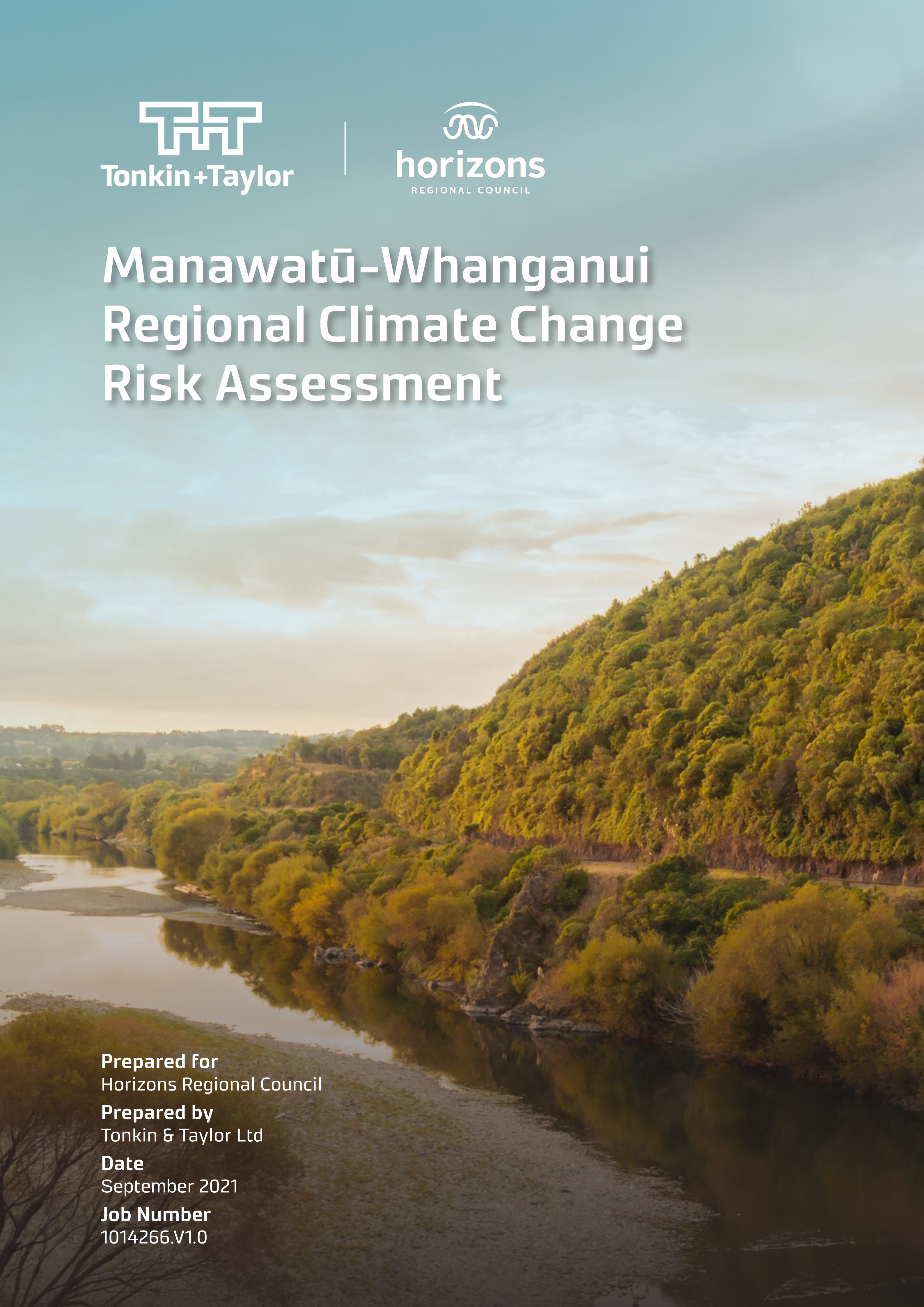

Manawatū-Whanganui Regional Climate Change Risk Assessment

Prepared for
Horizons Regional Council

Prepared by
Tonkin & Taylor Ltd

Date
September 2021

Job Number
1014266.V1.0

Document Control

Manawatū-Whanganui Regional Climate Change Risk Assessment
Version 1.0 published 02 September 2021

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Distribution

Horizons Regional Council	1 PDF copy
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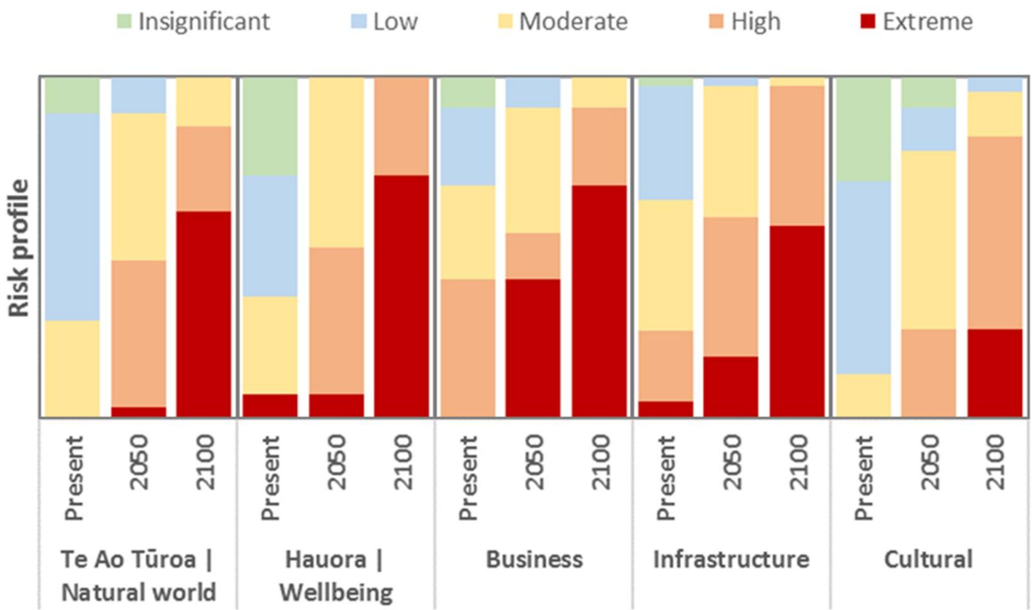
Executive summary

Climate change is one of humanity's greatest challenges. The impacts of climate change are already being felt within the communities, businesses, native ecosystems, and infrastructure within the region. Climate change, and its associated impacts will have significant social, economic, environmental and cultural implications for the region's communities.

This high-level risk assessment provides an important step in the formulation of climate changes strategies for the region. This Regional CCRA provides one of the first steps toward building resilience to climate change. Changes include increases in temperature, variations in precipitation, sea level rise, and changing wind speeds. These changes can lead to more frequent and acute events occurring such as flooding (coastal and inland), extreme storms and drought.

Risks were assessed within six community based values: Te Ao Tūroa | Natural world; Hauora | Wellbeing; Business; Infrastructure; Cultural; Governance. While the six established community values align closely to those values within the Treasury's Living Standards Framework, these have been tailored to the specific context faced by the communities within the region.

Risks from physical changes in climate for the Manawatū-Whanganui region are broad, incapsulating change through time across what our community values. Across all community values, risks are seen to increase in severity with time, with extreme risks making up over 50% of the risks identified for Te Ao Tūroa | Natural world, Hauora | Wellbeing, Business, and Infrastructure. Over 50% of present day risks are rated as moderate or above for Business and Infrastructure. All identified risks for Hauora | Wellbeing and the vast majority of Infrastructure risks are rated as high or extreme by 2100.



Summary risk profiles for each community value across present, 2050 and 2100 timeframes.

While many risks will be present across the region, these may present themselves at differing timeframes and levels of severity. With the differing geographies of the region, there is disparity with the hazards and associated risks that will be experienced. This includes differing patterns of rainfall and associated dry spells and droughts, with the east coast likely to experience more dry periods. Risks to population centres are primarily associated with flooding, sea level rise and coastal inundation. Coastal processes are of most concern for Whanganui, however those areas located on the Plains such as Manawatū, Rangitīkei, and Palmerston North have an increased exposure from inland flooding due to their location within floodplains.

Risks to business, especially tourism, in districts such as Ruapehu from reduced snow and ice are already present and projected to increase with climate change. Social inequalities will be exacerbated as a result of this, and wider changes in climate across the region. Land production and animal welfare are of concern, with pastoral land in the Horowhenua, Manawatū and Tararua districts having increased risk to flooding due to their exposure and the impact excess water can have on pasture and product growth.

This document provides a broad understanding of climate change risks within the Manawatū-Whanganui Region presently, and how these may change over time, based on current understanding of climate science and climate projections. This document forms part of an ongoing journey to understand and respond to climate change and is designed to help inform steps toward adaptation. Through undertaking this regional CCRA in collaboration with Treaty Partners, Regional Council, Territorial Authorities and wider stakeholders, it is hoped that each stakeholder group feels a level of ownership and continues this important journey toward climate adaptation.

To support the progression toward adaptation, the next step is to consider the risks highlighted within this document, and agree which should be prioritised for adaptation planning. This should continue through a collaborative approach, identifying risk owners, and the role of Horizons Regional Council for each of the risks. Horizons Regional Council's role relating to action for each risk could include direct ownership, along with the need to advocate for and inform other risk owners and decision makers. Ensuring buy-in across risk owners, stakeholders and the wider public is fundamental for effective action now and into the future.

This process of prioritising risks for adaptation planning could be undertaken in a number of ways, but will likely include:

- Review of the *risk ratings* and associated *strength of evidence* (including knowledge gaps);
- Consideration of *urgency* through establishing action already underway; and
- Wider consideration of *consequences*.

This regional CCRA sits within a wider cycle of climate risk assessment and associated adaptation at a local, regional and national level. The desire is that local risk assessments and adaptation plans inform those at a regional level, and subsequently these assessments inform the National Adaptation Plan (NAP) and associated National CCRA. The first NAP is due for publication in 2022, with timeframes for review likely every five years, aligned to that of the National CCRA.

This provides a natural cycle for local and regional risk assessments and associated adaptation planning, following a similar timeframe to that at a national level, ensuring publication of regional assessments and plans in advance of the NAP review. It is recognised that Long Term Planning (LTP) processes occur on a three year cycle, resulting in a potential mismatch in planning for climate adaptation, and associated implications on funding. Consideration on the cycle of adaptation planning is required to best inform the NAP while aligning to financial requirements of LTP.

1 Introduction

Climate change is one of humanity's greatest challenges. The impacts of climate change are already being felt within the communities, businesses, native ecosystems, and infrastructure within the region. Climate change, and its associated impacts will have significant social, economic, environmental and cultural implications for the region's communities.

This high-level risk assessment provides an important step in the formulation of climate changes strategies for the region. Horizons Regional Council and the Territorial Authorities across the region have committed to collaborative working in the face of climate change. As part of this commitment to work together the region's Mayors and Chair have agreed to undertake a range of work to build knowledge and understanding of the effects of climate change, with the aim of building resilience across the region.

Following on from the first National Climate Change Risk Assessment (NCCRA), this Regional Climate Change Risk Assessment (CCRA) looks to provide a basis for prioritising and responding to the impacts of climate change on community wellbeing in the region. The key project objectives are to:

- Identify community risks in the face of climate change.
- Build a common understanding of the issues across councils.
- Provide an initial prioritisation of risks for action.
- Support in the sharing of climate change vulnerabilities with communities and wider stakeholders.

This Regional CCRA provides one of the first steps toward building resilience to climate change. Changes include increases in temperature, variations in precipitation, sea level rise, and changing wind speeds. These changes can lead to more frequent and acute events occurring such as flooding (coastal and inland), extreme storms and drought. When assessing climate change risks, guidance is provided by the International Panel on Climate Change (IPCC), where risk sits at the intersection of physical hazards, exposure of human and natural systems to those hazards, and their vulnerability (in terms of sensitivity to change and ability to cope or adapt), shown in Figure 1.1.

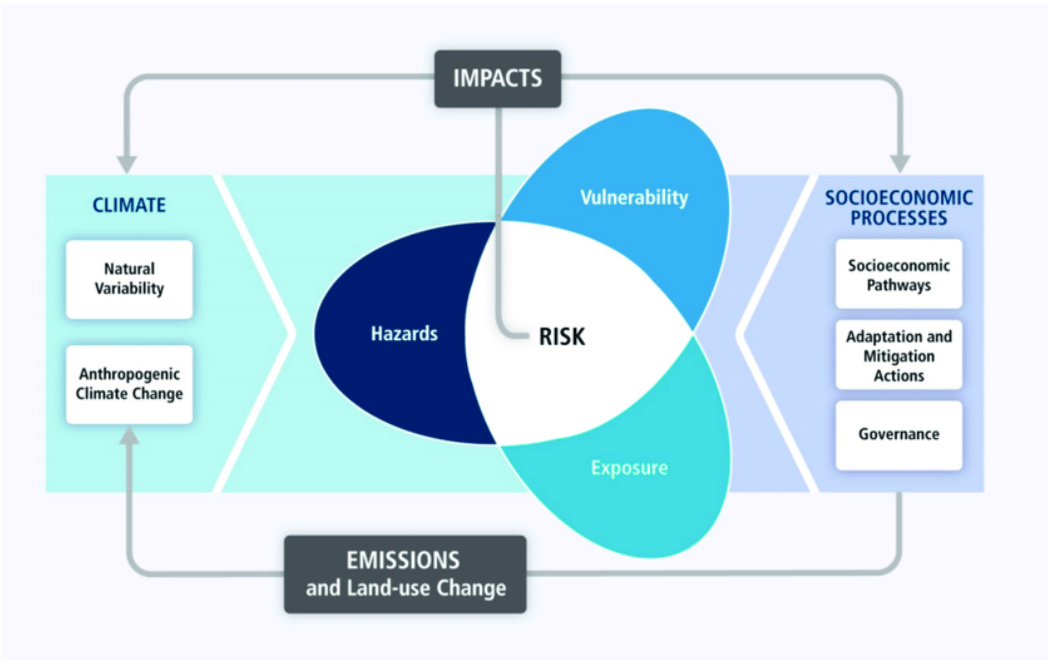


Figure 1.1: International Panel on Climate Change (IPCC) risk relationship.

2 Framework, method and approach

The project has taken a risk-based approach to identify impacts of climate change within the region, focusing on those negative impacts associated with physical climate changes. While important topics as part of the wider climate change discussions, efforts to reduce greenhouse gas emissions (mitigation), nor the risks associated with the shift to a lower carbon future (transition), are not part of this first Regional CCRA. Furthermore, with a focus on the negative impacts, opportunities arising from climate change have also not been captured as part of this assessment.

This section provides a high-level summary of the how community values are established and documented (*framework*), the way that risk has been assessed (*method*), and the way this was undertaken (*approach*). Each of these stages are discussed in more detail within the Interim Report (June 2021).

2.1 Framework

When considering risks from climate change, we first need to understand what could be at risk (our "values"). A bottom-up approach to define values has been used to reflect values that relate to the community. Development of the values framework has occurred in stages:

1. Broad engagement across the region (primarily through online interactive survey).
2. Refinement of values from broad engagement during hui with subject matter experts.
3. Testing the values during hui with subject matter experts.

Depicted as spokes within a bicycle wheel, community values form the structure and strength of the wheel. Each spoke is important in its own right, and functioning of all is fundamental to the success of the wheel. Reliance and interaction across each community value, just like spokes, is expected, with focus given to each to ensure a functioning wheel. The circular nature of the wheel not only demonstrates the wider climate change journey, but also the need for climate change work to be constant, without a start of end (linear).

While the six established community values align closely to those values within the Treasury's Living Standards Framework, these have been tailored to the specific context faced by the communities within the region. The six community values are:

- Te Ao Tūroa | Natural world.
- Hauora | Wellbeing.
- Business.
- Infrastructure.
- Cultural.
- Governance.

It is recognised that while risks associated with climate change and Governance often sit outside the regional control, their impact on the community is strongly felt, and therefore need to be reflected within this Regional CCRA, even if they are not assessed in a similar way to other risks.

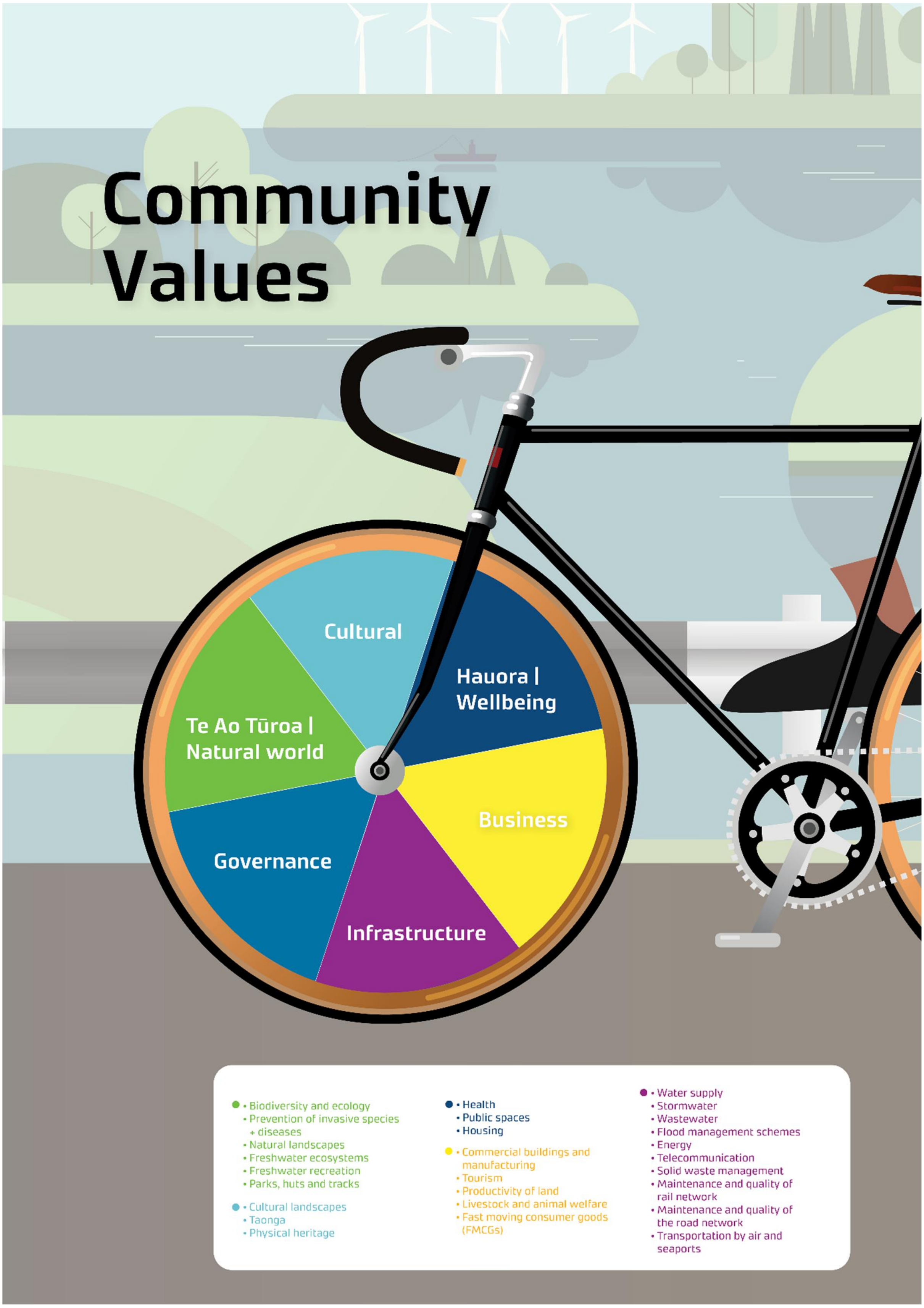


Figure 2.1: Community values framework.

Figure 2.2: Establishing community values

2.2 Method (assessing risk)

Through associating these criteria, it is possible to rate risk based on a qualitative assessment of exposure and vulnerability (relating to sensitivity and adaptive capacity), shown in Figure 2.3 below. Risks have been assessed against agreed climate hazards for RCP8.5, for three time-horizons (current, 2050 and 2100). This aligns to the NCCRA approach and subsequent report.

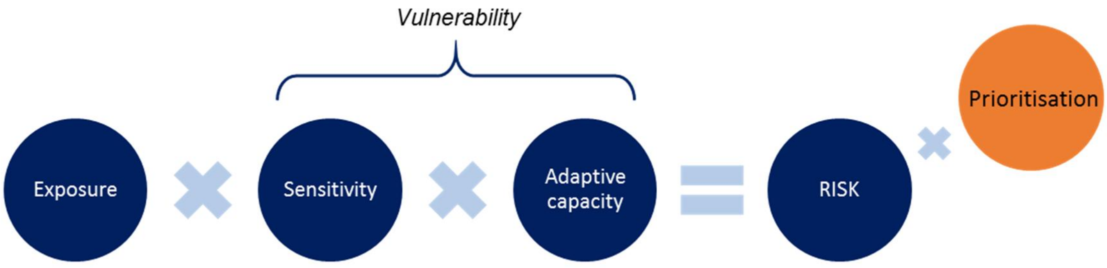


Figure 2.3: Risk equation based on exposure, sensitivity and adaptive capacity.

Risk has been rated out of five: *Insignificant*, *Low*, *Moderate*, *High*, *Extreme (*Table 2.1*)*. This allows a level of prioritisation of risk, with five distinct categories. Further prioritisation criteria are available to provide differing ways to rank risks, such as consequence, and urgency. These differing criteria have not been assessed as part of this Regional CCRA, however form a natural next step to enable further refinement of priorities for risk owners over the next five years.

Table 2.1: Risk rating descriptions adapted from AS 5334 – Climate change adaptation for settlements and infrastructure

Risk rating	Descriptor
Extreme	Extreme risk requiring immediate attention
High	High risk issue requiring detailed research and planning
Moderate	Moderate risk issue requiring change in approach
Low	Low risk requiring attention through routine processes
Insignificant	Insignificant risk to be monitored and reviewed in time

2.3 Approach

The approach to this Regional CCRA has combined differing engagement activities and literature review, including:

- A Literature review to provide a robust evidence base to understand risks in greater detail and to identify any gaps from the first phase screening process.
- Broad engagement across the region (primarily through online interactive survey).
- Subject Matter Expert Engagement: to elicit information specific to a particular value (or value “Domain”).
- Iwi Engagement: to elicit information specific to Te Āo Māori and iwi values.

2.3.1 Literature review

A literature review has been undertaken to gain an understanding of how climate change could impact on the region. This literature review complemented initial insights from the broad engagement (discussed below), building further knowledge on values, elements, and their relationships to climate hazards. This work has been ongoing throughout the project, informed by engagement activities.

2.3.2 Overall engagement approach

The engagement for the Regional CCRA sought to be a reciprocal process that allows for a mutually advantageous exchange of information. This is particularly important for climate change, which is a complex and sometimes overwhelming topic for stakeholders. Such an engagement approach is intended to foster meaningful long-term relationships, and to engender support for future work in identifying and adapting to climate change risks.

Our engagement uses a broad range of methods to achieve the project objectives and are aligned to stakeholder and partner needs, including:

- Targeted subject matter workshops.
- Focus groups.
- Kānohi-ki-te-kānohi (face to face) hui.
- Insights questionnaires (surveys).
- Targeted phone calls for gap analysis.

Workshops sought to have a broad group of attendees, reaching out to subject matter experts beyond local government, to best capture views within the region. A list of participating organisations is provided in Table 2.2 below.

Table 2.2: Engagement attendees (by organisation)

Horizons RC Horowhenua DC King Country Energy Palmerston North CC Rangitīkei DC Ruapehu DC Tararua DC Trust Power Whanganui DC	Manaaki Whenua Manawatū DC Manawatū-Whanganui CDEM Massey University Mid Central DHB Rangitāne o Manawatū Te Kaahui o Rauru Te Rūnanga o Raukawa

Note that while iwi are listed, this report may not reflect their views.

To enable elicitation of information specific to Te Āo Māori and iwi values, a specific iwi focused hui was undertaken. Recognising the limited capacity of Rūnanga, the invitation was open to all Rūnanga, while focusing on Rangatahi | young Māori. The objectives of the hui included:

- Identification of iwi specific values.
- Reflection of Te Āo Māori across values.
- Capture exposure for identified Te Āo Māori and iwi values.

Following this focused hui, workshops were run for vulnerability with representation across Treaty partners and Stakeholders to enable a holistic discussions. Knowledge gaps feature in section 11.

3 Summary of climate change for the region

The main measure of climate change relates to carbon dioxide emissions into the atmosphere, which has been modelled by the Intergovernmental Panel for Climate Change (IPCC). Continued emissions of greenhouse gases will cause further warming and changes within all parts of the climate system. Based on the models from the IPCC, four Representative Concentration Pathways, or RCPs, were defined, providing greenhouse gas concentration trajectories to the end of the century (Figure 3.1). The RCP 8.5 trajectory represents the "*high-end"* emissions scenario and is often the recommended scenario to use when screening for physical climate change impacts. We have used RCP8.5 for the climate change summary below, with three timeframes, present day, mid-term (2050) and long-term (2100).

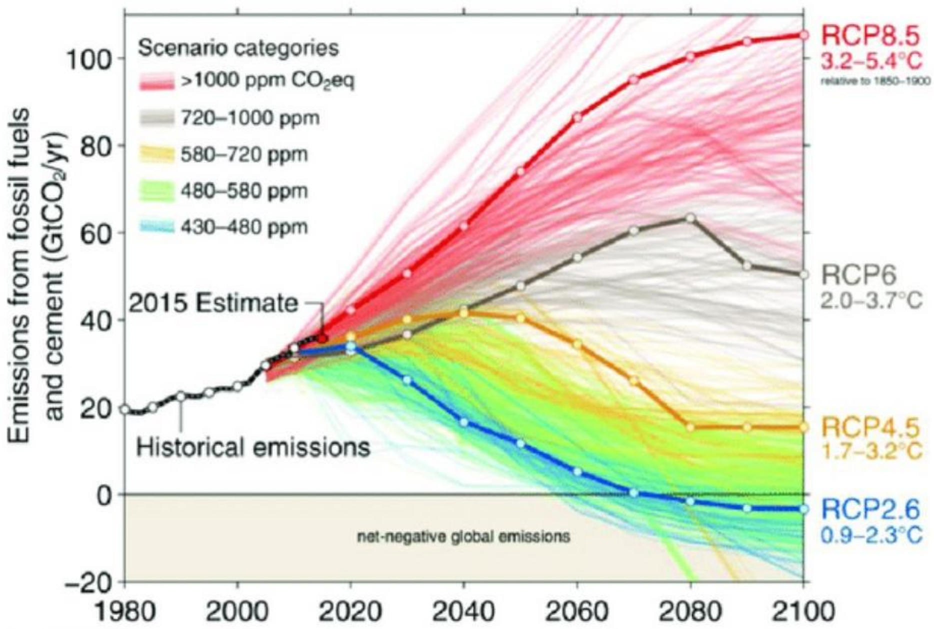
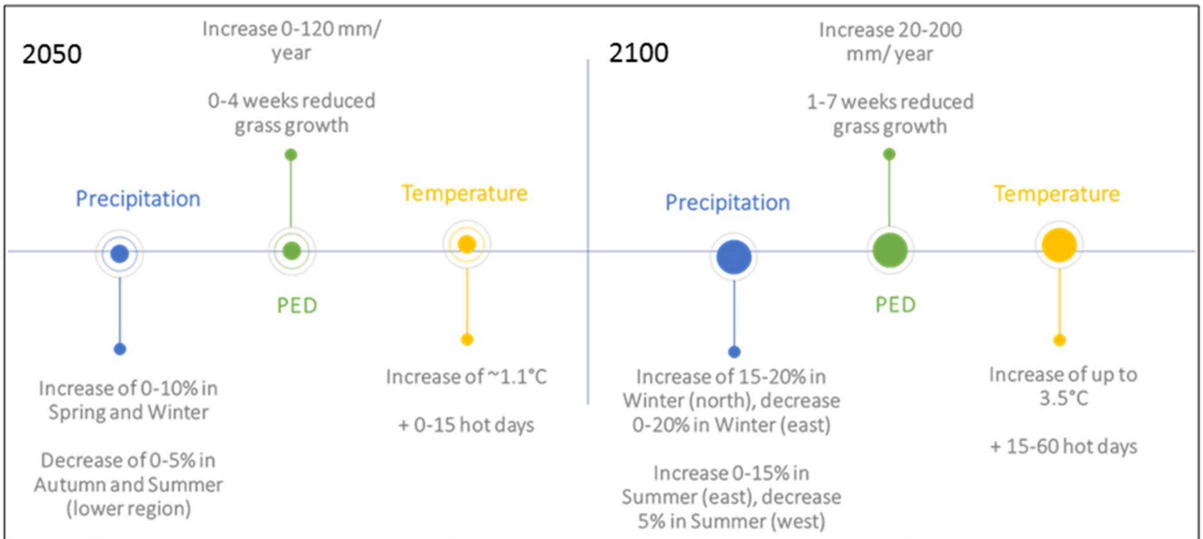


Figure 3.1: Global emission scenarios and the four RCP, with the historic emissions trajectory since 1980 (black), MfE 2018.

Gradual climatic changes such as temperature increase and changes in precipitation have been measured by the National Institute of Water and Atmospheric Research (NIWA) for the region out to the end of the century. It is projected that temperatures are likely to increase up to 1.2°C across the region by mid-century, with little variation at a district level. However, there is further granularity when considering the number of hot days (days > 25°C), where by mid-century there is likely to be an increase of 10-15 hot days in areas with lower elevations, whilst those areas such as Waiouru and Ohakune are expected to experience 0-5 more hot days than present day. There is a significant increase in the number of hot days when considering the 2100 timeframe. It is projected that areas such as Whanganui and the hill country around Taumarunui will experience between 50-60 more hot days per year, whilst other areas in lower elevations (Palmerston North City, Horowhenua and Tararua) are likely to experience 40-50 more hot days (NIWA, 2016). Prolonged increased temperatures and reduced rainfall can lead to drought conditions, which are projected to increase in frequency and intensity throughout the region.

Precipitation changes have seasonality and spatial variations throughout the region, particularly when looking out to the end of the century. Precipitation is projected to on average decrease on the eastern side of the Ruahine and Tararua ranges in the spring and winter months by mid-century, whilst there is a north- south divide present in summer precipitation changes. Northern areas of the region are projected to experience a 5% increase in summer precipitation, whilst southern areas are projected to have a 5% decrease. Winter rainfall by the end of the century is projected to increase by 20% in the north west of the region, and decrease by 20% in the south east of the region. The north-south divide is no longer present in summer months at the long-term timeframe, and spring rainfall is projected to increase by 5% across majority of the region (NIWA, 2016). Increases in precipitation can lead to the increased frequency and intensity of inland flooding and landslide events. Due to the geography (e.g. vast river networks) and geology (e.g. erodible soils) of the region increased precipitation is likely to exacerbate the impacts from these climate-induced hazard events.



