Community Adaptation Programme

Risk screening report:

Multicriteria analysis methodology

Report for the Far North District Council

Author: Matt de Boer, Adapterra Ltd January 2024

Table of Contents

1. High-level summary of risk screening process ... 3
2. Risk screening methodology ... 5
  2.1 Risk and vulnerability assessment ... 5
  2.2 Spatial reporting areas ... 7
  2.3 Multicriteria analysis (MCA) ... 9
3. Summary of multicriteria analysis results ... 14
  3.1 Collated results ... 14
  3.2 Short overview of results ... 16
  3.3 Sensitivity testing ... 18
  3.4 Risk clusters and programme stage areas ... 22
4. Prioritising locations for adaptation planning ... 23
  4.1 Councillor-defined selection criteria ... 23
  4.2 How the risk assessment results relate to the prioritisation criteria ... 23
  4.3 Programme recommendations ... 24
  4.4 How the risk assessment results support programme recommendations ... 27

1. High-level summary of risk screening process

1.1 Introduction

AdapTerra and Urban Intelligence were engaged to deliver a district-wide climate change risk screening to collate evidence on the comparative risk between locations. The results of the process informed the development of a programme of community adaptation planning, with a focus on coastal hazards. This report aims to provide a plain language explanation of the processes we used.

Developing recommendations for locations for community adaptation planning in the programme required an understanding of how different components of risk come together. While this is a somewhat complicated process, in essence it involves bringing 3 main elements of risk together (hazards, exposure and vulnerability) and understanding what these mean for the adaptation planning needs of different locations.

Understanding risk requires a technical process of using scientific and modelled data to produce analytical projections, but also requires an understanding of what that means in terms of how community values are likely to be impacted, by how much, and over which timeframes. Our analysis involved two main phases – spatial exposure and vulnerability assessment; and a multi-criteria analysis using the outputs of the first phase.

1.2 Exposure and vulnerability assessment

Urban Intelligence were engaged to undertake a district-wide climate risk assessment that considered the exposure of a range of elements (e.g. houses or assets) to coastal and flooding hazards. Hazard layers were used to test exposure of a range of spatial data for vulnerable elements supplied by FNDC and NRC.

Hazards: We used existing spatial information for four hazards including climate change projections for sea level rise and rainfall intensity over different timeframes. The methods used a geospatial analysis including the most current spatial hazard information from Northland Regional Council. Hazards assessed included catchment-based flooding (pluvial and fluvial), coastal erosion, coastal flooding (i.e. storm surge) and tidal inundation due to sea level rise, over a range of timeframes.

The focus on coastal and flood hazards meant we did not include significant climate risks such as bushfire, drought and water supply, earthquake or liquefaction. While we recognise their regional significance, due to a lack of spatial data our analysis did not include groundwater impacts, or landslide risk.

Exposure: Our analysis included a wide range of different assets or elements valued in different ways by different sections of the community. A spatial analysis measured which elements were exposed to different hazards, including measures of the degree of exposure such as flood depth or proximity to erosion. Elements included Council infrastructure and reserves, residential and commercial buildings, Māori land and buildings, marae, roads, airports, community facilities, critical lifelines and others. Elements were grouped into ‘domains’ of similar types in alignment with prioritisation criteria.

Vulnerability: Definitions of vulnerability include the potential impacts of different hazards on different assets/elements, as well as the influence of social vulnerability on the ability for local communities to cope with or adapt to hazard events. Each element was assessed for potential exposure and damage under different hazards and the results presented in an online viewer, the Resilience Explorer.[1]

This produced a large amount of quantitative data showing how risks vary spatially across the district; how these risks are influenced by different hazards, and how the risks change over time. The analysis also includes modelling of the impacts of hazard events on different assets using fragility functions to show the likelihood of impacts.

---

[1] www.resilience-explorer.com

1.3 Multicriteria analysis

In the second stage of the process, data from the risk assessment were exported for analysis and site selection. The data outputs included nearly 3.5 million data points across a range of different measurement units of exposure and damage results such as area of buildings or land, length of road, and number of facilities.

A peer-reviewed multi-criteria analysis process (MCA) was used by AdapTerra Ltd to derive meaningful insights from this large dataset. [2] Multicriteria analysis is a robust technique commonly used across the public and private sectors to compare different types of data in a wide range of decision-making processes.

The multicriteria analysis process involved assigning weightings to define the degree of impact for a given hazard on a specific element or asset, as well as the relative importance of impacts when considering the needs for different areas require adaptation planning. The technique creates comparative rankings for different data types and produces relative risk scores that show comparative differences in risk between locations. Social vulnerability data from the 2018 Census were also considered during this process.

The MCA process produced risk scores for each element, for different hazards scenarios, and these scores were collated for specific adaptation project areas.

1.4 Results

Results from the multi-criteria analysis were ultimately mapped to 27 'adaptation project areas', which are defined geographic areas that were developed with the FNDC Climate Action team. The definition of the areas considered a range of factors including iwi rohe, the 'clumping' of hazard exposure datapoints, catchment and geographic features, community and political boundaries and Census area units.

The results were assessed using visual interpretation, as well as numerical ranking, to inform recommendations for the adaptation programme. Criteria identified by councillors were used to help prioritise areas for the adaptation programme.

---

[2] Hawchar et. al. (2020), A GIS-based framework for high-level climate change risk assessment of critical infrastructure, Climate Risk Management, Volume 29, https://doi.org/10.1016/j.crm.2020.100235.

2. Risk screening methodology

2.1 Risk and vulnerability assessment

Urban Intelligence were engaged to undertake a district-wide spatial risk and vulnerability assessment across the Far North District, using their Resilience Explorer platform.

2.1.1 Hazard data

The most current spatial hazard information from Northland Regional Council was used to develop the assessment. Hazards assessed included catchment-based flooding (pluvial and fluvial), coastal erosion, coastal flooding (i.e. storm surge) and tidal inundation due to sea level rise. Details are shown in Table 1 below.

Hazard description	Hazard code
Pluvial and fluvial flooding 10%AEP[3]	river_flooding_ARI10
Pluvial and fluvial flooding 2%AEP	river_flooding_ARI50
Pluvial and fluvial flooding 1%AEP	river_flooding_ARI100
Pluvial and fluvial flooding 1%AEP with 1.2m of sea level rise and +17% rainfall intensity	river_flooding_ARI100_CC
Coastal flooding (no sea level rise)	coastal_flooding_SLR0
Coastal flooding (0.6m sea level rise)	coastal_flooding_SLR60
Coastal flooding (1.2m sea level rise)	coastal_flooding_SLR120
Coastal flooding (1.5m sea level rise)	coastal_flooding_SLR150
Coastal erosion (no sea level rise)	coastal_erosion_0SLR
Coastal erosion (o.6m sea level rise)	coastal_erosion_60SLR
Coastal erosion (1.2m sea level rise)	coastal_erosion_120SLR
Coastal erosion (1.5m sea level rise)	coastal_erosion_150SLR
Tidal inundation (mean high water springs + 0.6m sea level rise)	tidal_flooding_60SLR
Tidal inundation (mean high water springs + 1.2m sea level rise)	tidal_flooding_120SLR

Table 1. Hazard layers used in the risk screening

2.1.2 Element data

Hazard layers were used to test exposure of a range of spatial data for at-risk elements supplied by FNDC and NRC, such as Council infrastructure and reserves, residential and commercial buildings, Māori land and buildings, marae, roads, airports, community facilities, critical lifelines and others.

Vulnerable elements assessed for exposure in the risk assessment are shown in Table 2 below.

FNDC criteria/ objective	Criteria	Indicator Data
Community	**Risk to homes**	Building footprint areas
	Community facilities	Northland_Schools
		NZHPT_Historic_Places
		FNDC_Cemeteries
		Boat_Ramps
		FNDC_Reserves
	Commercial buildings	Building footprint areas
	Farmland	LINZ land-use layer
Honouring Tiriti	**Marae**	Marae Location
	Buildings on Maori land	Building footprint areas

[33] AEP = Annual exceedance probability

	Maori land	Maori_Freehold_Land
	Significant areas	FNDC sites of cultural significance to Maori
		FNDC_Archaeological_Sites
Transport	**Transport Assets**	NTA_FNDC_Roads
		State_Highways
		Airports
Lifeline services	**Lifeline utilities Assets**	Electricity transmission and distribution
		Telecomms (towers + lines)
	Lifeline services	Emergency services (police & fire)
		Civil_Defence Community_Centres
		Northland_Hospitals
		Northland_Medical_Centres
Other assets	**Council 3 waters assets**	FNDC wastewater treatment plants
		FNDC wastewater pump stations
		FNDC Water pump stations
		FNDC Water pipes
		FNDC Stormwater_and_Wastewater pipes
		Bore_sites
		Northland_Water_Treatment_Plants
	Hazardous sites	Northland_Waste_Transfer_Stations
		FNDC_Landfills
		Hazardous sites (SLUR)

Table 2. Vulnerable elements used in the risk screening

2.1.3 Exposure and vulnerability assessment

An assessment of exposure and potential damage under different hazards for each element was undertaken by Urban Intelligence, using their proprietary risk assessment software and processes. Potential likelihood of damage was calculated for selected elements using fragility functions that assess the impacts of specific hazards for different exposure measures (such as flood depth or proximity to erosion). A detailed explanation of the risk assessment methodology used by Urban Intelligence is available in their methodology report.

2.1.4 Risk portal

The results were presented in an online viewer, the Resilience Explorer.[4] Figure 1 below shows a screenshot from the viewer.

[4] www.resilience-explorer.com

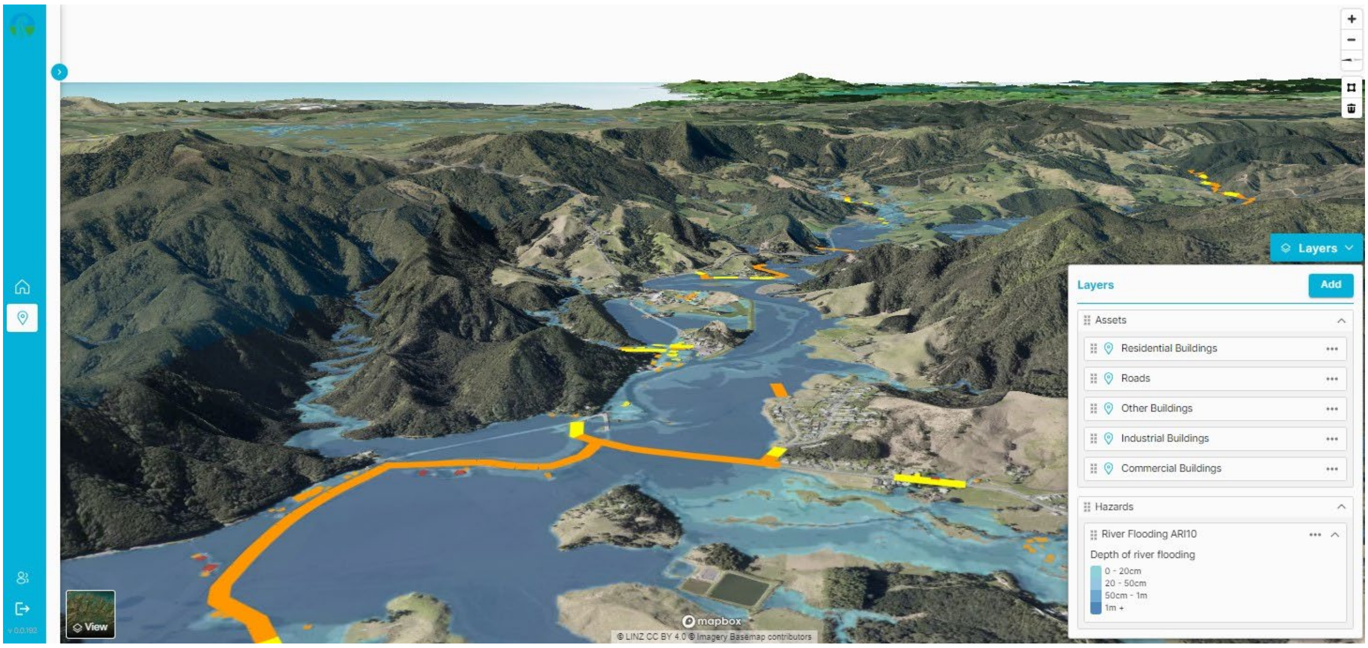


Figure 1. Risk assessment results as shown in the Resilience Explorer. Location near Kaeo, River flooding ARI10

2.2 Spatial reporting areas

The risk assessment generated a large volume of data including exposure and likelihood of damage. The results were reported spatial area cells that covered the district. Two sizes of cells were used: a uniform 7km wide hexagonal grid, and specially mapped ‘adaptation project areas’.

