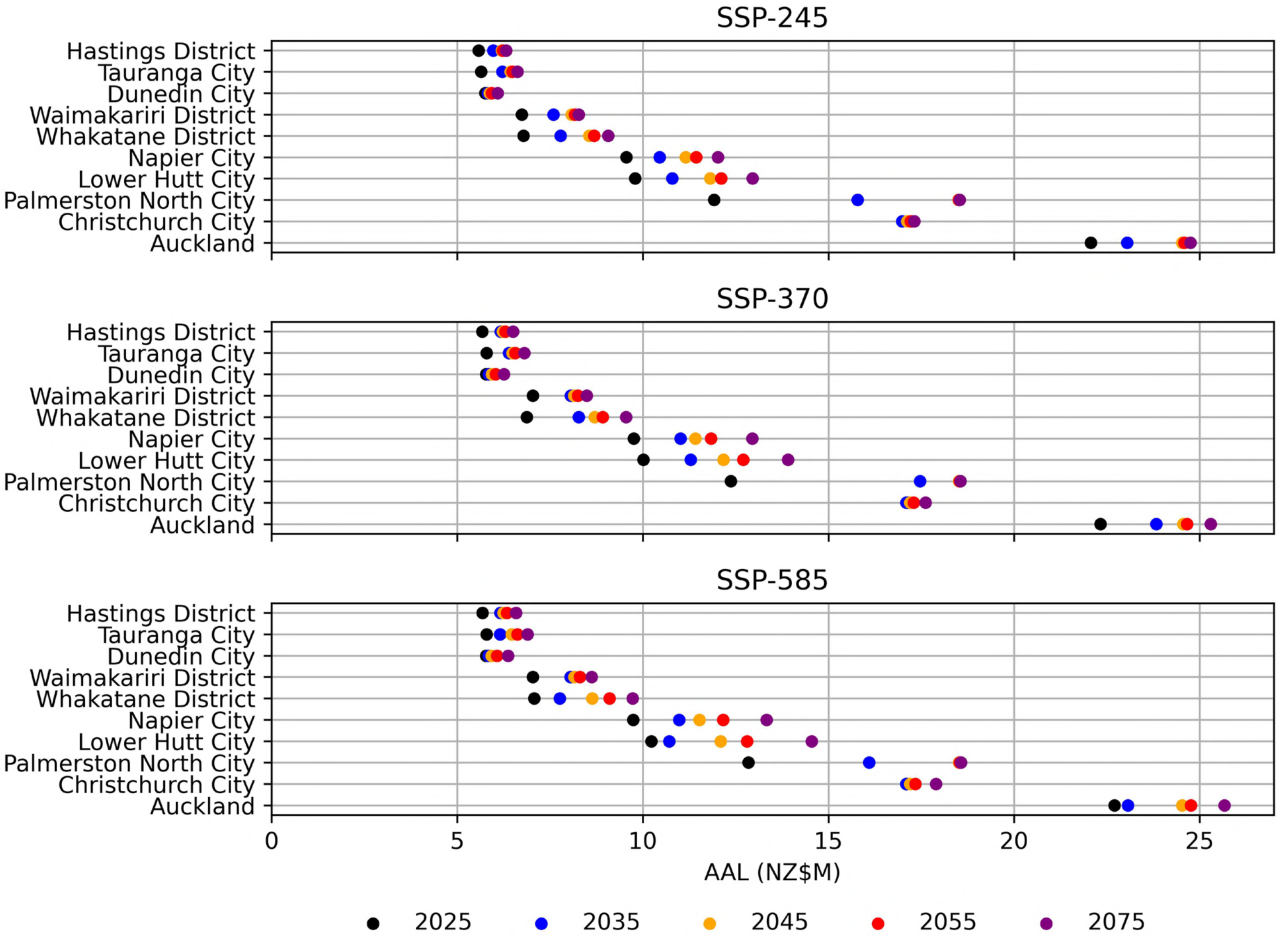

Figure A2.2 Vertical infrastructure (all buildings) average annual losses (AAL) in NZD$ million at the territorial authority level for flooding under temperature-change scenarios. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

Results for infrastructure at the sub-national level are shown in Figures A2.3–A2.8. The results shown are for the 10 territorial authorities with the highest AALs in 2025 for that sector.

Key observations include:

- Auckland, Christchurch and Palmerston North have the highest AALs for water, telecommunications, electricity and local government roads.
- For central government roads: Tasman, Waikato and Gisborne have the highest AALs.
- For rail: Waikato, Auckland and Tararua have the highest AALs.
- The increase in AALs under different climate scenarios shows that, similar to vertical infrastructure, the largest increase in AAL occurs by 2045, with small to moderate increases between 2045 and 2075.