	Climate change driver/variable	Mid term (2050) RCP8.5	Long term (2100) RCP8.5
	Higher temperature	+ 0.5- 1.25°C + 1-1.25°C (Summer)	+ 2.5- 3.5°C + 3.0 – 3.5°C (Summer)
	Average change in 'hot days' from present day (20)	+ 0-10 days (Central Plateau) + 15-20 days (Whanganui and hill country, Taumaranui)	+ 5-20 days (Central Plateau) + 50-60 days (Whanganui and hill country, Taumaranui)
	Annual rainfall	- 8-15% in summer rainfall + 10-15% winter rainfall	- 10-15% in summer rainfall + 4-8% in water rainfall
	Average change in 'cold nights' from present day	-0-10 cold nights (coastal) -10-40 cold nights (inland, high elevation)	- 0-10 cold nights (coastal) -30-90 cold nights (inland, high elevation)
	Sea level rise	+ 0.3 m	+ 0.8 m
	Inland flooding	+ 7% rainfall depth (24 hr, 100 yr)	+ 14% rainfall depth (24 hr, 100 yr)

Figure 3.2: Climate projections for the region at 2050 and 2100 (RCP 8.5) (NIWA, 2016)[1].

It is projected that by mid-century sea levels in New Zealand will rise by approximately 0.3 m and by the end of the century increase by 0.8 m when considering the RCP 8.5 scenario. Increases in sea level rise can influence the severity of coastal flooding events and exacerbate the impact.

The frequency of extremely windy days is not likely to change significantly across the region out to the end of the century. However, it is projected that there may be an increase in westerly wind flows

[1] Potential evapotranspiration deficit (PED) can be thought of as the amount of water that would need to be added, by rainfall or irrigation, to keep the pasture growing at its potential seasonal rate (NIWA, 2007).

during winter months and north-easterly flows during the summer months. Storms are projected to increase in intensity across the region with local wind extremes and thunder storms likely to occur (Ministry for the Environment, 2021).

4 Summary of climate change risks

Risks from physical changes in climate for the Manawatū-Whanganui region are broad, incapsulating change through time across what our community values. Across all community values, risks are seen to increase in severity with time, with extreme risks making up over 50% of the risks identified for Te Ao Tūroa | Natural world, Hauora | Wellbeing, Business, and Infrastructure. Over 50% of present day risks are rated as moderate or above for Business and Infrastructure., All identified risks for Hauora | Wellbeing and the vast majority of Infrastructure risks are rated as high or extreme by 2100.

Figure 4.1 shows this increasing risk profile with time, along with the presence of high and extreme risks across all community values and associated timeframes.

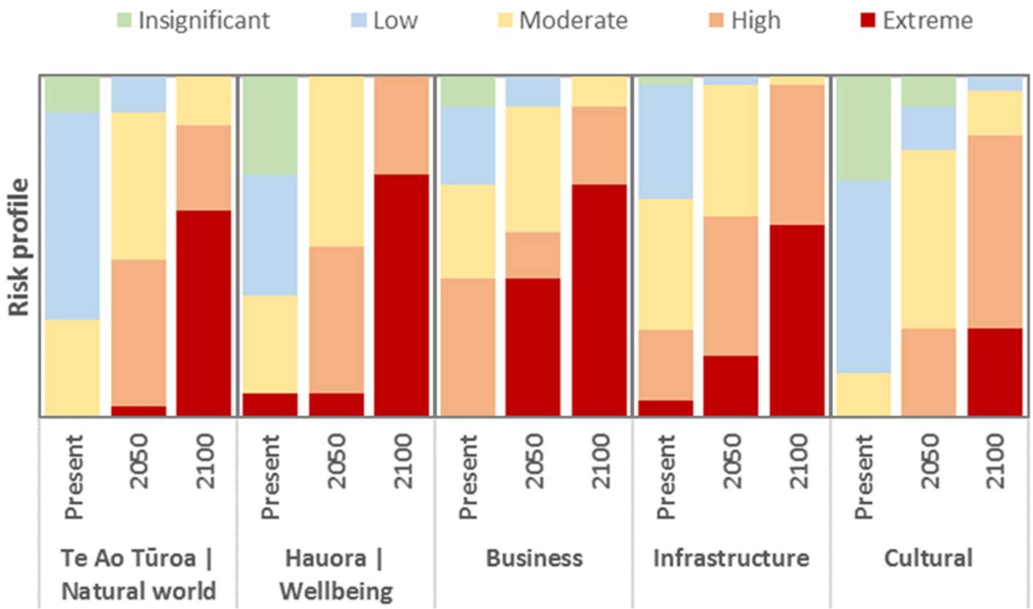


Figure 4.1: Summary risk profiles for each community value across present, 2050 and 2100 timeframes.

While many risks will be present across the region, these may present themselves at differing timeframes and levels of severity. With the differing geographies of the Manawatū-Whanganui region, there is disparity with the hazards and associated risks that will be experienced. This includes differing patterns of rainfall and associated dry spells and droughts, with the east coast likely to experience more dry periods. Risks to population centres are primarily associated with flooding, sea level rise and coastal inundation. Coastal processes are of most concern for Whanganui, however those areas located on the Plains such as Manawatū, Rangitīkei, and Palmerston North have an increased exposure from inland flooding due to their location within floodplains.

Risks to business, especially tourism, in districts such as Ruapehu from reduced snow and ice are already present and projected to increase with climate change. Social inequalities will be exacerbated as a result of this, and wider changes in climate across the region. Land production and animal welfare are of concern, with pastoral land in the Horowhenua, Manawatū and Tararua districts having increased risk to flooding due to their exposure and the impact excess water can have on pasture and product growth.

Figure 4.2 highlights some of the highest risks for the region, depicted for some population centres and differing geographies, such as the plains and hill country. While no means a complete picture, this helps portray the depth and breadth of risks for the region.

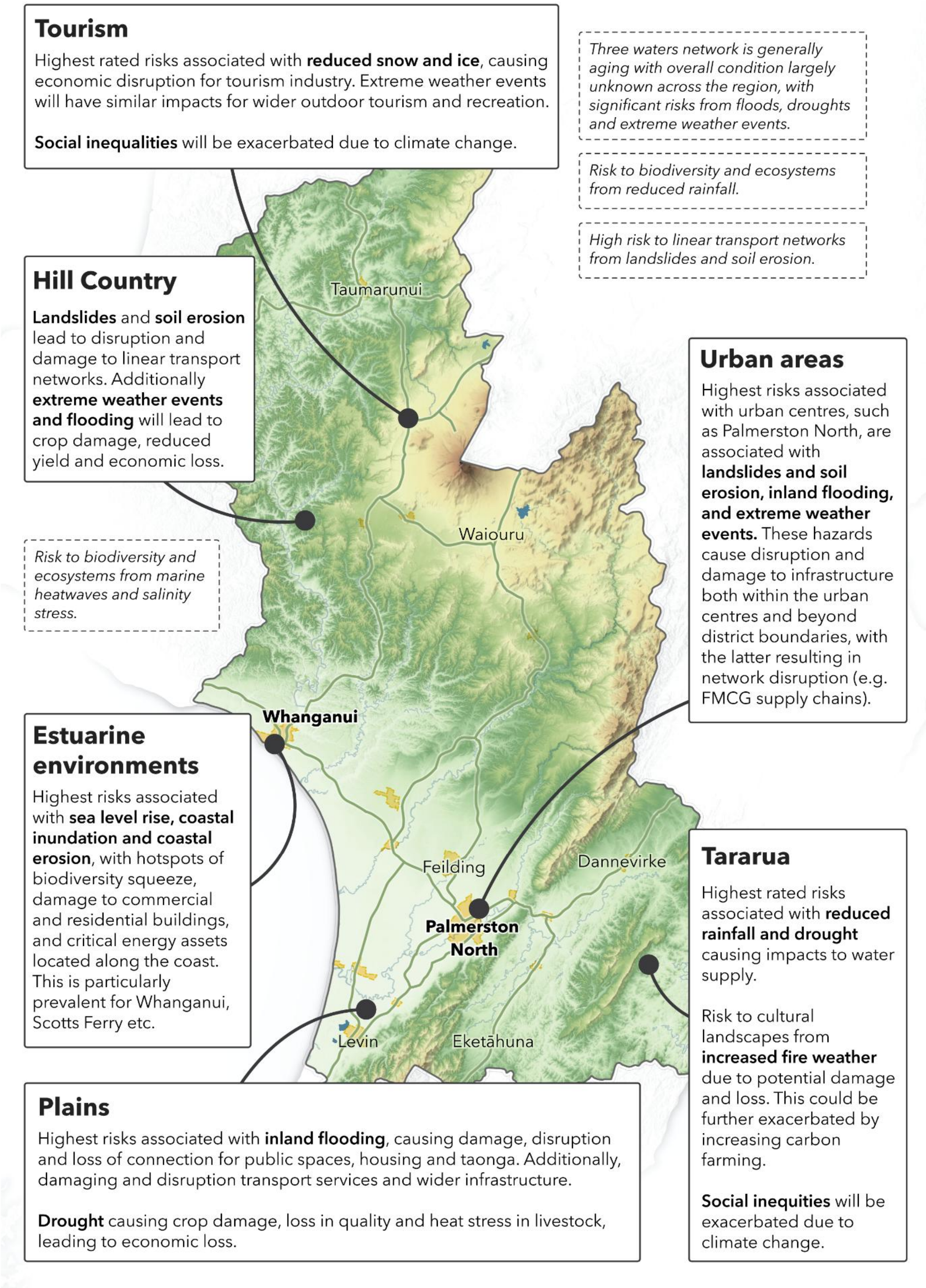


Figure 4.2: Overview of some of the highest risks for differing parts of the region.

Table 4.1: Summary of risks to values and elements for differing climate change hazards across the three timeframes, present, 2050 and 2100

		Higher temperatures			Inland flooding			Extreme weather events			Drought			Coastal flooding		
		Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Te Ao Tūroa | Natural world	Biodiversity and ecology	M	H	E							L	M	E	L	M	E
	Biosecurity	L	H	E				M	H	E	L	L	H			
	Freshwater ecosystems	M	H	E	L	H	H				L	H	H			
	Natural landscapes				L	M	M							L	M	H
Hauora | Wellbeing	Health	I	M	E				L	H	E	L	M	H			
	Housing				H	E	E	L	M	H				M	H	E
	Public spaces				M	H	E	I	M	H				I	M	E
	Social capital	I	L	L	L	H	E	I	L	H						
Business	Productivity of land	M	H	E	H	E	E									
	Livestock animal welfare	M	M	E	H	E	E	H	E	E				L	M	E
	Commerce				M	M	H	I	L	M						
	Goods and services	I	L	M	H	E	E	M	M	H						
	Tourism				M	H	E	H	E	E	I	L	M			
Infrastructure	Airports and seaports	L	M	H	M	H	E	M	H	E				M	H	E
	Energy - distribution	L	M	H	M	H	E	M	H	E						
	Energy - generation				L	M	H	L	M	H	L	M	H			
	Flood management				M	H	H	M	H	H						
	Rail networks	L	M	H	H	H	E	L	M	H						
	Road networks	L	M	H	H	H	E	L	M	H						
	Solid waste management				M	H	E	M	H	E				M	H	E
	Telecommunications and network infrastructure	I	L	M	M	M	H	M	M	H						
	Three waters - drinking water	L	M	H	L	M	H				H	H	E			
	Three waters - stormwater infrastructure				H	E	E	M	H	E	L	M	M			
	Three waters - wastewater infrastructure				H	E	E	M	H	E	L	M	H			
Cultural	Cultural landscapes				L	M	H									
	Parks, huts and tracks				L	M	H	L	L	H				I	I	M
	Physical heritage	L	M	H												
	Taonga	M	H	E												
	Freshwater recreation				M	H	E				L	M	H			

		Increased fire weather			Increasing landslides and soil erosion			Sea level rise and coastal erosion			Change in rainfall			River erosion		
		Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Te Ao Tūroa | Natural world	Biodiversity and ecology	L	M	E				L	M	E	M	M	E			
	Biosecurity															
	Freshwater ecosystems										L	H	H	L	H	H
	Natural landscapes	L	M	H	L	H	E	L	H	E						
Hauora | Wellbeing	Health															
	Housing	L	M	H	L	M	H	M	H	E				L	M	H
	Public spaces							I	M	E						
	Social capital				I	L	M	I	L	M						
Business	Productivity of land	M	H	E	M	H	H									
	Livestock animal welfare				M	H	H									
	Commerce															
	Goods and services															
	Tourism										L	M	H			
Infrastructure	Airports and seaports							L	M	M						
	Energy - distribution															
	Energy - generation										L	M	H			
	Flood management															
	Rail networks				H	H	E									
	Road networks				H	H	E	M	H	E						
	Solid waste management															
	Telecommunications and network infrastructure															
	Three waters - drinking water															
	Three waters - stormwater infrastructure															
	Three waters - wastewater infrastructure															
Cultural	Cultural landscapes	M	H	E	M	H	E	L	M	H						
	Parks, huts and tracks	I	L	L	L	H	E	I	I	M						
	Physical heritage															
	Taonga															
	Freshwater recreation													I	L	M

		Reduced snow and ice			Sea level rise and salinity stress			Marine heatwaves			Ocean acidification		
		Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Te Ao Tūroa | Natural world	Biodiversity and ecology				I	M	M	M	E	E	M	H	E
	Biosecurity												
	Freshwater ecosystems				L	M	H						
	Natural landscapes	L	H	E									
Hauora | Wellbeing	Health												
	Housing												
	Public spaces												
	Social capital												
Business	Productivity of land												
	Livestock animal welfare												
	Commerce												
	Goods and services												
	Tourism	H	E	E									
Infrastructure	Airports and seaports												
	Energy - distribution												
	Energy - generation												
	Flood management												
	Rail networks												
	Road networks												
	Solid waste management												
	Telecommunications and network infrastructure												
	Three waters - drinking water												
	Three waters - stormwater infrastructure												
	Three waters - wastewater infrastructure												
Cultural	Cultural landscapes												
	Parks, huts and tracks												
	Physical heritage												
	Taonga												
	Freshwater recreation												