2.2.1 Hexagonal grid

A uniform hexagonal grid was used to report exposure counts to provide a preliminary indication of spatial patterns of risk across the district. Each hexagonal cell is identical is area and is around 7km across.

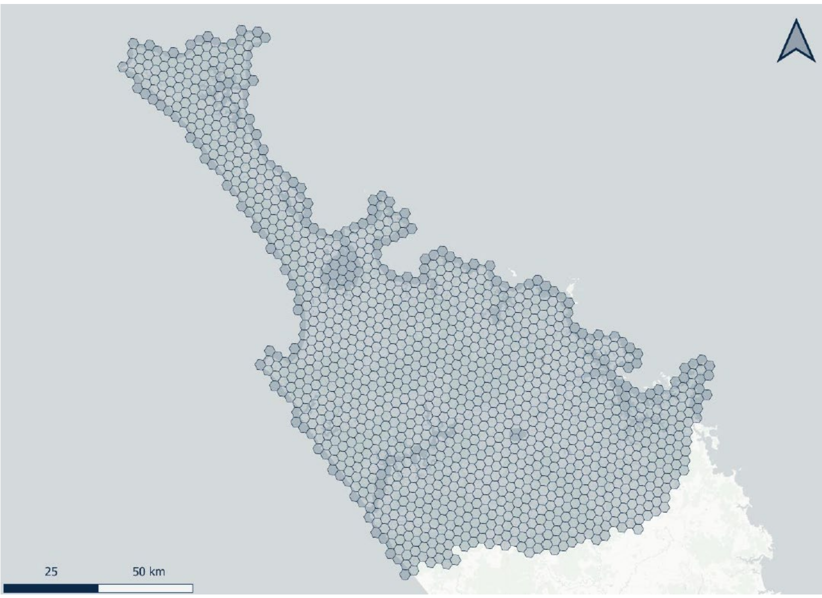


Figure 2: Spatial boundary of Far North District Council and overlay of hexagonal hierarchical geospatial indexing system at resolution 7.

2.2.2 Adaptation project areas

The adaptation project areas were developed with the FNDC Climate Action team specifically for the purposes of the adaptation programme, to help understand differences in climate risk between locations. The areas provide indicative boundaries to separate different places that may require adaptation planning, to support recommendations for the climate adaptation programme.

Twenty-seven adaptation areas were used across the 3 Far North District community board areas. The boundaries were based largely on Census SA2 area units, with minor changes to reflect existing geographic, social and cultural features, and are largely consistent with the community board boundaries.

The adaptation project areas are named as:

Te Hiku	Kaikohe-Hokianga	Bay of Islands-Whangaroa
Ahipara	Hokianga ki te raki	Kaeo
Awanui	Hokianga ki te tonga	Kawakawa
Herekino-Whangape**	Kohukohu	Kerikeri
Hihi	Mataraua Forest	Maromaku
Houhora	Kaikohe	Matauri
Peria	Omahuta Forest-Horeke	Rangitane-Purerua
Taipa	Omapere	Rawhiti
Tangonge	Waipoua Forest	Russell
Te Hiku		Waitangi-Paihia
Tokerau		

Table 3. Adaptation project area names

Of the 27 adaptation areas defined, 3 areas (Peria, Okaihau and Maromaku) have no coastal boundaries, and as a result only river flooding risk is reported for these areas. These areas have been excluded from the coastal adaptation programme.

**The Herekino-Whangape adaptation project area includes both Herekino and Whangape harbours, and was included in the Te Hiku community board area for preliminary grouping.

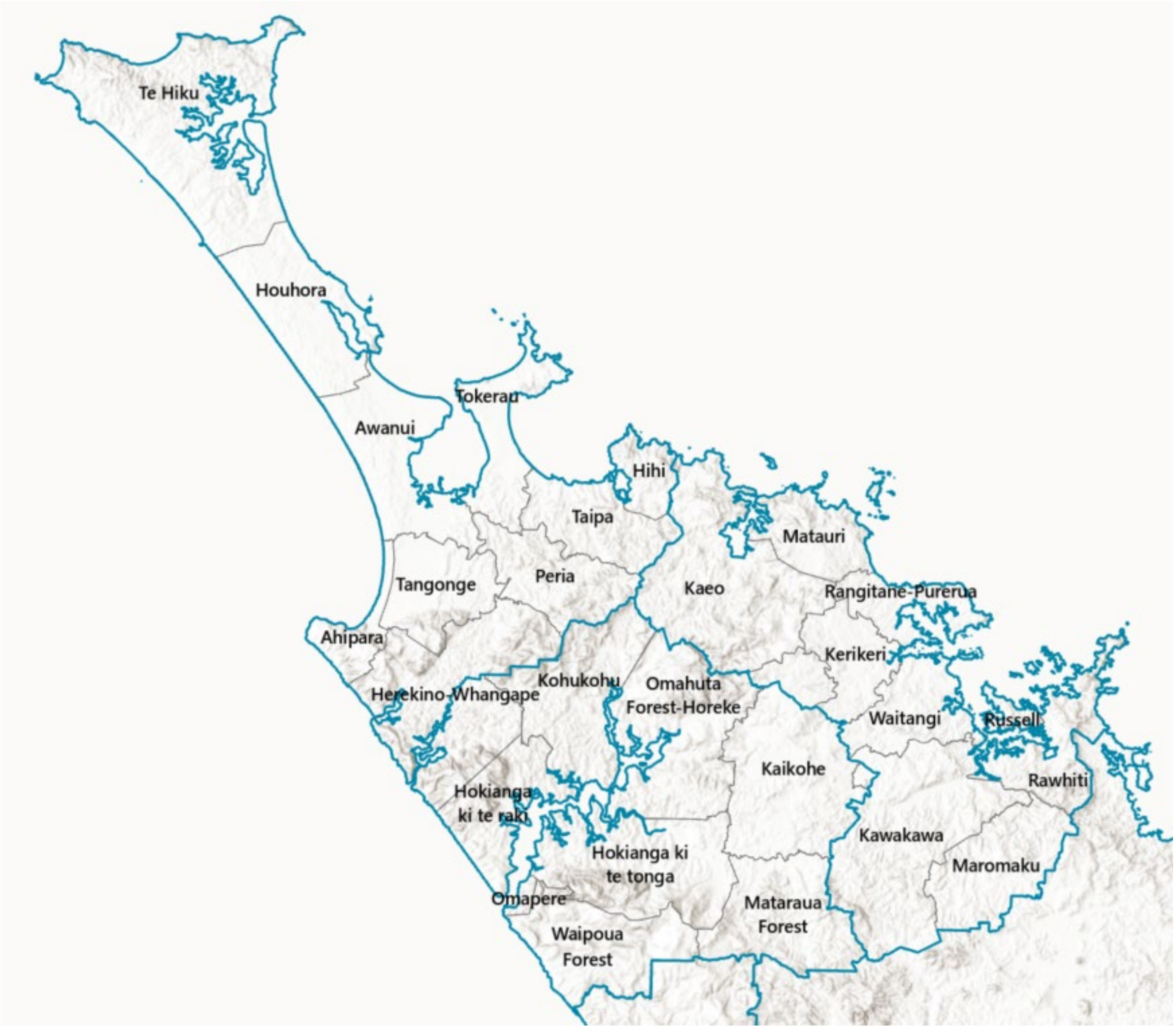


Figure 3. Far North adaptation project areas (grey borders) and community board areas (blue borders)

2.3 Multicriteria analysis (MCA)

2.3.1 The multicriteria analysis process

The data produced from the risk assessment included around 3.5 million data points from 1500 hexagonal cells, 16 hazards and 40 elements. Data included a range of different measurement units relating to exposure and damage results. This included, for example, area of buildings or land (m2), length of road (m), and number of facilities (count). While this data can be visually assessed by using the Resilience Explorer, it is difficult to make sense of the all the data across the district at once and understand how risk differs quantitatively across the district and between different types of elements. This is where multicriteria analysis adds value.

We used a peer-reviewed multicriteria analysis method (Hawchar et. al. 2020) to process the large dataset generated by the risk assessment. This enabled us to collate the results and derive meaningful insights to support recommendations for the adaptation planning programme. [5]

Multicriteria analysis is a robust technique commonly used across the public and private sectors to compare different types of data in a wide range of decision-making processes. The technique uses a process to create comparative

[5] Lara Hawchar, Owen Naughton, Paul Nolan, Mark G. Stewart, Paraic C. Ryan, A GIS-based framework for high-level climate change risk assessment of critical infrastructure, Climate Risk Management, Volume 29, 2020, https://doi.org/10.1016/j.crm.2020.100235.

rankings for different types of data (e.g. exposure measurements with different units such as count, length and area), which can then be combined into scores and compared.

2.3.2 Overview

The process used in the MCA is summarised in table 4 below. Formulae used are coded in the MCA results provided in spreadsheet format in the supplied results (Community Adaptation Programme: Risk screening multicriteria analysis results). A more detailed explanation of each step is provided in 2.3.4.

MCA Step	MCA Process	Result
1	exposure data (high, med, low) * unique element vulnerability factor **weighting**	hazard/element impact score (per high/med/low exposure data groups)
2	sum high, med, low impact scores	sum hazard/element impact score (sum across all exposure data groups)
3	(score -min)/(max-min)	standardised impact score
4	standardised impact score* unique element importance **weighting**	element risk score
5	sum of element risk scores (for a given domain/hazard)	domain risk score
6	sum of element risk scores (for a given hazard)	hazard risk score
7	sum of hazard risk scores (for a given scenario)	scenario risk score

Table 4. Overview of steps used in the MCA process

2.3.3 Multicriteria weighting

Weighting is used in the MCA process firstly to collate risk assessment exposure data between elements measures using different measurement units. It is secondly used to add user-generated value judgements to risk assessment exposure results to differentiate the perceived differences in importance between impacts on different elements.

Weighting can involve both expert judgement and value judgement. As such it should be open to scrutiny and testing to ensure personal preferences are not unduly influencing results. We used two stages of weighting in the MCA process: impact weightings and importance weightings.

Impact weighting

The first stage involved the allocation of unique weightings (vulnerability factors) for each element, for each hazard or damage likelihood (see Table 5 below). This weighting, which is used in step 1 above, provides an estimate of the extent of damage to the function of that element for a given hazard exposure (i.e. impact). The weightings, which can be adjusted as required, were initially set using expert judgement and tested with FNDC staff where possible.

Weighted impact scores were then summed and standardised (i.e. ranked from high to low across all hexagonal grid cells or adaptation project areas).

The weightings should be verified by asset managers to check that the impacts of different hazards on each asset is appropriately weighted. For example, the impact of flooding on a boat ramp is likely to be negligible regardless of depth, whereas the impact of flooding on a building will increase with depth. The impact of coastal erosion and permanent tidal inundation is likely to be relevant for all assets, given that those hazards represent permanent loss of function.

Element	Vulnerability									
	Coastal Flooding low	Coastal Flooding medium	Coastal Flooding high	River Flooding low	River Flooding medium	River Flooding high	Coastal Erosion low	Coastal Erosion medium	Coastal Erosion high	Tidal Flooding
Airports			1			1	0.6	0.8	1	1
Archaeological Sites			1			1	0.6	0.8	1	1
Areas of Significance to Māori			1			1			1	1
Boat Ramps			0			0	0.6	0.8	1	1
Bore Sites			0.5			0.1			1	1
Bridges			0.05			0.05			1	1
Camping Grounds			0.5			0.5			1	1
Carparks	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Cellphone towers			0.01			0.01			1	1
Cemeteries	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Civil Defence Community Centers	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Commercial Buildings	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Community Centers and Halls	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Contaminated Areas			1			1	0.6	0.8	1	1
Contaminated Sites			1			1	0.6	0.8	1	1
Drainage			0			0			1	1
Electricity Transmission Lines (Transpower)			0.01			0.01			1	1
Electricity Transmission Structures (Transpower)			1			1			1	1
Farm land	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Fire Stations	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
High Voltage Distribution Network (Top Energy)			0.01			0.01			1	1
Historic Places			1			1			1	1
Hospitals			1			1			1	1
Industrial Buildings	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Land Parcels	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Landfills	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Libraries	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Low Voltage Distribution Network (Top Energy)			0.01			0.01			1	1
Māori Land	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Marae	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Medical Centers	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Medium Voltage Distribution Network (Top Energy)			0.01			0.01			1	1
Other Buildings	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Parks and Reserves	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Police Stations	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Power Poles (Top Energy)			0.01			0.01			1	1
Public Toilets	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Residential Buildings	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Roads	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Schools	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
State Highways	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Stormwater Pipes	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Transfer Stations	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Wastewater Pipes	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Wastewater Pumpstations	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Wastewater Treatment Plants	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Water Pipes	0.2	0.4	0.6	0.2	0.4	0.6	0.6	0.8	1	1
Water Pumpstations	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1
Water Treatment plants	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1	1

Table 5. Vulnerability factor weightings for individual elements per hazard or damage likelihood ranking. Red shows elements where no vulnerability method was used in the risk assessment (i.e. no damage likelihood ranking is available).