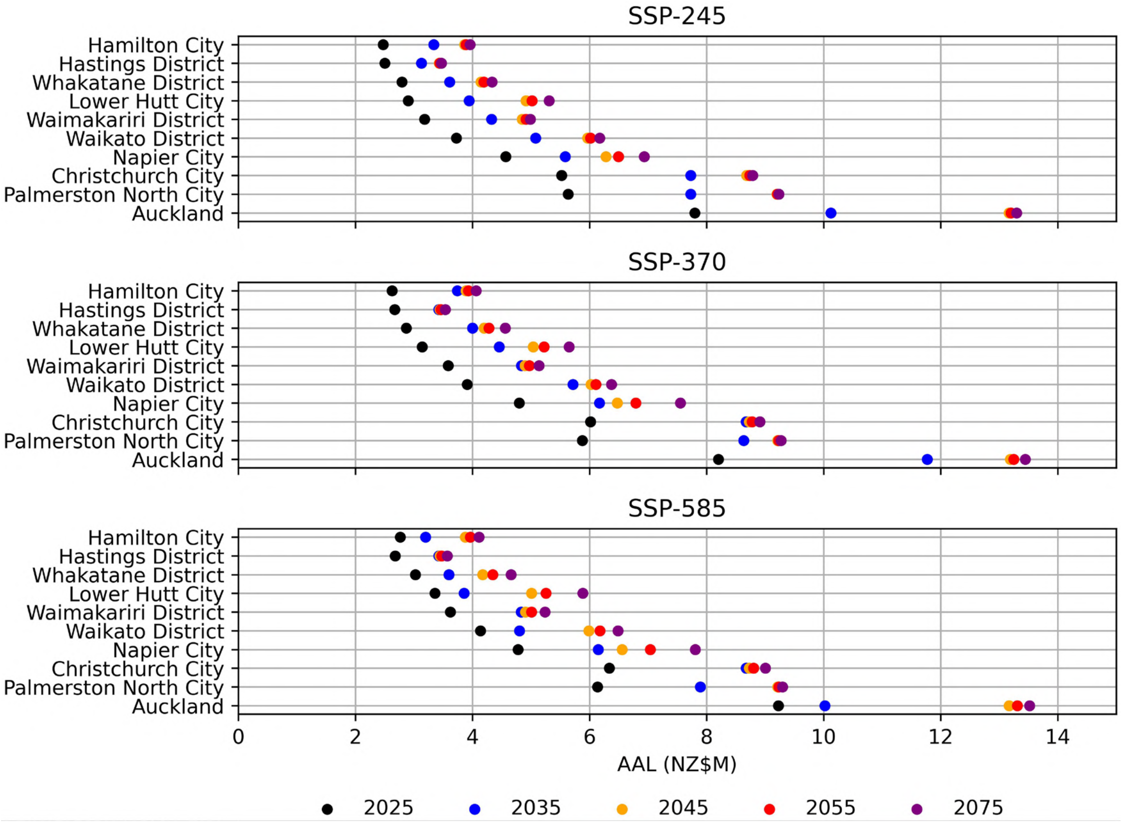

Figure A2.3 Water infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for flooding under temperature-change scenarios. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

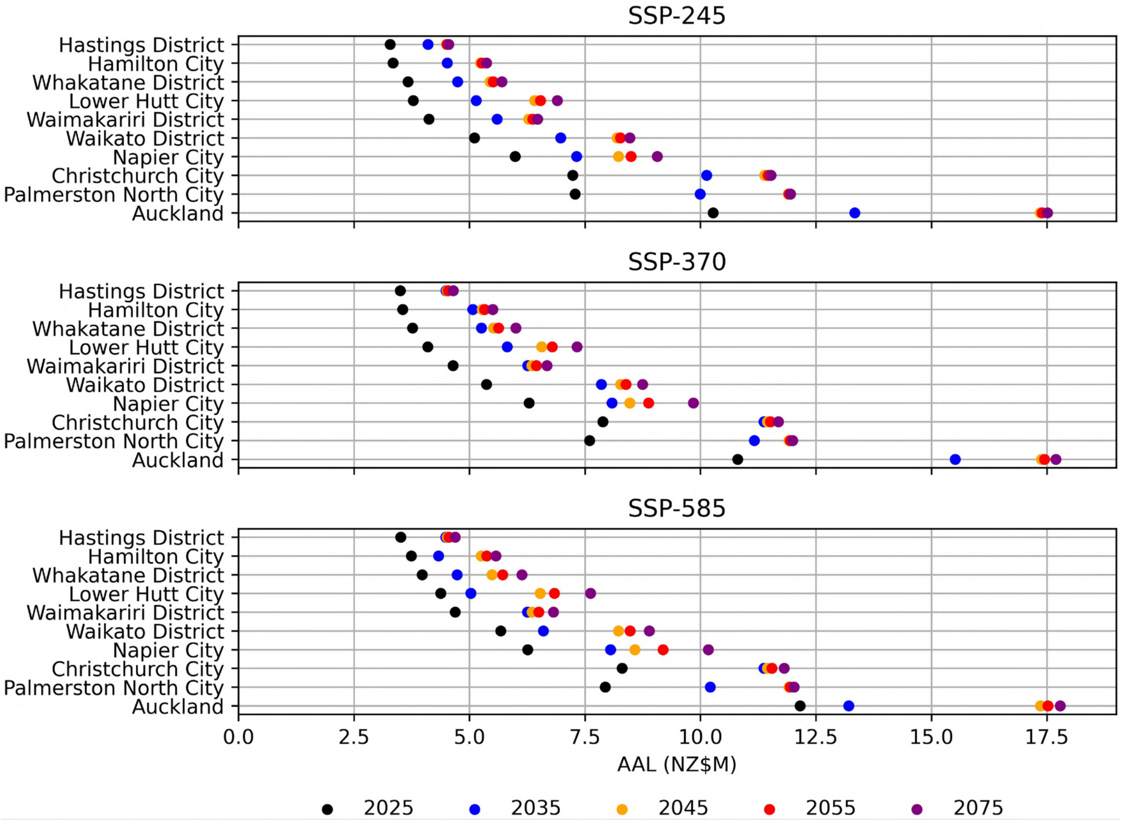

Figure A2.4 Electricity infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for flooding under temperature-change scenarios. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