4.1 District summaries

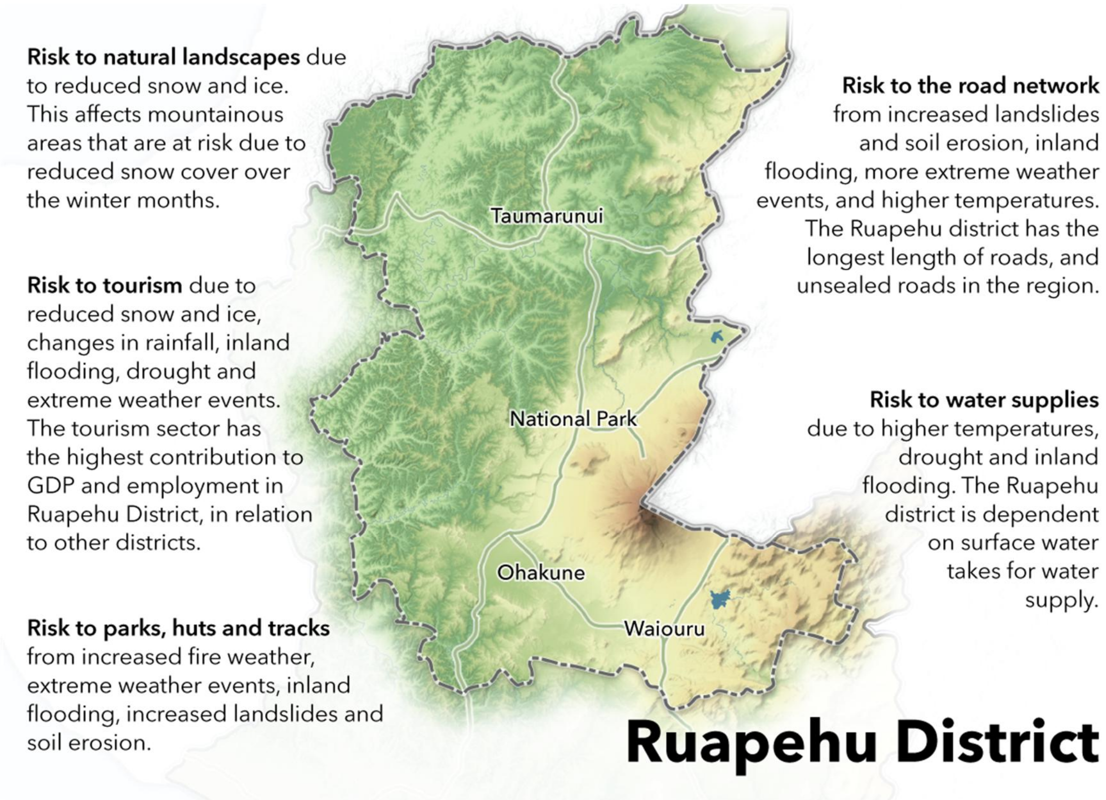


Figure 4.3: Overview of risks for Ruapehu District

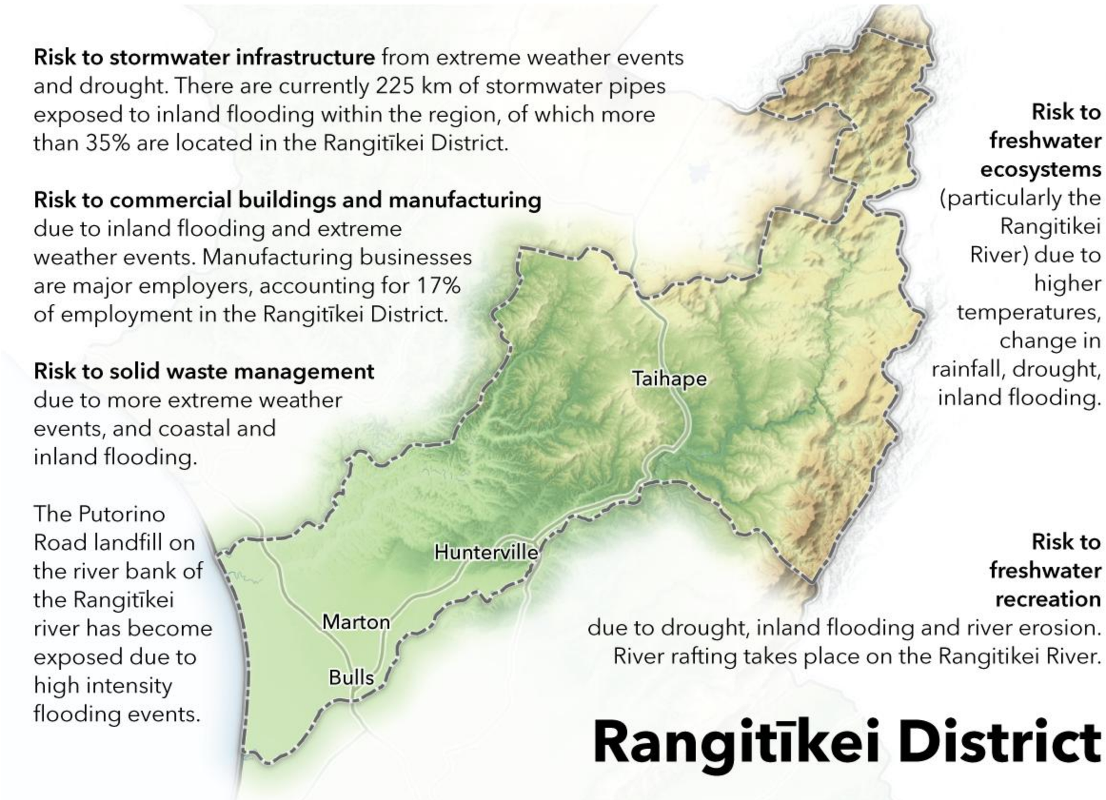


Figure 4.4: Overview of risks for Rangitīkei District

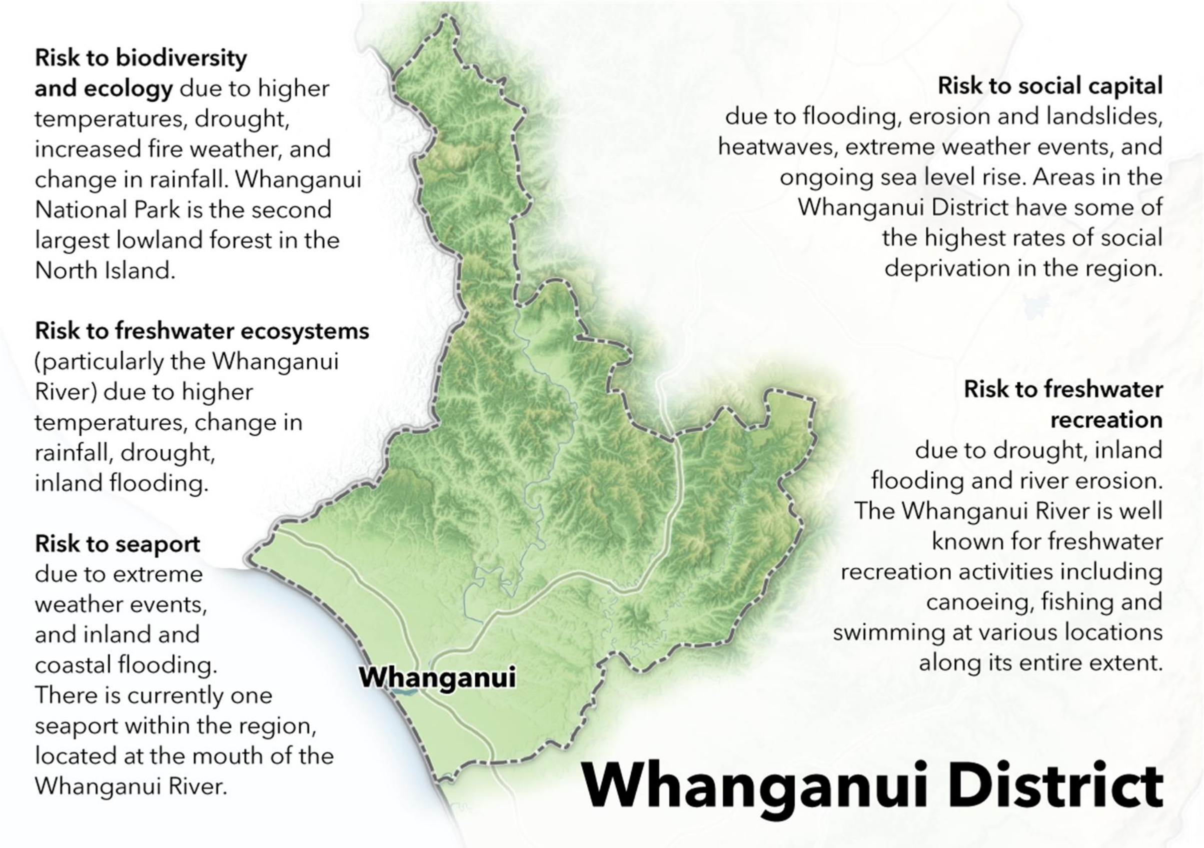


Figure 4.5: Overview of risks for Whanganui District

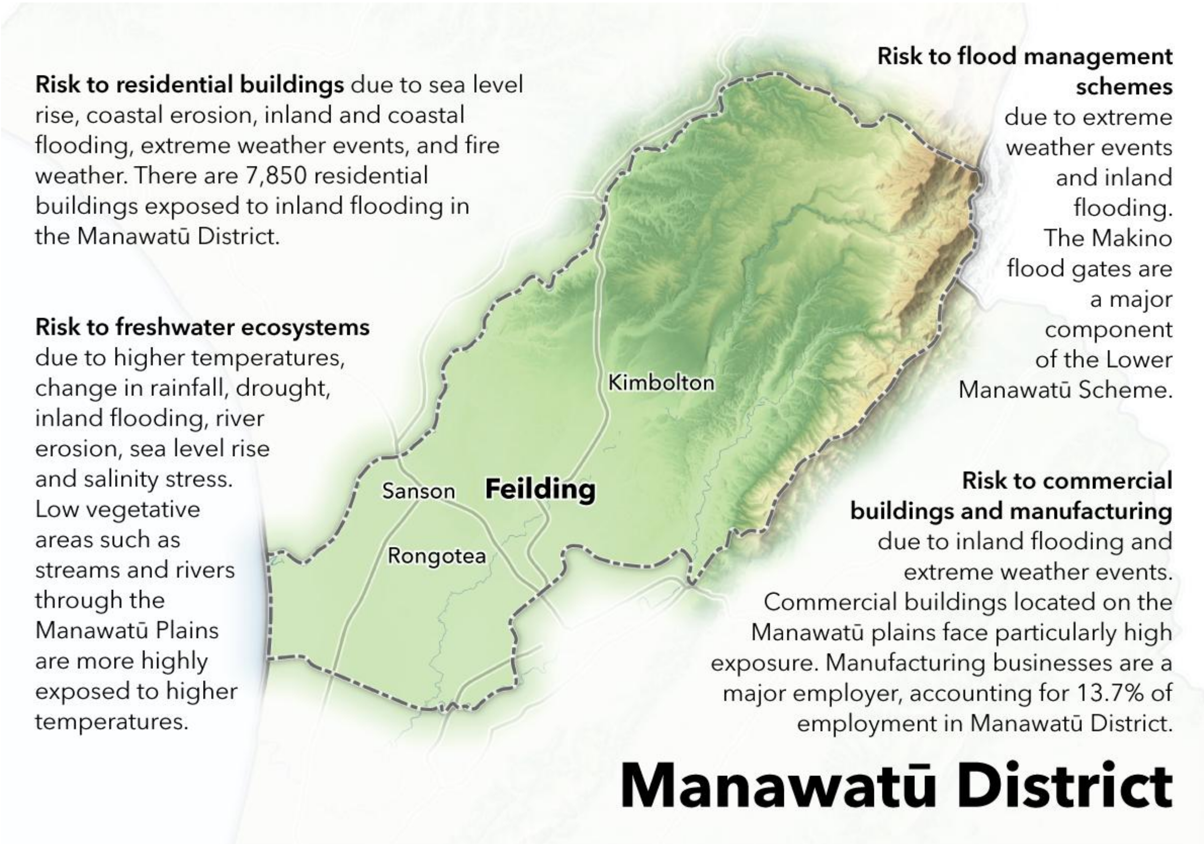


Figure 4.6: Overview of risks for Manawatū District

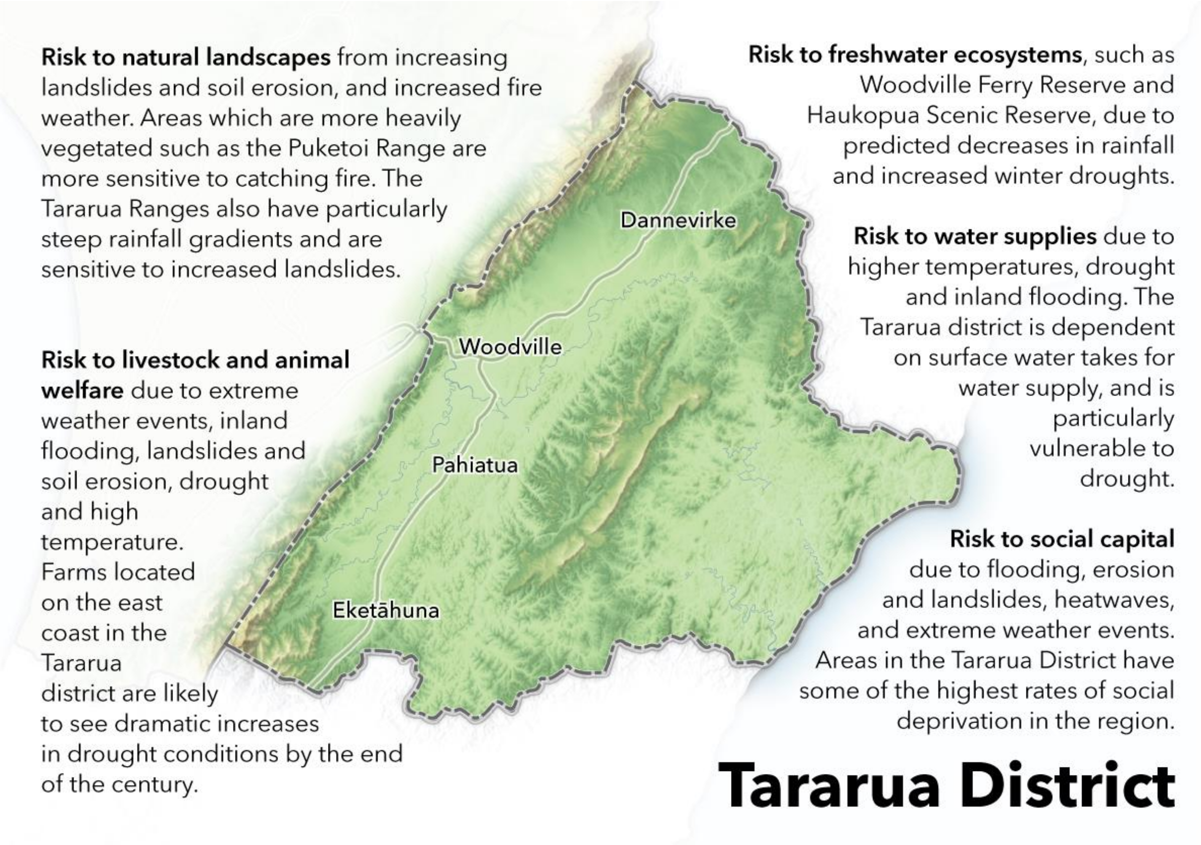


Figure 4.7: Overview of risks for Tararua District

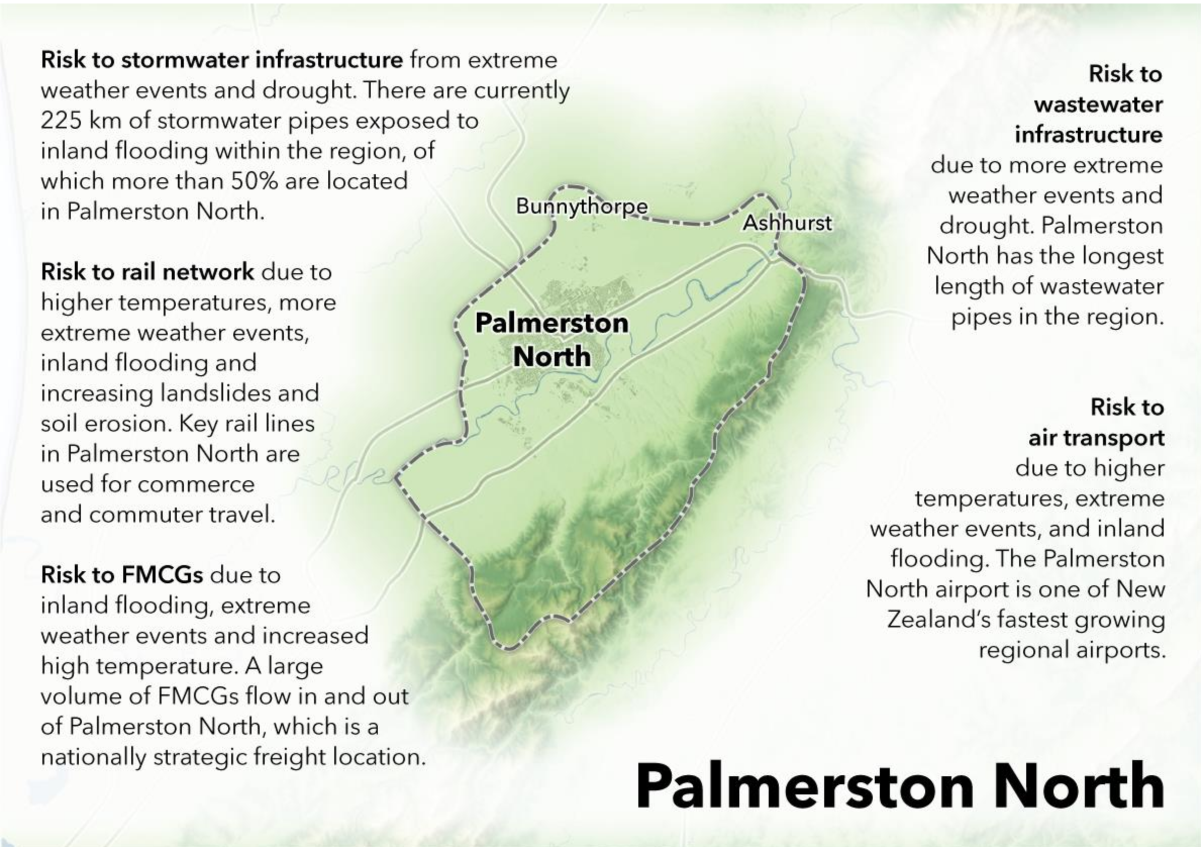


Figure 4.8: Overview of risks for Palmerston North

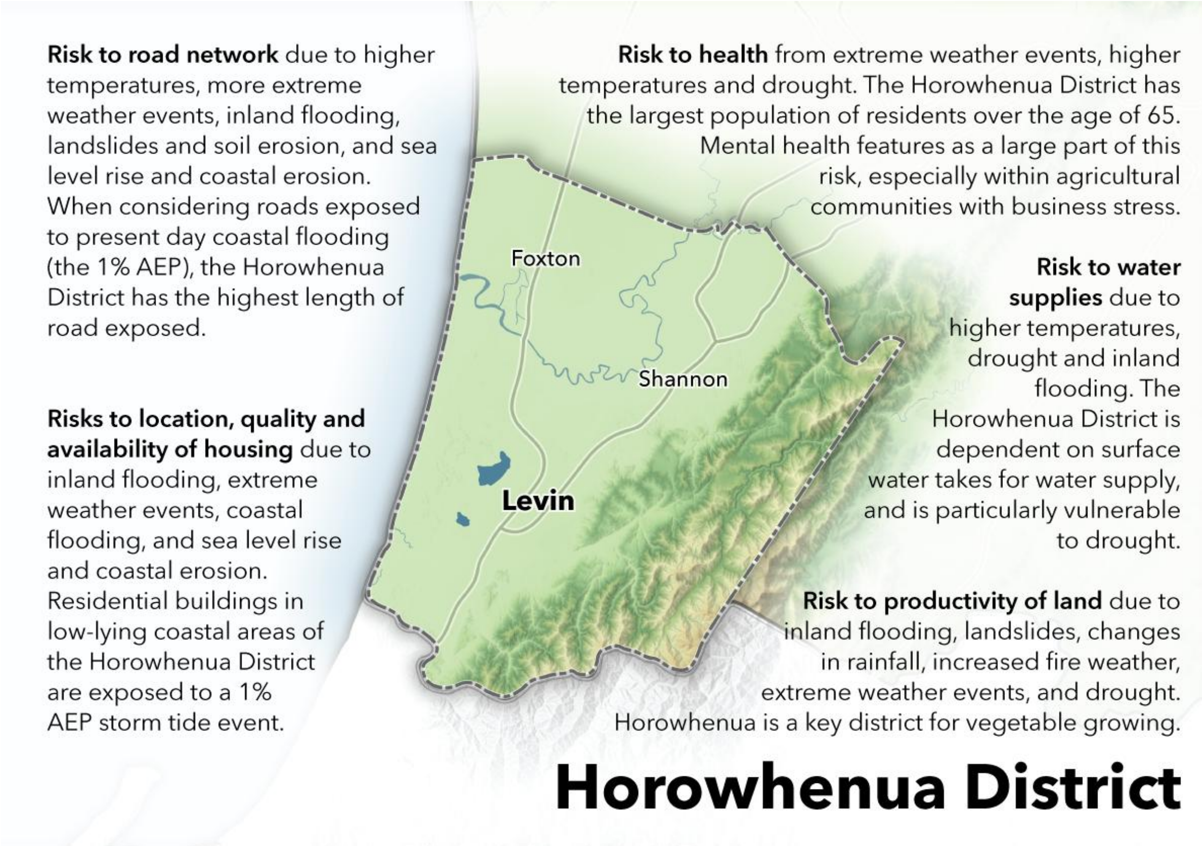


Figure 4.9: Overview of risks for Horowhenua District

5 Te Ao Tūroa | Natural world

Te ao Tūroa is the earth, nature and the enduring world. It is the longstanding environment and all its living components; whenua (the land), wai (water), āhurangi (the climate) and koiora (all living communities). The Manawatū-Whanganui region has a diverse physical environment and ecosystems including mountainous alpine environments, complex riverine systems and two coastlines (Figure 5.1).

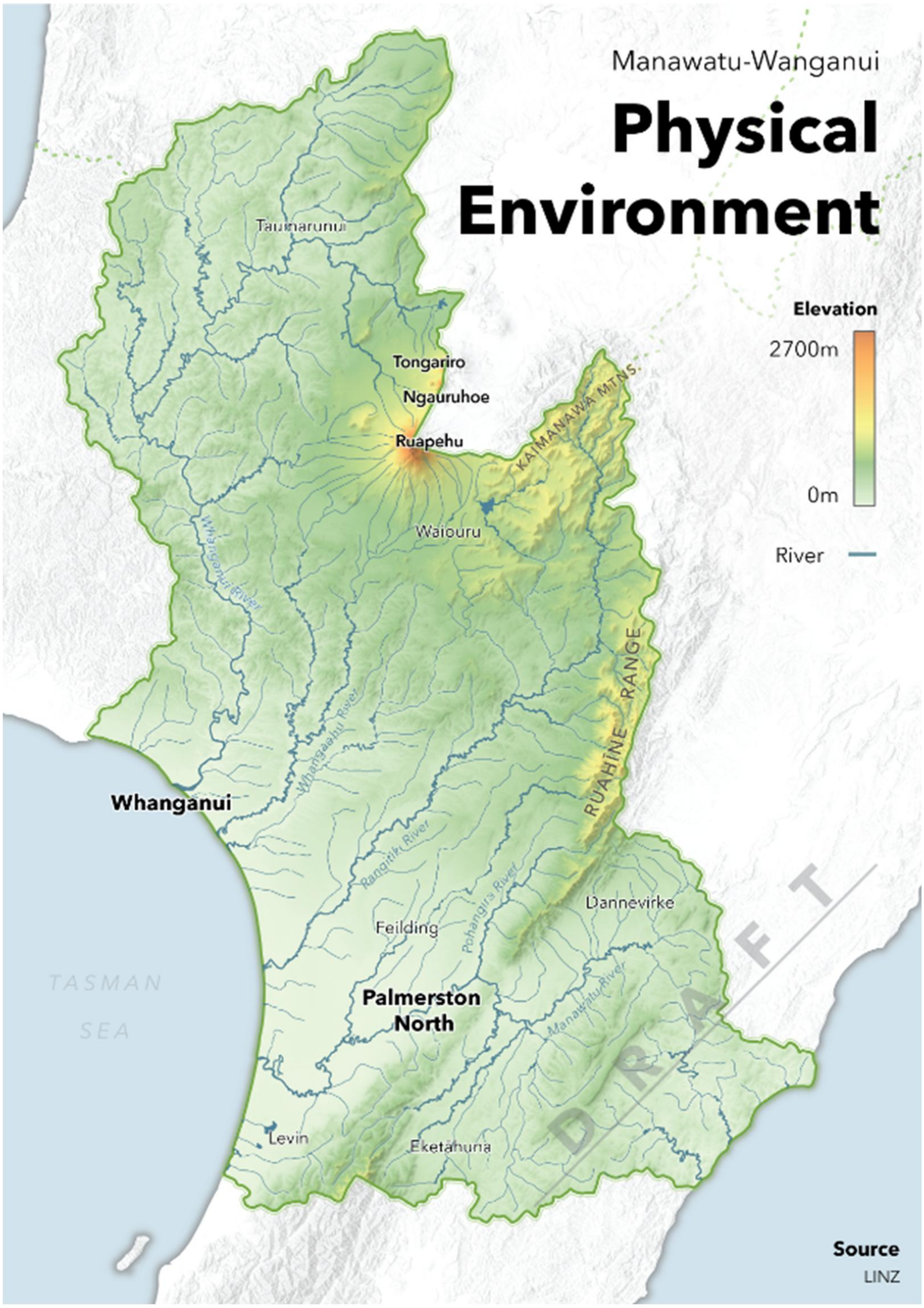


Figure 5.1: Physical environment of the Manawatū-Whanganui Region.

There are over 35,000 kms of waterways in the region, with three major rivers which divide it: the Whanganui (290 km), Manawatū (182 km), and Rangitīkei (241 km). The Whanganui is the second longest river in the North Island and has the second-largest catchment, draining the majority of the region west of Lake Taupō (Manawatū-Wanganui Emergency Management Group, 2019). There are also 226 lakes and over 400 wetlands or wet areas (Horizons Regional Council, 2019).

The region encompasses approximately 3,000 km^2 of Territorial Sea, comprising distinct and separate western and eastern coastlines. The west coastline spans approximately 120 km, characterised by narrow sandy beaches backed by sea cliffs in the north and dynamic dune systems to the south of Whanganui. The east coast spans 40 km and is characterised by rocky platforms backed by sandy beaches dotted with boulders (NIWA, 2018a).

Table 5.1 summarises the likely greatest risks of climate change to the natural world values in the Manawatū-Whanganui Region.

Table 5.1: Summary of risks to Te Ao Tūroa elements for differing climate change hazards

Te Ao Tūroa | Natural world	Higher temperatures			Inland flooding			Extreme weather events			Drought			Coastal flooding			Increased fire weather			Increasing landslides and soil erosion		
	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Biodiversity and ecology	M	H	E							L	M	E	L	M	E	L	M	E			
Freshwater ecosystems	M	H	E	L	H	H				L	H	H									
Natural landscapes				L	M	M							L	M	H	L	M	H	L	H	E
Biosecurity	L	H	E				M	H	E	L	L	H									

Te Ao Tūroa | Natural world	Sea level rise and coastal erosion			Change in rainfall			River erosion			Reduced snow and ice			Sea level rise and salinity stress			Marine heatwaves			Ocean acidification		
	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Biodiversity and ecology	L	M	E	M	M	E							I	M	M	M	E	E	M	H	E
Freshwater ecosystems				L	H	H	L	H	H				L	M	H						
Natural landscapes	L	H	E							L	H	E									
Biosecurity																					

5.1 Biodiversity and ecology

Risk to biodiversity and ecosystems due to higher temperatures, drought, increased fire weather, change in rainfall, coastal flooding, sea level rise and coastal erosion, salinity stress, ocean acidification and marine heatwaves.

5.1.1 Introduction

Biodiversity can be defined as the diversity of all living organisms. This section focuses on land and marine ecosystems and includes diversity within and between species and diversity of ecosystems (D.O.C, 2020). Freshwater ecosystems are explored further in section 5.4 below.

Over 30% of the region remains under native vegetation cover (Figure 5.2) and contains a number of significant habitat types (Horizons Regional Council, 2018a). Whanganui National Park is the second largest lowland forest in the North Island, is home to the largest population of brown kiwi and is one of seven key strongholds for whio (D.O.C, 2021c). Tōtara Reserve Regional Park located in the Pohangina Valley, covers 340 ha and is one of the best remaining examples of ancient forest (Horizons Regional Council, 2021c).

Figure 5.2: Vegetation cover in the Manawatū-Whanganui Region.

The region contains forty estuaries along the east and west coasts (Figure 5.3). The Ruapehu and Palmerston North districts are the only districts which do not contain a coastline or any coastal or estuarine ecosystems. Estuaries, where freshwater from the land meets and mixes with saltwater from the ocean, are among the most productive ecosystems in the world, providing habitat to unique and in New Zealand often endemic species (NIWA, 2001).

Figure 5.3: Estuary locations across the west (left) and east (right) coastline of the Manawatū-Whanganui Region.

5.1.2 Risk summary

Table 5.2: Risks to biodiversity and ecology from differing hazards

Hazard	Present	2050	2100	Commentary
Reduced snow and ice	Low	High	Extreme	Affects alpine environment - reduced snow and ice in Central Plateau and Ruahine/Tararua ranges (fewer cold nights, more hot days, some increased rainfall - rather than snow). Minor changes to 2050, then increasing exposure. Sensitivity likely to increase over time, low adaptative capacity.
Increasing landslides and soil erosion	Low	High	Extreme	Sensitivity likely to increase over time as affected areas become more eroded. Adaptative capacity - moderate - depends on multiple factors and human intervention.
Sea level rise and coastal erosion	Low	High	Extreme	Sea level rise leads to inundation of low-lying coastal areas, and increased erosion of coastal cliffs. Increasing exposure as sea level increases, increased sensitivity as coastal margin changes.
Increased fire weather	Low	Moderate	High	Primarily affects vegetation/fauna and surface soils, changing the way the landscape looks. Infer that fire weather will increase with increasing temperature, and decreasing summer rainfall. Sensitivity both to fire event and recovery from it.
Coastal flooding	Low	Moderate	High	Morphology changes to coastal areas. Exposure to increase over time
Inland flooding	Low	Moderate	Moderate	Exposure is related to major catchments, particularly where rivers carry significant water volumes (Manawatu/Whanganui Rivers). Intensity and prevelance of flood and storm events likely to increase. Sensitivity to floods likely to remain constant - the response isn't likely to change.

5.1.2.1 Terrestrial ecosystems

Risk to biodiversity from increased temperatures is currently rated *moderate* increasing to *extreme* by the end of the century. Small changes in mean temperature can have a significant impact upon ecosystems. It is projected that species distribution will move southward latitudinally and upwards to higher altitudes to areas which will have lower and more tolerable temperature ranges (Lenoir et al., 2010). Alpine species and ecosystems around the Central Plateau, Kaimanawa, and Ruahine ranges are more vulnerable as snow lines recede and treelines will rise in altitude with increasing temperatures in the future (Christie, 2014; D.O.C., 2020). The adaptive capacity of alpine species is limited by the restricted and isolated availability of their specific habitat and environmental conditions (Lenoir et al., 2010). Loss of alpine habitat will likely lead to increased fragmentation and reduced connectivity between communities, reducing genetic diversity and further reducing adaptive capacity. As habitat loss continues in alpine environments, local extinction of species will likely occur.

The risk from changes in rainfall to montane biodiversity and ecosystems is currently rated *moderate*. The lower Ruahine Ranges (a lower altitude environment) will have higher exposure to more frequent drought. The largest increases in drought conditions are expected east of Taihape due to lower projected summer rainfall. These changes in seasonal rainfall can affect ecosystem composition by altering biotic and abiotic processes and providing increased stress on species living at the edge of their tolerance ranges. In turn, this is likely to lead to an increase in the presence and impact of pests and diseases. Comparatively, Tongariro National Park (a higher altitude environment) will have the lowest exposure to drought. The central plateau areas of Taumarunui and Ohakune are expected to see the smallest increases of drought (NIWA, 2019). Although projected to have a smaller increase in drought conditions than other parts of the region, environments at higher altitudes are likely to be more vulnerable to increased drought due to narrower species tolerance ranges and fragmentation of suitable habitat, resulting in a risk rating of high by the end of the century.

Risk to terrestrial ecosystems from increased fire weather and associated events is currently rated *low*, as the spread of fire is typically centralised around agricultural land in the Manawatū Plains where biological diversity is lower (Scion Research, 2021). However, the risk of fire weather is predicted to increase to *extreme* by the end of the century in biologically sensitive areas. Many New Zealand native species are highly sensitive to fire and ecosystems have slow recovery times; the adaptive capacity of terrestrial species and ecosystems to fire is limited. Therefore, human intervention and management of fire risk during dry periods to prevent fire will be required.

5.1.2.2 Marine ecosystems

Marine heatwaves and ocean acidification are currently rated as a *moderate* risk to marine biodiversity and ecosystems, increasing to *extreme* by end of the century. The east and west coast currents will have a localised effect on changes, with exposure higher on the east coast where some particularly sensitive non-mobile species, such as deep water corals, coralline algae and sponges occur closer to the eastern coastline (NIWA, 2018a). Marine ecosystems will be particularly sensitive to warming and changes in ocean chemistry as these will alter both biotic and abiotic processes. Reduced calcium carbonate (resulting from ocean acidification) is particularly detrimental for the early life history stages of calcifying organisms such as molluscs and echinoderms, calcifying algae/coralline algae (Tait, 2014) and coral species. Species present within these groups are predicted to decline across marine communities with flow-on food web (Law et al., 2018) and economic (aquaculture) effects. Marine heatwaves (defined as warm water anomalies occurring for up to months in duration, and thousands of kilometres in size (Hobday et al., 2018) will most likely impact the life history and overall health of immobile marine species such as kelps - macroalgae and coralline algae, sponges, sea squirts and bivalves (Boyd et al., 2011). This could lead to a reduced abundance of such species. For example, macroalgae (primary producers and habitat formers in coastal ecosystems throughout New Zealand) may be more vulnerable to increases in temperature as seen in recent research in Canterbury where the bull kelp species *Durvillaea* were eliminated during heatwaves in 2017/2018 in one bay in Lyttelton Harbour and replaced by the invasive kelp *Undaria pinnatifida* (Thomsen et al., 2019).

Adaptive capacity at a species level is dependent upon species range shifts and ability for rapid evolution to suit new conditions. Human intervention through the protection of coastal habitats and the creation of marine and coastal reserves (known as marine protected areas or MPAs) are likely to assist adaptation by promoting intact and complex ecosystems with high diversity and an increased abundance of species (Roberts et al., 2017). MPAs can support adaptation by providing stepping-stones for dispersal, protecting ecosystem connectivity, and increasing reproductive output and because of this the risk is rated as medium (Bernhardt & Leslie, 2013; Roberts et al., 2017). However, it should be noted that some in the scientific community doubt that the creation of MPA's alone will be sufficient to meet global targets for marine biodiversity management due to the limitations associated with the funding and management of MPA's (Gill et al., 2017; Plumeridge & Roberts, 2017).

Risk from sea level rise, coastal erosion and coastal flooding to coastal and marine ecosystems is currently rated *low* but will increase to *extreme* by the end of the century as sea level rise will likely reduce the availability of coastal margin habitat. The west coast has higher exposure where coastal inundation is already occurring above the projected national rate (NIWA, 2019). Coastal ecosystems will be highly sensitive to sea level rise and storm surges where coastal flooding can lead to increased coastal erosion and sedimentation, reducing foraging and breeding grounds and increasing habitat destruction in the near-shore environment (D.O.C, 2020). Sea level rise will also force estuaries into smaller areas and/or lead to estuarine habitat loss. It may be possible to reduce the vulnerability of estuaries through proactive restoration of estuarine habitat and work to prevent habitat loss. Estuaries themselves also protect coastlines from the effects of storm surges by soaking up floodwaters (D.O.C, 2021a).

Risk to coastal ecosystems from salinity stress is currently rated *insignificant*, however this is projected to increase to *moderate* over the mid to long term associated with increased degree of ocean inundation from sea level rise (Paulik, Stephens, et al., 2019). Increased salinity in coastal areas can affect species distribution, flora and fauna diversity and life cycles. Diadromous fish such as eel, mullet and freshwater flounder are particularly sensitive because they migrate to and from freshwater to marine environments and utilise differing salinity regimes at certain parts of their life cycles (NIWA, 2021).

5.2 Biosecurity

Risk of increased impact of invasive species and diseases and the arrival of new pests and diseases due to higher temperatures, drought and extreme weather events.

5.2.1 Introduction

This biosecurity category covers the potential of increased risk to natural habitats, native species, and human health resulting from the spread and increased abundance and impact of existing invasive species or diseases and the arrival of new invasive species and diseases as induced by climate change.

The introduction and increased presence of invasive species can reduce ecosystem health and alter ecosystem dynamics. Invasive species and disease can also impact upon human way of life: new diseases can impose travel restrictions, invasive species can destroy wilderness experiences and invasive species and disease can reduce animal, plant and fishing stocks (M.P.I, 2020).

The success of invasive species is largely attributed to their 'invasive' traits including: their ability to tolerate a wide range of abiotic and environmental conditions, high fecundity, multiple reproductive strategies, rapid population growth potential, long-distance natural dispersal potential, their tendency to be habitat generalists, the absence of predators, and because they are often opportunistic feeders. The consequence of this is that many invasive species are better equipped than native species to survive in changing environmental conditions, they will often out-compete native species in stressed environments, and they are likely to more rapidly occupy habitat left vacant by the mortality of native species.

Under the Biosecurity Act 1993, Horizons Regional Council produces and implements the Regional Pest Management Plan (2017 – 2037) to manage predators such as possums, cats and stoats, browsers such as goats and deer, and pest plants (Figure 5.4). Monitoring across New Zealand has shown that predator impacts have not reached an equilibrium and native species will continue to decline – many to extinction - where nothing is done. This rate of decline is likely to be exacerbated by climate change because of increased environmental stress imposed on indigenous species and ecosystems (D.O.C, 2020).

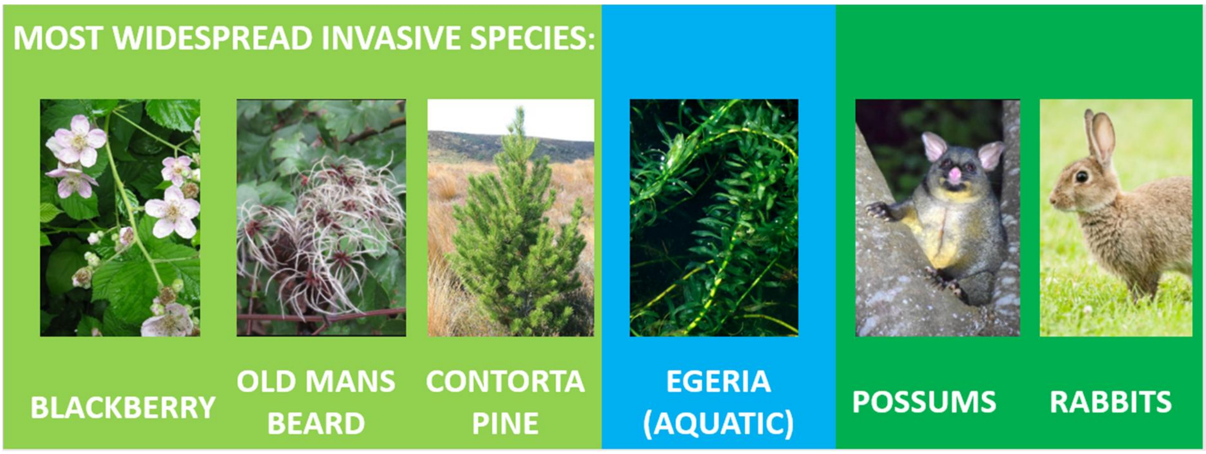


Figure 5.4: Most widespread invasive species in the Manawatū Whanganui Region.

5.2.2 Risk summary

Table 5.3: Risks to biosecurity from differing hazard

Hazard	Present	2050	2100	Commentary
Extreme weather events	Moderate	High	Extreme	Invasive pests are better colonisers and will outcompete natives to re-establish in an area. Infectious disease outbreaks often follow extreme weather events where environmental conditions are disrupted. Low exposure increasing overtime as frequency and severity of events increases. Moderate sensitivity and moderate adaptive capacity dependent on human intervention and medical advancements.
Higher temperatures	Low	High	Extreme	Increased risk to human health where increased temperatures bring in new diseases and create more favourable breeding environments. Low exposure increasing overtime where rate of disease or infection may increase. Moderate adaptive capacity dependent on human intervention e.g. biosecurity and medical advancements
Drought	Low	Low	High	Invasive plant species are better suited to drought conditions, and will grow at a quicker rate than/ out compete native species during drought.
Drought	Insignificant	Low	Moderate	Increased risk to human health due to water shortages and low flows, increasing level of pollutants of waterborne diseases within water. Medium adaptive capacity through water filtration and cleansing measures.

Risk of increased impact of invasive species and disease on native species and natural habitats due to rising temperatures is currently rated *low* but is expected to rise to *extreme* by 2100 (McGlone & Walker, 2011). Predicted warmer temperatures favour colonisers, new diseases and the proliferation of pest species. Native flora in the alpine environments of Tongariro National Park, Kaimanawa and Ruahine ranges are more vulnerable where native flora will likely retreat to higher altitudes, allowing invasive colonisers to grow in the lower reaches (Christie, 2014). For example, rabbits have established a population on Mt Ruapehu at an altitude of 1800 m, well above the normal altitudinal range of this species, and it is possible their range may expand further as the snow level recedes (McGlone & Walker, 2011). Adaptive capacity is tied to human intervention, which can assist in ecosystem protection and reduce pest/disease range expansion through pest control and localised eradication programmes (Horizons Regional Council, 2017a). Adaptive capacity has been rated medium due to the extent of works required to reduce pest densities to levels under which native species will survive (D.O.C, 2020). Looking out to the end of the century, risk to native species increases to extreme associated with increased exposure and vulnerability to climatic conditions more favourable to pests and increased pressures from predation.

Risk from drought, where invasive species and disease may be favoured over native species, is currently rated *low* for native species and habitats, increasing to high by 2100, and *insignificant* to human health, increasing to *moderate* by the end of the century. Invasive species are more likely to be adapted to drought conditions and will out-compete natives species. As rainfall decreases, drought can also lead to an increase in viral and bacterial contamination of both surface water and groundwater. A large number of pathogens thrive in shallow warm waters which exist during drought (C.D.C., 2020). Rural communities have higher exposure where they are not connected to water systems and are reliant on private wells for drinking water supply such as at Pipiriki, Kakahi and Hunterville (Ruapehu District Council, 2021b). Adaptive capacity for native species is rated low because of the generally low individual species tolerances to drought conditions (McGlone & Walker, 2011). The development of tools to anticipate drought, water conservation measures to increase storage capacity, and targeted upgrading of community water systems will improve adaptive capacity for human health and is therefore rated medium (Manning et al., 2011).

There will be increased risk to native fauna and flora from invasive pests and disease following extreme weather events that cause widespread habitat loss over an area. Risk levels will be *extreme* by 2100 associated with increased frequency and severity of extreme events (NIWA, 2019). Following extreme weather events invasive species, which are often better colonisers as a result of their competitive traits will likely displace native species. New diseases are also more likely to take hold in altered environmental conditions (McMichael, 2014). Habitat at higher elevations around the Central Plateau will be exposed to more high wind events, and low-lying areas along the Manawatū and Whanganui rivers may have a higher prevalence of extreme flooding. These areas are potentially more vulnerable to invasive colonisers and new diseases because of the altered environmental conditions after such events (Chappell, 2015a). Adaptive capacity of ecosystems to invasive pests is rated moderate with the application of emergency response and recovery procedures after extreme events. Monitoring and management of invasive species will assist in moderating this risk. The removal of debris and effective clean-up after extreme events can help to reduce the growth and spread of new bacteria and viruses (C.D.C, 2019).

Invasive species and diseases also pose a substantial future risk to marine ecosystems. As sea temperatures rise invasive organisms currently more common in subtropical waters will spread south (sometimes transported by shipping) and displace existing native species.

5.3 Natural landscapes

The risk to natural landscapes due to reduced snow and ice, increased fire weather, increased landslides and soil erosion, inland flooding, coastal flooding, sea level rise and coastal erosion.

5.3.1 Introduction

This natural landscapes category covers community connection to natural landscapes and how those landscapes are incorporated into community identity. Community identity is at risk from the physical effects of climate hazards, where the appearance of natural landscapes may be altered, damaged or destroyed completely (Environment Foundation, 2018). For example, in the Ruapehu District, the mountainous areas typically have snow cover over the winter months. The visual appearance and use of snow cover is strongly connected to the identity of local communities and their way of life, and any alteration to the presence of snow during the winter period could impact upon community identity (Stakeholder Engagement, 2021a). Schedule G of the Horizons Regional Council One Plan identifies over 15 regionally outstanding natural features and landscapes. Distribution of these landscapes across the region is shown on Figure 5.5 below.