Importance weighting

Importance weightings were then applied to each element to determine the degree of influence each element type has on the overall risk score. There is no 'right' way of assigning value to different elements, as there are likely to be many different interpretations of what's important between different project team members, partners and stakeholders. We used this functionality to sensitivity test the results, by comparing how risk was spatially distributed when different weightings of domains were used.

Importance weightings are made up of two components. The first is the weighting of how important an individual asset is within its domain, which is shown in the 'importance score within domain' column in Table 6 below, displayed as percentiles in the 'Importance normalised within domain' column. The purple bars show the relative contribution of different assets to each domain.

The second component is the weighting of each domain to the overall risk score for that specific hazard scenario.

Weightings for each individual elements, using equal weighting between all domains (Community 20%; Māori 20%, Transport 20%; Lifelines 20%; Other assets 20%) are shown in the column on the far-right of Table 6 below. In this example, the relative risk score for an adaptation project area relating to the exposure of schools will contribute 10.4% to the overall risk score for that specific hazard scenario, while the relative risk score for marae will contribute 17.4%.

FNDC criteria/ objective	Criteria	Indicator Data	Importance score within domain	Importance normalised within domain	Importance score* domain weighting
Community	Residential buildings	Building footprint zoned residential	1	0.052	1.0%
Community	Community facilities	Northland_Schools	10	0.518	10.4%
Community	Community facilities	Libraries	3	0.155	3.1%
Community	Community facilities	Community centres	3	0.155	3.1%
Community	Community facilities	NZHPT_Historic_Places	0.3	0.016	0.3%
Community	Community facilities	FNDC_Cemeteries	0.3	0.016	0.3%
Community	Community facilities	Boat_Ramps	0.05	0.003	0.1%
Community	Community facilities	FNDC_Reserves	0.3	0.016	0.3%
Community	Commercial buildings	Building footprint zoned commercial	1	0.052	1.0%
Community	Farmland	LINZ land-use layer agricultural	0.35	0.018	0.4%
Honouring Tiriti	Marae	Building footprint * Marae Location	16	0.870	17.4%
Honouring Tiriti	Buildings on Maori land	Building_Footprint * Maori land	1	0.054	1.1%
Honouring Tiriti	Maori land	Maori_Freehold_Land	0.4	0.022	0.4%
Honouring Tiriti	Significant areas	FNDC sites of cultural significance to Ma	0.5	0.027	0.5%
Honouring Tiriti	Significant areas	FNDC_Archaeological_Sites	0.5	0.027	0.5%
Transport	Transport Assets	NTA_FNDC_Roads	1	0.250	5.0%
Transport	Transport Assets	State_Highways	2	0.500	10.0%
Transport	Transport Assets	Airports	1	0.250	5.0%
Transport	Transport Assets	Bridges	0	0.000	0.0%
Lifeline services	Lifeline utilities Assets	Electricity transmission low	0.05	0.003	0.1%
Lifeline services	Lifeline utilities Assets	Electricity transmission medium	0.05	0.003	0.1%
Lifeline services	Lifeline utilities Assets	Electricity transmission high	0.05	0.003	0.1%
Lifeline services	Lifeline utilities Assets	Power poles	0.3	0.016	0.3%
Lifeline services	Lifeline utilities Assets	Cell towers	0.3	0.016	0.3%
Lifeline services	Lifeline services	Emergency services (police & fire)	3	0.160	3.2%
Lifeline services	Lifeline services	Civil_Defence_Community_Centres	3	0.160	3.2%
Lifeline services	Lifeline services	Northland_Hospitals	10	0.533	10.7%
Lifeline services	Lifeline services	Northland_Medical_Centres	2	0.107	2.1%
Other assets	Council assets	FNDC wastewater treatment plants	10	0.311	6.2%
Other assets	Council assets	FNDC wastewater pump stations	1	0.031	0.6%
Other assets	Council assets	Wastewater pipes	0	0.000	0.0%
Other assets	Council assets	Northland_Water_Treatment_Plants	10	0.311	6.2%
Other assets	Council assets	FNDC_Water_pump stations	1	0.031	0.6%
Other assets	Council assets	FNDC_Water pipes	0.1	0.003	0.1%
Other assets	Council assets	FNDC_Stormwater pipes	0.1	0.003	0.1%
Other assets	Council assets	Bore_sites	1	0.031	0.6%
Other assets	Hazardous sites	Northland_Waste_Transfer_Stations	3	0.093	1.9%
Other assets	Hazardous sites	FNDC_Landfills	3	0.093	1.9%
Other assets	Hazardous sites	Contaminated sites (SLUR)	3	0.093	1.9%

Table 6. Weightings for individual elements using equal weighting between domains (Community 20%; Māori 20%, Transport 20%; Lifelines 20%; Other assets 20%).

The MCA outputs provided in Appendix 1 are specifically designed to allow adaptation planners, stakeholders, partners, FNDC staff or councillors an opportunity to test how risk scores change when different weightings of importance are used to generate comparative scores.

2.3.4 Multicriteria analysis steps

Step 1. This estimates the impact of a given hazard on the specific element, where likelihood of damage rankings (high, medium or low) were available in the risk assessment results.

Process: Multiply the exposure score for each vulnerability/damage class (high/med/low) by the corresponding asset- and hazard-specific unique vulnerability weighting (Tab 3 MCA results).

The example used below in the following steps is taken from Tab 7 in the MCA results spreadsheet, showing the exposure of residential buildings to a 10yr ARI flooding event (the yellow highlighted cells are the result of the step, using the value in the grey cells, plus any relevant weightings).

region_id	RF_ARI10	RF_ARI10_community	RF_ARI10_tiriti	RF_ARI10_transport	RF_ARI10_lifelines	RF_ARI10_assets	residential_buildings_exposed_Count	residential_buildings_low_Count	residential_buildings_medium_Count	residential_buildings_high_Count	residential_buildings_exp_wt_all	residential_buildings_exp_wt_low	residential_buildings_exp_wt_medium	residential_buildings_exp_wt_high	residential_buildings_sum_exp_wt	residential_buildings_std_sum	residential_buildings_domain_wt_std_sum
te_hiku	0.028	0.001	0.004	0.023	0.000	0.000	2	2	0	0		1.2	0	0	1.2	0.004	0.000
kawakawa	0.293	0.046	0.165	0.058	0.002	0.020	58	25	32	1		15	25.6	1	41.6	0.130	0.002
kaeo	0.372	0.045	0.182	0.113	0.022	0.006	41	9	27	5		5.4	21.6	5	32	0.100	0.002

Step 2. This calculates the impact score for that specific element/hazard combination.

Process: Add together the high, medium and low impact scores from step 1.

region_id	RF_ARI10	RF_ARI10_community	RF_ARI10_tiriti	RF_ARI10_transport	RF_ARI10_lifelines	RF_ARI10_assets	residential_buildings_exposed_Count	residential_buildings_low_Count	residential_buildings_medium_Count	residential_buildings_high_Count	residential_buildings_exp_wt_all	residential_buildings_exp_wt_low	residential_buildings_exp_wt_medium	residential_buildings_exp_wt_high	residential_buildings_sum_exp_wt	residential_buildings_std_sum	residential_buildings_domain_wt_std_sum
te_hiku	0.028	0.001	0.004	0.023	0.000	0.000	2	2	0	0		1.2	0	0	1.2	0.004	0.000
kawakawa	0.293	0.046	0.165	0.058	0.002	0.020	58	25	32	1		15	25.6	1	41.6	0.130	0.002
kaeo	0.372	0.045	0.182	0.113	0.022	0.006	41	9	27	5		5.4	21.6	5	32	0.100	0.002

Step 3. This standardises the scores across all adaptation project areas (or hex grid units). It creates a relative ranking of scores between zero and one across all adaptation project areas for that asset/hazard combination.

Process: Calculate the difference between the area's impact score (n) and the minimum score from all areas (min), then divide this by the difference between the maximum and minimum impact scores from all areas i.e. (n-min)/(max-min).

region_id	RF_ARI10	RF_ARI10_community	RF_ARI10_tiriti	RF_ARI10_transport	RF_ARI10_lifelines	RF_ARI10_assets	residential_buildings_exposed_Count	residential_buildings_low_Count	residential_buildings_medium_Count	residential_buildings_high_Count	residential_buildings_exp_wt_all	residential_buildings_exp_wt_low	residential_buildings_exp_wt_medium	residential_buildings_exp_wt_high	residential_buildings_sum_exp_wt	residential_buildings_std_sum	residential_buildings_domain_wt_std_sum
te_hiku	0.028	0.001	0.004	0.023	0.000	0.000	2	2	0	0		1.2	0	0	1.2	0.004	0.000
kawakawa	0.293	0.046	0.165	0.058	0.002	0.020	58	25	32	1		15	25.6	1	41.6	0.130	0.002
kaeo	0.372	0.045	0.182	0.113	0.022	0.006	41	9	27	5		5.4	21.6	5	32	0.100	0.002

Step 4. This uses an element-specific weighting to estimate the importance of that element to the overall risk score.

Process: Multiply the standardised impact score by the element importance weighting (tab 4 MCA results).

This includes the weighting of how much each element contributes within its domain, as well as the weightings assigned across all domains (See importance weighting in previous section). For example, an 'equal weighting' will use a weighting for each element as they make up their proportion of the risk score for their domain; but will place equal weighting (i.e. 20%) between all domains to calculate the domain risk score.

region_id	RF_ARI10	RF_ARI10_community	RF_ARI10_tiriti	RF_ARI10_transport	RF_ARI10_lifelines	RF_ARI10_assets	residential_buildings_exposed_Count	residential_buildings_low_Count	residential_buildings_medium_Count	residential_buildings_high_Count	residential_buildings_exp_wt_all	residential_buildings_exp_wt_low	residential_buildings_exp_wt_medium	residential_buildings_exp_wt_high	residential_buildings_sum_exp_wt	residential_buildings_std_sum	residential_buildings_domain_wt_std_sum
te_hiku	0.028	0.001	0.004	0.023	0.000	0.000	2	2	0	0		1.2	0	0	1.2	0.004	0.000
kawakawa	0.293	0.046	0.165	0.058	0.002	0.020	58	25	32	1		15	25.6	1	41.6	0.130	0.002
kaeo	0.372	0.045	0.182	0.113	0.022	0.006	41	9	27	5		5.4	21.6	5	32	0.100	0.002

Step 5. This creates a risk score for each domain per adaptation project area, relevant to the hazard being considered.

Process: Add up all the element risk scores for each domain, for that hazard (i.e. from the selection of elements making up that domain).

region_id	RF_ARI10	RF_ARI10_community	RF_ARI10_tiriti	RF_ARI10_transport	RF_ARI10_lifelines	RF_ARI10_assets	residential_buildings_exposed_Count	residential_buildings_low_Count	residential_buildings_medium_Count	residential_buildings_high_Count	residential_buildings_exp_wt_all	residential_buildings_exp_wt_low	residential_buildings_exp_wt_medium	residential_buildings_exp_wt_high	residential_buildings_sum_exp_wt	residential_buildings_std_sum	residential_buildings_domain_wt_std_sum
te_hiku	0.028	0.001	0.004	0.023	0.000	0.000	2	2	0	0		1.2	0	0	1.2	0.004	0.000
kawakawa	0.293	0.046	0.165	0.058	0.002	0.020	58	25	32	1		15	25.6	1	41.6	0.130	0.002
kaeo	0.372	0.045	0.182	0.113	0.022	0.006	41	9	27	5		5.4	21.6	5	32	0.100	0.002

Step 6. This creates an overall risk score per adaptation project area, for the specific hazard being considered.