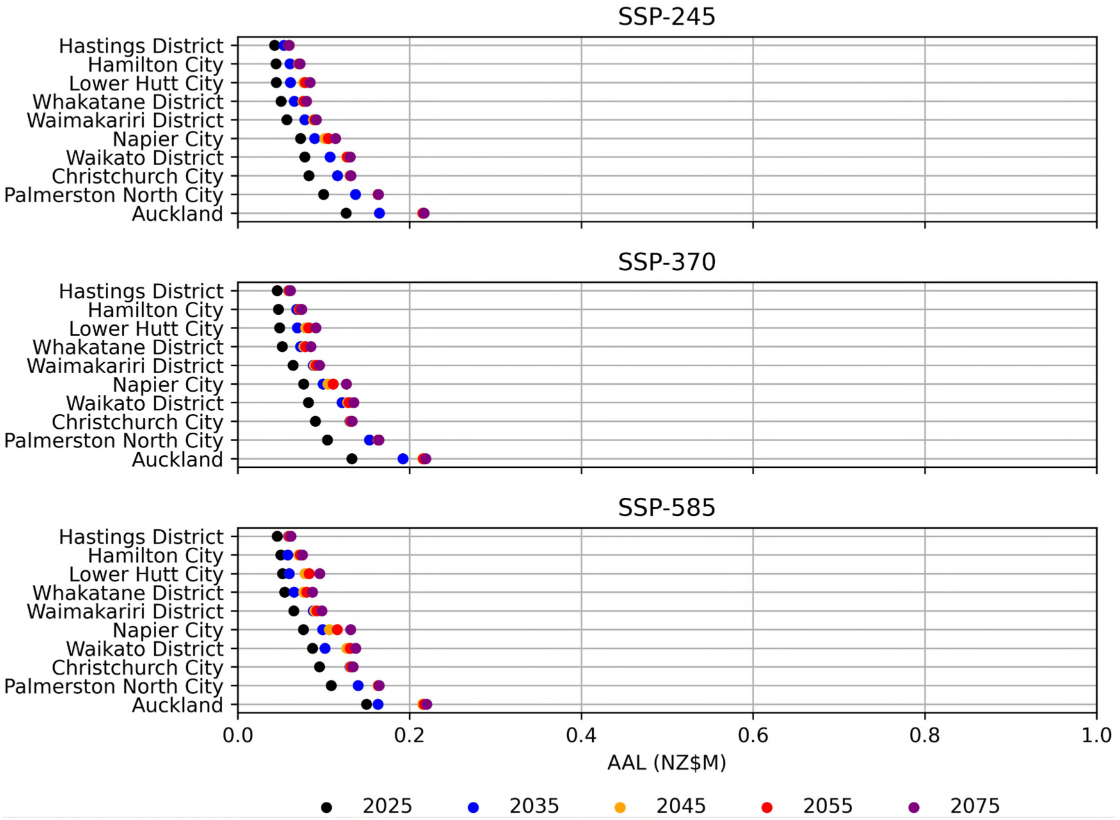

Figure A2.5 Telecommunications infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for flooding under temperature-change scenarios. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

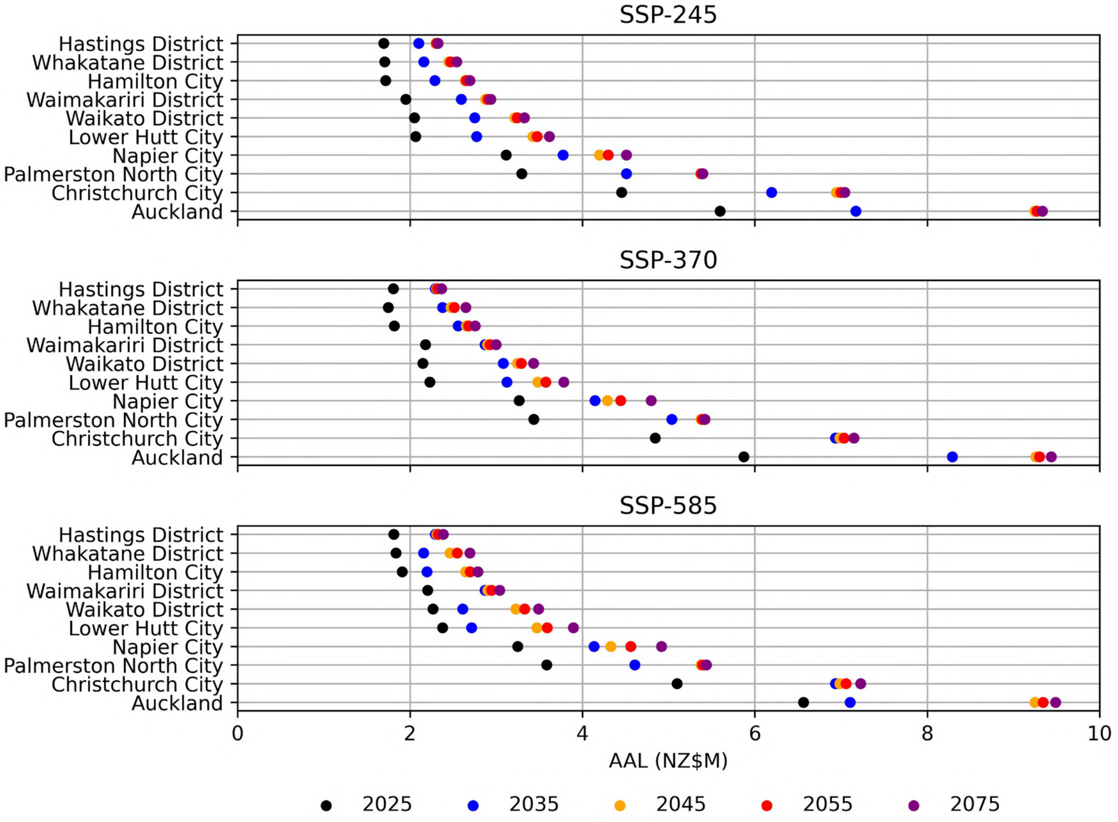

Figure A2.6 Local government road infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for flooding under temperature-change scenarios. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