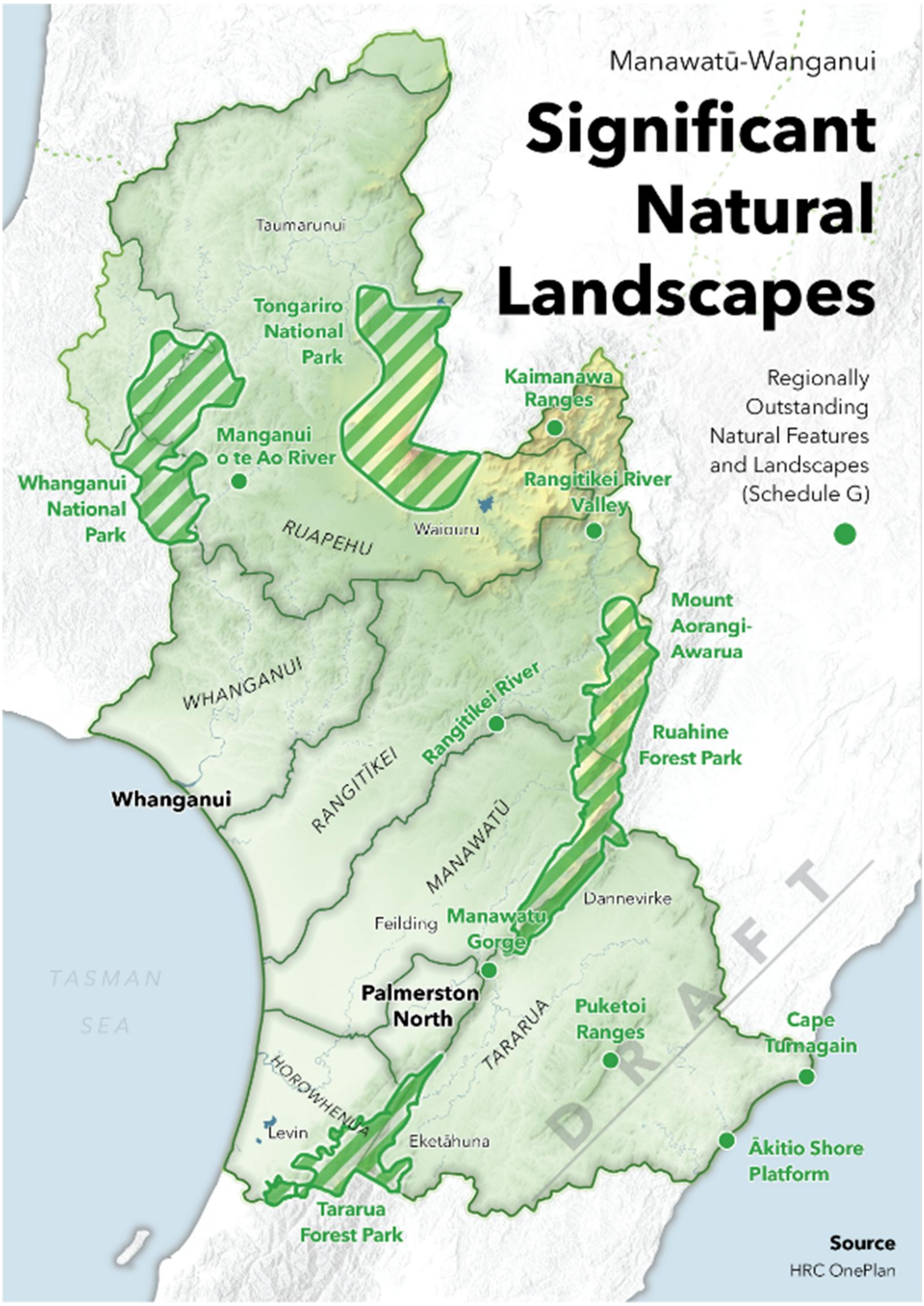


Figure 5.5: Regionally outstanding natural features and landscapes in the Manawatū-Whanganui Region.

5.3.2 Risk summary

Table 5.4: Risks to natural landscapes from differing hazard

Hazard	Present	2050	2100	Commentary
Reduced snow and ice	Low	High	Extreme	Affects alpine environment - reduced snow and ice in Central Plateau and Ruahine/Tararua ranges (fewer cold nights, more hot days, some increased rainfall - rather than snow). Minor changes to 2050, then increasing exposure. Sensitivity likely to increase over time, low adaptative capacity.
Increasing landslides and soil erosion	Low	High	Extreme	Sensitivity likely to increase over time as affected areas become more eroded. Adaptative capacity - moderate - depends on multiple factors and human intervention.
Sea level rise and coastal erosion	Low	High	Extreme	Sea level rise leads to inundation of low-lying coastal areas, and increased erosion of coastal cliffs. Increasing exposure as sea level increases, increased sensitivity as coastal margin changes.
Increased fire weather	Low	Moderate	High	Primarily affects vegetation/fauna and surface soils, changing the way the landscape looks. Infer that fire weather will increase with increasing temperature, and decreasing summer rainfall. Sensitivity both to fire event and recovery from it.
Coastal flooding	Low	Moderate	High	Morphology changes to coastal areas. Exposure to increase over time
Inland flooding	Low	Moderate	Moderate	Exposure is related to major water catchment basins, particularly where major rivers carry significant water volumes (Manawatu/Whanganui Rivers). Flood events are likely to increase and intensity of storm events to increase. Sensitivity to floods likely to remain constant - the response isn't likely to change.

Adaptive capacity for natural landscapes is generally rated low where the only thing likely to change overtime is how individuals and communities value natural landscapes. Overtime, community values and identity will change with associated changes to the visual appearance and use of natural landscapes.

Risk to natural landscapes from reduced snow and ice is currently rated *low* but is projected to rise to *extreme* by the end of the century on the Central Plateau (Mt Ruapehu, Mt Ngāuruhoe and Mt Tongariro), and the Kaimanawa and Ruahine Ranges. Exposure increases with projected increases in hot days across the region, reduced cold nights and increased rainfall in place of snow (NIWA, 2016). Under a mid-range climate change scenario, by mid-century it is projected that maximum snow depths at upper elevations will be reduced to 93-79% of current depths and lower elevation decreases will be even more pronounced (NIWA, 2010).

Risk from increased landslides and soil erosion will also increase to *extreme* by the end of the century associated with the projected accelerated erosion of already highly erodible land. The region has the largest area of hill country in New Zealand and highly erodible soil types. The Tararua and Ruahine ranges, the headwaters of the Whanganui, and the mountainous areas of the Central Plateau have particularly steep rainfall gradients and are therefore more sensitive to increased landslides. The largest predicted increase in sediment load for the region is for the Ōhau catchment in the Tararua Ranges (Basher et al., 2020). A large storm event in February 2004 caused widespread land-slippage across 120,000 ha of hill country and approximately 100 million cubic metres of soil was lost. Additionally, in April 2017 Ex Cyclone Debbie created widespread landslides between Raetihi and Whanganui and within Manawatū Gorge (NIWA, 2018b).

Adaptive capacity is rated medium because the occurrence and impact of landslides and erosion can be reduced by the use of engineered solutions and erosion control measures. The planting of trees, afforestation and riparian retirement of erosion prone land can improve resilience against storm events and associated increased landslides (Basher et al., 2020).

Risk to natural landscapes from increased fire weather is currently rated *low*, with the highest exposure centralised around the Manawatū Plains and Tararua Forest Park (Scion Research, 2021). Risk increases from *moderate* to *high* in the mid to long term associated with decreased summer rainfall and increased number of hot days. Natural landscapes are highly sensitive to fire which can damage or completely destroy the visual appearance of landscapes, particularly horizon lines (Stakeholder Engagement, 2021a). Areas which are more heavily vegetated such as Tararua Forest Park are more sensitive to catching fire, compared to natural landscapes such as the margins of the Manawatū River where fuel sources for fire are low. Adaptive capacity is rated medium because of the ability to apply fire prevention measures. Firebreaks and fuel-breaks can be constructed between areas of high flammability and natural landscapes to reduce the spread of fire (BeSafeNet, 2021).

Risk to natural landscapes from inland flooding is also currently rated *low*, increasing to *moderate* over the mid to long term, associated with an increase in the intensity and frequency of heavy rainfall events (NIWA, 2019). The exposure of natural landscapes to inland flooding is also limited to those landscapes which are located in proximity to rivers or rivers that are considered to be natural landscapes themselves. Major catchments such as the Manawatū and Whanganui rivers are more sensitive due to the extent of area drained and quantity of rainfall captured. Historic flood events along the Whanganui River and Manawatū River in 2015 and 2017 resulted in the alteration of the surrounding landscapes and the generation of large volumes of debris (NIWA, 2018b).

The risk of sea level rise and coastal erosion to natural landscapes is projected to increase from the current *low* rating to *extreme* risk by the end of the century, associated with the inundation of low-lying coastal areas such as Ākitio Shore Platform and increased erosion of areas such as Castlecliff Coastal Cliffs. Exposure increases as sea level rises and sensitivity increases as the coastal margin erodes and changes (Paulik, Stephens, et al., 2019). Coastal flooding risk increases to high by the end of the century associated with increased exposure from changes in coastal morphology. In July 2008, strong south-west winds generated 5 m high waves at Castlecliff beach, depositing debris beyond the high tide mark and rendering the beach inaccessible (NIWA, 2018b). As the frequency and intensity of storm tides increases, low-lying features at beaches such as Castlecliff and Himatangi Dunes are more sensitive than estuarine features such as Manawatū estuary, where estuaries are able to soak up the flood surges (D.O.C, 2021a).

5.4 Freshwater ecosystems

Risk to freshwater ecosystems due to higher temperatures, change in rainfall, drought, inland flooding, river erosion, sea level rise and salinity stress.

5.4.1 Introduction

Waterways, wetlands and lakes make up an important network of freshwater ecosystems across the region (Figure 5.6). Rivers and streams have been described as one of the most impacted ecosystems on the planet, highly affected by human activities and urban land uses, and climate change has the potential to exacerbate these impacts. Rivers and streams contain a high proportion of native and endemic species of ecological significance to the region. Wetlands are also highly sensitive receptors and one of the most threatened ecosystems in New Zealand. Wetlands support a high diversity of invertebrates, algae, birds, plants and fish, and offer refuge to a number of threatened species. Wetlands help to improve water quality, mitigate flooding and reduce carbon (D.O.C, 2020).

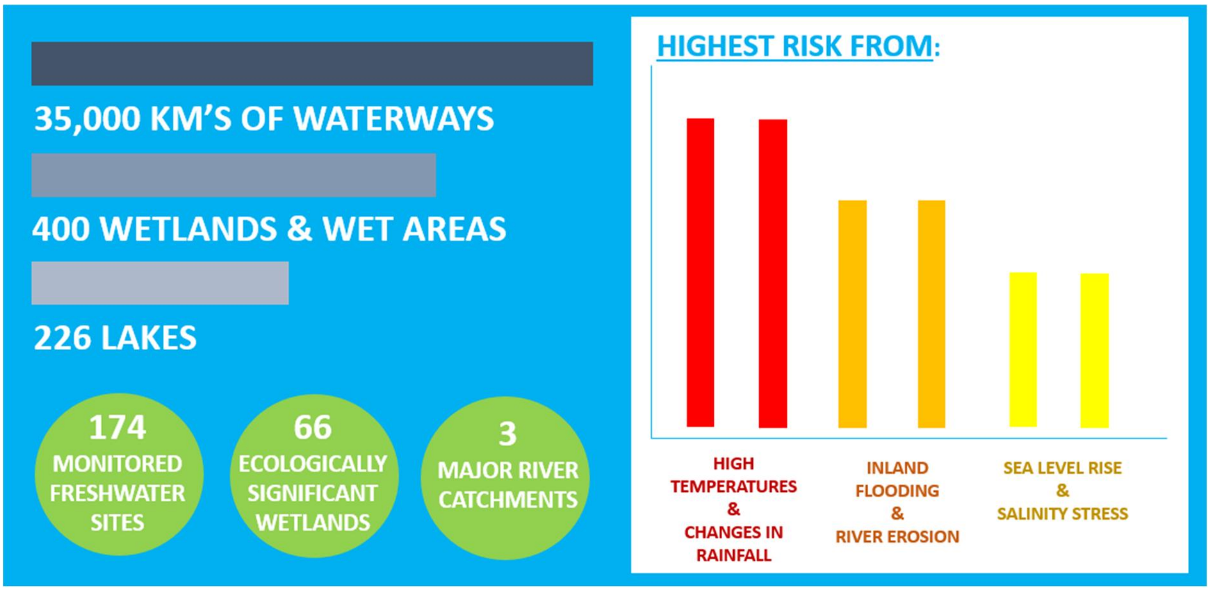


Figure 5.6: Freshwater ecosystems in the Manawatū Whanganui Region.

5.4.2 Risk summary

Table 5.5: Risks to freshwater ecosystems from differing hazard

Hazard	Present	2050	2100	Commentary
Higher temperatures	Moderate	High	Extreme	Most freshwater species sensitive/intolerant of increases in temperature, with water temperature expected to increase with air temperature.
Change in rainfall	Low	High	High	Changes in rainfall expected to alter river/ lake water balances - putting stress on freshwater ecosystems.
Drought	Low	High	High	Changes in rainfall expected to alter river/ lake water balances - putting stress on freshwater ecosystems.
Inland flooding	Low	High	High	Freshwater ecosystems flooding more frequently - with associated increase in sedimentation rates from catchment erosion - sedimentation likely to affect success/populations of freshwater species.
River erosion	Low	High	High	Freshwater ecosystems at risk from increased erosion of rivers during floods/storms - changes in morphology/bed substrate, loss of bank-side habitat.
Sea level rise and salinity stress	Low	Moderate	High	Salinity increases of groundwater and in wetlands close to the coast likely to change species distribution/assemblage. Changes to salinity at river mouths and further upstream, reducing extent of freshwater habitat within rivers.

Risk from higher temperatures to freshwater ecosystems is rated *moderate*, increasing to *extreme* by the end of the century, where predicted increases in air temperatures will also lead to higher water temperatures (NIWA, 2019). Low vegetative areas such as streams and rivers through the Manawatū Plains and open rural land are more highly exposed due to reduced shade and altered natural flow patterns (e.g. through water extraction for agriculture). Some native freshwater species (including but not limited to fish, macroinvertebrates, periphyton and macrophytes) are sensitive to increases in water temperature and some lifecycle stages are intolerant to increases in maximum temperatures (e.g. migration and spawning are impacted by these changes) (Olsen et al., 2012). As temperatures increase in freshwater environments, habitats may be altered and associated ecosystem composition may change. Adaptive capacity of native species is low, dependent upon the ability of individual species to adapt to altered environmental conditions and find and migrate to other suitable freshwater habitats further upstream where temperatures are more tolerable (D.O.C, 2020).

By the end of the century risk to freshwater ecosystems from changes in rainfall will increase to *extreme* from the current rating of *moderate* as the alteration of water balances within rivers, lakes and wetlands will increase stress on freshwater ecosystems (D.O.C, 2020). Wetlands and other freshwater ecosystems in east Tararua District, such as Woodville Ferry Reserve and Haukopua Scenic Reserve, have higher exposure due to predicted decreases in rainfall and increased winter droughts (NIWA, 2019). Changes in rainfall will threaten sensitive wetland ecosystems due to changes in hydrological regime. Risk to freshwater ecosystems from drought is currently rated low but increases to high by mid-century in association with changes in rainfall. Increased summer droughts in the east and increased winter droughts in the west will alter river and lake water balances (this may affect freshwater ecosystem dynamics). Low flows in the Manawatū River are only expected to show a minor increase by the end of the century, with an overall decline in low flows predicted for the rivers across the rest of the region (NIWA, 2019). Adaptive capacity of species (including but not limited to fish, macroinvertebrates, periphyton and macrophytes) is rated low but there may be opportunity for protection through human intervention. This could be focused on stabilizing water flow dynamics, environmental enhancements and reducing adverse land-use changes, and may include practices such as reducing water-takes, wetland restoration, afforestation and upstream river regulation methods (Helmschrot, 2016).

Risk from inland flooding and river erosion to freshwater ecosystems is currently rated *low*, increasing to *high* by mid-century. Freshwater ecosystems are highly sensitive to an increase in flooding occurrence, duration and size, resulting in serious degradation of freshwater habitats. Inputs of pollutants and sediments from domestic, agricultural and industrial land are increased in rivers and lakes during flood events and can lead to the partial or total loss of species in certain areas due to pollutant levels beyond species tolerances and disruptions to life cycles (D.O.C, 2013). Exposure to river erosion also increases with the severity and frequency of flood events (NIWA, 2019). River erosion creates changes in river morphology including to bed substrate and loss of bank-side habitat. The adaptive capacity of freshwater ecosystems is low, limited to ongoing monitoring and research to predict how certain species and their associated habitats may interact with altered flow regimes and flood events. Proactive management strategies may be implemented off the back of this research, with the designation of key sites for species protection (D.O.C, 2013).

Sea level rise and salinity stress are rated to pose a *high* risk to freshwater ecosystems in the long term. The balance between freshwater flow inputs and sea level rise will determine the extent of salinity intrusion upstream of freshwater bodies adjoining the coast. Therefore, exposure increases overtime as sea level rises and freshwater habitats are reduced (D.O.C, 2013). Freshwater wetlands near the coast will be highly sensitive; minor increases of salinity in groundwater can change species distribution and community composition (D.O.C, 2020). For example, the upper extent of Manawatū Estuary is characterised by low salinity conditions and this is very important to the lifecycles and distribution of several species (Horizons Regional Council, 2017b). Sea level rise may eliminate this low salinity area. Adaptive capacity of freshwater wetlands is low. Some river outlets at the coast may transition to estuarine type environments, creating a shift in species distribution inland for species with lower saline tolerances (D.O.C, 2013).

6 Hauora | Wellbeing

Hauora is a Māori holistic approach to describing wellbeing and the needs of an individual, their whanau, their communities and the environments within which they live. Since the early 1980s, hauora has been associated with the whare tapa whā model developed by Professor Mason Durie which looks at wellbeing across the; taha tinana (physical), taha hinengaro (mental), taha whanau (social) and taha wairua (spiritual), and remains a widely applied way to approach wellbeing in a holistic manner.

Drawing on this approach, this section focuses on measures of wellbeing in relation to health and access to health services, public spaces and housing. Climate change will likely impact upon the regions built communities, mental, physical and spiritual health, equality, equity and diversity. Climate hazards will also affect the network of relationships within communities which enable them to function, and provide for overall community wellbeing. Climate change will also exacerbate inequalities within communities.

A third of the region's population lives in small towns or rural areas, with the region having an average population density of 10.3 people per km^2 compared to the national average of 13.1 (Manawatū-Wanganui Emergency Management Group, 2019). The population of the region is diverse, with multiple ethnicities and religious practices.

A summary of the risk elements associated with Hauora | Wellbeing are shown in Table 6.1.

Table 6.1: Summary of risks to Hauora | Wellbeing elements for differing climate change hazards

Hauora | Wellbeing	Higher temperatures			Inland flooding			Extreme weather events			Drought			Coastal flooding			Increased fire weather		
	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Health	I	M	E				L	H	E	L	M	H						
Housing				H	E	E	L	M	H				M	H	E	L	M	H
Public spaces				M	H	E	I	M	H				I	M	E			
Social capital	I	L	L	L	H	E	I	L	H									

Hauora | Wellbeing	Increasing landslides and soil erosion			Sea level rise and coastal erosion			Change in rainfall			River erosion			Reduced snow and ice			Sea level rise and salinity stress			Marine heatwaves			Ocean acidification		
	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Health																								
Housing	L	M	H	M	H	E				L	M	H												
Public spaces				I	M	E																		
Social capital	I	L	M	I	L	M																		

6.1 Health

Risk to health from extreme weather events, higher temperatures and drought.

6.1.1 Introduction

Climate change will impact access to health services, the physical and mental health of people, and the overall wellbeing of communities across the region. The health and wellbeing of people within the region will be impacted both directly and indirectly by climate hazards. Communities across the region are already experiencing health impacts from climate hazards such as floods, droughts and extreme weather events.

Climate change will result in direct impacts to healthcare services as a result of flooding and extreme weather events, and this will be especially disruptive for remote communities. There are three major hospitals within the region, all of which have main access routes via State Highway 4, State Highway 1 and State Highway 3. Damage to these transport links will disrupt access to healthcare and emergency services.

As shown in Figure 6.1, over 30% of the population is identified to be within a vulnerable age group, or have one or more activity limitations (the impairment of walking, seeing, hearing, cognition, self-care or communication) (Stats NZ, 2018). Vulnerable populations are at higher risk of climate-related health impacts due to increased sensitivity to heat-related illness and deaths, the presence of pre-existing conditions, and lower levels of adaptive capacity.

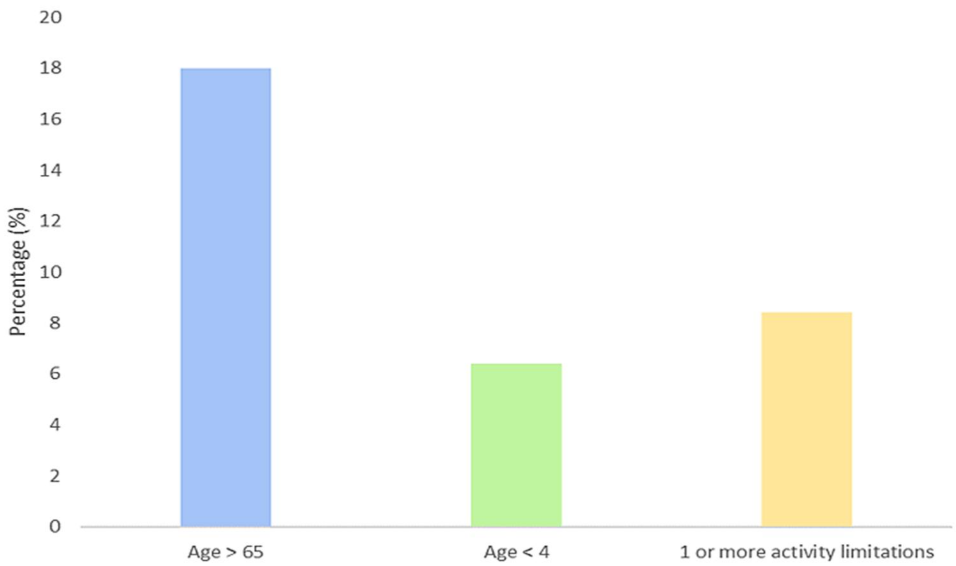


Figure 6.1: Vulnerable communities Manawatū Whanganui region.

6.1.2 Risk summary

Table 6.2: Risks to health from differing hazard

Hazard	Present	2050	2100	Commentary
Extreme weather events	Low	High	Extreme	Both direct health effects as the result of increased extreme events such as flooding and increased storminess which may increase transmission of diseases, and mental health effects as a result of increased stresses. Exposure increases as severity and intensity increases. Rural communities more sensitive given more limited services and infrastructure.
Higher temperatures	Insignificant	Moderate	Extreme	Health risk associated with heatwaves. Elderly, infants and those with activity limitations or severe illness are more vulnerable to the effects of increased temperatures and heat.
Drought	Low	Moderate	High	Drought puts stress on communities both mentally and physically in relation to water supply - drought reduces water availability and water quality for drinking - dehydration, increased toxins in water, water is unsafe to drink. Exposure increases with increased hot days and reduced summer rainfall. Communities most vulnerable are those that rely on surface water takes/ little to no groundwater available.

The risk to health is currently rated as *low*, increasing to *extreme* by the end of century. The current exposure of health to extreme weather events is moderate, increasing to extreme by 2100 as the frequency and severity of events is predicted to increase overtime (NIWA, Climate change implications for the Manawautū-Whanganui Region, 2019).

Access to health services and key buildings, including clinics and hospitals, may be at risk due flooding and coastal inundation. The climate hazards may result in a disruption of transport links, affecting access to critical services such as hospitals, medicines, and support services. Rural communities may be at the highest risk due to dependence on exposed roads and the use of private vehicles to access health service locations (MidCentral District Health Board, 2020). Climate hazards may also result in interruptions to water and electricity supply due to flooding, droughts and extreme weather events, which may also disrupt the supply of health services.

Given the projected increases in the frequency and severity of extreme weather events, emergency management capacity must be supported in the region to ensure responsiveness. The adaptive capacity of the health system, more broadly, will also need to be strengthened to cope with the impact of climate change on physical and mental health.

The exposure of health to higher temperatures is currently low, increasing to high by 2100 as the number of hot days and mean surface temperature increases (NIWA, 2019). Heatwaves are currently rare in New Zealand; however, exposure will likely increase overtime as the number of heatwaves experienced increases.

Higher air temperatures may result in an increase in heat-related deaths, particularly for vulnerable populations such as the elderly. The elderly, infants, and individuals with pre-existing medical conditions are the most sensitive to changes in maximum daily temperatures (Wilson et al., 2011). Moreover, people located in urban areas, due to the urban heat island effect, and households without air conditioning are also at increased sensitivity to higher air temperatures (Oleson et al., 2015).

Horowhenua District has the largest population of residents over the age of 65 and is therefore more exposed to increased temperatures than Palmerston North which has the lowest population of residents over 65. Although it is expected that exposure will increase across the region as populations over the age of 65 are expected to increase significantly in line with predicted national trends (Manawatū-Wanganui Emergency Management Group, 2019). The elderly are also at a higher risk due to impacts from other climate change hazards, including flooding, and this, coupled with an ageing population and increasing number of aged care facilities, will likely result in increasing demand for healthcare services.

The provision of improved housing design and urban spaces with shade will help to strengthen adaptative capacity to heat-related health impacts (Capon et al., 2019). Given the uncertainty of air temperature projections, these actions should be implemented as needed depending on the increases in air temperatures witnessed throughout the century.

The projected increase in temperatures can also result in health benefits, due to higher indoor air temperatures in winter. This may reduce the incidence of winter mortality rates, but this is uncertain due to other factors including household crowding, moisture levels and the performance of buildings (Davie et al., 2007).

Climate change has several implications for the mental health and wellbeing of people in the region, as the injuries and damage from heatwaves, extreme weather events, flooding, droughts and sea level rise can result in mental trauma (Berry et al., 2010). Rural farming communities may be particularly sensitive to mental health impacts, due to extreme drought, flooding and rainfall events impacting upon their livelihoods (Bolton, 2018).

Current exposure of health to drought is low, increasing to high by 2100 with predicted reduced summer rainfall and increased hot days (NIWA, 2019). There is a larger number of aquifers in the southern region compared to the north, where Horowhenua and Ruapehu districts are dependent on surface water takes. For example, Ohakune, Raetihi, Dannevirke and Woodville all take water from small streams and are therefore more exposed to health risks from drought than communities that have access to groundwater (Stakeholder Engagement, 2021b).

Changes in rainfall, reduced water flows, and higher air temperatures may also result in water shortages and water contamination due to bacterial and algal growth. Heavy rainfall events can also cause animal excrement and other pollutants to run off into water sources, resulting in drinking water contamination (Royal Society | Te Apārangi, 2017).

Human health will also be impacted indirectly through risks to economic livelihoods, food security, potential increases in the prevalence of pandemics, and impacts on other systems that support health and wellbeing.

Vulnerable populations in the region are particularly sensitive to the health impacts of climate change, as adverse impacts are exacerbated by economic disadvantage and the existence of pre-existing health conditions (Jones et al., 2014). Māori are particularly sensitive to health-related risks from climate change. Colonisation has had profound negative consequences on Māori populations leading to social change and systemic issues that have diminished rights overtime (Barnes & McCreanor, 2019). These factors have contributed to a disproportionate number of Māori living in deprived circumstances and experiencing higher rates of most major diseases than non-Māori (Jones et al., 2014).

6.2 Public spaces

Risk to public spaces from extreme weather events, inland flooding, coastal flooding, sea level rise and coastal erosion.

6.2.1 Introduction

Public spaces covers community spaces, services and events, which forms the social fabric of the region. Community spaces include public halls, marae, libraries, local council offices, hospitals, and health centres. There are 20 town halls, 10 district courts, 28 libraries and 18 fire stations across the region, centred within the main settlement areas. There are three major hospitals in the region located at Taumarunui, Whanganui and Palmerston North, and other settlements, such as Raetihi, Marton and Levin, also have health centres.

These locations and sites can have significant social and economic benefits. Community spaces, such as town halls and libraries, are a democratic forum for citizens and can bring communities together. As well as building the cultural identity of communities, well-designed public spaces can also result in economic benefits and help to improve physical and mental health (CABE Space, 2004). The holding of public events can also result in social benefits through facilitating positive social interactions, building community cohesion and improving the community's identity and confidence (Shone & Parry, 2019). Lastly, many of these public buildings also provide public services that the community depends on for their wellbeing, including fire stations and hospitals, and managing the climate risk to these sites is therefore critical.

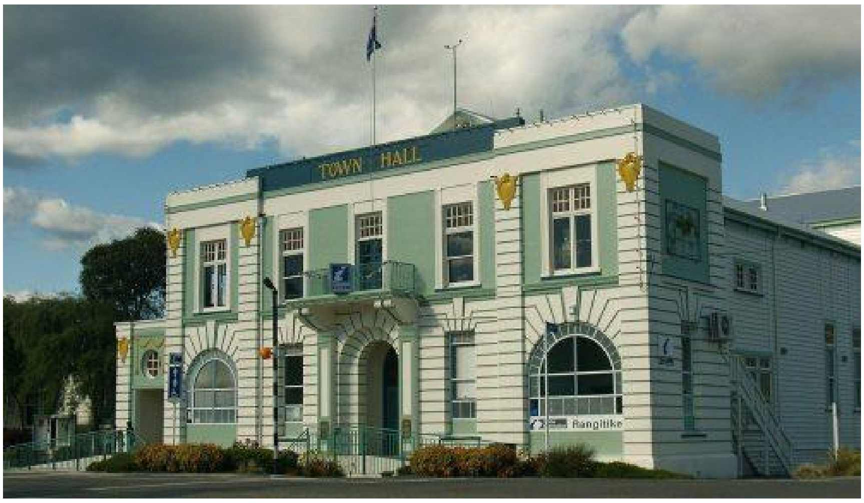


Figure 6.2: The Taihape Town Hall (Source: (Rangitīkei District Council, 2021).

6.2.2 Risk summary

Table 6.3: Risks to public spaces from differing hazards

Hazard	Present	2050	2100	Commentary
Inland flooding	Moderate	High	Extreme	Higher exposure of community spaces in settlements around larger river catchments. Exposure increasing overtime as flood frequency and severity increases.
Coastal flooding	Insignificant	Moderate	Extreme	Low number of settlements directly located within low lying coastal zone. Higher sensitivity at these locations where materials can corrode, swell and damage.
Sea level rise and coastal erosion	Insignificant	Moderate	Extreme	Exposure increases as coastal area continues to be inundated, public spaces and erosion effects may damage buildings. Medium adaptive capacity connected with retreat, relocation and engineered human interventions.
Extreme weather events	Insignificant	Moderate	High	Low exposure increasing overtime. Effects on community spaces due to extreme weather events associated with power outages, transport links and physical damage to buildings from flood water, high winds and heavy snowfall.

Public spaces are at risk due to extreme weather events, inland flooding, coastal flooding, sea level rise and coastal erosion, with most hazards leading to *extreme* risk to public spaces by 2100.

The exposure of public spaces to inland flooding is currently high, increasing to extreme with predicted changes in rainfall and increases in the frequency and severity of flood events (NIWA, 2016). A large number of settlements are located along the region's major river systems and within the mapped flood extents of the Manawatū, Rangitīkei, Whanganui, Whangaehu, Turakina, Mangawhero and Makotuku rivers (Horizons Regional Council, 2021d). 25,206 buildings of which approximately 150 are identified as community buildings, are located within the flood hazard zone (NIWA, 2019). Current exposure of public spaces to extreme weather events is currently low, assessed as increasing to high by 2100 as extreme events become more frequent and severe (NIWA, 2016).