Process: Add up all the element risk scores for that hazard (i.e. from all domains)

region_id	RF_ARI10	RF_ARI10_community	RF_ARI10_tiriti	RF_ARI10_transport	RF_ARI10_lifelines	RF_ARI10_assets	residential_buildings_exposed_Count	residential_buildings_low_Count	residential_buildings_medium_Count	residential_buildings_high_Count	residential_buildings_exp_wt_all	residential_buildings_exp_wt_low	residential_buildings_exp_wt_medium	residential_buildings_exp_wt_high	residential_buildings_sum_exp_wt	residential_buildings_std_sum	residential_buildings_domain_wt_std_sum
te_hiku	0.028	0.001	0.004	0.023	0.000	0.000	2	2	0	0		1.2	0	0	1.2	0.004	0.000
kawakawa	0.293	0.046	0.165	0.058	0.002	0.020	58	25	32	1		15	25.6	1	41.6	0.130	0.002
kaeo	0.372	0.045	0.182	0.113	0.022	0.006	41	9	27	5		5.4	21.6	5	32	0.100	0.002

Step 7. This creates a summary risk score for more than one hazard (i.e. a hazard scenario). It can also be used to sum risk scores for all hazards.

Process: Add up all the hazard risk scores relevant to the scenario (e.g. near-term, all hazards - See Tab 2. MCA results).

				RISK DATA – Weighted MCA scores – Present day				RISK DATA – Weighted MCA scores – 2080						RISK DATA – Weighted MCA scores – 2130M					RISK DATA – Weighted MCA scores – 2130H+					
Adaptation area	**Community board area**	RF_ARI10	RF_ARI50	RF100_1	CF0_1	CE0_1	**Current day all hazards**	RF100_11	CF60_1	CE60_1	TI60_1	**Near-term all hazards (2080)**	**Near-term coastal hazards (2080)**	RF100CC_1	CF120_1	CE120_1	TI120_1	**Long-term all hazards (2130)**	RF100CC_1	CF150_1	CE150_1	TI120_1	**Long-term all hazards (2130 H+)**	**Long-term all hazards * vulnerability**
ahipara	Te Hiku	0	0.1	0	0	0	0.013313082	0	0	0.1	0	0.087107291	0.084326255	0	0	0.1	0	0.092503729	0	0	0.3	0	0.360890266	0.140674784
awanui	Te Hiku	0.1	0.1	0.1	0	0	0.124905215	0.1	0.1	0	0	0.171000731	0.127804592	0.2	0.3	0	0.1	0.524437618	0.2	0.3	0	0.1	0.526344145	0.23988436
herekino_takahue	Te Hiku	0.1	0.2	0.1	0.3	0	0.437608081	0.1	0.3	0	0	0.460394657	0.672418501	0.3	0.3	0	0.3	0.960993251	0.3	0.3	0	0.3	0.956920378	0.631548504

2.3.5 Multicriteria analysis outputs

The multicriteria analysis process generated comparative risk scores that integrate exposure and vulnerability/fragility measures from all elements and hazards. These scores were reported to spatial area units including both hexagonal grid cells and adaptation project areas. The results were first reported as tabular data (see Table 8 below), but also exported as GIS maps to visually represent how comparative risk is distributed across the district.

A sensitivity testing exercise was undertaken to test how different combinations of weightings between domains affected the distribution of risk scores across the district. Multiple runs of results were generated through the MCA, then mapped in GIS for visual assessment (a range of these are shown below in Section 3.2 Sensitivity testing).

A selection of vulnerability scores were also applied during the sensitivity testing process. Vulnerability data was sourced from the 2018 Census and based on the Social Vulnerability Index developed by Massey University.[6] Vulnerability datasets used covered four themes: Having enough money to cope with crises and losses; Awareness, knowledge and skills to cope with hazards and emergencies; Safe, secure and healthy housing and Enough food and water to cope with shortage. The vulnerability data for the relevant adaptation project areas were normalised and an average score multiplied against the risk scores.

Results of the MCA are discussed in brief below.

3. Summary of multicriteria analysis results

3.1 Collated results

The collated results of the MCA process are shown below in Table 7, with individual hazard risk scores (i.e. RF100_11, CF60_1 etc.) summarised into hazard scenario groupings (i.e. Near-term all-hazards 2080 etc).

[6] https://www.ehinz.ac.nz/projects/social-vulnerability-indicators/

Adaptation area	Current day all hazards	RF100_11	CF60_1	CE60_1	TI60_1	Near-term all hazards (2080)	Near-term coastal hazards (2080)	RF100CC_1	CF120_1	CE120_1	TI120_1	Long-term all hazards (2130)	RF100CC_1	CF150_1	CE150_1	TI120_1	Long-term all hazards (2130 H+)	Long-term all hazards * vulnerability
Kaeo	0.62	0.44	0.17	0.02	0.16	0.78	0.52	0.49	0.22	0.01	0.19	0.91	0.49	0.24	0.02	0.19	0.94	0.52
Waitangi	0.25	0.09	0.08	0.14	0.05	0.36	0.42	0.26	0.13	0.31	0.06	0.75	0.26	0.15	0.32	0.06	0.78	0.25
Hokianga ki te tonga	0.29	0.18	0.16	0.00	0.05	0.40	0.32	0.23	0.20	0.00	0.33	0.76	0.23	0.18	0.00	0.33	0.74	0.51
Herekino-Whangape	0.35	0.10	0.24	0.00	0.04	0.38	0.52	0.26	0.23	0.00	0.22	0.71	0.26	0.23	0.00	0.22	0.71	0.47
Kohukohu	0.51	0.31	0.16	0.00	0.07	0.54	0.43	0.32	0.17	0.00	0.16	0.65	0.32	0.20	0.00	0.16	0.69	0.46
Taipa	0.18	0.10	0.18	0.07	0.04	0.40	0.37	0.15	0.21	0.09	0.06	0.51	0.15	0.22	0.20	0.06	0.63	0.32
Awanui	0.16	0.11	0.09	0.01	0.01	0.22	0.17	0.19	0.27	0.01	0.11	0.58	0.19	0.30	0.01	0.11	0.60	0.27
Tangonge	0.45	0.45	0.00	0.00	0.00	0.45	0.00	0.49	0.00	0.00	0.00	0.49	0.49	0.00	0.00	0.00	0.49	0.22
Kawakawa	0.34	0.32	0.03	0.00	0.01	0.36	0.06	0.39	0.07	0.00	0.03	0.48	0.39	0.07	0.00	0.03	0.49	0.13
Omahuta forest- Horeke	0.20	0.14	0.08	0.00	0.06	0.28	0.19	0.20	0.13	0.00	0.06	0.39	0.20	0.11	0.00	0.06	0.37	0.25
Hokianga ki te raki	0.18	0.15	0.03	0.00	0.03	0.22	0.10	0.26	0.03	0.00	0.04	0.33	0.26	0.03	0.00	0.04	0.32	0.30
Matauri	0.15	0.10	0.03	0.03	0.02	0.18	0.12	0.15	0.05	0.03	0.02	0.26	0.15	0.08	0.04	0.02	0.30	0.13
Ahipara	0.02	0.01	0.01	0.08	0.00	0.10	0.10	0.01	0.01	0.08	0.00	0.11	0.01	0.01	0.26	0.00	0.28	0.11
Omapere	0.19	0.08	0.01	0.12	0.00	0.21	0.24	0.07	0.02	0.17	0.00	0.27	0.07	0.02	0.17	0.00	0.26	0.16
Russell	0.10	0.08	0.05	0.02	0.03	0.18	0.13	0.08	0.08	0.01	0.03	0.20	0.08	0.10	0.01	0.03	0.22	0.04
Rangitane - Purerua	0.02	0.00	0.07	0.00	0.01	0.09	0.10	0.06	0.06	0.00	0.10	0.22	0.06	0.05	0.00	0.10	0.21	0.04
Tokerau	0.09	0.04	0.06	0.04	0.01	0.15	0.16	0.04	0.06	0.08	0.02	0.20	0.04	0.06	0.08	0.02	0.20	0.05
Hihi	0.06	0.05	0.04	0.02	0.01	0.12	0.08	0.06	0.05	0.02	0.07	0.20	0.06	0.05	0.02	0.07	0.20	0.04
Rawhiti	0.05	0.03	0.04	0.00	0.04	0.10	0.10	0.05	0.04	0.00	0.04	0.13	0.05	0.04	0.00	0.04	0.13	0.07
Peria	0.10	0.10	0.00	0.00	0.00	0.10	0.00	0.12	0.00	0.00	0.00	0.12	0.12	0.00	0.00	0.00	0.12	0.08
Houhora	0.06	0.04	0.02	0.00	0.02	0.08	0.07	0.05	0.04	0.00	0.02	0.12	0.05	0.04	0.00	0.02	0.11	0.06
Kerikeri	0.04	0.03	0.00	0.00	0.01	0.04	0.02	0.08	0.00	0.00	0.01	0.09	0.08	0.00	0.00	0.01	0.09	0.01
Te Hiku	0.06	0.03	0.02	0.00	0.02	0.07	0.07	0.04	0.03	0.00	0.01	0.08	0.04	0.03	0.00	0.01	0.08	0.04
Waipoua Forest	0.09	0.09	0.00	0.00	0.00	0.09	0.01	0.07	0.00	0.00	0.00	0.08	0.07	0.00	0.00	0.00	0.08	0.05
Maromaku	0.04	0.04	0.00	0.00	0.00	0.04	0.00	0.06	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.06	0.03
Mataraua Forest	0.02	0.02	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.02	0.02
Kaikohe	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00

Table 7. MCA results showing all hazard scenarios plus hazard groupings, ranked according to 'long-term all-hazards (2130H+)'.

Adaptation project areas are ranked according to the 'long-term, all hazards 2130H+' scenario scores (second from right column). Scores for the 'long-term, all hazards' scenario including vulnerability are shown in the far-right column.

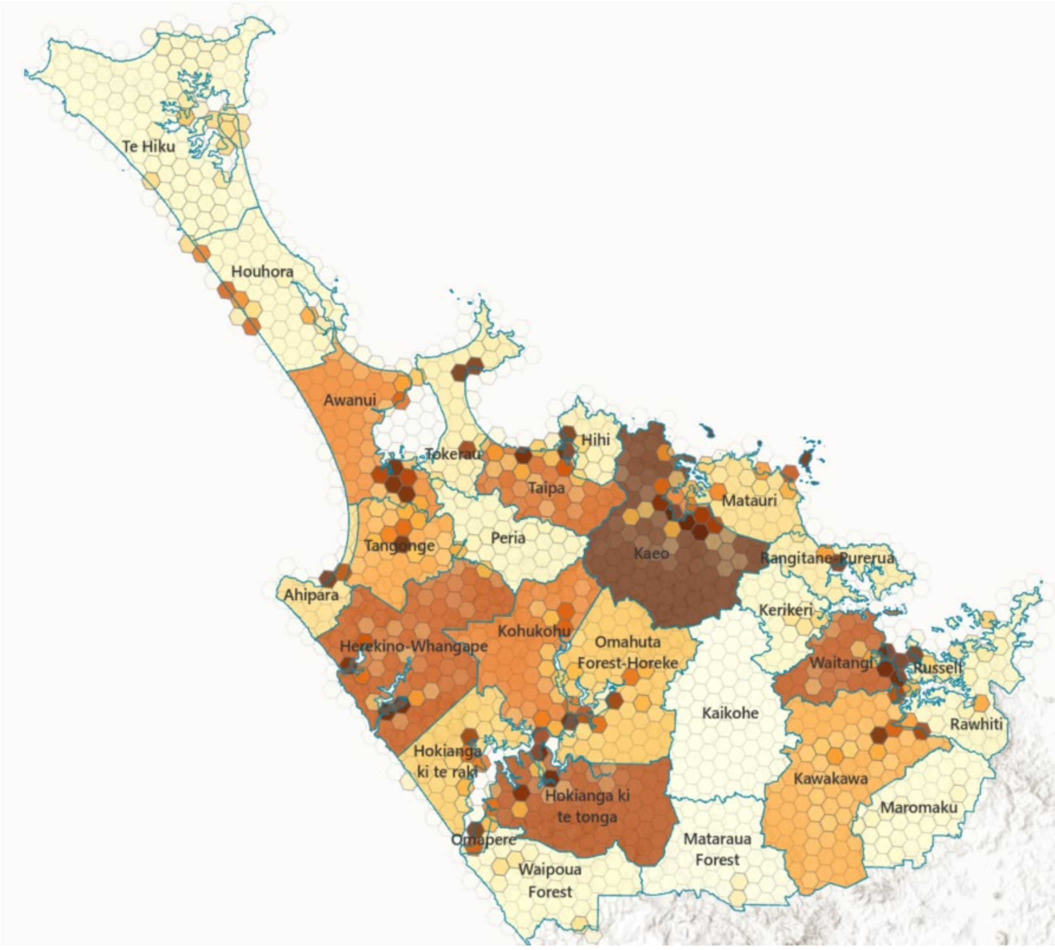


Figure 4. MCA risk screening results (equal weighting between domains) reported to both Adaptation project areas and hex grid.