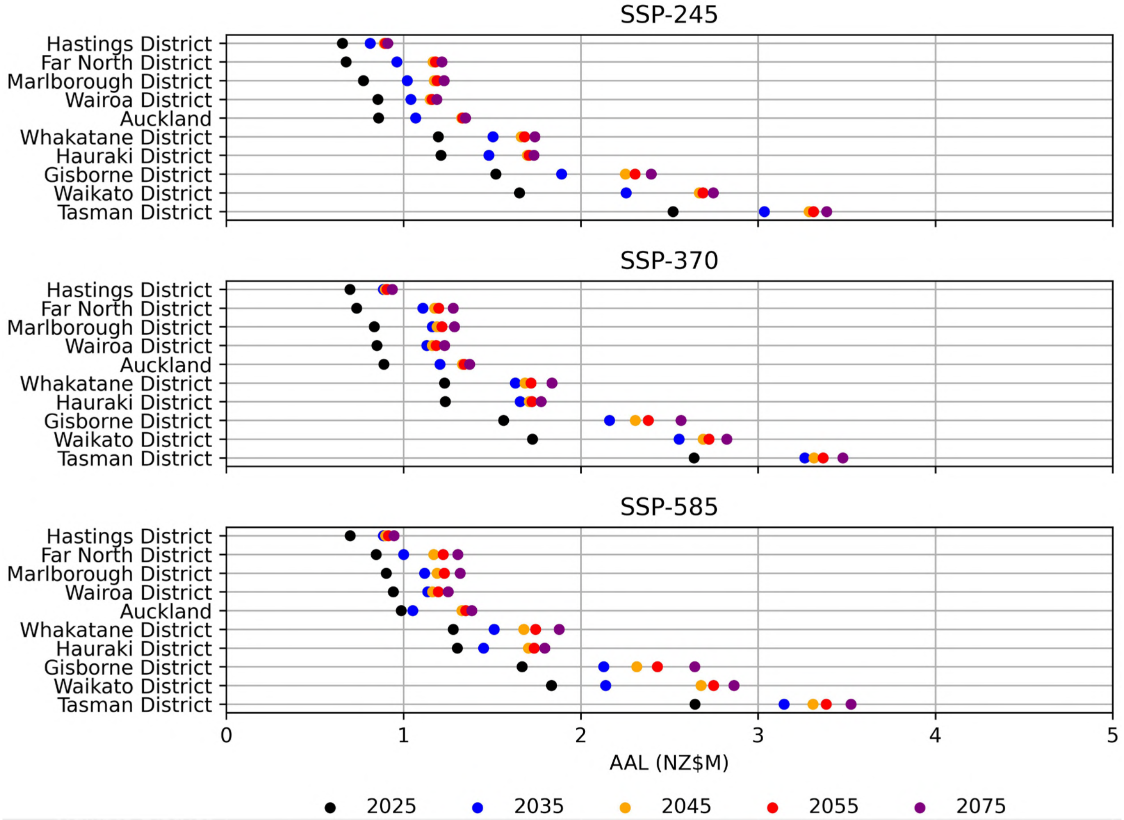

Figure A2.7 Central government road infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for flooding under temperature-change scenarios. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

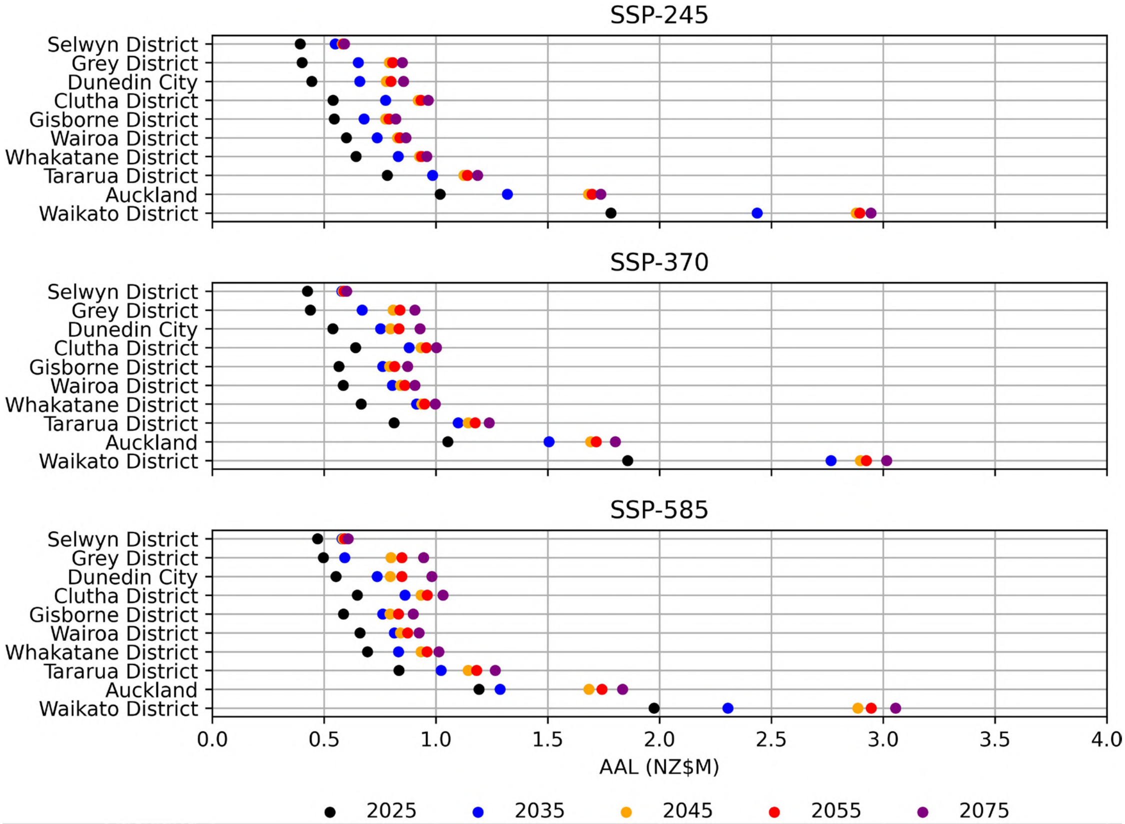

Figure A2.8 Rail infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for flooding under temperature-change scenarios. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

A2.2 Coastal Flooding

Figure A2.9 and Table A2.2 show the national-level losses as AAL (NZD$ million) for the various infrastructure sectors.

At the national-level, key observations of the results are:

- **Under SSP2-4.5:**
  - All sectors increase in AAL by 2075, with the highest increase percentage occurring in the government, education and hospital sectors. The smallest increase is for rail. However, all of these results are off a low absolute AAL.
  - Unlike flooding, AALs increase across all sectors at a relatively consistent rate, with the largest increase in AAL occurring between 2055 and 2075.
  - The increase in AAL percentage is relatively consistent across all sectors (35–64% increase) between 2025 and 2075.
- **Under SSP3.7.5:**
  - This SSP shows a much larger increase in AAL over time, with the largest increase occurring between 2055 and 2075.
  - There is some variability in increase in AAL between 2025 and 2055, which reflects the 'rocky road' nature of this SSP through regional variations in greenhouse emissions and subsequent mean sea-level rise.
- **Under SSP5-8.5:**
  - This SSP has the largest increase in AALs across all sectors. The largest increase occurs between 2055 and 2075, which is similar in size to the increase between 2025 and 2055.