Public spaces currently have a low exposure to sea level rise and coastal erosion, increasing to high by 2100 as sea level rises, coastal inundation increases, and inland area is reduced. The region has two coastlines, with the main settlements along the west coast, such as Whanganui, Himantangi and Foxton, being more highly exposed than the small coastal communities on the east coast, including Ākitio and Herbertville (NIWA, 2019).

Public spaces are sensitive to direct damage to buildings from inland and coastal flooding, high winds and heavy rainfall, and these climate hazards could also disrupt the delivery of public services and events. Moreover, coastal hazards could result in inundation of public spaces, and buildings could be impacted due to erosion and ground instability.

Gardens and parks in the region may be vulnerable to droughts and increased air temperatures, which may result in a larger volume of water for irrigation. The impact on gardens and parks is considered to be of a lower priority than other elements of risk, such as the provision of public health services.

There are also indirect impacts due to climate change: Power outages at public locations may make spaces unusable, and damaged transport links may reduce accessibility to public spaces (Stakeholder Engagement, 2021b).

Cultural landscapes across the region are also exposed and vulnerable to climate change hazards. Cultural landscapes in the region cover both landscapes significant to Māori and to the wider community, including the farming community.

Some Māori communities are concerned about degradation of coastal spiritual and heritage sites, including pā, marae, urupā (burial grounds) and food-gathering sites, and the potential abandonment of these sites due to managed retreat. Cultural and heritage sites, including marae, may also be at risk due to inland flooding.

The identity of the region is also strongly linked to rural production, particularly sheep and beef farming, and this may be at risk due to climate change impacts and potential maladaptive consequences of climate change mitigation measures. The destruction of rural landscapes from increased fires and the plantation of forests over productive areas could negatively impact the landscapes and cultural identity of the region (Stakeholder Engagement, 2021b).

Tongariro National Park is also a key cultural and spiritual site to both Māori and non- Māori. The national park is listed on the UNESCO World Heritage List as a cultural landscape; where the mountains have cultural and religious significance to Māori and symbolize the spiritual link of communities to the environment (UNESCO, 2021). This area is at risk due to a number of climate hazards, particularly increased air temperature, as noted throughout this report.

6.3 Location, quality and availability of housing

Risk to residential buildings due to sea level rise, coastal erosion, inland and coastal flooding, extreme weather events, and fire weather.

6.3.1 Introduction

The majority of the building stock in New Zealand is wooden and masonry houses, with an average age of 50 years (Buckett et al., 2011; Uma et al., 2008). In the Manawatū- Whanganui region, the building stock is generally older in age with majority of new developments occurring in Palmerston North, Ohakune, Levin and Feilding. The building quality in the region is relatively low in comparison to elsewhere in New Zealand, due to social deprivation within the region (Stakeholder Engagement, 2021b).

There are 90,810 occupied, 11,187 unoccupied and 552 occupied non-private dwellings within the region (Stats NZ, 2018). There were 101,600 properties within the region in 2017, of which 37,100 were rental properties. In 2013, 42,228 homes were owned or partially owned within the region, and 11,067 were owned by a family trust. Average house prices between 2007 and 2017 were between $160,000 and $190,000 which has increased to $371,558 in 2019 (Johnson et al., 2018; MBIE, 2020).

The supply of affordable and healthy housing is important for maintaining the wellbeing of households across the region. Access to housing in the region is already problematic for many people in the region, and this is due to a number of factors including high housing costs and poor quality buildings.

For lower-income households, high housing costs can result in severe financial difficulties, and can leave households with insufficient income to meet other basic needs such as food, clothing, transport, medical care and education – climate change may exacerbate these financial difficulties, especially in highly exposed areas. In addition, low-income households are more likely to rent, which can result in poorer economic, social and health-related outcomes (Waldegrave & Urbanová, 2016).

6.3.2 Risk summary

Table 6.4: Risks to location, quality and availability of housing from differing hazards

Hazard	Present	2050	2100	Commentary
Inland flooding	High	Extreme	Extreme	Exposure highest in the Plains. High sensitivity as timber and masonry buildings can swell, damage can occur to plasterboard wall linings. Older buildings generally have a higher sensitivity. Generally medium adaptive capacity for existing buildings with alterations possible.
Extreme weather events	Low	Moderate	High	Currently low exposure to extreme weather events increasing to high by the end of the century. High sensitivity as homes can be damaged by flood waters, high winds and heavy snow fall. Low adaptive capacity due to permanent nature however changes to design standards could improve resilience.
Coastal flooding	Moderate	High	Extreme	Moderate exposure to coastal flooding within the region, particularly in the Whanganui, Foxton and Levin areas. High sensitivity as materials can corrode, and swelling and damage can occur to wall linings.
Sea level rise and coastal erosion	Moderate	High	Extreme	
Increased fire weather	Low	Moderate	High	Currently low exposure to increased fire weather, but increasing to high by the end of the century due to increased drought conditions and higher temperatures. High sensitivity particularly for those houses made from timber (compared to brick).
Increasing landslides and soil erosion	Low	Moderate	High	Moderate exposure increasing to extreme by the end of the century due to the erodibility of soils within the region. Moderate sensitivity as building foundations can be designed with soil erosion in mind. Landslides however can completely destroy homes.
River erosion	Low	Moderate	High	Moderate exposure to river erosion. Large sediment loads likely to be exacerbated due to more intense flooding events, which can lead to more river scour. This can reduce the amount of land available for housing and damage/ destroy buildings.

Buildings in the Manawatū-Whanganui region are exposed to sea level rise, coastal erosion, inland and coastal flooding and extreme weather events. The vulnerability of residential housing is a function of the condition and age of the building. In general, buildings that are built prior to 1990 are in a poorer condition and are therefore more sensitive to climate hazards (Buckett et al., 2011). The majority of residential housing in the region was built pre 1990, and housing is therefore particularly sensitive to damage from climate hazards.

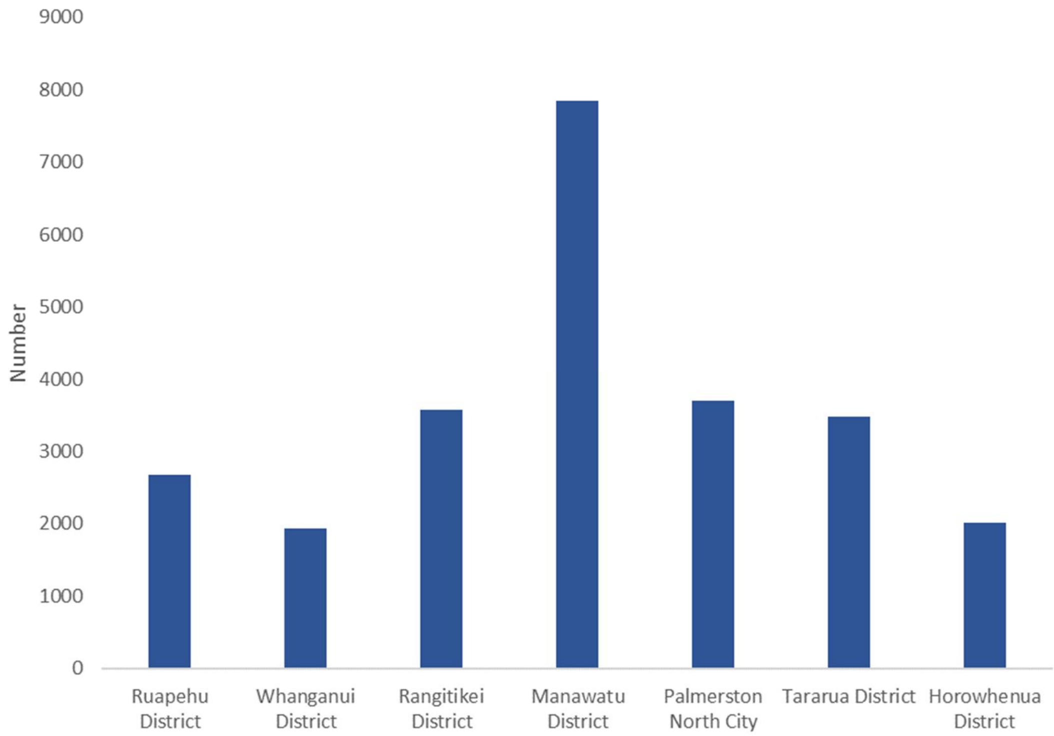


Figure 6.3: Number of buildings in the Manawatū-Whanganui region exposed to inland flooding (Paulik, Craig, et al., 2019).

There are over 25,000 buildings exposed to inland flooding within the region, of which 7,846 are located in the Manawatū District. It is estimated that the replacement cost for the buildings exposed to inland flooding within the region is approximately $1.74 billion (Paulik, Craig, et al., 2019). Figure 6.3 presents the number of buildings exposed per district to inland flooding, with all districts in the region having buildings exposed.

There are 1,459 buildings exposed to the 1% AEP storm tide event in the Manawatū-Whanganui region. This increases to 1,926 with 0.3 m of sea level rise and 2,454 with 0.6 m of sea level rise. Of those buildings exposed at the 1% AEP storm tide event, 563 are located in the Horowhenua District, followed by 445 in the Manawatū District (Figure 6.4). The number of buildings exposed increases with 0.3 m of sea level rise to 846 for Horowhenua, and 535 for the Manawatū. With 0.6 m sea level rise the buildings exposed increases to 1218 in Horowhenua and 634 in the Manawatū (Paulik, Stephens, et al., 2019).

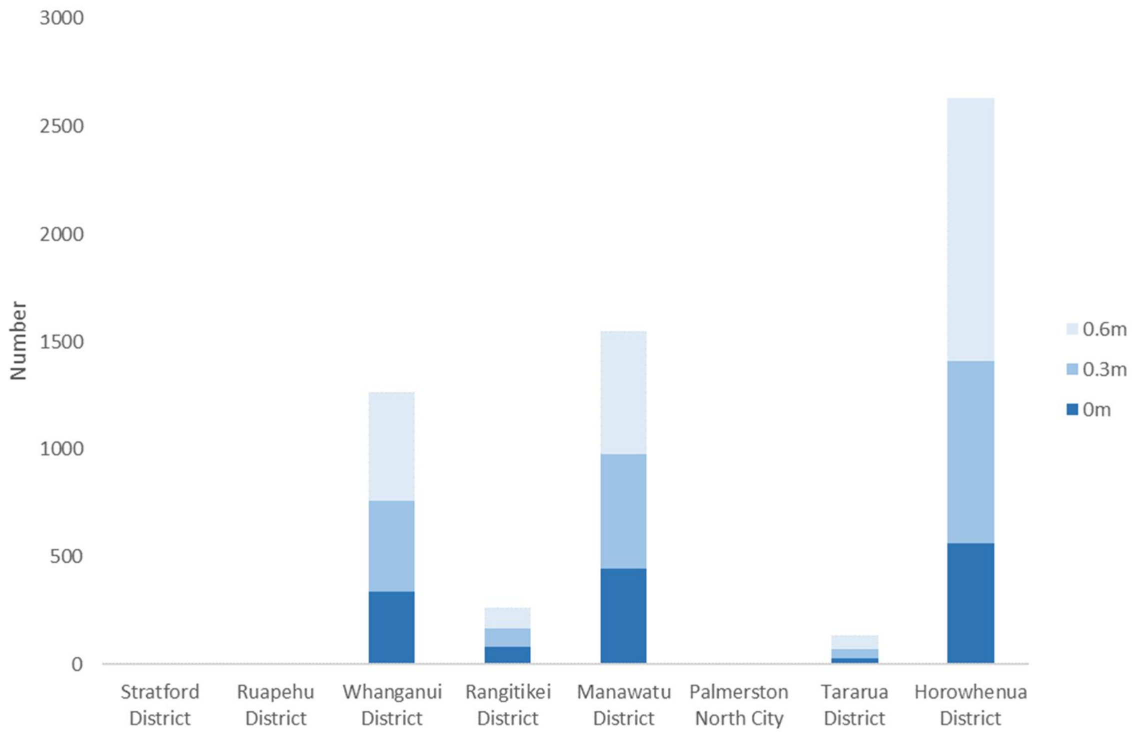


Figure 6.4: Number of buildings in the Manawatū-Whanganui region exposed to coastal inundation and sea level rise (Paulik, Stephens, et al., 2019).

There is high sensitivity to both inland and coastal flooding, as buildings are not designed to withstand the flood levels that are occurring and the sensitivity is exacerbated due to the poor quality of housing (Stakeholder Engagement, 2021b). Increased rainfall, alongside coastal and inland flooding, can cause damage to wooden and masonry buildings due to the swelling and damage that can occur to the plasterboard wall linings, a problem which is exacerbated when houses are in a poorer condition and are of older age (Jacques et al., 2015; Reese & Ramsay, 2010). New subdivisions such as the one located on Centennial Drive in Palmerston North have the opportunity to be built in a way that they are designed to adapt better to future climatic events (Stuff, 2019a).

Adaptive capacity to flooding, increases in rainfall and extreme weather events is moderate, and is lower for pre-existing buildings than newly constructed developments. The design of future buildings can include adaptive measures, such as lifting foundations off the ground level to prevent flood waters from damaging buildings. Communities and households at high risk could also be relocated, such as was completed following devastating floods in Grantham, Australia. In this case, it was seen that the risk was too high to keep the town located adjacent to the Lockyer Creek, so the local community forged a plan and the regional council brought 378 hectares of land on the surrounding hills, which is now the home to 80 families. The relocation cost approximately $18 million (Brisbane Times, 2020). A similar approach could be undertaken for relocating at-risk communities in the Manawatū-Whanganui region. In Whangaehu, for example, flooding events have destroyed homes multiple times, and this could lead to eventual insurance withdrawal due to unacceptable levels of risk (Stakeholder Engagement, 2021b).

Exposure to landslides and increasing soil erosion is currently moderate, increasing to extreme by the end of the century due to the projected increase in rainfall and erodibility of the soils in the region (Dymond & Shepherd, 2006). Residential buildings located in steeper terrains and hill country (e.g. Taihape, Ruapehu, Pohangina, Taumarunui), and on slopes angled greater than 15 degrees, were found to have a higher exposure to landslides (Manawatū District Council, 2021b). Dependent on the severity of the exposure, these houses are also sensitive to damage from landslides and soil erosion.

The majority of residential areas within the Manawatū-Whanganui region are located in areas with limited tree cover and vegetation, and therefore the exposure to wildfire is generally low at present. Rural buildings are more likely to be located closer to native bush or plantation forests, and therefore have a relatively higher exposure to wildfire (Manawatū District Council, 2021b). For buildings located near tree cover and vegetation, exposure to increased fire weather increases to high by the end of the century due to the projected increases in temperature and drought conditions that fuel fire weather (NIWA, 2016). Adaptive capacity to increased fire weather is assessed as moderate, as reducing exposure to fire weather is possible through relocating buildings and reducing tree cover in high-risk areas (Manawatū District Council, 2021b).

6.4 Social capital

Risk to social capital due to flooding, erosion and landslides, heatwaves, extreme weather events, and ongoing sea level rise.

6.4.1 Introduction

The social capital of communities is at risk due to more frequent flooding, erosion and landslides, heatwaves, and extreme weather events, and gradual changes over time, particularly ongoing sea level rise.

Social capital refers to the social connections, attitudes and norms that contribute to maintaining community cohesion, collaboration, cooperation and well-being (OECD, 2020). Social capital has also been defined as “the features of social life – networks, norms, and trust – that enable participants to act together more effectively to pursue their shared objectives” (Putnam, 1995).

Social capital is described by the Organisation for Economic Co-operation and Development (OECD) as a particular strength of New Zealand, which results in strong institutions, low levels of corruption, and better democratic functioning (OECD, 2019). Social capital can be measured by the rate of volunteering, level of trust in others, the police and government, government stakeholder engagement, gender outcomes, and levels of corruption – New Zealand scores well globally in these measures (OECD, 2020).

Climate change can impact and diminish social capital in a number of ways, including through the loss of regional and community level identity, weakening of institutions, reduction in wellbeing, and exacerbation of social inequities. The potential impact of climate change on social capital in the Manawatū-Wanganui region is not well understood, but it is likely to have differing impacts in urban, rural and socially deprived communities.

A third of the region’s population lives in small towns or rural areas, with the region having an average population density of 10.3 people per km^2 compared to the national average of 13.1 (Manawatū-Wanganui Emergency Management Group, 2019). As shown in Figure 6.5, the population of the region is diverse, with multiple ethnicities and religious practices.

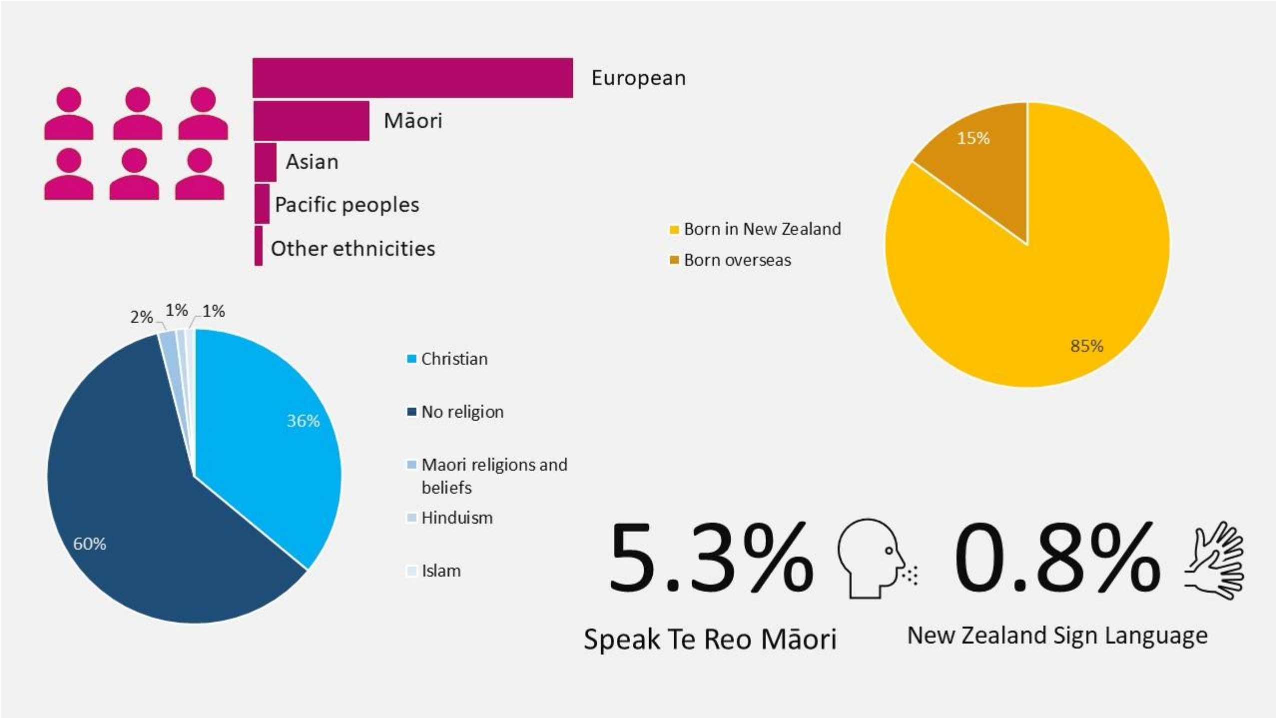


Figure 6.5: Diversity of the Manawatū-Wanganui region.

Figure 6.6 shows the spatial variation of social deprivation in the region. The highest deprivation shown around Whanganui, Taumarunui, Tararua rural areas, and least deprived areas are surrounding Palmerston North.

The socio-economic disparities between Māori and non-Māori communities in the region mean that Māori communities in the region are more sensitive to climate change impacts (Manning et al., 2011). Māori have unique spiritual, cultural and economic connections with the whenua (land), moana (sea), and the environment, including an inherent whakapapa connection (genealogy). Climate change as a consequence, may erode the foundations of social capital within Māori communities.

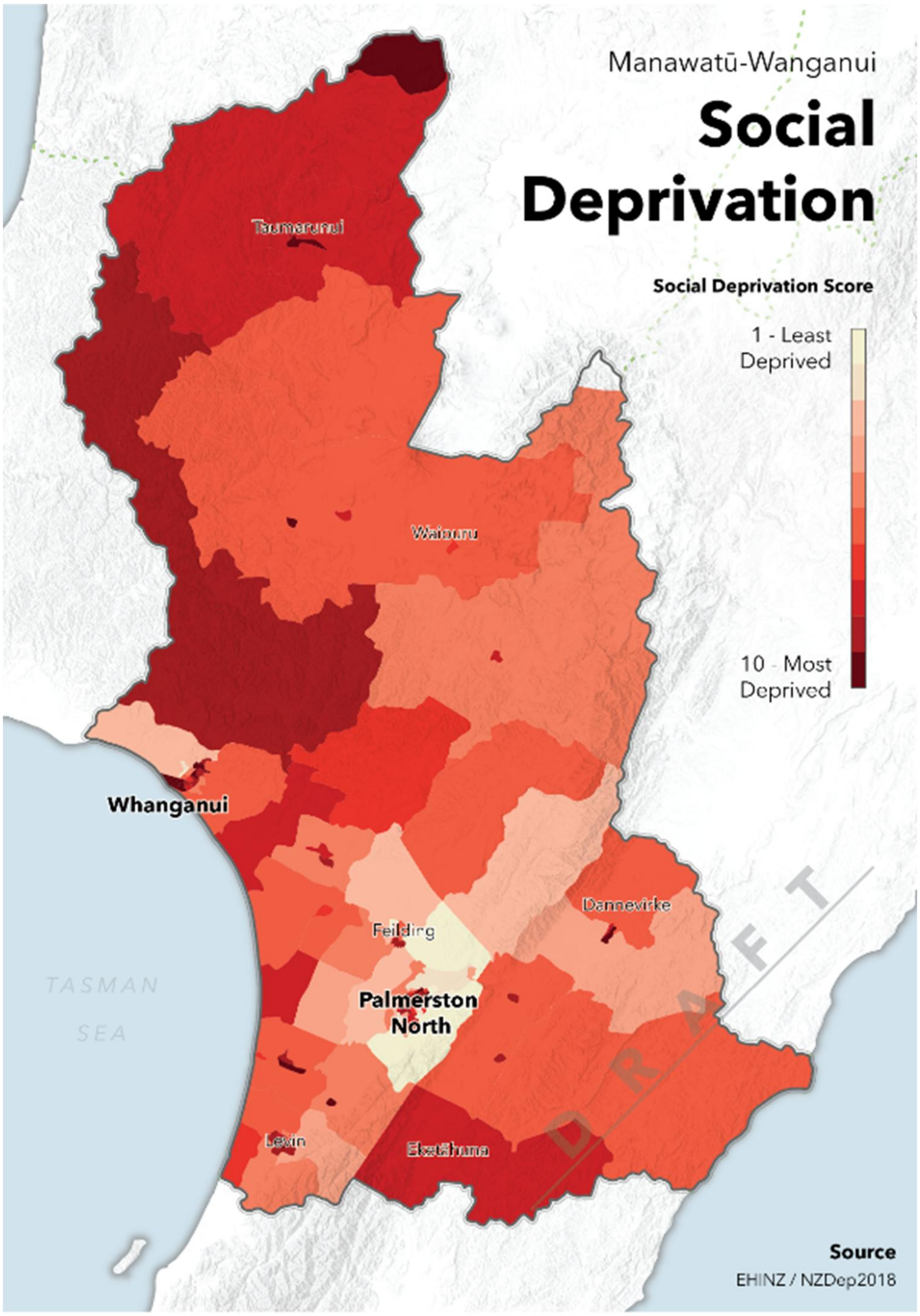


Figure 6.6: Social deprivation map 2018 (ehinz, 2018).

6.4.2 Risk summary

Table 6.5: Risks to social capital from differing hazards

Hazard	Present	2050	2100	Commentary
Inland flooding	High	Extreme	Extreme	Exposure of farmland located in the plains, set to increase through time. Sensitivities include destruction of crop/ feed, damage the integrity of the farm, animal welfare and reduction of overall yield.
Increasing landslides and soil erosion	Moderate	High	High	Exposure concentrated on foothills, with increasing incidences of landslides into the future, and likely increasing use of higher sloping hills in time.
Increasing landslides and soil erosion	Moderate	High	High	Exposure particularly on the hill country farms. Soil erosion already issue for farmers based on livestock movements, so will be exacerbated by climate change. High sensitivity as it can damage/ destroy farmland resulting in economic loss. Medium adaptive capacity as relocation possible.
Extreme weather events	High	Extreme	Extreme	High sensitivity as animals can drown if not evacuated or shifted and flood waters are high enough, crops can be destroyed limiting feed for stock, influencing the amount of yield produced. Medium adaptive capacity as improved farming practises can be put in place/ retreat of farming in particular locations if it is not viable. Or practices can change i.e. dairy changing sheep and beef etc.
Inland flooding	High	Extreme	Extreme	

The region's low lying coastal areas are exposed to ongoing sea level rise, extreme weather events, and associated impacts on groundwater access. The rural, inland communities are exposed to flooding, landslides and soil erosion, and extreme weather events, including droughts and heatwaves. Urban areas are less exposed to flooding, landslides and soil erosion, but are more highly exposed to heatwaves.

Climate hazards, such as drought, flooding and storms, will likely exacerbate inequalities in rural and Māori communities which have reduced capacity to respond (Jones et al., 2014). Social inequalities will likely be exacerbated and social capital more highly exposed around the Whanganui, upper Ruapehu and lower Tararua districts, compared to the central region around Palmerston North (ehinz, 2018).

The level of social capital in communities across the region will be directly sensitive to climate hazards, and is also sensitive to cascading risks from economic, environmental and social impacts.

High levels of social capital help with preparing, responding to, and recovering from extreme weather events and natural disasters (Jakes & Langer, 2012). The impacts of climate change can result in reductions of social capital, and thereby increased risk due to extreme weather events. The communities that are most exposed to these risks are likely to be rural communities and Māori communities.

Rural communities and communities with high levels of tourism are sensitive due to a high reliance on the natural environment for their livelihoods, geographic isolation, and infrastructure risks. For example, farming communities are highly sensitive to events that disrupt farming practices and communities reliant on tourism are highly sensitive to climatic changes, which may lead to economic impacts, resulting in declining wellbeing and reduced social capital.

Māori sovereignty has been critiqued as being progressively eroded since the signing of Te Tiriti ō Waitangi (Barnes and Tim McCreanor, 2019). These impacts over time mean that the social capital of Māori communities is also highly sensitive to extreme weather events and other climate hazards. The spiritual connectivity of the collective (wairuatanga) will be reduced as climate hazards impact the practice of tikanga and mātauranga Māori, across Māori networks, and within interest groups (Independent Māori Statutory Board, 2021). Remote marae and Māori communities, such Paraweka Marae at Pipiriki and Kaitupeka Marae near Taumarunui, will be particularly sensitive to reduced levels of social capital (Stakeholder Engagement, 2021b).

Therefore, the social capital of some communities and groups are at a higher risk, and this may exacerbate a number of social and economic indicators, including the social deprivation and inequities of the region. The social capital of communities across the region may be at particular risk due to a number of factors, including:

- Exposure to climate hazards that result in high damages or a need for relocation, including low-lying coastal communities and communities on floodplains. As the frequency of these disruption increases, so does the likelihood that those who have the resources to relocate will move (Lawrence et al., 2018).
- Ethnically and culturally homogeneous communities, who may experience a decline in social capital as diversity increases (Laurence and Bentley, 2016).
- Members of society who rely on strong social networks for support are more sensitive to loss of social capital (Wistow et al., 2015).

The impact of climate change on social capital will result in reduced adaptive capacity as trust declines, cooperation diminishes and community cohesion is impacted. Maintaining social capital will require good governance, strong institutions, and inclusive planning processes at the community, regional and national levels. It is particularly important that communities that are at risk of declining social capital are identified and provided with anticipatory support and adaptation options to reduce long-term social risks.

7 Business

The Manawatū-Whanganui region is known as the land of "Milk and Honey", which describes the economic, social and cultural importance of land-use and farming activities in the region. The key business sectors that contribute to maintaining the economic livelihoods of households and communities are tourism, agricultural and horticultural land-use, manufacturing and service industries (see Figure 7.1). Economic activity within the region is enabled by its infrastructure, supply chains and distribution centres, stock of commercial and industrial buildings, and the Manawatū-Whanganui labour force.

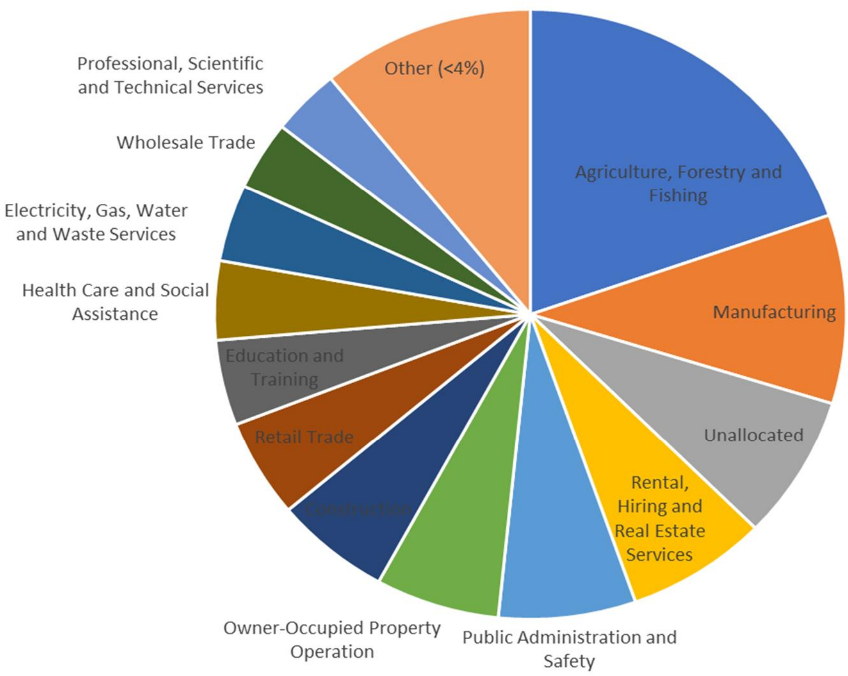


Figure 7.1: Industry proportion of GDP in the Manawatū-Whanganui region (excluding Tararua, Whanganui and partial districts) directly sourced from (Infometrics, 2021).

The key present-day and 2050 climate change risks facing businesses in the region are shown in Table 7.1.