3.2 Short overview of results

Table 8 below shows the relative risk scores for different adaptation project areas. Four hazard scenarios are shown: *'Current day all hazards'*, *'Near-term coastal hazards'*, *'Long-term all hazards'*, and *'Long-term all-hazards with vulnerability'*. The results are ranked high-low in terms of the *'Long-term all-hazards with vulnerability'* scenario.

Perhaps unsurprisingly, the results show that the spatial distribution of risks across the Far North is not uniform, and that some areas exhibit higher relative risk than others. Relative risks for locations across the Far North also differ according to the type of hazard, the types of elements exposed, and the timing of the hazard scenarios.

Adaptation area	Community board area	Current day all hazards	Near-term coastal hazards (2080)	Long-term all hazards (2130 H+)	Long-term all hazards * vulnerability
Kaeo	Bay of Islands-Whangaroa	0.62	0.52	0.94	0.52
Hokianga ki te tonga	Kaikohe-Hokianga	0.29	0.32	0.74	0.51
Herekino-Whangape	Te Hiku	0.35	0.52	0.71	0.47
Kohukohu	Kaikohe-Hokianga	0.51	0.43	0.69	0.46
Taipa	Te Hiku	0.18	0.37	0.63	0.32
Hokianga ki te raki	Kaikohe-Hokianga	0.18	0.10	0.32	0.30
Awanui	Te Hiku	0.16	0.17	0.60	0.27
Waitangi	Bay of Islands-Whangaroa	0.25	0.42	0.78	0.25
Omahuta forest- Horeke	Kaikohe-Hokianga	0.20	0.19	0.37	0.25
Tangonge	Te Hiku	0.45	0.00	0.49	0.22
Omapere	Kaikohe-Hokianga	0.19	0.24	0.26	0.16
Matauri	Bay of Islands-Whangaroa	0.15	0.12	0.30	0.13
Kawakawa	Bay of Islands-Whangaroa	0.34	0.06	0.49	0.13
Ahipara	Te Hiku	0.02	0.10	0.28	0.11
Peria	Te Hiku	0.10	0.00	0.12	0.08
Rawhiti	Bay of Islands-Whangaroa	0.05	0.10	0.13	0.07
Houhora	Te Hiku	0.06	0.07	0.11	0.06
Tokerau	Te Hiku	0.09	0.16	0.20	0.05
Waipoua Forest	Kaikohe-Hokianga	0.09	0.01	0.08	0.05
Rangitane - Purerua	Bay of Islands-Whangaroa	0.02	0.10	0.21	0.04
Te Hiku	Te Hiku	0.06	0.07	0.08	0.04
Hihi	Te Hiku	0.06	0.08	0.20	0.04
Russell	Bay of Islands-Whangaroa	0.10	0.13	0.22	0.04
Maromaku	Bay of Islands-Whangaroa	0.04	0.00	0.06	0.03
Mataraua Forest	Kaikohe-Hokianga	0.02	0.00	0.02	0.02
Kerikeri	Bay of Islands-Whangaroa	0.04	0.02	0.09	0.01
Kaikohe	Kaikohe-Hokianga	0.01	0.00	0.01	0.00

Table 8. Relative risk scores for adaptation project areas, ranked high-low for long-term all hazards including vulnerability.

High-level observations of relative risk across the district indicate that:

- Without including vulnerability, Kaeo is ranked highest relative risk score overall and Waitangi second.
- When relative risk scores are combined with vulnerability measures, four of the six highest ranked adaptation project areas, are in proximity of the Hokianga harbour: Hokianga ki te tonga, Herekino-Whangape, Kohukohu, and Hokianga ki te raki.
- Taipa and Awanui both show high relative risk scores with and without vulnerability applied
- In addition to the above areas, Omapere, Matauri and Ahipara also have comparatively high relative risk scores.
- Tangonge (which includes Kaitaia) and Kawakawa, and to a lesser degree Peria, exhibit high relative risk scores that are almost completely driven by river flooding risks rather than coastal hazards.

Figure 4 below shows a map of the relative risk scores depicted by colour (darker colours indicate higher risk) for adaptation project areas across the district. The map shows results using a long-term, all hazards scenario (i.e. risks due to river and coastal flooding, coastal erosion, and high-tide inundation, in 100+ years including 1.2 to 1.5m of sea level rise).

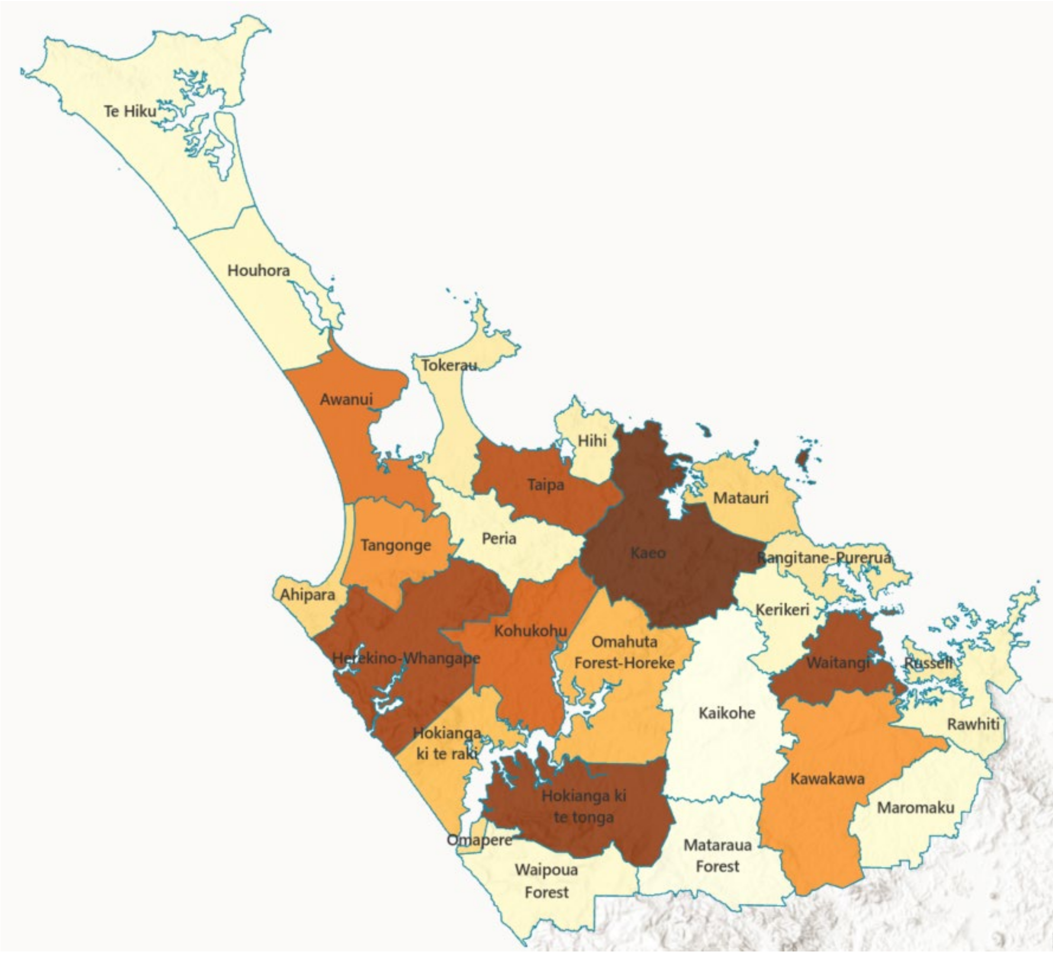


Figure 4. Relative risk scores reported to adaptation project areas (darker = higher relative risk score)

3.3 Sensitivity testing

By adjusting the domain weightings it's possible to compare how the distribution of risk changes across the district when different elements are prioritised. The following maps (Fig. 5-10 show examples where risk scores from only one or two domains are show on each map. Visual examination of the patterns of risk shows that the distribution of risks changes significantly when exposure scores from different elements are selected.

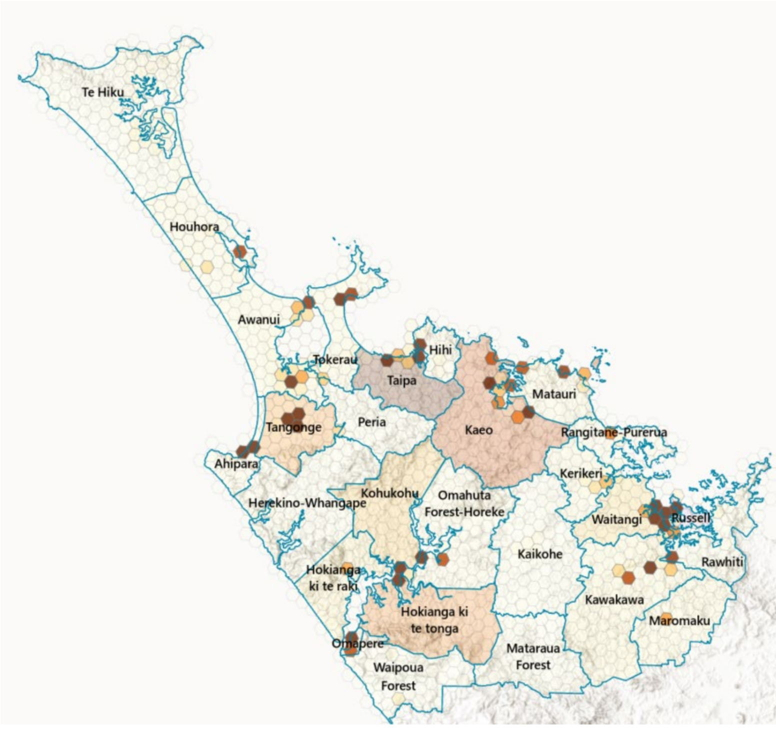


Figure 5. FNDC MCA results: “Community assets” domain only; all hazards (2130 H+) scenario.

Figure 6. FNDC MCA results: “Māori assets” domain only; all hazards (2130 H+) scenario.

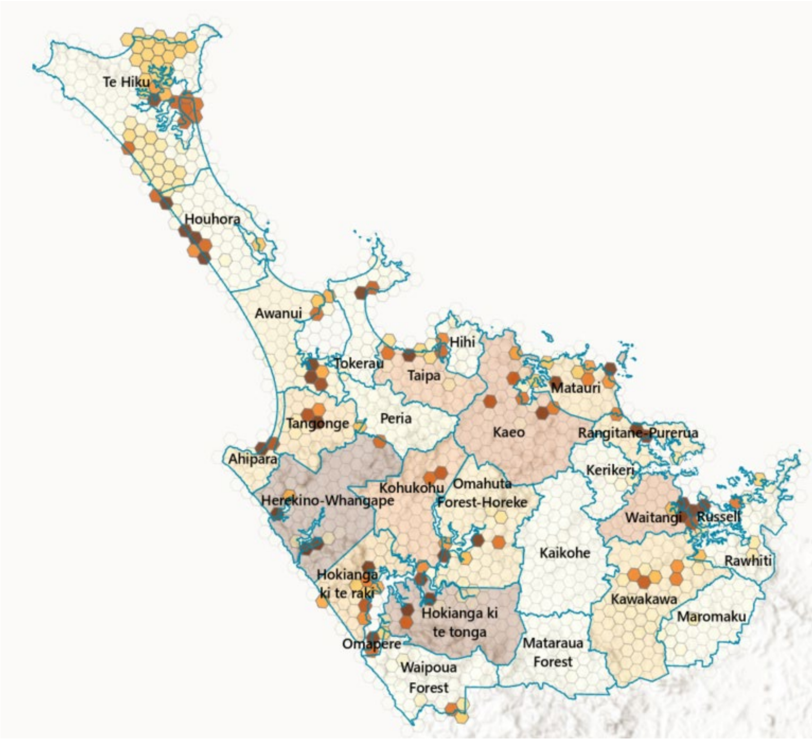


Figure 7. FNDC MCA results: “Community and Māori assets” domains equally weighted: all hazards (2130 H+) scenario.