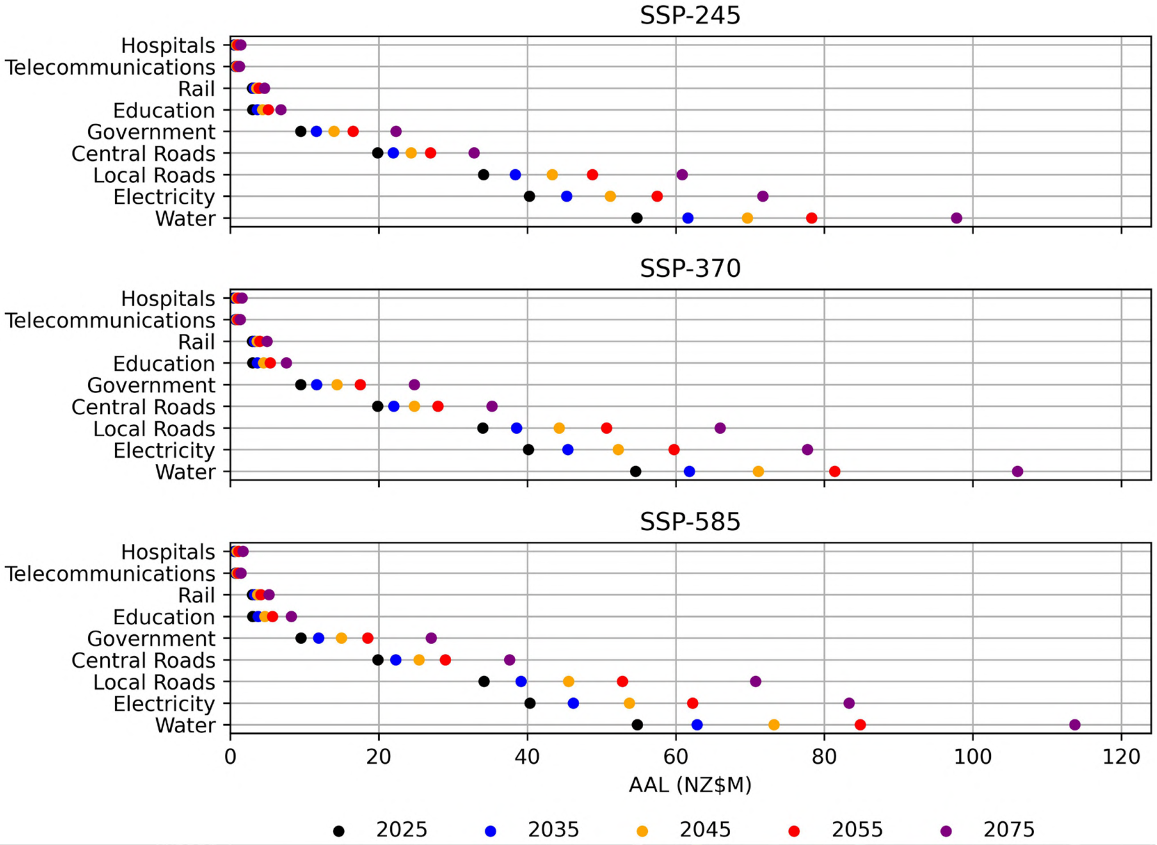

Figure A2.9 Infrastructure sector average annual losses (AAL) in NZD$ million at the national level for extreme-sea-level-driven coastal flooding and sea-level-rise scenarios.

Table A2.2 Infrastructure sector average annual losses (AAL) in NZD$ million at the national level for extreme-sea-level-driven coastal flooding and sea-level-rise scenarios.

Infrastructure Sector	**2025**	**2035**	**2045**	**2055**	**2075**
SSP2-4.5					
Electricity	54.72	61.60	69.63	78.29	97.77
Water	40.26	45.28	51.15	57.47	71.70
Local Roads	34.11	38.37	43.36	48.74	60.85
Central Roads	19.84	21.95	24.34	26.94	32.81
Government	9.49	11.59	13.95	16.51	22.29
Rail	3.00	3.62	4.33	5.09	6.79
Education	2.95	3.21	3.53	3.87	4.60
Hospitals	0.68	0.77	0.87	0.98	1.22
Telecommunications	0.52	0.66	0.82	1.00	1.39
SSP3-7.0					
Electricity	54.57	61.83	71.10	81.39	106.01
Water	40.15	45.46	52.22	59.73	77.71
Local Roads	34.00	38.52	44.28	50.65	65.95
Central Roads	19.84	22.00	24.79	27.94	35.23
Government	9.47	11.62	14.37	17.48	24.78
Rail	3.00	3.65	4.47	5.37	7.53
Education	2.96	3.24	3.59	3.98	4.94
Hospitals	0.68	0.77	0.89	1.02	1.33
Telecommunications	0.51	0.66	0.85	1.06	1.55
SSP5-8.5					
Electricity	54.81	62.86	73.19	84.84	113.71
Water	40.33	46.20	53.74	62.25	83.34
Local Roads	34.16	39.15	45.56	52.79	70.74
Central Roads	19.86	22.28	25.42	28.96	37.60
Government	9.50	11.89	14.97	18.48	27.03
Rail	3.01	3.73	4.65	5.67	8.20
Education	2.97	3.28	3.67	4.11	5.22
Hospitals	0.68	0.78	0.91	1.06	1.42
Telecommunications	0.52	0.68	0.88	1.12	1.71

Results for coastal-flooding losses for vertical infrastructure (buildings) at the territorial authority level are noted in Figure A2.10, showing the top 10 territorial authorities by AAL (in 2025). The results show that Auckland, Christchurch and Thames-Coromandel have the highest estimated AALs from coastal flooding. Christchurch, Tauranga, Whakatāne and Hauraki are the most sensitive to changes in climate, showing the largest increases in AAL across all three SSPs between 2025 and 2075.

Figure A2.10 Vertical infrastructure (all buildings) average annual losses (AAL) in NZD$ million at the territorial authority level for extreme-sea-level-driven coastal flooding and sea-level rise. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

Results for infrastructure at the sub-national level are shown in Figures A2.11–A2.16. The results shown are for the 10 territorial authorities with the highest AALs in 2025 for that sector.