Table 7.1: Summary of risks to Business elements for differing climate change hazards

Business	Higher temperatures			Inland flooding			Extreme weather events			Drought			Coastal flooding			Increased fire weather			Increasing landslides and soil erosion			Sea level rise and coastal erosion			Change in rainfall			River erosion			Reduced snow and ice			Sea level rise and salinity stress			Marine heatwaves			Ocean acidification		
	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Commerce				M	M	H	I	L	M																																	
Fast Moving Consumer Goods (FMCGs)	I	L	M	H	E	E	M	M	H																																	
Livestock animal welfare	M	M	E	H	E	E	H	E	E				L	M	E				M	H	H																					
Productivity of land	M	H	E	H	E	E										M	H	E	M	H	H																					
Tourism				M	H	E	H	E	E	I	L	M													L	M	H				H	E	E									

7.1 Commerce: commercial buildings and manufacturing

Risk to commercial buildings and manufacturing due to inland flooding and extreme weather events.

7.1.1 Introduction

Manufacturing is a key driver of the regional economy, contributing to 10.6% of the Gross Domestic Product (GDP) of the Manawatū District, 12.7% of the GDP of the Rangitīkei District and 6.5% of the GDP of the Ruapehu District (Infometrics, 2021). Manufacturing business are also major employers within the region, accounting for 13.7% of employment in Manawatū District, 17% of employment in the Rangitīkei District and 5.7% of employment in the Ruapehu district.

There are a number key commercial buildings and manufacturing facilities across the region. Key commercial buildings are centred in major urban centres such as Palmerston North, Whanganui, Ohakune, Waiouru, and Feilding. Across the region, there are also facilities for manufacturing plastics, metal production, and processing forestry products, grains and milk. Major facilities include:

- Dairy processing at Fonterra Pahiatua.
- WPI Tangiwai Sawmill and Karioi Pulpmill.
- Hautapu Pine Products.
- PlastAx (Wheelie bin) manufacturing located in Whaganui.
- Paint manufacturers.
- The Mars manufacturer for pet food was located in Castlecliff Whanganui but was closed in 2019 leaving 152 workers without jobs (2019).

7.1.2 Risk summary

Table 7.2: Risks to commercial buildings and manufacturing for differing hazards

Hazard	Present	2050	2100	Commentary
Inland flooding	Moderate	Moderate	High	Increasing intensity of flood events increasing exposure through time. Moderate sensitivity which can be influenced by material and condition of the building. Most commercial buildings are made from concrete. Medium adaptive capacity due to ability for alterations/ resilience measures.
Extreme weather events	Insignificant	Low	Moderate	Projected increases in storm events increasing exposure through time. Most commercial buildings are made from concrete so are less likely to suffer damage like the residential stock would.

Manufacturing buildings and associated supply chains are exposed to inland flooding and extreme weather events. The exposure to inland flooding at present is rated as high, and exposure is projected to increase to extreme by 2040 with projected increases in rainfall (NIWA, 2016).

There are 4,802 industrial buildings (which includes primary production related buildings) exposed to flooding within the region. The Manawatū-Whanganui region has the third most industrial buildings exposed to flooding nationally (Figure 7.2). Moreover, there are approximately 380 commercial buildings within the region exposed to flooding, which have an estimated replacement cost of around $700 million (Paulik, Craig, et al., 2019). Commercial buildings located on the Manawatū plains face particularly high exposure. Commercial/manufacturing buildings are largely constructed with concrete slab floors, and either concrete or metal sheet walls. Due to these materials and the design of the buildings, damage from minor inland flooding events and extreme weather events is unlikely to occur (Reese & Ramsay, 2010). As exposure increases, the adaptive capacity of buildings could be strengthened through retrofitting of the structures to flood impacts.

Commercial/ industrial buildings in Castlecliff, such as PlastAx, are located adjacent to the Whanganui River and fall within the flood modelled extents, and are therefore highly exposed to flooding and extreme weather events (Horizons Regional Council, 2021b). The Fonterra Pahiatua processing plant is located between the Mangatainoka and Mangahao Rivers and is currently not located within current flood modelling extents, however with projected increase in rainfall and the intensity and frequency of flooding events, this factory may become exposed (Horizons Regional Council, 2021b).

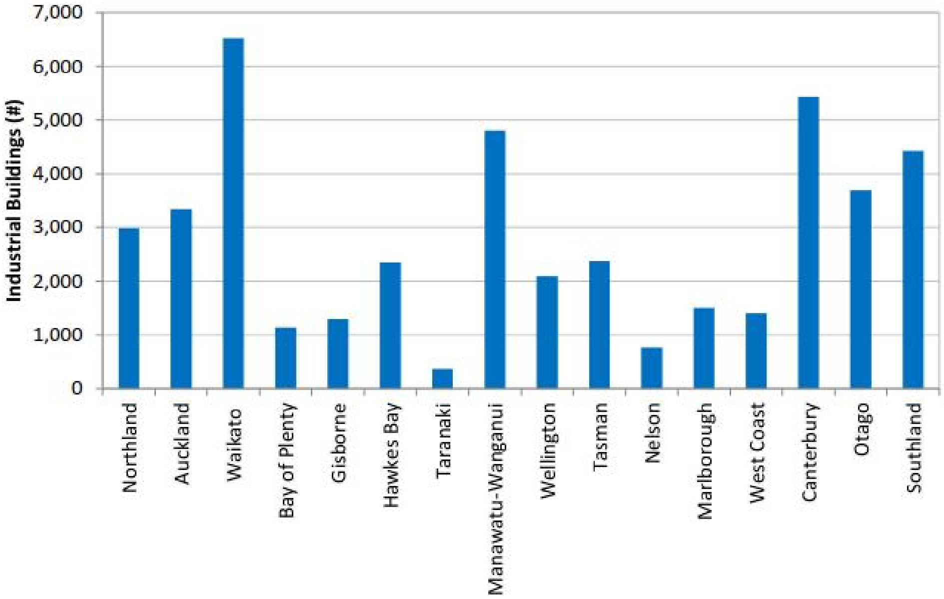


Figure 7.2: Number of industrial buildings exposed to inland flooding nationally (Paulik, Craig, et al., 2019).

While current risk from extreme weather events is rated low, projected increases in storm events will likely increase to this risk high by the end of the century. Flooding events in the plains are likely to occur, whilst storms and high winds are likely in the hill country/ mountainous areas.

Commercial and manufacturing buildings are also reliant on supply chains for the supply of inputs and the transport of finished products to markets. These supply chains are dependent on road and rail linkages, which are vulnerable to inland flooding (this risk is assessed in Section 8).

7.2 Fast moving consumer goods (FMCGs)

Risk to FMCGs due to inland flooding, extreme weather events and increased high temperature.

7.2.1 Introduction

Fast moving consumer goods (FMCG) are products that are sold quickly and at a relatively low cost. The region is a centre for distribution of FMCGs, particularly nondurable goods (e.g. fruit, vegetables, milk) because of significant amount of primary sector production in the region. There are also a number of businesses involved in the FMCG supply chain, including distribution centres, which contribute to employment in the region.

A large volume of FMCG's flow in and out of Palmerston North, which is a nationally strategic freight location. Goods for domestic and export markets move to the city from Auckland and the upper North Island, Taranaki, Hawke's Bay and Wellington. The role of Palmerston North as a critical freight distribution centre for the lower North Island is expected to grow, with KiwiRail currently progressing plans for developing a high-tech, inter-modal freight hub.

Palmerston North is also the location of major food distribution centres such as Foodstuffs and Provida Foods. The Foodstuffs Roberts Line distribution centre in Palmerston North caters to all of Foodstuffs dry goods distribution needs in the Lower North Island region. The facility holds the equivalent of 30,000 pallets, and distributes more than 600,000 pallets per annum. A second Foodstuffs distribution centre in Palmerston North looks after the Lower North Island chilled and frozen distribution requirements (Foodstuffs, 2021). Provida Foods opened a distribution centre in Palmerston North in 2015 because it was seen to be a progressive hub for Taranaki, Hawke's Bay and Wellington. The distribution centre was also opened due to the distribution industry in the city growing at double the national average (Stuff, 2014).

FMCGs are heavily reliant on accessibility and the road/rail network to transport goods around the region. In March 2018, central government announced a $10 million commitment to complete a business case for the regional freight ring road within the region to enable better hubbing and distribution throughout the Manawatū (Accelerate25, 2021). This alongside, the re-routing of SH3 and other major transport upgrades are likely to increase the efficiency of distribution throughout the region.

7.2.2 Risk summary

Table 7.3: Risks to Fast Moving Consumer Goods (FMCGs) from differing hazards

Hazard	Present	2050	2100	Commentary
Inland flooding	High	Extreme	Extreme	High sensitivity as accessibility into Palmerston can be inhibited which can result in impacts to the entire region. Medium adaptive capacity as progressive changes can be made to ensure goods last for more than three days. Limited redundancy currently.
Extreme weather events	Moderate	Moderate	High	High winds can also cause trucks to topple over or reduce speeds which can have an impact on delivery.
Higher temperatures	Insignificant	Low	Moderate	If temperatures reach above design standards for road and rail structures then disruption to the service of FMCG can occur. Increased vulnerability due to there being only one hub for distribution within the region.

The transport and quality-control of FMCGs are at risk from inland flooding, extreme weather events and increased air temperature. There are likely to be cascading risks to other sectors, including agriculture, horticulture, tourism and retail, as a result of disruption to FMCG supply chains. The transport of FMCGs are heavily reliant on accessibility to the roading/rail network to transport goods around the region. Maintaining the accessibility to transport networks out of Palmerston North is particularly important, given the status of the city as a nationally strategic freight location. A lack of road transport spending could increase this risk into the future.

The transport of FMCGs is currently exposed to climate related hazards such as inland flooding and extreme weather events. FMCGs rely on accessibility to critical roads (SH1, SH3, SH57) and rail lines (North Island Main Trunk Line) for delivering goods throughout the region, and these are currently exposed to inland flooding and extreme weather events. SH1 and SH4 to the north of the region are also exposed to extreme weather events such as snowfall which can close the roads, whilst SH1 and SH3 to the south can close due to flooding and landslides. As assessed in Section 8, the roading and rail network infrastructure is also vulnerable to climate hazards.

The transport of FMCGs by road is also exposed and vulnerable to high winds, which can result in trucks toppling over. Those trucks that are greater in height have a greater sensitivity to be toppled in high winds compared to those that have a smaller surface area and are lower to the ground (Zhang, 2015).

The quality of FMCGs, particularly non-durable goods such as fruits and vegetables, are vulnerable to these hazards as supply chain disruptions would result in longer transport times, and could lead to spoilage and contamination of products and economic losses (Davis et al., 2021). Increased air temperatures may also result in increased risk of spoilage of sensitive non-durable goods, particularly if FMCGs are not collected and delivered with refrigerated transportation (Mbow et al., 2019). This may necessitate changes in distribution infrastructure, including the provision of increased refrigerated transportation capacity in the future.

The key FMCG buildings, the Foodstuffs and Provida food distribution centres, are not currently located within modelled flood extents. However, exposure is likely to increase by mid-century with the projected changes in rainfall and the frequency and intensity of flooding events (Horizons Regional Council, 2021b). The selection of new distribution hub locations within the region has involved an exposure assessment to ensure limited impact from natural hazards (KiwiRail, 2021).

In addition, the Whanganui port is an important link in the supply chain and providing a public good for the region. The climate risk to the port has not been assessed as a part of this project, but it is likely to provide alternative shipping options if other transport links are affected by climate hazards.

7.3 Livestock and animal welfare

Risk to livestock and animal welfare due to extreme weather events, inland flooding, landslides and soil erosion, coastal flooding, drought and high temperature.

7.3.1 Introduction

The livestock sector is a pillar of the region's economy, with the agriculture sector contributing 9% to regional GDP in 2017-2018 (MBIE, 2020). Sheep, beef and dairy farming are also key employers in region, with sheep and beef farming accounting for 2.8% and dairy farming accounting for 5.1% of total employment in the region in 2020 (Infometrics, 2021).

The main forms of livestock production in the region are arable dairy farming and pastoral farming. There are other types of animals farmed, such as horse, pig, chicken and deer, but these are produced at a much lower scale (Horizons Regional Council, 2019).

The structure of the livestock sector has faced changes over the past two decades. Since 1994, the number of dairy cows has increased by 155,000, whereas beef stock numbers have decreased by 239,000 and sheep numbers have decreased by 2.4 million (Figure 7.3) (Horizons Regional Council, 2019). Even with these changes, sheep are the most dominant farmed animal in the region, and more sheep are farmed in the Manawatū-Whanganui region than any other region in Aotearoa –

with 40% of the nation's lamb production occurring in the region (Horizons Regional Council, 2019; Stats NZ, 2021).

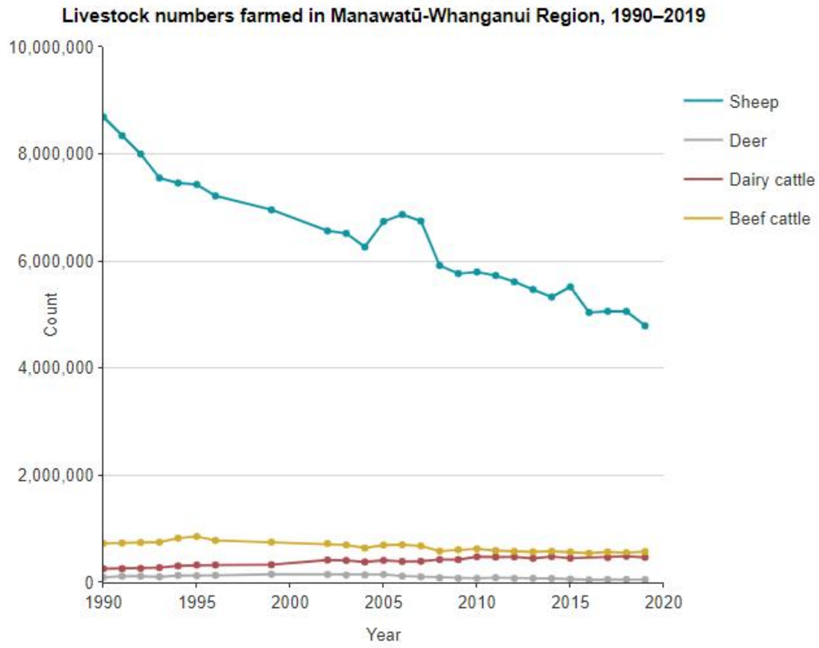


Figure 7.3: Change in livestock numbers from 1990 to 2017 (Stats NZ, 2021).

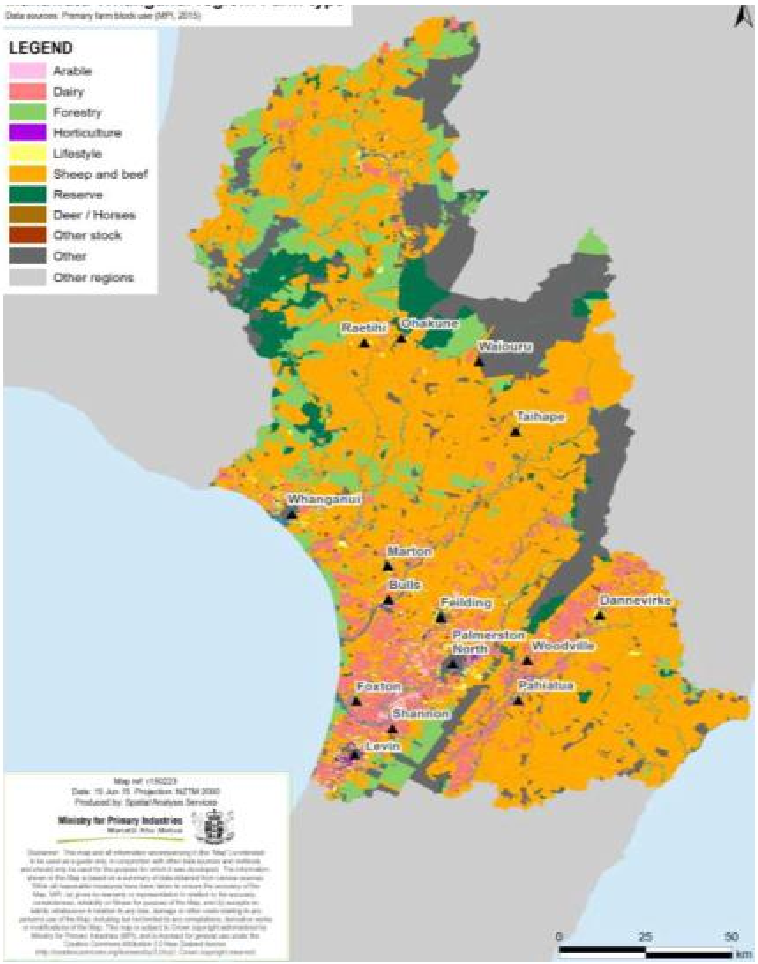


Figure 7.4: Land use patterns within the Manawatū- Whanganui region (MPI, 2015).

As shown in Figure 7.4, the type of livestock farmed differs between the region's geographic areas. Beef and sheep farming are centred in the hill country (and this represents 45% of land use in the region), while dairy farming is located in the plains (representing 8% of land use) (Horizons Regional Council, 2019).

7.3.2 Risk summary

Table 7.4: Risks to livestock from differing hazards

Hazard	Present	2050	2100	Commentary
Extreme weather events	High	Extreme	Extreme	High sensitivity as animals can drown if not evacuated or shifted and flood waters are high enough, crops can be destroyed limiting feed for stock, influencing the amount of yield produced. Medium adaptive capacity as improved farming practises can be put in place/ retreat of farming in particular locations if it is not viable. Or practices can change i.e. dairy changing sheep and beef etc.
Inland flooding	High	Extreme	Extreme	
Drought	Moderate	Moderate	Extreme	Potential evaporation deficit percentages increasing and the number of hot days increasing through time, dictating exposure. Conditions below optimal for animal comfort plus their production (wool, milk or meat). Lack of feed can also occur during drought conditions. Medium adaptive capacity as improved farming practises can be put in place/ retreat of farming in particular locations if it is not viable.
Coastal flooding	Low	Moderate	Extreme	Lower exposure of animals within coastal flood prone areas comparative to inland flood areas
Higher temperatures	Low	Moderate	Extreme	Low exposure to increased temperatures, increasing over time. High sensitivity due to heat-stress for livestock.
Increasing landslides and soil erosion	Moderate	High	High	Exposure concentrated on foothills, with increasing incidences of landslides into the future, and likely increasing use of higher sloping hills in time.

Livestock production is highly exposed to climate change, particularly extreme weather events, drought and increased air temperatures. Livestock species and farming operations are also vulnerable to climate hazards, as the productivity of the livestock sector is highly dependent on climate conditions.

Beef and sheep (pastoral) farming occurs largely in the hill country of the region, and is exposed to heavy rainfall, inland and coastal flooding, extreme weather events, landslides and soil erosion, fire weather, drought, and increased air temperatures. Dairy farming on the plains is exposed to heavy rainfall, inland and coastal flooding, extreme weather events and increased air temperatures.

At present, pastoral farming has a high exposure to inland flooding (with the flood hazard area estimated at 700 km^2) and a low exposure to coastal flooding from storm surges and sea level rise (it is estimated that 2 m of sea level rise could result in 28 km^2 of pastoral land exposed to the 1% AEP storm tide event) (NIWA, 2019). Dairy farming was also found to have high exposure to inland flooding in the present day, and this was projected to increase to extreme by mid-century, particularly on the plains and within the Manawatū, Whanganui and Rangitīkei River catchments. It is also estimated that 562 km^2 of dairy land could be exposed to inland flooding, and that 2 m of sea level rise would result in 100 km^2 of dairy land being exposed to the 1% AEP storm event (NIWA, 2019) – exposure in 2100 is assessed as being high. Dairy farming sheds and infrastructure are also exposed to flooding, although the number of structures exposed is not known.

Both pastoral and dairy farming is exposed and vulnerable to changes in seasonal weather and rainfall. Increased precipitation can result in early pasture growth during September-November, and unseasonably cold and wet periods during spring can also lead to nitrogen deficient pastures throughout the region (Osborn & Cowie, n.d.).

Both pastoral and dairy farms across the region are exposed and vulnerable to extreme weather events. In 2015, a significant storm event had a substantial impact on livestock farms and animal welfare across the region. In this extreme event, sheep and beef farms and associated infrastructure were damaged due to landslides and flooding. Approximately 460 sheep and beef farms were affected, with 100 of those having significant levels of infrastructure damage and lost productive capacity (MPI, 2015). This event resulted in damaged fences and wandering stock, which reduced the ability to control pasture utilisation and reduced productivity. Some farmers were also unable to move stock due to landslides and this prevented normal seasonal work such as shearing and scanning ewes. The estimated on-farm impact for pastoral farms was $57.6 million, with $37 million in infrastructure damage and $20.6 million in production losses. Dairy farms faced less damage, and were mainly impacted by silt from flooding which resulted in an estimated on-farm economic impact of $6.4 million. Approximately 236 dairy farms were affected overall with 36 having moderate to significant levels of damage to farm infrastructure and pasture. While there was little disruption to milking on winter milking farms and the timing of the storm had little impact on the regions annual milk production, a number of dairy farmers reported having to return cows and in-calf heifers three to four weeks earlier than the normal wintering period as a result of this storm (MPI, 2015). Moreover, unseasonably cold and stormy weather can result in a lack of feed and stressful conditions for livestock, which can cause acidosis, ketosis and other metabolic troubles in dairy cows (Osborn & Cowie, n.d.).

In an earlier extreme weather event in 2004, there were stock losses from flooding which resulted in drowning and loss of grazing areas (Sutton, 2004). The 2004 floods estimated to cost the agricultural and forestry sectors $159-$180 million. Damage to roads meant accessibility for Fonterra trucks was inhibited, and therefore there were halts to milking. There were also temporary loss of grazing due to severe silting of the land and permanent loss of grazing in newly formed riverbeds (Sutton, 2004).

Currently, there is moderate exposure to landslides and soil erosion within the region, particularly on the hill country farms. There is 273,000 hectares of highly erodible land within the region of which 260,000 hectares is land in pasture (Horizons Regional Council, 2019). The river catchments with highly erodible land without protective vegetation are: Whanganui (95,000 ha), Whangaehu (42,000 ha), Turakina (27,000 ha), Rangitīkei (35,000 ha) and the Manawatū (39,000 ha). These areas particularly have a higher exposure to soil erosion (Dymond & Shepherd, 2006). Steeper areas, particularly those with slopes greater than 15 degrees have a higher exposure to landslides due to the degree of slope.

While hill country by definition covers Class 5, 6, 7 and 8 lands, it is Class 6 land that offers the greatest potential for productivity increases across the region. This land is less steep than Class 7 land, and is therefore less prone to soil loss from erosion. Improving the pastures of Class 6 land could support stock carrying capacities in the order of 13.3-16.7 stock units (su) per hectare. Soil conservation plantings of poplars and willows at a spacing of 12-15 metres are appropriate to provide the necessary erosion control (Cameron, 2016). Approaches that can be used to prevent land erosion are stream fencing, poplar planting and reversion of land in pasture back to native cover (Horizons Regional Council, 2019).The planting of vegetation on at-risk land is being incentivised, as noted in Section 2.3, which will help to build adaptive capacity to the impact of erosion and landslides.

The risk to livestock from drought is currently rated moderate, and this is assessed as increasing to extreme by the end of the century due to the increases in the number of hot days throughout the region and the potential evapotranspiration deficit (PED). Farms located in the northwest area of the region around Taihape and on the east coast in the Tararua district are likely to see dramatic increases in PED by the end of the century, with increases up to 200 mm per year. This is equivalent to approximately 6 weeks of reduced grass growth (30 mm = 1 week of reduced grass growth) (NIWA, 2016; Stakeholder Engagement, 2021b). Livestock are sensitive to drought due to the conditions being below optimal for animals comforts plus their production (wool, milk or meat) (Dairy NZ, 2021; van Wettere et al., 2021). Lack of feed can also occur during drought conditions which can impact animal welfare and therefore have economic impacts on the farmer and the region. Drought-prone areas are also likely to see increased fire weather associated with drought conditions. In 2015, for example, fires spread across Bainesse, Turitea, Tangimoana and Kaitoke, destroying 100 acres of farmland including hay bales and a farm shed (Stuff, 2015).

Table 7.5: Impact of increased air temperature on dairy cows and milk production in the lower North Island (Dairy NZ, 2021).

Weather station	Average hours per day too warm for comfort	Average hours per day warm enough to reduce milk production	Days warm enough to reduce milk production	Estimated milk solids impact per cow each summer
Waipawa	11	7	66	6.2
Palmerston North	12	5	58	4.1
Levin	13	5	54	3.4
Dannevirke	10	5	53	3.6
Pahiatua	10	5	57	4.2

At present, there is low exposure to increased temperatures with average annual temperatures ranging from 6-15 degrees across the region. Temperatures are predicted to increase over time by 1.1 degrees (2040) and 3.1 degrees (2090) under RCP 8.5, and therefore exposure increases to high by the end of the century (NIWA, 2016). Livestock are sensitive to changes in temperature, with the comfort zone for cows being between 4-20 degrees (Dairy NZ, 2021). Table 7.5 outlines the average hours per day in which cows within the lower North Island are outside comfort levels. Lambs and sheep are also sensitive to temperature changes, with temperature affecting rates of lamb growth (as shown in Figure 7.5).

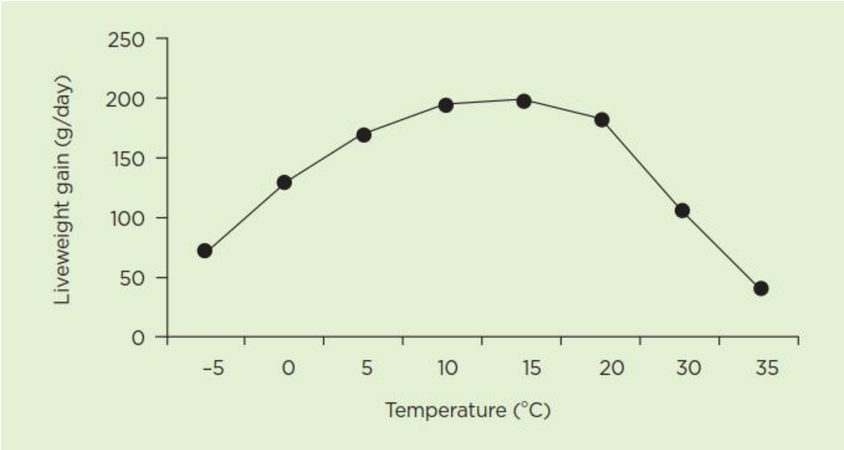


Figure 7.5: The effect of temperature on lambs (Ames & Brink, 1977).

Higher average temperatures could result in both benefits and risks to farms across the region. Increased air temperatures can improve pasture growth (if sufficient moisture is available), and reduce cold conditions in winter. Conversely, the projected increased frequency of hot days could result in heat stress to livestock, which can lead to less milk production and impact the efficiency of lamb/mutton and wool production (van Wettere et al., 2021).

Climate change is likely to result in increasing costs to livestock producers in the region. The regions exposure to climate hazards, and vulnerability of farming systems, will result in increased operational costs. These costs are due to the responses required, and could include land rehabilitation (following extreme weather and flooding events and landslides), feed planning and water planning (in response to drought conditions), infrastructure repair (due to extreme weather, flooding events and landslides), and managing direct impacts of climate hazards on stock health and welfare (NIWA, 2019). While farmers can respond to these climate hazards, there is likely to be limited capacity to finance these additional costs.

Investing in measures to reduce exposure and vulnerability is likely to be more cost effective than responding to the impacts of climate hazards. Adaptation measures could include expanding of tree planting and other ecosystem-based approaches to reduce exposure to inland floods and landslides, providing more vegetation cover to allow livestock to shelter from high heat conditions, relocating roads and infrastructure outside of hazard zones, and providing financial support to farmers for investing in preparedness activities (Dobie, 2018; Stokes & Howden, 2011). Reducing the vulnerability of farming infrastructure and systems to climate hazards would also reduce damage costs, and this could include climate proofing sheds to withstand flooding events.

Lastly, over the long term, changes in land use may be required if climate conditions are not favourable for particular types of farming (e.g. due to changes in precipitation) and this could include, for example, switching from dairy farming to pastoral farming (Stokes & Howden, 2011).

7.4 Productivity of land

Risk to productivity of land due to inland flooding, landslides, changes in rainfall, increased fire weather, extreme weather events, and drought.

7.4.1 Introduction

The land of the Manawatū-Whanganui region is considered to be the most valuable asset, and land-use activities are key contributors to regional GDP and employment. There are a range of horticulture and forestry activities in region, as described below and shown in Figure 7.6[2].

Particular geographic areas of the region have specialised land-use activities, with horticulture centred on the plains and mixed-land use activities common across the region. Forestry is mostly located on the fringes of the region. With our changing climate, areas of the region that are historically suitable to the growth of certain species may become less suitable throughout this century.

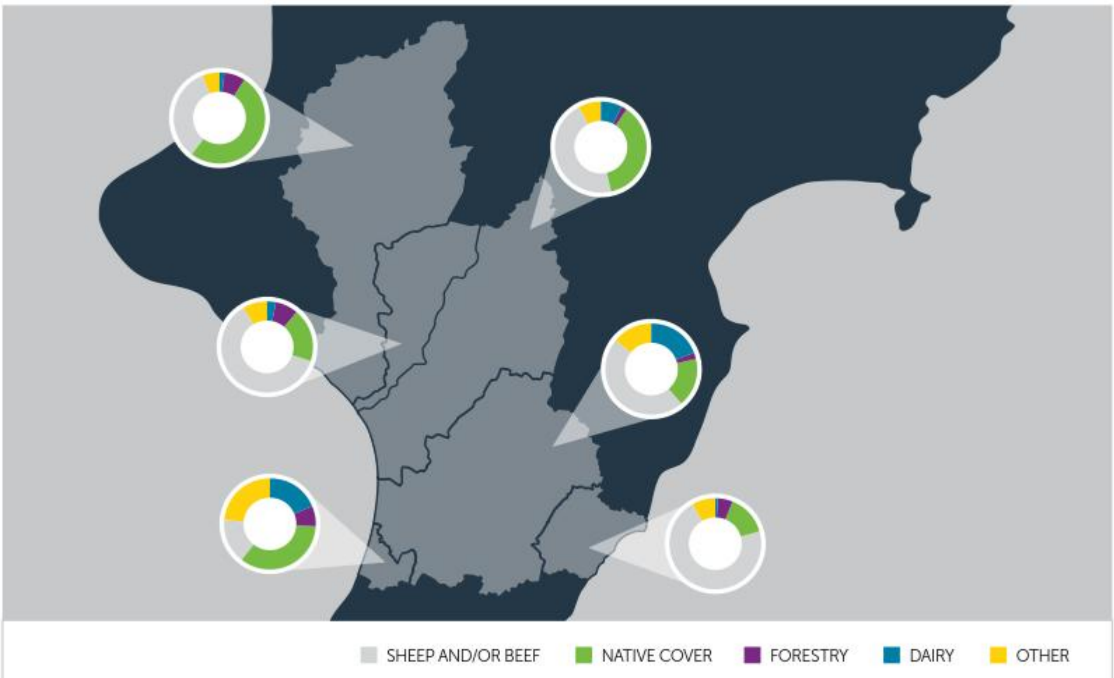


Figure 7.6: Proportion of land use types within each district of the Manawatū- Whanganui region (Horizons Regional Council, 2019).