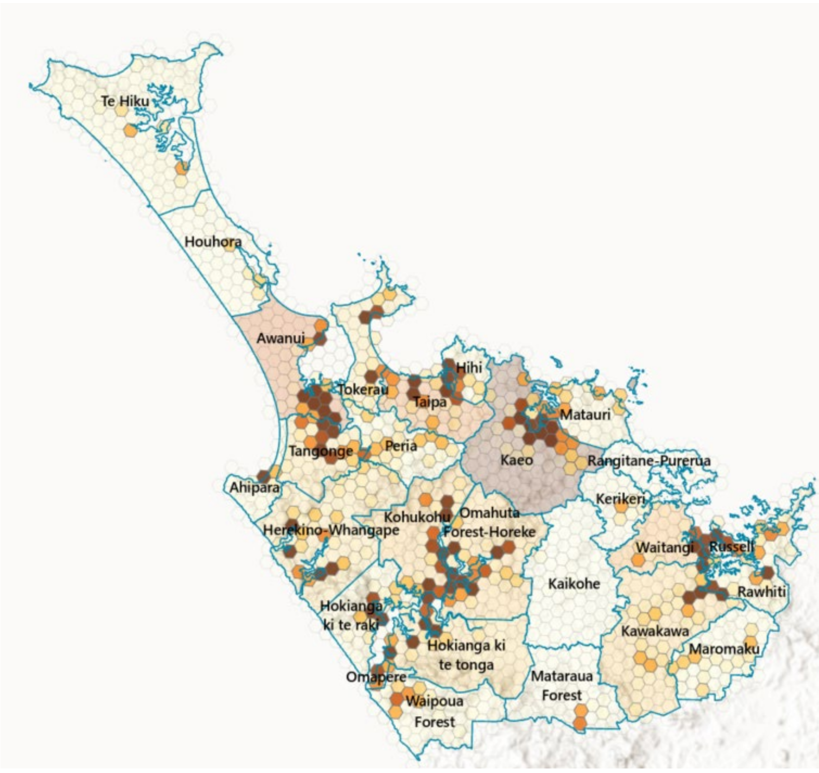


Figure 8. FNDC MCA results: “Transport assets” domain only; all hazards (2130 H+) scenario.

Figure 9. FNDC MCA results: "Critical lifelines assets" domain only; all hazards (2130 H+) scenario.

Figure 10. FNDC MCA results: 'Other assets' domain only; all hazards (2130 H+) scenario.

3.4 Risk clusters and programme stage areas

Based on visual assessment the 'clumping' distribution of relative risk scores by hex areas, we characterised the distribution of risk in seven major risk groupings:

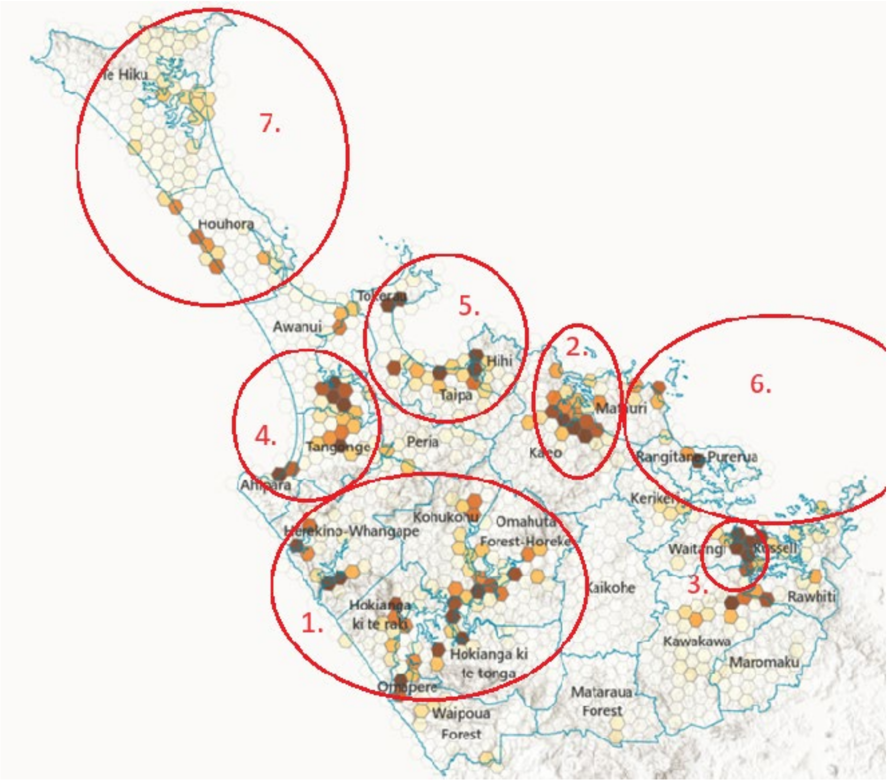


Figure 11. FNDC MCA results: Equal weighting, results exported to hex grid only, all hazards (2130 H+)

1. Hokianga-Herekino-Whangape harbours
2. Kaeo-Whangaroa
3. Waitangi-Paihia
4. Awanui and Ahipara
5. Doubtless Bay
6. Smaller coastal settlements from Matauri Bay to the Bay of Islands
7. Te Hiku

These areas formed the basis for initial considerations in developing a programme of community-led adaptation planning. Adaptation project areas were grouped together to form larger 'programme stage' areas where adaptation planning could be delivered together within one 'project'.

As well as risk 'clusters', groupings were also informed by iwi rohe boundaries, appropriate sizes for undertaking adaptation planning projects, natural geographic features, connected communities, and infrastructure systems.

Within adaptation project areas or programme stage groupings, more defined adaptation sub-areas may need to be identified later during the scoping phase. These could for example be used to show areas of higher risk where adaptation planning pathways may be needed during the development of an adaptation plan.

4. Prioritising locations for adaptation planning

4.1 Councillor-defined selection criteria

In December 2022, FNDC councillors voted on criteria that should be used to identify communities where FNDC adaptation planning should start. The results of the poll are shown below in Table 9 below. The top four criteria identified by councillors were '*Exposure to coastal hazards*', '*Honouring Tiriti*', '*Critical community lifelines*', and '*What's at stake*'. The criteria were used both as a guide to grouping datasets in the risk assessment process, and as specific questions to guide the selection process.

Criteria assessed	Criteria	Score	Normalised score
Adaptation project area prioritisation criteria	**Exposure to coastal hazards**	31	15
	Honouring Titiri	29	13
	Critical community lifelines	26	10
	What's at stake	26	10
Influence on programme timing	**Representativeness**	22	6
Not assessed			
Additional considerations for FNDC (out of scope in this report)	Active communities and stakeholders	20	4
	Existing governance structures in place	20	4
Not assessed	Data availability	20	4
	Process value	19	3
	Organisational ablity and resourcing to respond	19	3
	Strategic alignment	17	1

Table 9. 2022 FNDC Councillor poll results: Considerations for prioritisation of adaptation planning project area locations and timing

4.2 How the risk assessment results relate to the prioritisation criteria

We interpreted the top three criteria in relationship to exposure data in the risk screening process. The criterion '*Exposure to coastal hazards'* relates to exposure of elements in all domains, while '*Honouring Tiriti'* relates solely to Māori cultural assets. '*Critical community lifelines*' relates to exposure of elements within the Transport and Lifelines domains but could also include regional transport connectivity.

The multicriteria analysis process allows weightings to define how the Councillor-voted criteria contribute to relative risk scores. Weightings were developed using expert judgement and tested where possible with FNDC staff. However, the process is flexible, and weightings can be easily changed to see how they influence relative risk scores.

We used a flexible approach through sensitivity testing to test a range of weightings and look for patterns in the data to help identify priority adaptation planning locations. This included running separate analyses for individual selection criteria to show key differences in relative risk scores when weightings were changed.

For example, the results of considering only the 'community' domain (which includes residential and commercial buildings and community facilities such as schools), shows different patterns of risk distribution to those seen when considering only the 'Māori cultural assets' domain (which includes marae, buildings on Māori land, Māori freehold land, archaeological sites and sites of significance).

We interpreted the criterion '*What's at stake*' as an assessment of vulnerability or adaptive capacity. Social vulnerability indices developed by Massey University were used as a measure of vulnerability or adaptive capacity and used to sensitivity test the risk results.

The criterion *'Representativeness'* was interpreted to mean the degree to which adaptation project areas cover all three community board areas across the Far North District. We used this criterion to inform the timing and phasing of adaptation planning projects, while maintaining a risk-based prioritisation process.

The remaining criteria were agreed to be largely out of scope for this assessment. The criteria *'active communities and stakeholders'* and *'existing governance structures in place'* may be used as additional considerations by council when undertaking early engagement and establishing appropriate methodologies in priority adaptation planning project locations. The remaining criteria were deemed to have low analytical value due to limited variation between sites.

4.3 Programme recommendations

At the time of writing, we made the following recommendations, based on the evidence generated by the risk assessment and multi-criteria analysis:

4.3.1 The programme

Communities within the following adaptation project areas should be prioritised for adaptation planning over coming years (see Section 2 for the rationale):

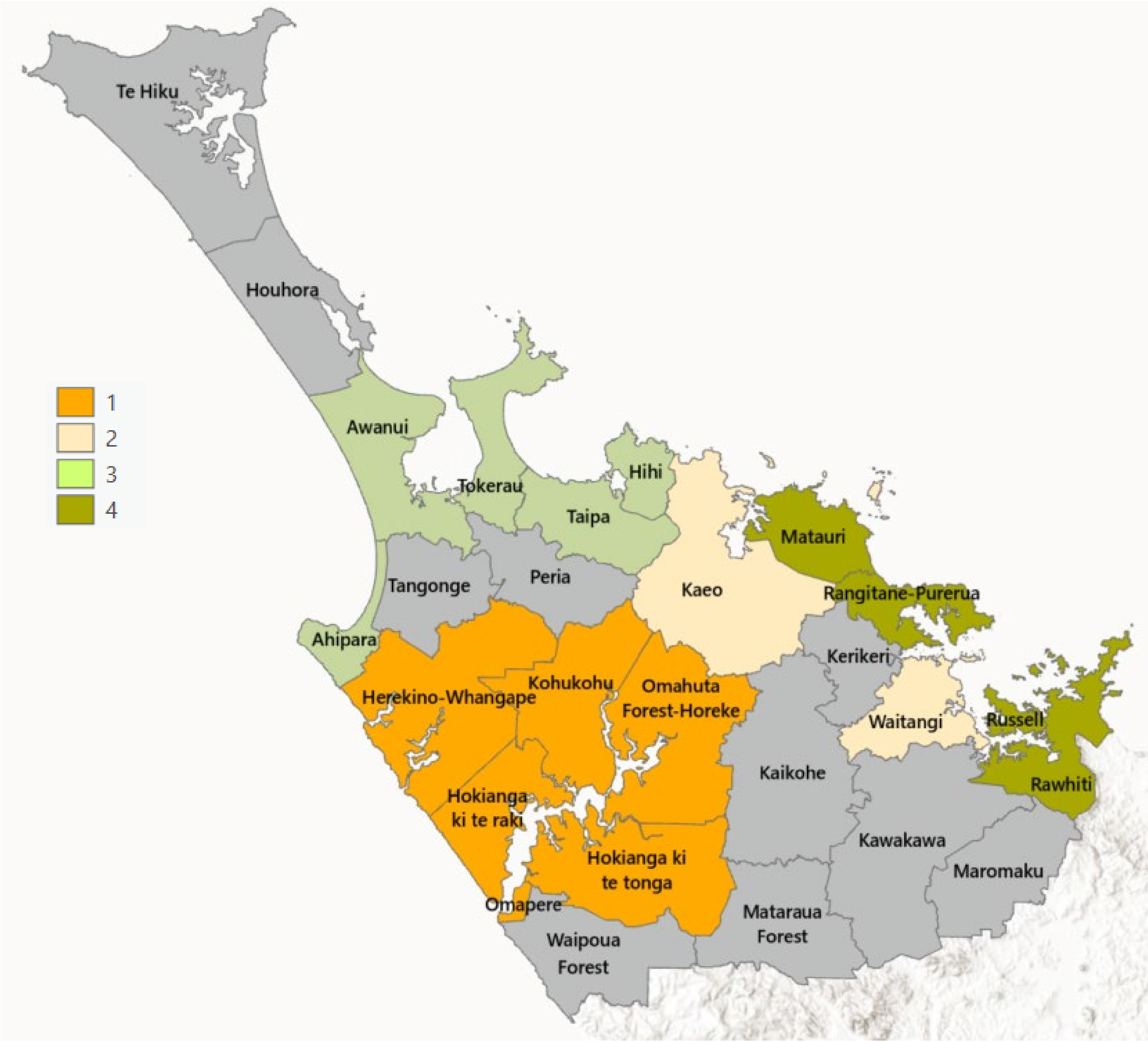
Stage One (2024-2026)
- Hokianga harbour
- Herekino and Whangape harbours

Stage Two (2027-2029)
- Kaeo
- Waitangi-Paihia

Stage Three (2030-32)
- Doubtless Bay (Taipa-Hihi)
- Awanui
- Tokerau
- Ahipara

Stage Four (2033-2035)

a. Matauri and Rangitane-Purerua
b. Russell and Rawhiti



Stage	Indicative year	Adaptation project areas
Stage one	2024-26	Hokianga ki te tonga Kohukohu Hokianga ki te raki Omahuta forest- Horeke Omapere Herekino-Whangape
Stage two	2027-29	Kaeo Waitangi-Paihia
Stage three	2030-31	Awanui Ahipara Taipa Tokerau Hihi
Stage four	2033-35	Matauri Rangitane - Purerua Russell Rawhiti

4.3.2 Other considerations

We recommend that additional considerations that were out of scope for this report should also be taken into account by Council when confirming adaptation planning site locations. These include, for example, the degree of community readiness and level of engagement, and the existence of any planned or upcoming major projects or infrastructure works.