Key observations include:

- Auckland, Christchurch, Invercargill and Napier have the highest AALs for the water, telecommunications, local government roads and electricity sectors.
- For central government roads: Kaipara, Auckland and Thames-Coromandel have the highest AALs.
- For rail: Auckland, Invercargill and Dunedin have the highest AALs.
- The increase in AALs under different climate scenarios shows that, similar to vertical infrastructure, the largest increase in AAL occurs by 2045, with small to moderate increases between 2045 and 2075.
- There is variability between territorial authorities in the percentage increase in AALs by 2075. Auckland, Christchurch, Napier and Hauraki have large increases in AAL between 2025 and 2075 across all three SSPs, while the Far North, Whangārei, Kaipara and Invercargill have smaller increases between 2025 and 2075.

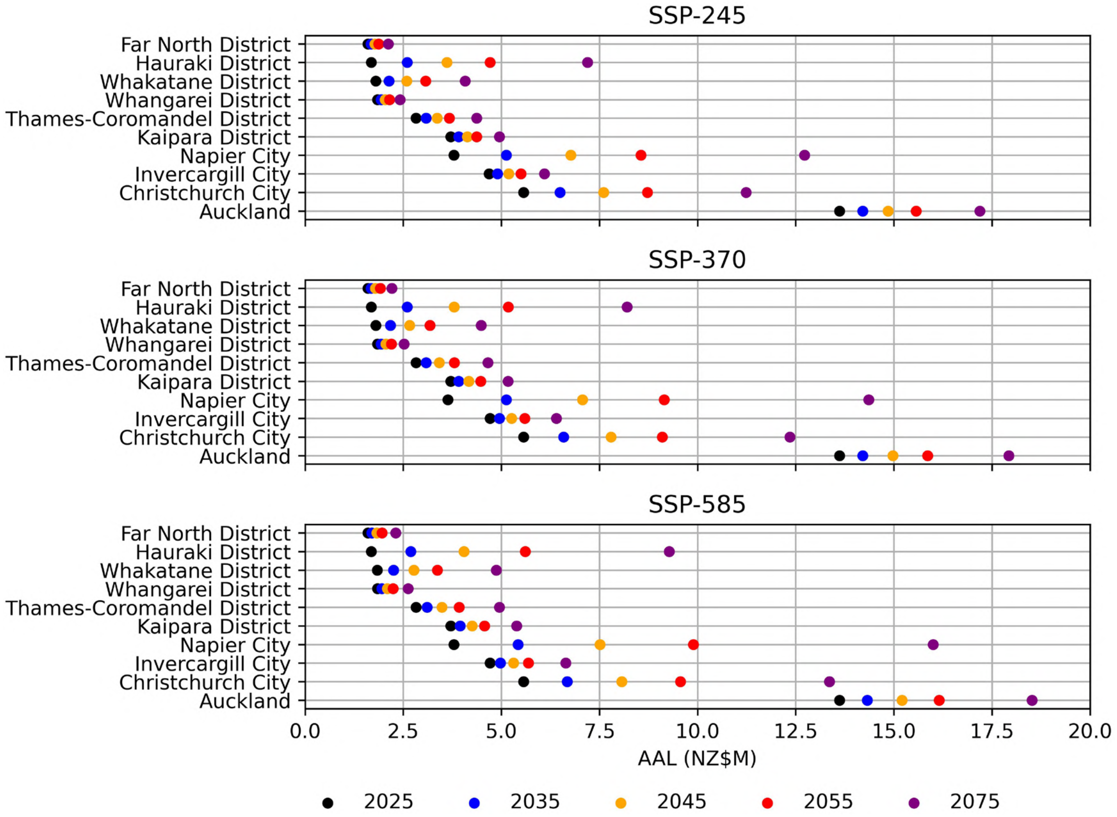

Figure A2.11 Water infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for extreme-sea-level-driven coastal flooding and sea-level rise. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

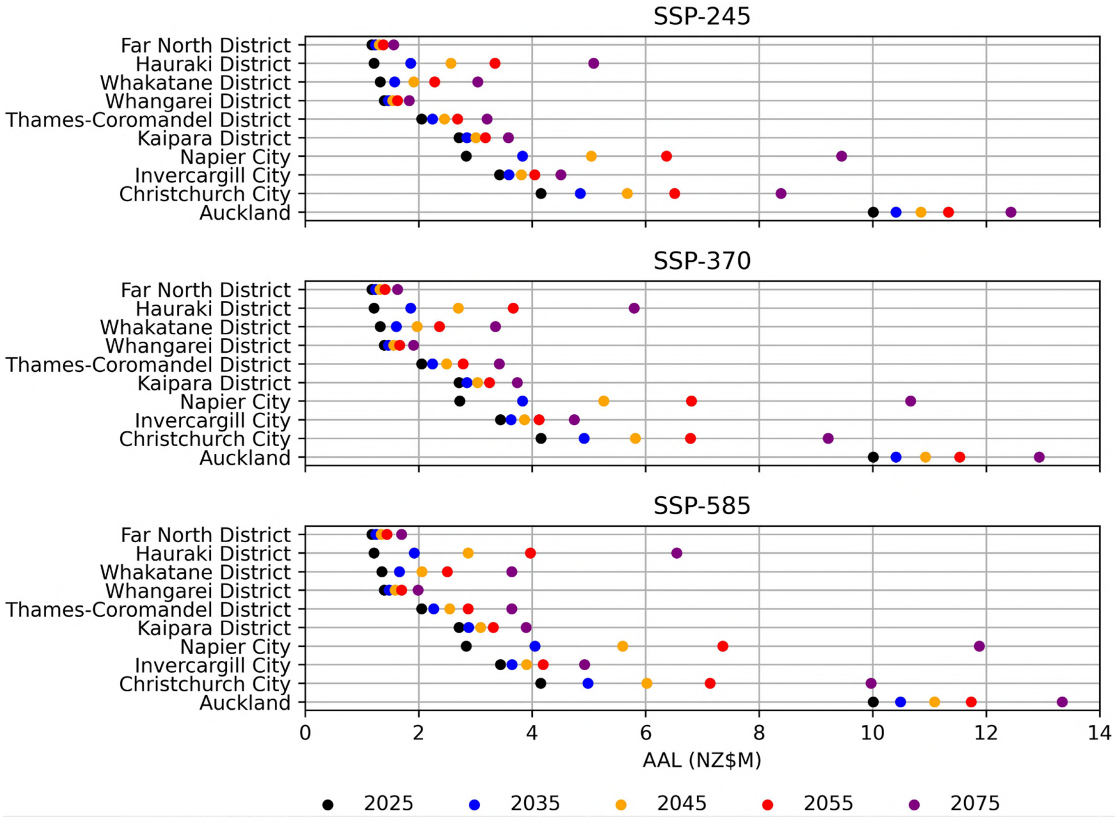

Figure A2.12 Electricity infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level extreme-sea-level-driven coastal flooding and sea-level rise. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