The crops grown in the region include vegetables and fruits, grains and cereals, and grapes and olives. There have been changes in the types of crops grown in recent decades, with cropping in wheat, barley and apples declining and cropping in onions, indoor tomatoes, and squash increasing.

The region is competitive at growing vegetables and has significant areas of high quality soils (the area of class 1 soils is over 25,000 ha and class 2 soils is 150,000 hectares). The vegetable sector is relatively small, contributing around $85 million (or 1% of GDP) per annum to the regional economy, but the productivity of crops has been considered high (MPI, 2015). There are 120 vegetable growers within the region, of which 10 produce 90% of the volume. At present the vegetable growing sector is losing jobs due to regulatory requirements and a lack of workers, and will continue unless some major initiative is taken (MPI, 2015).

[2] This section focuses on horticulture and forestry. Risks to livestock are assessed separately.

Areas with the most favourable environments for growing vegetable crops include Ohakune, Levin and the lower part of the Rangitīkei District (MPI, 2015). The Rangitīkei District has a focus on mixed broad acre vegetables and arable cropping, including yams, potatoes and squash. Bulk handling of onions and potatoes is completed in the Manawatū and Rangitīkei districts. In the Horowhenua area, the largest businesses are Kapiti Green and Woodhaven Gardens who together operate over 600 hectares, employ 120 people and have annual revenue of $16-$18 million. A third large venture, Tender Tips, operate one of the nation's largest asparagus growing ventures (MPI, 2015). The focus in the Horowhenua area is on domestic market greens and brassicas as well as potatoes for processing and export. Ohakune grows two-thirds of the North Island's carrots and vegetable growing in Ohakune employs 135 full time employees, and contributes $14 million or 1.5% of the Districts GDP (MPI, 2015).

Large scale forestry is located around the fringes of the region and is in proximity to national parks and conservation areas. With approximately 130,000 hectares of planted production forest within the region, 5% of land-use is for forestry (MPI, 2015). Plantation forests are on average 18 years old and have an estimated standing volume of 24 million tonnes. In addition, the native forest coverage of the region is 33% of the land area (Horizons Regional Council, 2019). It is recognised that carbon farming is also a growth areas in the Tararua, with NZ Carbon Farming now the largest land owners in the Tararua (Stakeholder Engagement, 2021). This brings with it increased afforestation.

7.4.2 Risk summary

Table 7.6: Risks to productivity of land from differing hazards

Hazard	Present	2050	2100	Commentary
Inland flooding	High	Extreme	Extreme	Exposure of farmland located in the plains, set to increase through time. Sensitivities include destruction of crop/ feed, damage the integrity of the farm, animal welfare and reduction of overall yield.
Increased fire weather	Moderate	High	Extreme	Fire weather exposure increasing through time with potential evaporation deficit percentages and number of hot days increasing. Fire can destroy crops and stock which can have a substantial economic impact. Medium adaptive capacity as measures can be undertaken to reduce fire weather starters.
Change in rainfall	Moderate	High	Extreme	Increases in rainfall are projected for winter months. Crops generally rely on a sufficient amount of rainfall to provide for stock, not enough and that can impact the amount of yield, and too much can waterlog crops also reducing yield. Medium adaptive capacity as strategies can be undertaken to reduce waterlogging of soils.
Increasing landslides and soil erosion	Moderate	High	High	Exposure particularly on the hill country farms. Soil erosion already issue for farmers based on livestock movements, so will be exacerbated by climate change. High sensitivity as it can damage/ destroy farmland resulting in economic loss. Medium adaptive capacity as relocation possible.
Drought	Moderate	Moderate	High	Moderate exposure to drought in the present day but increases to high by the end of the century. High sensitivity to drought as it can reduce the amount of feed or viable land available for stock which can then impact animal welfare, milk quality and quality of crop. Medium adaptive capacity as there are alternative crops that can be used for feed.
Extreme weather events	Low	Moderate	High	Currently low exposure to extreme weather events, increasing to high by the end of the century with projected increases in the frequency and intensity of storms. High sensitivity due to waterlogged soils from flooding.

The quality and quantity of horticulture and forestry output faces risks from extreme events and ongoing, gradual climatic changes. The productivity of land is particularly at risk due to changes in rainfall, inland flooding, landslides, extreme weather events, drought and increased fire weather.

Precipitation is key factor for crop production and forestry growth. At present, there is moderate exposure to changes in rainfall and this is assessed as increasing to extreme exposure by the end of the century. Increases in rainfall are projected for winter months, while reductions are projected for the summer months. Farms located around Taihape (northeast of the region) are likely to see an increase in rainfall in both winter and summer (NIWA, 2016).

The exposure to flooding is currently high, particularly on farmland located on the plains. Flooding on farmland is exacerbated as it is used during flood events to remove water from within the river system – an example of this is the flood gates near Foxton. It is also estimated that approximately 40 km^2 of arable land, 562 km^2 of dairy land, and 700 km^2 of pastoral land is exposed to flooding within the region (NIWA, 2019). This land exposure is distributed relatively equally across the Horowhenua, Manawatū and Tararua districts (Figure 7.7).

Crop yields can decline as a result of surplus rain and inland flooding. These impacts could result in declining profits, as yields and therefore sales could decrease, along with increased operational costs for individuals (irrigation) and the community (with the need for increased rain and flood defences).

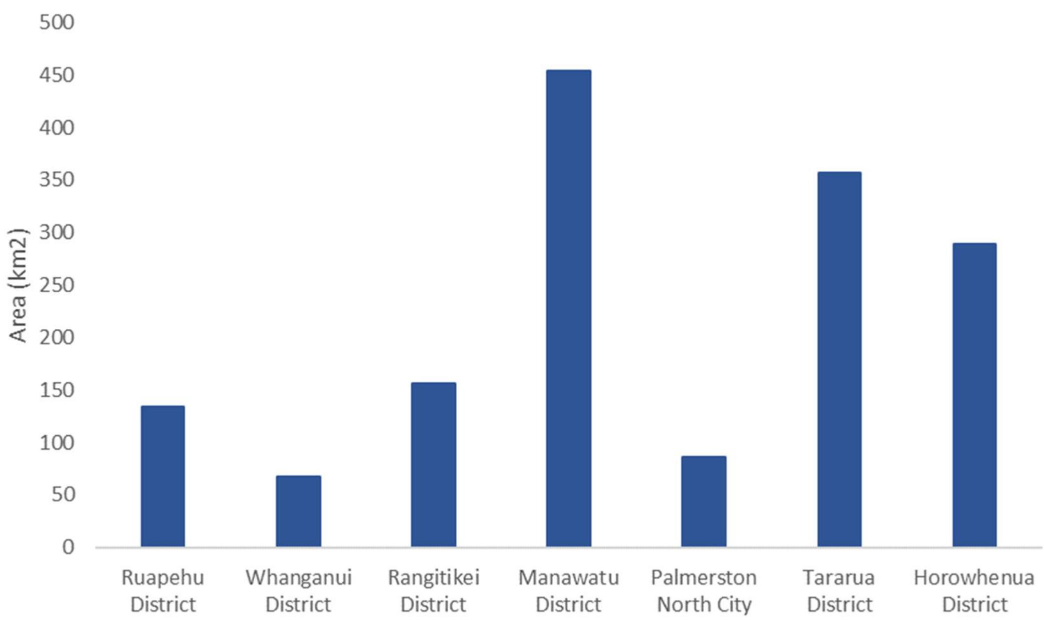


Figure 7.7: Area of productive land exposed to inland flooding (per district) within the Manawatū- Whanganui region (Paulik, Craig, et al., 2019).

Heavy rainfall and flooding can also lead to landslides. At present, there is moderate exposure to landslides and soil erosion within the region, although this is mostly on hill country farms. Forestry plantations are both impacted by landslides and soil erosion, and can also be used as a method for erosion control. The Horizons Regional Council has adopted innovative approaches, such as joint ventures with farms and land-use planning changes, to use afforestation to mitigation land erosion. The Horizons Regional Council Sustainable Land Use Initiative (SLUI) is the main mechanism for tackling accelerated erosion control. Over the past 10 years, 16 million trees have been planted creating around 13,700 hectares of new forestry within the region (Horizons Regional Council, 2019).

The horticulture sector is particularly exposed and vulnerable to drought conditions. There is moderate exposure to drought conditions currently, and these are projected to increase to high by the end of the century due to the potential evapotranspiration deficit and the number of hot days increasing, particularly in the northwest area of the region around Taihape and on the east coast around Waione/southeast of Dannevirke.

The sensitivity of crops to changes in rainfall, and drought conditions is high, as insufficient moisture can result in lower yields and increased reliance on irrigation. In particular, carrots and squash crops are sensitive to low rainfall and droughts, which can result in slowing crop growth and declining crop yields. Low rainfall can also affect the processing of crops, and in 2016 carrot production was affected by limited water supplies for washing of carrots (Stuff, 2016c). Increasing air temperatures can also affect crop growth and quality. For example, the exposure of carrot crops to prolonged hot weather can stunt growth and cause undesirable strong flavours and coarseness. In contrast, cooler temperatures increase the quality of carrot crops – making the roots longer, more slender and paler in colour (Reid & Morton, 2019; Wilcox Goodness, 2021). Climate change is also likely to increase the distribution of pests and diseases in New Zealand, posing risks to primary production (Watt et al., 2019).

Fire weather, which is projected to become more frequent, is a significant threat to the forestry industry in the region. It is likely that the frequency and intensity of fire events will increase into the future, particularly in the West of the North Island (Pearce et al., 2011). Both commercial forestry plantations and native forest ecosystems are sensitive to fire weather, and the increasing exposure to fire weather is likely to result in economic costs to the forestry industry from the loss of forest stocks. The proximity of plantation forests to native forests could also result in fire spreading, which could result in increased risk.

There is currently low exposure to extreme weather events, increasing to high by the end of the century with projected increases in the frequency and intensity of storms. The 2015 storm across the Manawatū-Whanganui region resulted in losses to the forestry sector. Landslides impacted several young forests less than five years old, and bare land prepared for planting and forestry infrastructure. The storm damaged approximately 800-900 hectares (1%) of plantation forest area (MPI, 2015). Replanting activity and re-establishment of damaged forests was estimated to total $1.2 million. The impact assessment did not include damage to forestry roads and infrastructure. There was little damage overall to the horticultural sector. Fewer than 20 fruit growers and approximately 600 hectares of market gardens were affected by flooding and surface water to a greater or lesser extent. A small proportion of potato crops and near-to-harvest green vegetables were lost to silt, waterlogging and bacterial contamination. A small number of kiwifruit and pear orchards had areas of silt deposits of up to 30 centimetres deep. Removal of deep silt is a challenge, particularly in kiwifruit orchards as the vine support structure limits machinery access. The cost of horticulture crop losses was estimated to total $1.2 million. The impact assessment did not include clean-up and infrastructure repair costs for horticultural properties, nor any financial impacts from disruptions to vegetable crop schedules (MPI, 2015).

7.5 Tourism

Risk to tourism due to reduced snow and ice, changes in rainfall, inland flooding, drought and extreme weather events.

7.5.1 Introduction

Tourism is a key sector in the region, contributing to GDP growth and employment. Over the past 5 years, regional tourism expenditure has grown by 3% with the total expenditure in the region increasing to $980 million for the year ending April 2020 (MBIE, 2020). Table 7.7 shows the tourism sector GDP contribution by district and the percentage of the population employed within the tourism sector in each district (excluding Tararua, Palmerston North and Whanganui districts).

Table 7.7: Tourism GDP for districts within the region and employment percentages (Infometrics, 2021)

District	GDP %	Employment %
Horowhenua	3.9	4.6
Manawatū	2	2.7
1 Palmerston North	No data	No data
2 Rangitīkei	4.3	6.5
3 Ruapehu	13.9	19.4
4 Tararua	No data	No data
5 Whanganui	No data	No data

Tourism is attracted to the spectacular mountains, rivers and natural capital of the Manawatū-Whanganui region. Key tourism activities include skiing and alpine activities, tramping, mountain biking, horse trekking, and canoeing and white-water rafting. In summer, beaches on both the east and west coasts are also popular sites to visit and rivers across the region are used as swimming sites.

Tourism tends to be seasonal with high visitor numbers in summer and slightly lower, but still significant numbers, in the winter for skiing (MPI, 2015). Although largely centred around the natural environment, tourism in the region also includes other activities and attractions including but not limited to:

- Ohakune Carrot, Giant Gumboot (Taihape).
- Big Bull (Bulls).
- National Army Museum.
- New Zealand Rugby Museum.
- Whanganui Regional Museum.
- Gardens (Apiti Lavender Farm, Tiro Roa Gardens and Nursery).
- Waimarie Paddle Steamer.
- War memorials.
- Art galleries.
- Golf.

Given the region's location in the lower North Island and presence of key roads connecting major cities such as Wellington, Auckland and Tauranga, domestic and international tourists frequently travel through the region. These tourists also visit key sites and attractions, and contribute to the regional economy.

7.5.2 Risk summary

Table 7.8: Risks to tourism from differing hazards

Hazard	Present	2050	2100	Commentary
Reduced snow and ice	High	Extreme	Extreme	Ski seasons are changing with snow becoming more frequent later in the year. High to extreme sensitivity as ski fields cannot operate if there is not enough snow. Generally low adaptive capacity. Snow machines like that on Whakapapa can be used, but not for the entire ski field.
Extreme weather events	High	Extreme	Extreme	Attractions such as skiing and walking can be affected due to high winds and snow storms. Low adaptive capacity as these attractions get closed for public safety reasons.
Inland flooding	Moderate	High	Extreme	Accessibility to tourist attractions can be cut off due to flood waters, and some attractions can be closed due to flooding or associated hazards such as landslides or scour. Low adaptive capacity as accessibility is generally out of tourist operators control.
Change in rainfall	Low	Moderate	High	Current exposure to changes in rainfall are moderate, but increase with projected increases in rainfall particularly around the ranges. Moderate sensitivity as increases in rainfall can lead to track closure and therefore less foot traffic, as well as flooding that can block accessibility to tourist attractions. Medium adaptive capacity as tracks can be maintained to ensure they are not damaged by increased rainfall.
Drought	Insignificant	Low	Moderate	Currently low exposure to drought conditions, but is projected to increase to high by the end of the century. Drought conditions are not generally seen in the mountainous areas of the region, but more on the plains.

There are a number of direct physical climate risks to the tourism sector, particularly from reduced snow and ice, extreme weather events and inland flooding.

Figure 7.8: Snowfall depth at Whakapapa ski field over a 10-year time frame (On the Snow, 2021).

The ski fields on Mount Ruapehu are a key source of tourism for Ohakune and the surrounding areas, and winter alpine activities are highly sensitive to reduced snow and ice from projected increases in air temperature (Figure 7.8 shows the trend in snowfall depth over the past ten years). While snowmaking machines are increasingly being used to supplement snow cover, the use of snowmaking technologies incur a significant economic cost and are unlikely to provide sufficient levels of snow coverage across a large geographic area (Stuff, 2017). Therefore, the adaptive capacity of the skiing industry is likely to be limited, particularly with projected temperature increases this century.

Skiing and other alpine activities are also at risk from extreme weather events, including large snowfall events, high winds and inland flooding, which can reduce access to alpine sites, damage infrastructure, and result in unsuitable conditions. For example, high winds can result in shutting down of ski lifts, as the operation of ski lifts are unsafe above particular wind speeds.

Other nature-based tourism activities in the region are walking and tramping, mountain biking, white water rafting, and visiting iconic sights such as Mount Ruapehu. These activities and sights are sensitive to heavy rainfall and associated inland flooding and landslides/erosion, which can damage walking/tramping tracks and reduce accessibility to tourism locations. Drought conditions, reduced seasonal rainfall and declining snow cover may reduce river flows, which could inhibit activities such as white water rafting from occurring. In general, there is low adaptive capacity to these climate hazards, but improved flood management (such as ecosystem-based measures) could help maintain accessibility in flooding events.

There are large infrastructure requirements throughout the region due to high population fluctuations – for example, during school holiday weeks, towns with a population of 750-1000 people can increase to a population of 10,000 (Stakeholder Engagement, 2021b). Thus, there is a substantial capital investment in assets, such as buildings and infrastructure, in proximity to seasonal tourism sites. For the ski fields and surrounding communities, there is a risk that these assets could become stranded as the demand for winter tourism declines with reduced snow coverage (Caldecott et al., 2016).

There are options to substitute alpine activities for activities that are less vulnerable to climate change, such as mountain biking and white-water rafting, but this may reduce the comparative advantage of the region in relation to other tourism hotspots which may already have significant market capture in these alternative activities.

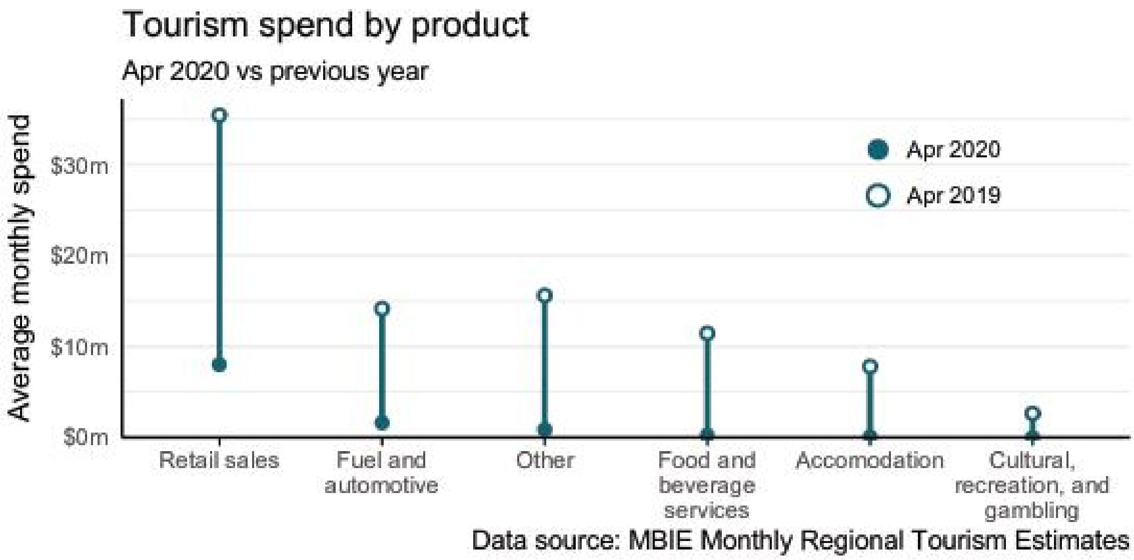


Figure 7.9: Tourism spend by product (MBIE, n.d.).

There are also tourism sites and businesses in urban areas, including museums, attractions, food and beverage businesses, and accommodation providers in Palmerston North, Whanganui, and Waiouru. The tourism sector is highly connected to other economic sectors, as the expenditure on tourism includes spending on retail products, transport and fuel, food and beverage services, accommodation, and cultural and recreational activities (Tourism New Zealand, 2020). The tourism spend by product is shown in Figure 7.9. While businesses involved in the accommodation, hospitality and cultural sectors are likely to be less exposed and vulnerable to direct physical climate risks than tourism businesses involved in nature-based tourism activities, there are a range of cascading and indirect risks that can impact all business activity in the tourism sector. If key supply chains, e.g. the provision of food goods, are disrupted due to climate hazards, this will result in risks to the tourism sector (McKinsey Global Institute, 2020).

8 Infrastructure

Communities within the Manawatū-Whanganui region rely on critical infrastructure and lifeline utilities such as water, wastewater, telecommunication, gas, electricity, road, rail and solid waste management.

These are essential services that play a vital role in the safety and security of the community. A reliable electricity supply is a critical service as almost all other services rely on it, including communication, health services, agriculture, manufacturing, transportation and water (Burillo, 2018). Communities are reliant on a clean and reliable water supply for everyday use including health, and hygiene. Solid waste management and wastewater infrastructure are critical within a community to ensure waste is managed in a way that minimises the adverse effects on the environment and public health (Community & Public Health, 2021). Transportation and accessibility routes are critical in their role of connecting communities and allowing the movement of people, goods and services throughout the region.

Infrastructure within the region is owned and operated by various stakeholders including local and central government, private entities (such as power companies), Waka Kotahi, and KiwiRail. This diverse ownership can influence how risks within the region are prioritised and funded.

For the purpose of this assessment, infrastructure includes the three waters network, flood management schemes, electricity generation, transmission and distribution, telecommunication infrastructure, solid waste management, road and rail transport and airports and seaports. A summary of the highest risks identified within each element is provided in Table 8.1, and the following sections provide detail around each of the risk elements.

Table 8.1: Summary of risks to Business elements from differing climate change hazards

Infrastructure	Higher temperatures			Inland flooding			Extreme weather events			Drought			Coastal flooding			Increased fire weather			Increasing landslides and soil erosion			Sea level rise and coastal erosion			Change in rainfall			River erosion			Reduced snow and ice			Sea level rise and salinity stress			Marine heatwaves			Ocean acidification		
	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Airports and seaports	L	M	H	M	H	E	M	H	E				M	H	E							L	M	M																					
Energy - distribution	L	M	H	M	H	E	M	H	E																																				
Energy - generation				L	M	H	L	M	H	L	M	H													L	M	H																		
Flood management				M	H	H	M	H	H																																				
Rail networks	L	M	H	H	H	E	L	M	H										H	H	E																								
Road networks	L	M	H	H	H	E	L	M	H										H	H	E	M	H	E																					
Solid waste management				M	H	E	M	H	E				M	H	E																														
Telecommunications & network infrastructure	I	L	M	M	M	H	M	M	H																																				
Drinking water	L	M	H	L	M	H				H	H	E																																	
Stormwater infrastructure				H	E	E	M	H	E	L	M	M																																	
Wastewater infrastructure				H	E	E	M	H	E	L	M	H																																	

8.1 Water supply

Risk to water supplies due to higher temperatures, drought and inland flooding.

8.1.1 Introduction

All communities and businesses within the Manawatū-Whanganui region rely on safe, secure and affordable drinking water. As the region continues to grow, the physical nature of many of the waterways, structures and flood protection works has altered, particularly in the Manawatū Plains. This has led to a decline in the state of physical health of the waterways in the region which also provide water for potable supply (Horizons Regional Council, 2019).

Water supply sources vary within the region and include both groundwater and surface water – and are used for drinking water supply, stock watering, irrigation and electricity generation. The Whanganui district relies solely on groundwater sources, whilst the Ruapehu, Horowhenua and Tararua rely solely on surface water sources. The remaining councils used a combination of both (Figure 8.2).

More than 70% of water in the region is allocated to hydroelectricity (Figure 8.1A). Hydroelectric power generation takes are primarily concentrated in the Ruapehu and Rangitīkei. Consented allocations for water use other than hydroelectricity have increased by over 161% since 1997, for uses such as agriculture, water supply and water bottling (Horizons Regional Council, 2019). Water allocation is greater within the agricultural and horticultural sector in the Manawatū and Rangitīkei districts, whilst water allocation is more predominantly used for municipal water supply in the Whanganui district (Figure 8.1B).

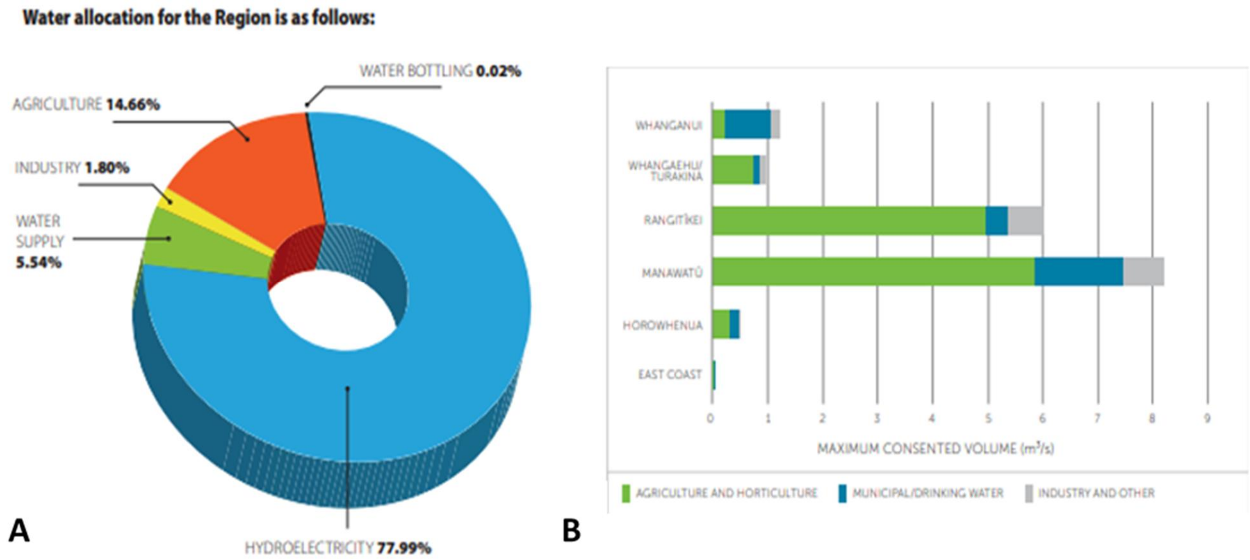


Figure 8.1: A: Water supply source types. B: Water allocation per Freshwater Management Unit (FMU), excluding hydroelectricity (Horizons Regional Council, 2019).

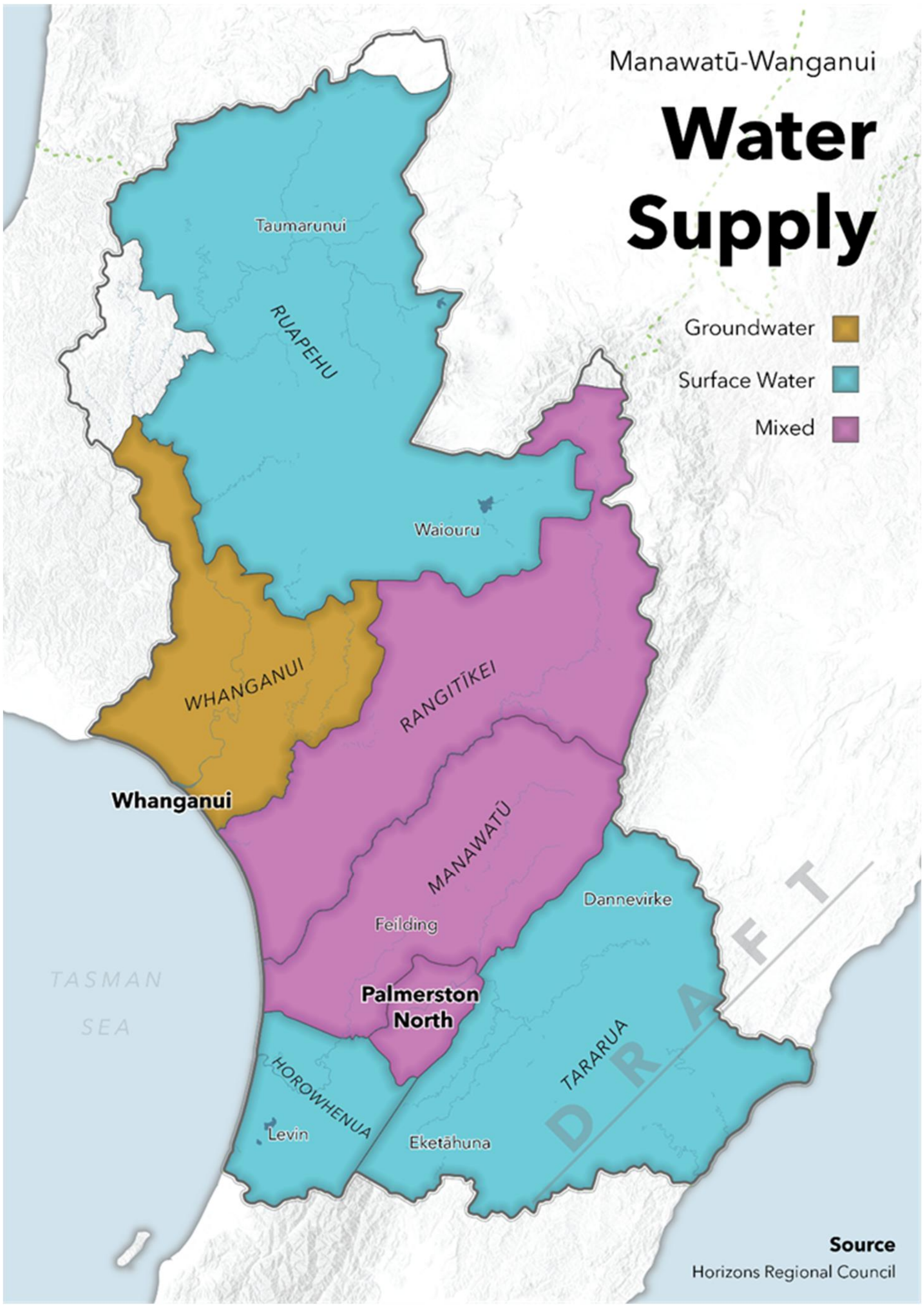


Figure 8.2: Water supply source types in the region (LAWA, 2021).

8.1.2 Risk summary

The key risks to water supplies (sources and infrastructure) are from higher temperatures, drought and inland flooding (Table 8.2).

Table 8.2: Risks to water supply by hazard

Hazard	Present	2050	2100	Commentary
Drought	High	High	Extreme	Increased exposure of water supply sources with time, with Tararua district liekly to be the most affected. Sensitivities include reduced flows, over allocation, and reduced water availability and quality. Water restrictions and metering can help reduce the impacts of drought.
Higher temperatures	Low	Moderate	High	sources with time, with Tararua district liekly to be the most affected. Sensitivities include reduced flows, over allocation, and reduced water availability and quality. Water restrictions and metering can help reduce the impacts of drought.
Inland flooding	Low	Moderate	High	Increased exposure on the Manawatū Plains (including Manawatū, Rangitīkei and Whanganui). Flood waters can overwhelm groundwater wells and cause rivers to swell, leading to contamination. Legislation is in place to improve water quality within the region through One Plan and Water Matters.