Council will also need to consider the level of resourcing made available to support community adaptation planning projects including LTP funding, staff capacity and capability, and any external support or funding available.

The timeframes and phasing order are indicative of the level of risk based on information available. Council may wish to reassess the recommended phasing in light of other considerations or information.

4.3.3 Next steps

We further recommend that engagement and consultation with the relevant iwi-hapu, and key community representatives should be undertaken as soon as possible to confirm the support and commitment of the respective communities.

Following affirmation from iwi-hapu and communities, the necessary preparations for adaptation planning should begin. Preparations should include early community engagement, project scoping, project governance and hazard and risk assessments. These should be undertaken prior to starting a structured adaptation planning process.

Appropriate adaptation planning methodologies should be developed in response to the needs of tangata whenua, and as appropriate for different communities, including addressing the desire or requirement for tangata whenua-led adaptation planning processes to address specific issues or risks to cultural assets or taonga.

4.3.4 Future programme flexibility

A flexible approach should be taken by Council that allows the programme to respond to changes in external circumstances that could alter the timeframes or phasing of the programme. This could include, for example the opportunities and availability (or lack thereof) of external funding, or a major hazard event occurring.

While the above programme is based on robust available climate risk data, over time additional information, modelling or data on future climate risks (such as impacts of drought and groundwater salination, wildfire or public health impacts), are likely to become available. Such risks should be assessed and included as part of an updated and integrated risk assessment process.

The programme should be reviewed each three years as part of Council's Long-term planning cycle, with progress toward project objective and timeframes monitored and reported as appropriate.

Where there are communities that are not included in the programme that express a wish to undertake community adaptation planning, we recommend that a responsive and flexible approach be taken by Council to consider their case. Support for projects initiated and led by tangata whenua or communities should be considered on a case-by-case basis, and supported alongside the programme to the degree that funding allows.

4.4 How the risk assessment results support programme recommendations

4.4.1 Exposure to coastal hazards

The risk assessment results show that some adaptation project areas consistently exhibit high levels of risk when considering different hazard scenarios or domain weightings. Table 10 below shows the frequency of a site being ranked within the top third across different hazard scenarios:

Adaptation project area	Number of times in highest third
Kaeo	6
Kohukohu	6
Herekino-Whangape	6
Hokianga ki te tonga	6
Waitangi	6
Taipa	5
Tangonge	4
Kawakawa	4
Omahuta forest- Horeke	4
Awanui	4
Omapere	2
Hokianga ki te raki	1

Table 10. Frequency of sites occurring in the highest third of site rankings across six hazard scenarios

How the results influenced our recommendations

Stage One includes the adaptation project areas in the vicinity of the Hokianga harbour, including the Herekino and Whangape harbours, which represent some of the highest relative risk scores.

The Herekino-Whangape adaptation project area shows 2 marae and around 10km of roads or state highways are exposed to most high tides with 1.2m of sea level rise. 4 marae and 53 buildings on Māori land are projected to be within flood zones for a 100yr flooding event with 1.2m of sea level rise.

Taken collectively, adaptation project areas across the Hokianga harbour show very high exposure to tidal inundation of roads and state highways, with nearly 44km of roads expected to be underwater every high tide with 1.2m of sea level rise. Given the isolated nature of many these communities and the lack of alternative access, this is especially significant. Hokianga adaptation areas collectively have 12 marae and 235 buildings on Māori land exposed to large (100yr ARI) flooding events with 1.2m of sea level rise.

Two of the highest ranked adaptation project areas, Kaeo and Waitangi, are planned for Stage Two. Data for Kaeo shows that 2 marae, 28 buildings on Māori land and 140 homes are exposed to a large flood event (i.e. 100yr return period storm) with 1.2m of sea level rise. Over 16km of road is projected to be underwater at most high tides with 1.2m of sea level rise.

The Waitangi adaptation project area, which includes the nationally significant cultural elements of the Treaty grounds, and Te Tiriti o Waitangi marae, as well as the commercial areas of Paihia and Opua, shows high exposure to a range of hazards across all elements. Of note are nearly 70 homes exposed to tidal inundation with 1.2m of sea level rise, and over 3km of roads and state highways exposed to coastal erosion under 1.5m of sea level rise.

Stage Three includes sites within the Te Hiku community board area, including high-risk sites Taipa, Awanui and Ahipara. While not as highly ranked in terms of relative risk, Tokerau and Hihi are included due to their specific local risks to residential properties and geographic connection to the other sites.

In the Awanui adaptation project area, 26 buildings on Maori land are exposed to tidal inundation under 1.2m of SLR, with 53 in the coastal flood zone. 14km of roads and state highways are projected to be underwater at high tide with 1.2m of SLR. Significant existing issues with overtopping of coastal stopbanks at king tides and storm surge events.

In Ahipara one marae, 288 homes, and nearly 3.3km of roads and state highways exposed to coastal erosion under 1.5m of sea level rise. 172 houses are exposed to a 1:100 yr flood with 1.2m of sea level rise. While not highly ranked for total risk, Tokerau shows high exposure of residential buildings to coastal flooding (276) and coastal erosion (203) under 1.5m of sea level rise, with nearly 3.5km of road exposed to coastal erosion under a 1.5m sea level rise.

Stage Four includes the coastal settlements along the east coast of the Bay of Islands-Whangaroa community board, including Mataui, Rangitane-Purerua, Russell and Rawhiti adaptation project areas. Matauri and Rangitane-Pureroa adaptation project areas show nearly 160 homes exposed to coastal flooding under 1.5m of sea level rise. Across all Stage four areas, nearly 50 houses and 17km of roads are projected to be inundated at high tide with 1.2m of sea level rise.

4.4.2 Honouring Tiriti

When only Maori cultural assets are included in the relative risk scoring, Herekino-Whangape, Hokianga ki te tonga and Waitangi show extremely high risk scores (see figure 12 below). Nonetheless, the distribution of 27 marae projected to be exposed to a 1:100yr river flood event with 1.2m of sea level rise illustrates the broad spread of risk across the district.

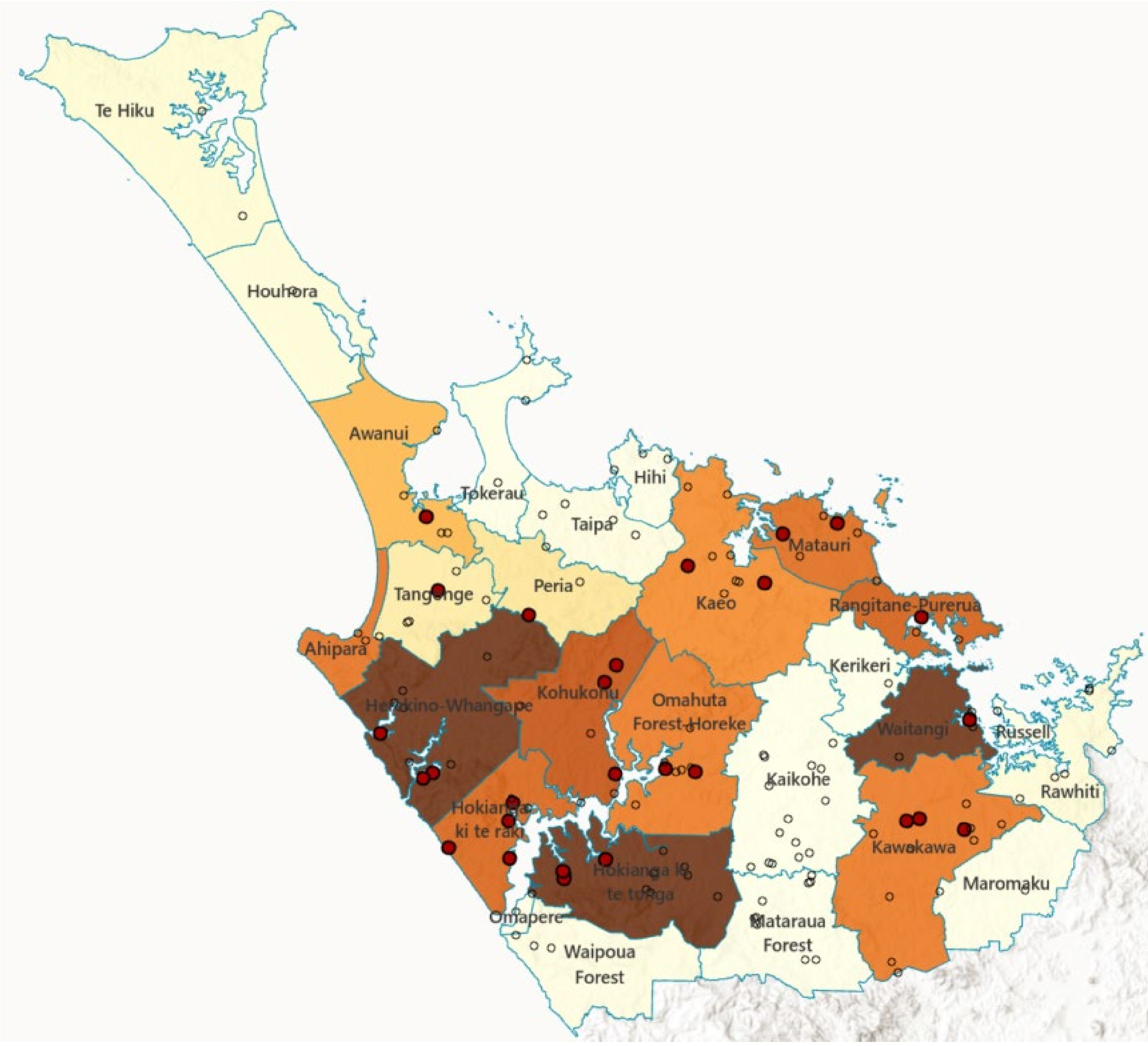


Figure 12. Marae exposed to 100yr flood event with 1.2m of sea level rise (red circles), and relative risk scores (considering Māori cultural assets only) reported to adaptation project areas (darker = higher relative risk score)

Adaptation area	Community board area	Long-term all hazards (2130 H+)
herekino_whangape	Te Hiku	1.81
kaeo	Bay of Islands-Whangaroa	1.67
waitangi	Bay of Islands-Whangaroa	1.47
omahuta_forest_horeke	Kaikohe-Hokianga	1.31
hokianga_ki_te_tonga	Kaikohe-Hokianga	1.18
kohukohu	Kaikohe-Hokianga	1.05
matauri	Bay of Islands-Whangaroa	0.94
hokianga_ki_te_raki	Kaikohe-Hokianga	0.94
kawakawa	Bay of Islands-Whangaroa	0.92
ahipara	Te Hiku	0.92
awanui	Te Hiku	0.55
rangitane_purerua	Bay of Islands-Whangaroa	0.54
tokerau	Te Hiku	0.49
peria	Te Hiku	0.34
tangonge	Te Hiku	0.30
te_hiku	Te Hiku	0.08
rawhiti	Bay of Islands-Whangaroa	0.06
houhora	Te Hiku	0.06
Kaikohe	Kaikohe-Hokianga	0.05
waipoua_forest	Kaikohe-Hokianga	0.04
taipa	Te Hiku	0.03
kerikeri	Bay of Islands-Whangaroa	0.01
maromaku	Bay of Islands-Whangaroa	0.01
hihi	Te Hiku	0.01
omapere	Kaikohe-Hokianga	0.01
mataraua_forest	Kaikohe-Hokianga	0.00
russell	Bay of Islands-Whangaroa	0.00

Table 11. Relative risk scores (Long-term, all hazards scenario) considering only Māori cultural assets

How the results influenced our recommendations

Of the top ten sites scoring the highest relative risk for Māori cultural assets only, 7 are included in Stage One and Two.