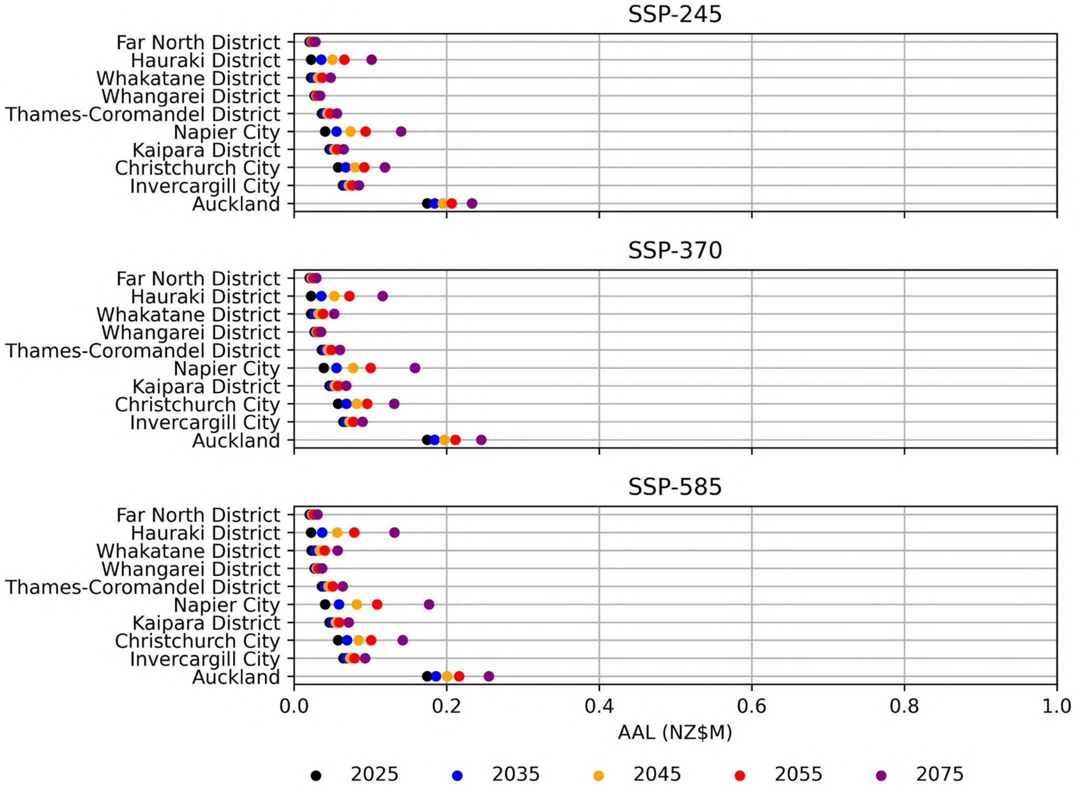

Figure A2.13 Telecommunications infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for extreme-sea-level-driven coastal flooding and sea-level rise. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

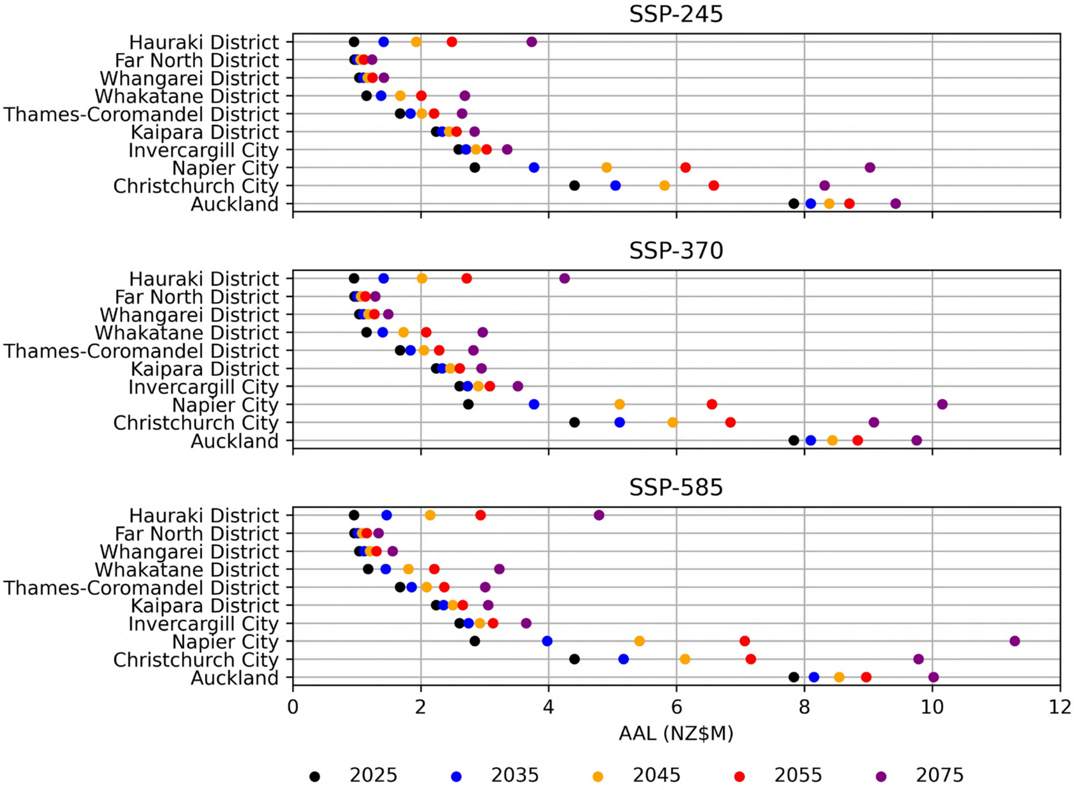

Figure A2.14 Local government road infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for extreme-sea-level-driven coastal flooding and sea-level rise. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