The prioritisation of the Hokianga and Herekino-Whangape adaptation project areas in Stage One is a direct response to the high levels of risk to Māori cultural assets in those areas, and an acknowledgement of the urgent need for forward planning to avoid increasing harm from hazards.

Waitangi is a site of national cultural significance, being the signing place of te Tiriti o Waitangi, and is included in Stage Two. However, given the significance of the site the authors suggest that a period of building close relationships with tangata whenua prior to embarking on adaptation planning will result in more enduring outcomes.

Kaeo ranks second highest when only Māori cultural assets are included in the relative risk scores. While obviously a high priority, given the complexity of the asset systems and the large flood work programme being implemented by NRC over the next two years, adaptation planning is recommended for the second Stage.

Stages 3 and 4 cover the remainder of sites in the top 50% of the highest scoring sites in terms of relative risks due to exposure of Māori cultural assets, excluding Kawakawa and Peria where risks are due to river flooding only.

4.4.3 Critical lifelines

Roading asset systems across the Far North are likely to be a key consideration in adaptation planning. A full investigation into road route resilience, flood outage durations and isolation effects was outside the scope of this report. However, an inspection of road exposure data can help indicate some locations which are highly likely to be impacted by climate change into the future, for example from tidal inundation due to sea level rise.

The Kohukohu adaptation project area alone, for instance, is expected to have nearly 15km of roads under water during most high tides with 1.2m of sea level rise. When all of Stage Two adaptation areas in the Hokianga-Herekino-Whangape harbour areas are included, this figure increases to over 50km (see Figure 13 below). This will have detrimental impacts on the future connectivity of local communities, and exacerbate flooding impacts during severe weather events.

In terms of regional and national connectivity, Kaeo is projected to have over 5.5km of state highway inundated at high tide with 1.2m of sea level rise. Given the area's importance as the only alternative northern route to the often-damaged Mangamuka gorge, this is an urgent issue to address.

How the results influenced our recommendations

Impacts on critical lifelines played a key role in our recommendations to prioritise the Hokianga-Herekino-Whangape adaptation project areas in Stage One, and Kaeo in Stage Two. In addition, projected impacts on roading in Awanui and Taipa (Stage Three) and Russell and Rawhiti (Stage Four) influenced our recommendations for phasing of those sites.

Tidal inundation 1.2m SL	Roads	State highways
kohukohu	14993	100
awanui	12819	1161
omahuta_forest_horeke	12289	688
kaeo	10437	5650
herekino_takahue	9940	0
rawhiti	8485	0
hokianga_ki_te_raki	7653	0
taipa	6934	700
hokianga_ki_te_tonga	6381	1700
russell	4400	0
matauri	4158	0
tokerau	2836	50
hihi	2263	0
waitangi	1876	1137
ahipara	871	0
kerikeri	481	0
waipoua_forest	468	0
kawakawa	453	1226
houhora	399	200
te_hiku	100	400
rangitane_purerua	71	0
omapere	50	50
kaikohe	0	0
maromaku	0	0
mataraua_forest	0	0
peria	0	0
tangonge	0	0

Table 12. Length of roads and state highways (m) exposed at high tide per adaptation project area, with 1.2m of sea level rise

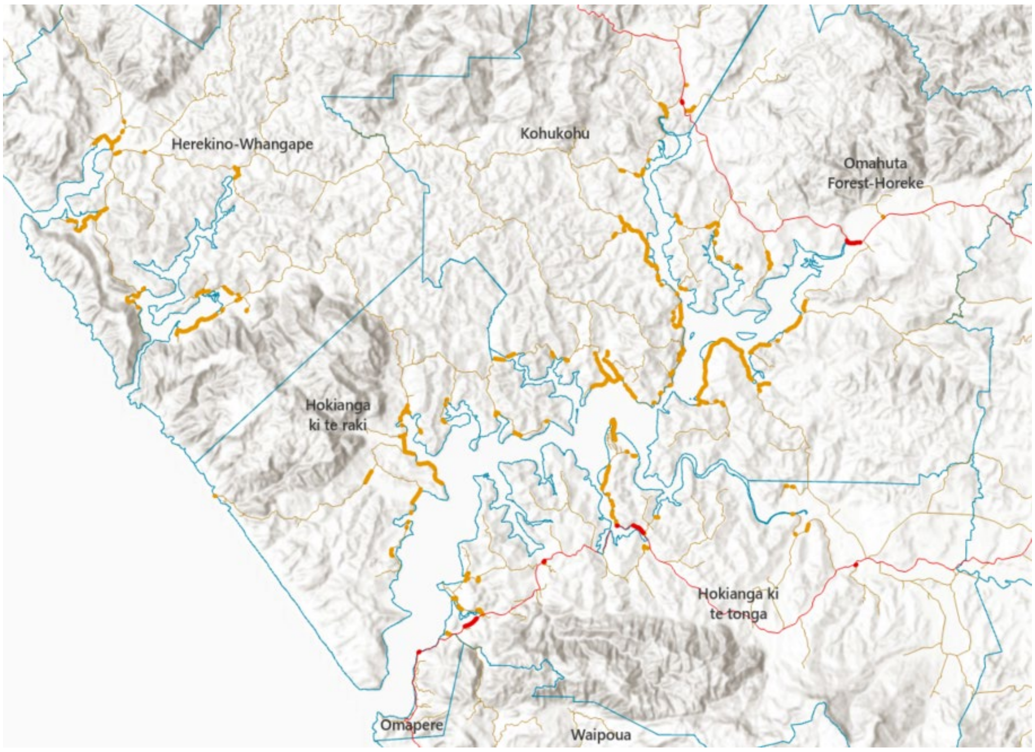


Figure 13. Roads (orange) and State highways (red) inundated (thick lines) in high tide flooding with 1.2m of sea level rise – Hokianga harbour area

4.4.4 What's at stake – vulnerability

While there remain concerns and questions over the use of the term vulnerability, and the use of census data in risk assessment, some measures of vulnerability can be useful indicators of differences across the district. Vulnerability data was sourced from the 2018 Census and based on the Social Vulnerability Index developed by Massey University.[7] The datasets used covered four themes: Having enough money to cope with crises and losses; Awareness, knowledge and skills to cope with hazards and emergencies; Safe, secure and healthy housing and Enough food and water to cope with shortage. A map of combined vulnerability indices is shown below in Figure 14.

How the results influenced our recommendations

The results especially reinforced the need for working with communities in the Hokianga area, and to a lesser extent, Kaeo and Rawhiti. When applied to the risk assessment results, vulnerability scores can highlight potential differences in the ability of communities to respond, recover and adapt to climate risks.

[7] https://www.ehinz.ac.nz/projects/social-vulnerability-indicators/

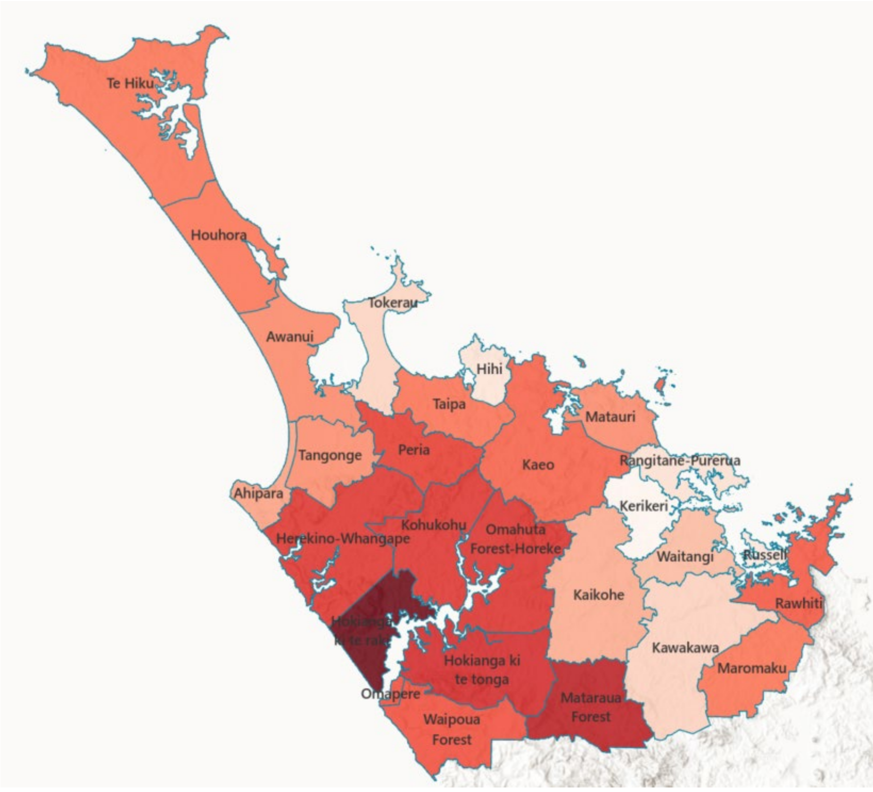


Figure 14. Social Vulnerability Index scores reported to adaptation project areas (darker = higher social vulnerability score)

4.4.5 Development of the programme using relative risk scores

Drawing on the insights from the analysis of the MCA results described in the previous section, we grouped adaptation project areas into 'programme stages' and used the relative risk scores to help prioritise the order in which adaptation planning could be delivered over time.

Within each programme stage, detailed project scoping will be required to articulate the specific locations requiring adaptive pathways planning, based on more detailed local risk assessment and an understanding of community readiness and needs through early engagement with communities and project partners.

Table 13 below shows relative risk scores of the adaptation project areas grouped according to Programme stages. The column to the far right shows the sum risk scores across all adaptation project areas for a given Programme stage.

Programme	Adaptation area	Community board area	Current day all hazards	Near-term coastal hazards (2080)	Long-term all hazards (2130 H+)	Long-term all hazards * vulnerability
Stage One	Hokianga ki te tonga	Kaikohe-Hokianga	0.29	0.32	0.74	0.51
	Herekino-Whangape	Te Hiku	0.35	0.52	0.71	0.47
	Kohukohu	Kaikohe-Hokianga	0.51	0.43	0.69	0.46
	Omahuta forest- Horeke	Kaikohe-Hokianga	0.20	0.19	0.37	0.25
	Hokianga ki te raki	Kaikohe-Hokianga	0.18	0.10	0.32	0.30
	Omapere	Kaikohe-Hokianga	0.19	0.24	0.26	0.16
Stage Two	Kaeo	Bay of Islands-Whangaroa	0.62	0.52	0.94	0.52
	Waitangi	Bay of Islands-Whangaroa	0.25	0.42	0.78	0.25
Stage Three	Taipa	Te Hiku	0.18	0.37	0.63	0.32
	Awanui	Te Hiku	0.16	0.17	0.60	0.27
	Ahipara	Te Hiku	0.02	0.10	0.28	0.11
	Tokerau	Te Hiku	0.09	0.16	0.20	0.05
	Hihi	Te Hiku	0.06	0.08	0.20	0.04
Stage Four	Matauri	Bay of Islands-Whangaroa	0.15	0.12	0.30	0.13
	Russell	Bay of Islands-Whangaroa	0.10	0.13	0.22	0.04
	Rangitane - Purerua	Bay of Islands-Whangaroa	0.02	0.10	0.21	0.04
	Rawhiti	Bay of Islands-Whangaroa	0.05	0.10	0.13	0.07
	Tangonge	Te Hiku	0.45	0.00	0.49	0.22
	Kawakawa	Bay of Islands-Whangaroa	0.34	0.06	0.49	0.13
	Peria	Te Hiku	0.10	0.00	0.12	0.08
	Houhora	Te Hiku	0.06	0.07	0.11	0.06
	Kerikeri	Bay of Islands-Whangaroa	0.04	0.02	0.09	0.01
	Te Hiku	Te Hiku	0.06	0.07	0.08	0.04
	Waipoua Forest	Kaikohe-Hokianga	0.09	0.01	0.08	0.05
	Maromaku	Bay of Islands-Whangaroa	0.04	0.00	0.06	0.03
	Mataraua Forest	Kaikohe-Hokianga	0.02	0.00	0.02	0.02
	Kaikohe	Kaikohe-Hokianga	0.01	0.00	0.01	0.00

Table 13. Relative risk scores for adaptation project areas, grouped according to recommended Programme Stages.