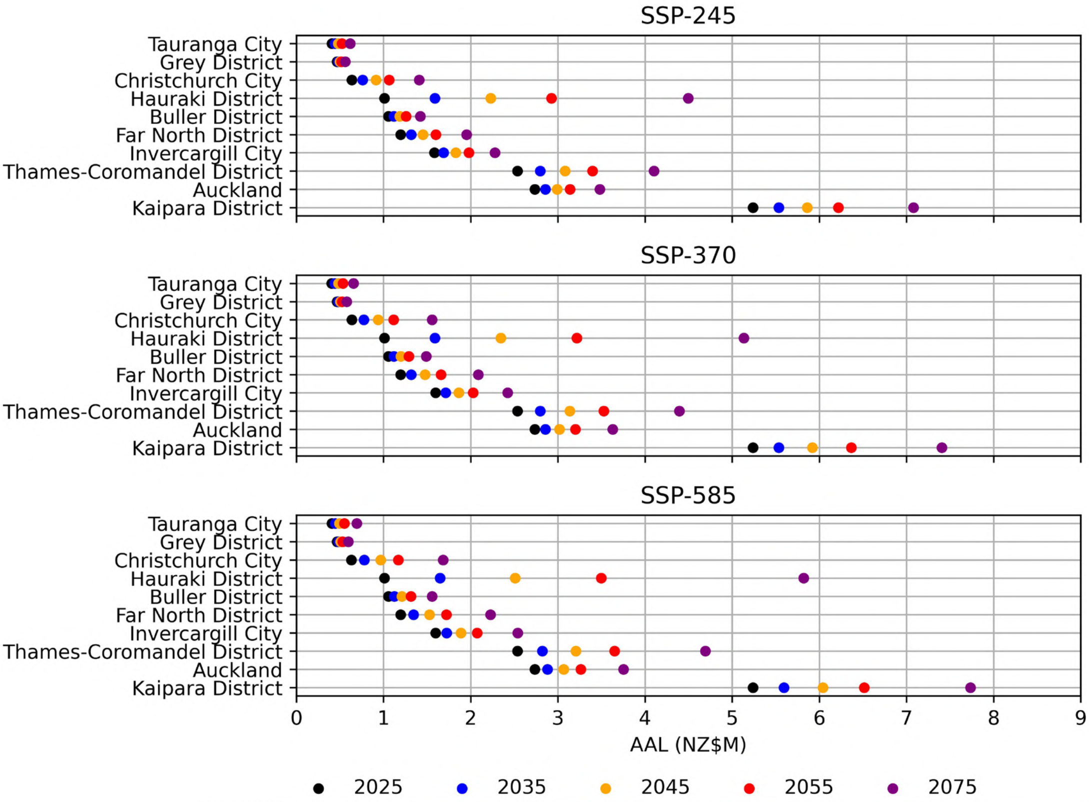

Figure A2.15 Central government road infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for extreme-sea-level-driven coastal flooding and sea-level rise. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

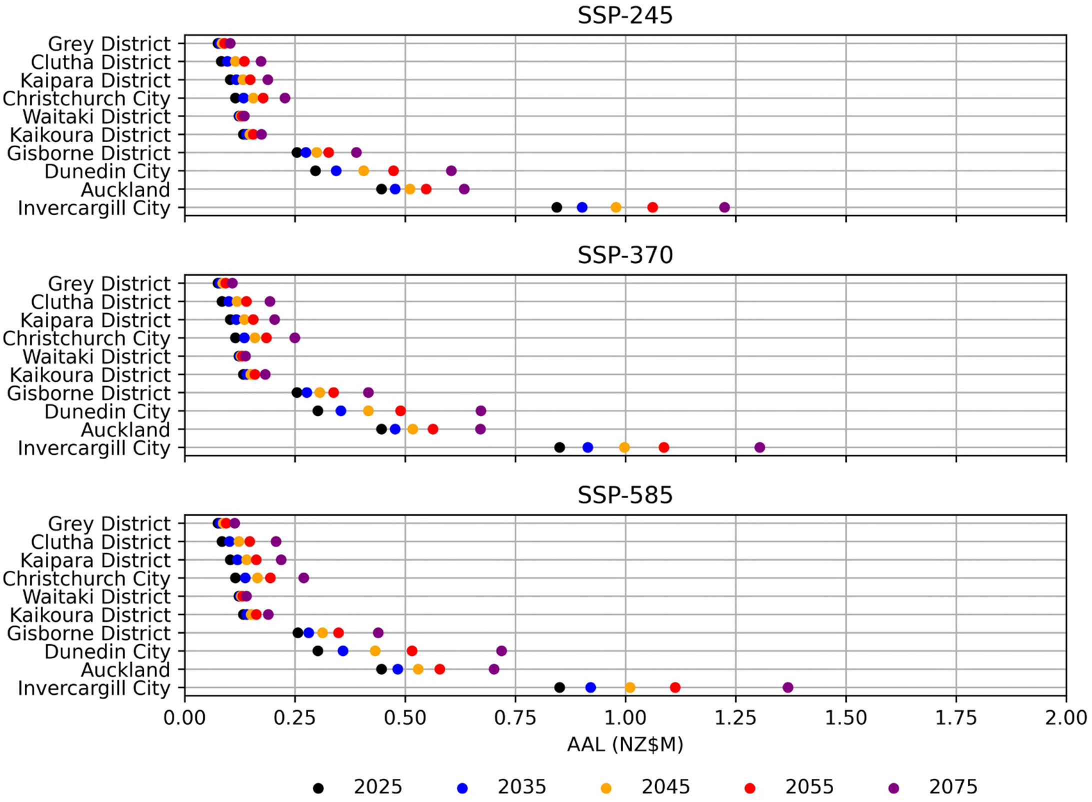

Figure A2.16 Rail infrastructure average annual losses (AAL) in NZD$ million at the territorial authority level for extreme-sea-level-driven coastal flooding and sea-level rise. The 10 highest territorial authorities by AAL are presented, with all results available in the digital deliverables (see Appendix 1).

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