Water supply sources within the region are currently at risk from gradual climatic changes such as increased temperatures and associated hazards such as drought. When considering drought conditions, projected temperature increases, rainfall changes and hydrological impacts can all influence the severity of drought and future demand levels. The current and mid-century risk to water supply sources from drought is rated *high,* which is projected to increase to *extreme* by the end of the century, due to the projected increases in temperature and changes in rainfall patterns, particularly in the Tararua district (NIWA, 2016).

Figure 8.3 indicates that a number of upper catchment areas are either fully or over-allocated in terms of surface water (Upper Manawatū, Upper Rangitīkei, Upper Whanganui). In terms of groundwater, Manawatū, Rangitīkei and Whanganui are all nearing full allocation. Parts of the Rangitīkei catchment appear to have high levels of allocation of both surface and groundwater.

In general however, there is water available within most catchments. Groundwater monitoring and research in the region has indicated that there is sufficient groundwater for all users at a regional scale (Horizons Regional Council, 2020a).

As an example, when the Tamaki River in Tararua is in low flow, the volume of water allocated is less than the amount Dannevirke consumes, increasing the source's vulnerability to drought (Tararua District Council, 2021b). Tararua also had the greatest average daily residential water use over the

2018/2019 period, indicating that there is potentially an imbalance between water availability and water usage in the district (Water New Zealand, 2021) (Figure 8.3).

In general, water demand levels generally increase during times of higher temperatures, due to increased water use for showering and outdoor watering. This can exacerbate water shortages in the region due to the natural low flows that occur in the region during the summer period (Hendy et al., 2018; Horizons Regional Council, 2020a).

In relation to the above, all districts within the region (except Manawatū District) have applied some form of water restrictions over the last couple of years due to insufficient water storage, or low flows within surface water sources. The most recent restrictions being in Tararua (June 2021), Horowhenua (lifted May 2021) and Rangitīkei and Palmerston North (March 2020).

Those districts that rely solely on one water supply source such as Tararua and Horowhenua, have an increased sensitivity from drought. This can lead to water quality and quantity issues, impacting human health, and agricultural practises within the region (Hendy et al., 2018).

Adaptive capacity of water supply sources within the region will rely on the maintenance/ enhancement of storage and the ability to manage water demand levels - particularly in areas such as Palmerston North, Ohakune, Feilding and Levin where development and growth is occurring. Targeted interventions such as demand management and behaviour changes could improve water efficiency within the region (Tortajada & Joshi, 2013).

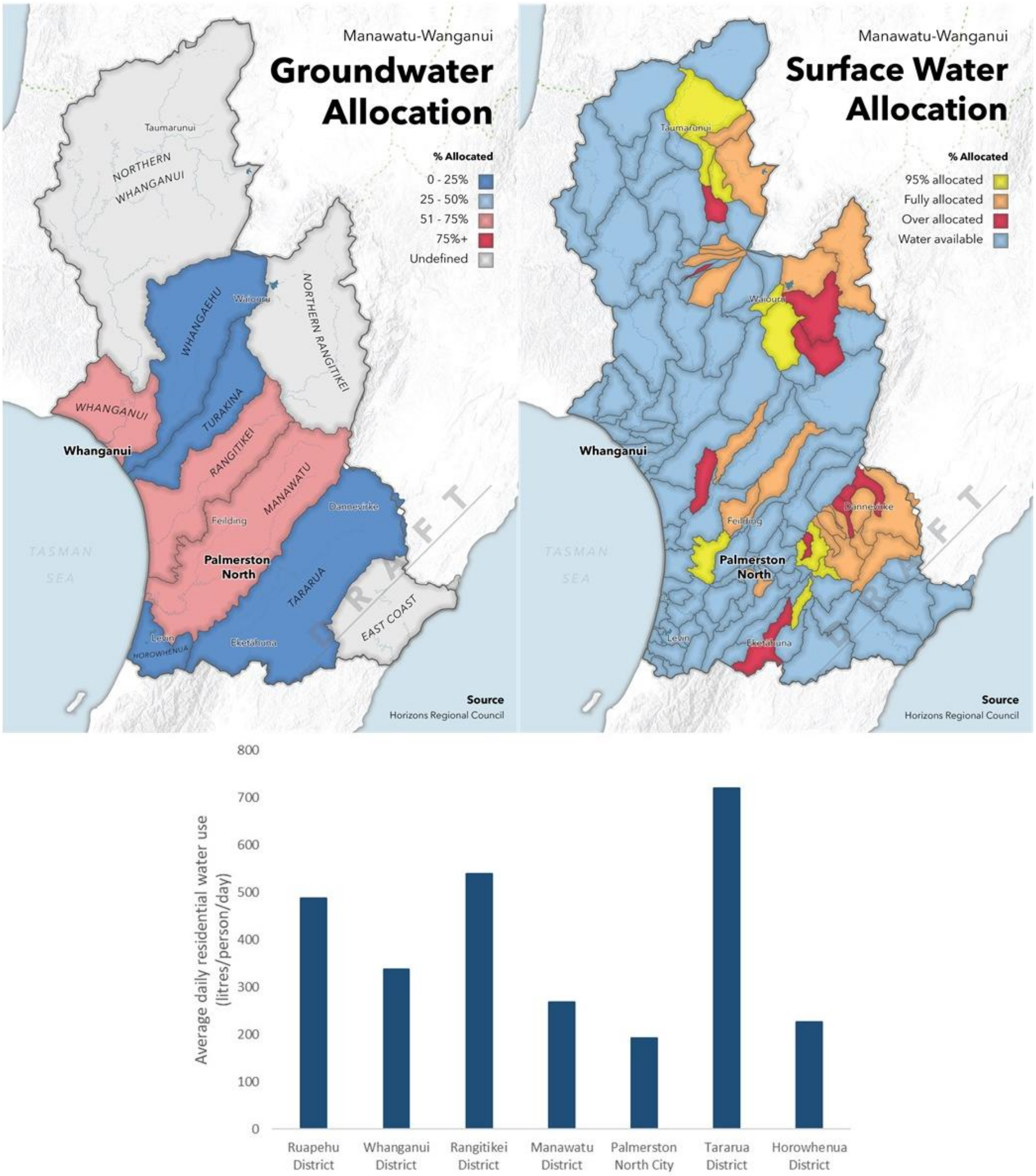


Figure 8.3: Percentage of groundwater and surface water allocation and average daily residential water use for 2018/2019 (LAWA, 2021; Water New Zealand, 2021).

The current risk to water supply sources from inland flooding is rated low, which increases to moderate by mid-century and high by the end of the century. This is due to the projected increases in rainfall and frequency and intensity of flooding events, particularly on the Manawatū Plains (NIWA, 2016). Flooding can overwhelm groundwater wells and cause rivers to swell which can lead to the contamination of water supply sources (both ground and surface), and health impacts within communities (Andrade et al., 2018) (Figure 8.4). Contamination of these sources is likely to occur more frequently in the future for areas such as Manawatū and Rangitīkei due to the increased frequency and intensity of rainfall events. A recent example of this includes high flow conditions in Horowhenua during June 2021, where the high turbidity stopped water abstraction (Stakeholder engagement, 2021). Residents and businesses in Tokomaru and Shannon were impacted by this.

There is currently legislation in place to improve water quality within the region (One Plan) and Horizons Regional Council currently have initiatives in place to monitor the quantity and quality of water, with their “Water Matters” project (Horizons Regional Council, 2020a). Further monitoring and infrastructure may need to be established to help reduce the impacts of flooding on these sources (MPI, 2014).

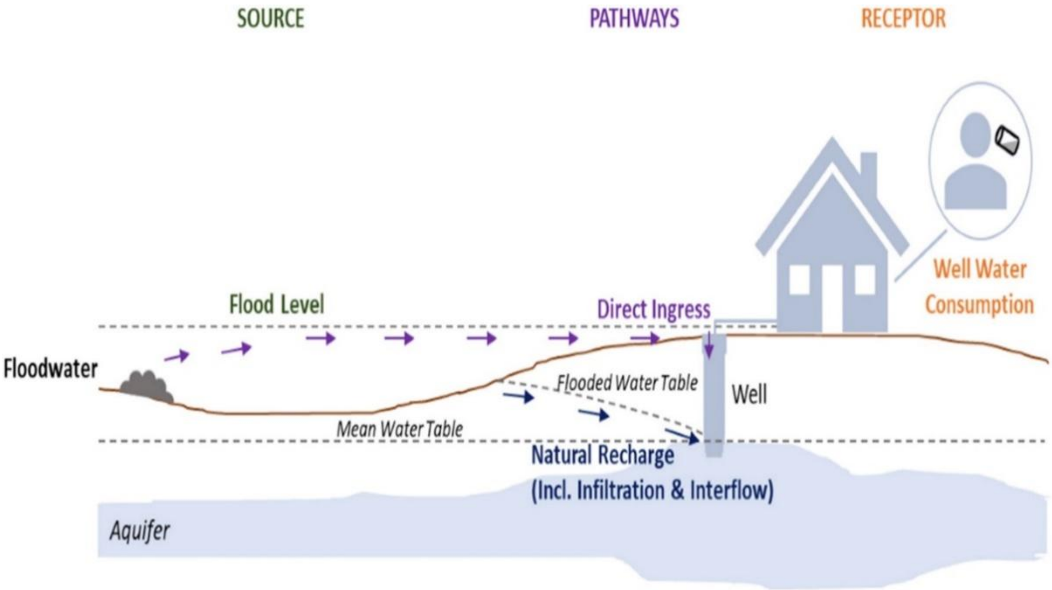


Figure 8.4: Flood water impacts on groundwater sources (Andrade et al., 2018).

8.2 Stormwater

Risk to stormwater infrastructure due to extreme weather events and drought.

8.2.1 Introduction

Stormwater systems consist of conveyance and treatment systems. This section addresses conveyance risks only.

Within conveyance systems, there are primary and secondary systems. Primary stormwater systems include pipes and channels, and are required to cater for flows generated by a specified ‘design’ rainfall event – typically the 10% Annual Exceedance Probability (AEP). Secondary systems consist of overland flow paths/channels which are activated once the capacity of the primary system is exceeded. Both these types of systems are utilised within the region.

Stormwater infrastructure is critical to communities and to other infrastructure such as the road network, as without appropriate stormwater systems, communities can flood, and road failures can occur.

Figure 8.5 shows the approximate length of pipes for each district, with Palmerston North having around 270 km and Whanganui around 150 km. The majority of stormwater infrastructure is located in urban centres and there are also smaller stormwater and drainage systems that can be found in rural areas of each district.

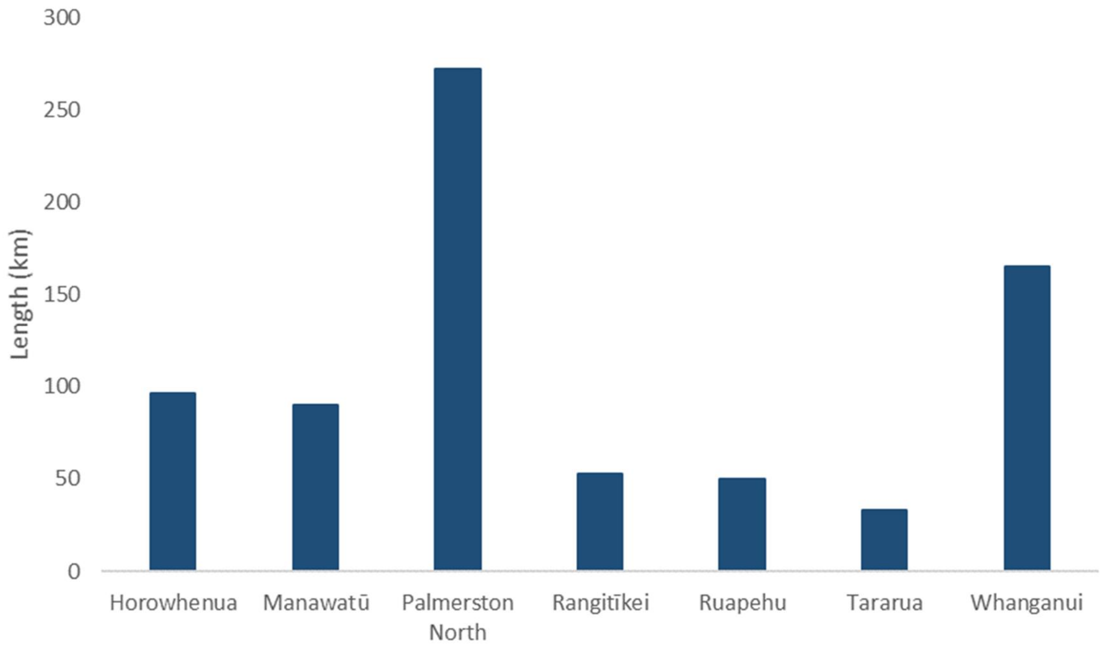


Figure 8.5: Length of stormwater pipe per district within the region[3].

8.2.2 Risk summary

The key risks to stormwater infrastructure are from more extreme weather events and drought.

Table 8.3: Risk to stormwater infrastructure from differing hazards

Hazard	Present	2050	2100	Commentary
Extreme weather events	Moderate	High	Extreme	225 km of pipe exposed to inland flooding, which is set to increase with projected increase in high intensity rainfall events Sensitivities include damage to infrastructure (scour and erosion), overwhelmed systems and increased contaminants. Low adaptive capacity due to vast network and funding issues.
Drought	Low	Moderate	Moderate	All stormwater infrastructure is exposed to drought, particularly in Tararua, whanganui and Tamaranui Sensitivities include increased contamination, scour, and capacity breaches due to reduced base flows, and ground settlement. Low adaptive capacity due to vast network and costly.

[3] Sources: (Horowhenua District Council, 2021; Manawatū District Council, 2021a; Palmerston North City Council, 2021; Rangitīkei District Council, 2018; Ruapehu District Council, 2018; Tararua District Council, 2021b; Whanganui District Council, 2018).

Table 8.3 indicates that stormwater infrastructure is currently rated as a moderate risk from extreme weather events, including high intensity rainfall which can result in systems being overwhelmed, exceeding levels of service. The risk is projected to increase to high by mid-century and extreme by the end of the century. This is due to the exposure increasing over time, with projected increases in the frequency of short duration, high intensity events, that can cause flash flooding and soil erosion (NIWA, 2016).

There are currently 225 km of stormwater pipes exposed to inland flooding within the region, of which more than 50% are located in Palmerston North (Figure 8.6) (Paulik, Craig, et al., 2019). This exposure combined with the ageing and poor (in some cases unknown) condition of infrastructure particularly in the Horowhenua, Whanganui, Rangitīkei and Manawatū districts[4] increases the risk from extreme weather events. Increased instances of flooding can directly damage stormwater infrastructure (through scour and erosion), leading to subsequent community impacts such as residential and commercial property flooding (White et al., 2017).

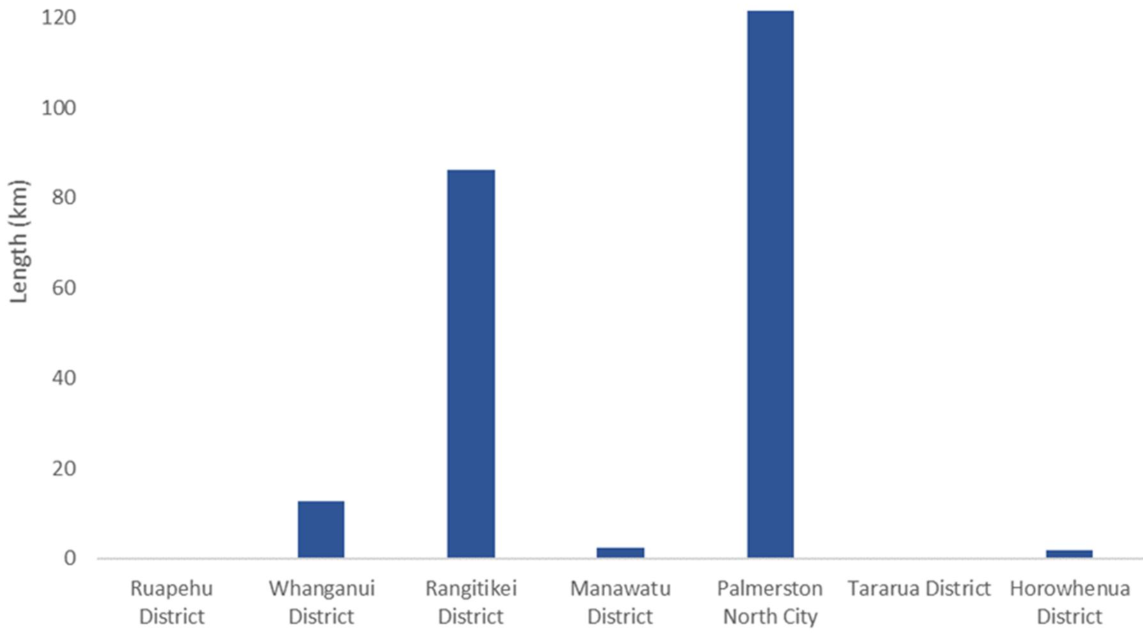


Figure 8.6: Length of stormwater pipes exposed to inland flooding per district within the region (Paulik, Craig, et al., 2019).

The Foxton area in particular has increased risk during high intensity rainfall events, as the drainage scheme that serves the town and rural catchment is known to have undersized pipes, in poor condition – that can result in both infrastructure damage, and community flooding (Horizons Regional Council, 2021a).

Higher risks are also likely in areas where future growth, urbanisation and associated imperviousness is projected, putting pressure on existing systems – that will also be exacerbated by climate change. Examples include Palmerston North, Ohakune, Feilding and Levin where significant growth is projected.

Without investment into existing infrastructure, and improved design parameters for new systems, the likelihood of system failure will only increase with climate change (White et al., 2017).

[4] Confidence in asset condition assessments is currently low in most districts as it has been historic practise to establish asset information when the asset is created, but to not update it when additional information is collected over its life (Manawatū District Council, 2021a).

Decreases in rainfall and prolonged hot days can lead to drought conditions which can cause increased contaminant concentrations, sedimentation and reductions in baseflows within stormwater systems. This can result in blockages within pipes due to limited sediment transport and can lead to subsequent ecological impacts within receiving environments (Hughes et al., 2019). The risk to stormwater infrastructure from drought is currently rated as a *low* risk for the region which increases to *moderate* out to the end of the century.

Adaptive capacity is generally considered *low* for these assets due to their complex and permanent nature. However, due to the ageing networks within most districts, there is potential for upgrades to occur, including: improving capacity and design standards; designing for a "safe to fail" rather than a "failsafe" approach; implementing water-sensitive design approaches (Hughes et al., 2019; White et al., 2017).

8.3 Wastewater

Risk to wastewater infrastructure due to more extreme weather events and drought.

8.3.1 Introduction

Wastewater systems are critical pieces of infrastructure for a community to ensure waste is conveyed, treated and discharged into the environment in a way that reduces the impact on the environment and protects public health.

Wastewater systems are typically a network of pipes that collect and convey wastewater from urban centres or towns to wastewater treatment facilities. There are several types of wastewater systems including combined and separated systems. It is understood the vast majority of systems in the region are separated systems.

All districts, with the exception of Whanganui and Horowhenua, discharge their wastewater into rivers/ streams or natural waterways.

At present, the Manawatū system has a dual treatment process which allows discharge to land when the river is in low flow. The Manawatū District Council intends to undertake a centralisation project, which will transfer wastewater from six communities within the district to the Feilding Wastewater Treatment Plant. This will result in improved environmental outcomes through removed discharges to small waterways and improved treatment (Manawatū District Council, 2021c).

Wastewater discharge in the Whanganui district is through an ocean outfall approximately 1.7 km off South Beach. It is the only discharge in the region that discharges to the ocean (Whanganui District Council, 2018).

In the Horowhenua district, there are six treatment plants of which four discharge to land, one to a wetland, and in a world first, one that irrigates a mānuka/kanuka forest in Levin. The Horowhenua district council is committed to improving the quality of its waterways therefore is in the process of shifting all discharges to land (Horowhenua District Council, 2021).

Palmerston North has the longest length of wastewater pipes in the region, while Tararua has the least (Figure 8.7). As the region grows, wastewater system upgrades may need to occur, particularly in the Ruapehu district where growth is occurring, and tourism is present (increased demand for services).

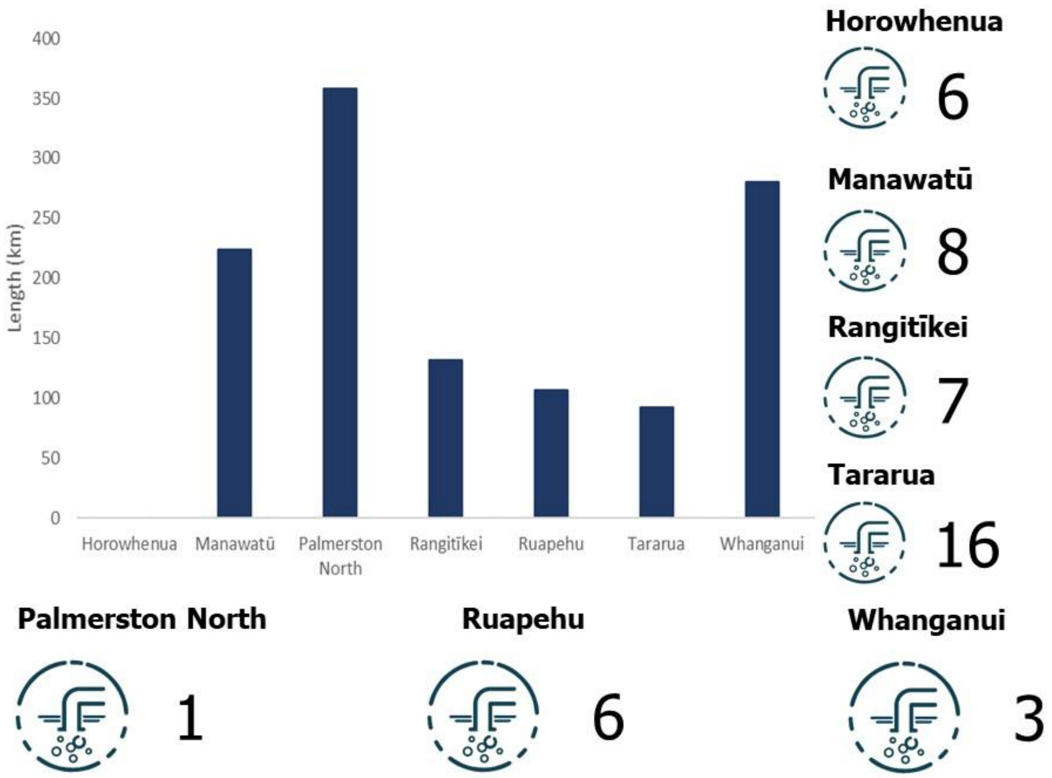


Figure 8.7: Summary of wastewater pipe lengths and number of treatment plants.

8.3.2 Risk summary

The key risks to wastewater infrastructure are from more extreme weather events and drought.

Table 8.4: Risk to wastewater infrastructure from differing hazards

Hazard	Present	2050	2100	Commentary
Inland flooding	High	Extreme	Extreme	Exposure of the wastewater network to flooding is high in the present day due to the location of the network in modelled wet extent areas throughout the region. With the increased likelihood of flooding due to climate change, this exposure will increase to extreme overtime. High sensitivity due to the potential for capacity being breached, blockages and spills can occur resulting in damage and health concerns. Low adaptive capacity, however upgrades can be made to improve capacity- however costly.
Extreme weather events	Moderate	High	Extreme	150 km of pipes exposed to inland flooding, of which 40% is in Palmerston North. Sensitivities include, blockages within pipes, overflows leading to health impacts within communities and disruption to services. Generally low adaptive capacity, however upgrades/improvements can be made to adapt to current and future flows.
Drought	Low	Moderate	High	Increased exposure in Taihape and Dannevirke and lower elevations. Sensitivities include, blockages, siltation, increased contaminants and odour Adaptive capacity is low due to vast network and permanent nature.

Table 8.4 indicates that wastewater infrastructure is currently rated at a moderate risk from extreme weather events, due to high intensity rainfall events causing systems to be overwhelmed. This risk increases to high by mid-century and extreme by the end of the century.

The risk increase overtime due to the projected increases in winter rainfall, particularly in those areas with high elevations such as Taumarunui, as well as on the Plains. The frequency and intensity of flooding events is also projected to increase (NIWA, 2016).

There are currently 150 km of wastewater pipes exposed to inland flooding in the region, of which approximately 40% are located in Palmerston North City (Paulik, Craig, et al., 2019) (Figure 8.8). This infrastructure is likely to experience an increase of 5-10% annual rainfall in spring and winter by mid-century (RCP 8.5), increasing its exposure to extreme weather events (NIWA, 2016).

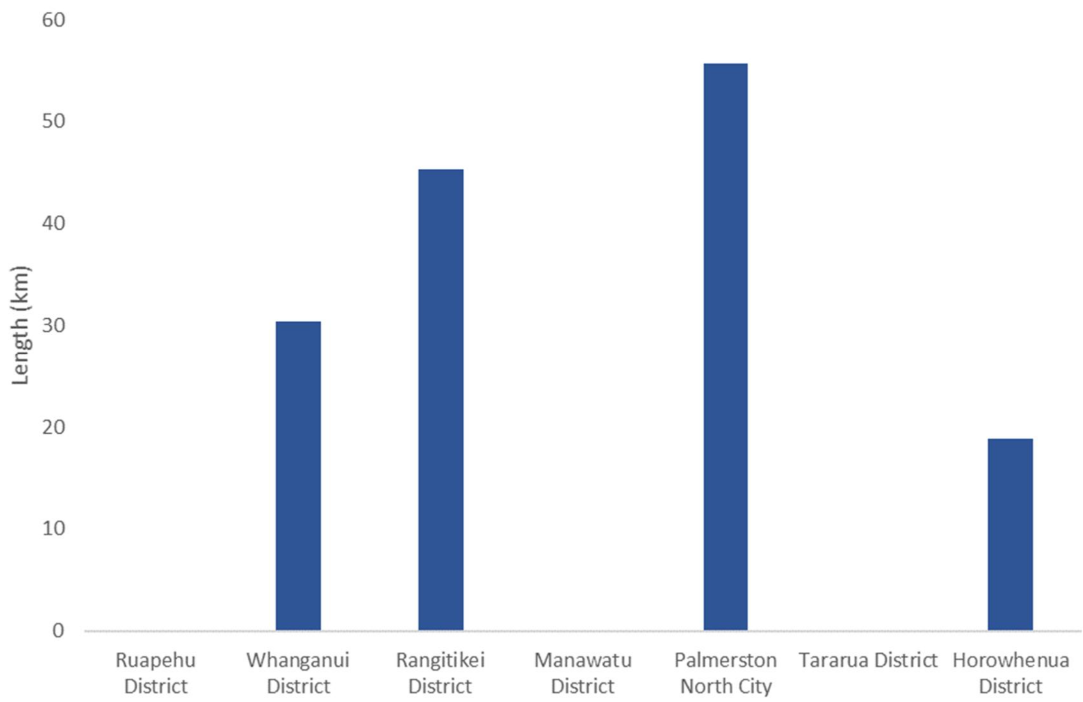


Figure 8.8: Length of wastewater pipe exposed to inland flooding per district within the region (Paulik, Craig, et al., 2019).

Increased rainfall can lead to a range of impacts on wastewater systems. A key impact is the potential for increased instances of inflow and infiltration into systems, causing overflows into receiving environments. This, in turn, can impact on water quality, stream health, public health, fluvial and marine ecosystems and water supplies, ability to gather mahinga kai etc. (White et al., 2017). An example of this occurring was in Palmerston North during the 2015 floods (Figure 8.9) (Stuff, 2019b). These impacts are likely to occur more frequently in the future due to the overloading and overflowing of wastewater infrastructure.

Increased rainfall can also cause waterlogged soils which can lead to floatation of pipes/chambers as well as causing damage and service disruption (Hughes et al., 2019; White et al., 2017).

Age, condition and capacity can influence the sensitivity of wastewater infrastructure to extreme weather events. The majority of the wastewater infrastructure within the region is greater than 50 years old, and is generally not designed for future climate conditions. Therefore, capacity breaches (overflows) are more likely to occur (Stakeholder Engagement, 2021a).

Figure 8.9: Wastewater overflowing on streets near Palmerston North's wastewater treatment plant during 2015 floods (Stuff, 2019b).

The current risk to wastewater infrastructure from drought and reduced rainfall is rated low, increasing to moderate by mid-century and high by the end of century, due to the projected increases in temperature and reductions in rainfall. Exposure is elevated in areas such as Taihape and Dannevirke, where drought conditions are projected to be more severe due to increases in the potential evaporation deficit (PED) (NIWA, 2016).

Drought conditions can cause corrosion within wastewater pipes due to low flows which increases the concentration of contaminants, impacting, in turn, on the efficiency of treatment processes. Additionally, blockages/ siltation can occur as well as increased odours (Hughes et al., 2019).

8.4 Flood management schemes

Risk to flood management schemes due to extreme weather events and inland flooding.

8.4.1 Introduction

The Plains within the region are prone to flooding from the three major river networks: Whanganui, Rangitīkei and the Manawatū. River management schemes including flood protection and land drainage are critical pieces of infrastructure to protect communities and livelihoods from flood waters. Horizons Regional Council's river management team is responsible for maintaining the river and drainage schemes in the region to minimise erosion and provide flood protection for communities (Horizons Regional Council, 2021e).

Many urban centres and communities are located on flood plains within the region, therefore it is important to have an appropriate standard of flood risk mitigation for the safety of the community and productivity of land. Horizons Regional Council currently manages 34 river and drainage schemes, and maintains over 500 km of stopbanks, 1090 km of drains, 23 pumping stations and 54 dams (Figure 8.10). There is currently 75,000 hectares of land and 11 urban areas included within scheme areas which covers approximately 40% of the region (Horizons Regional Council, 2021e).

There is various flood management infrastructure in the region including dams, levees, stop banks, floodgates and drains. One of note is the Moutoa Sluice Gates and Floodway which are a major component of the Lower Manawatū Scheme. Every time the gates are opened, they allow floodwaters to be discharged to the sea by releasing them into a 10 km floodway that bypasses approximately 30 km of the Manawatū River. These sluice gates played a key role in protecting the Lower Manawatū Plain during the 2004 floods (Horizons Regional Council, 2021e).

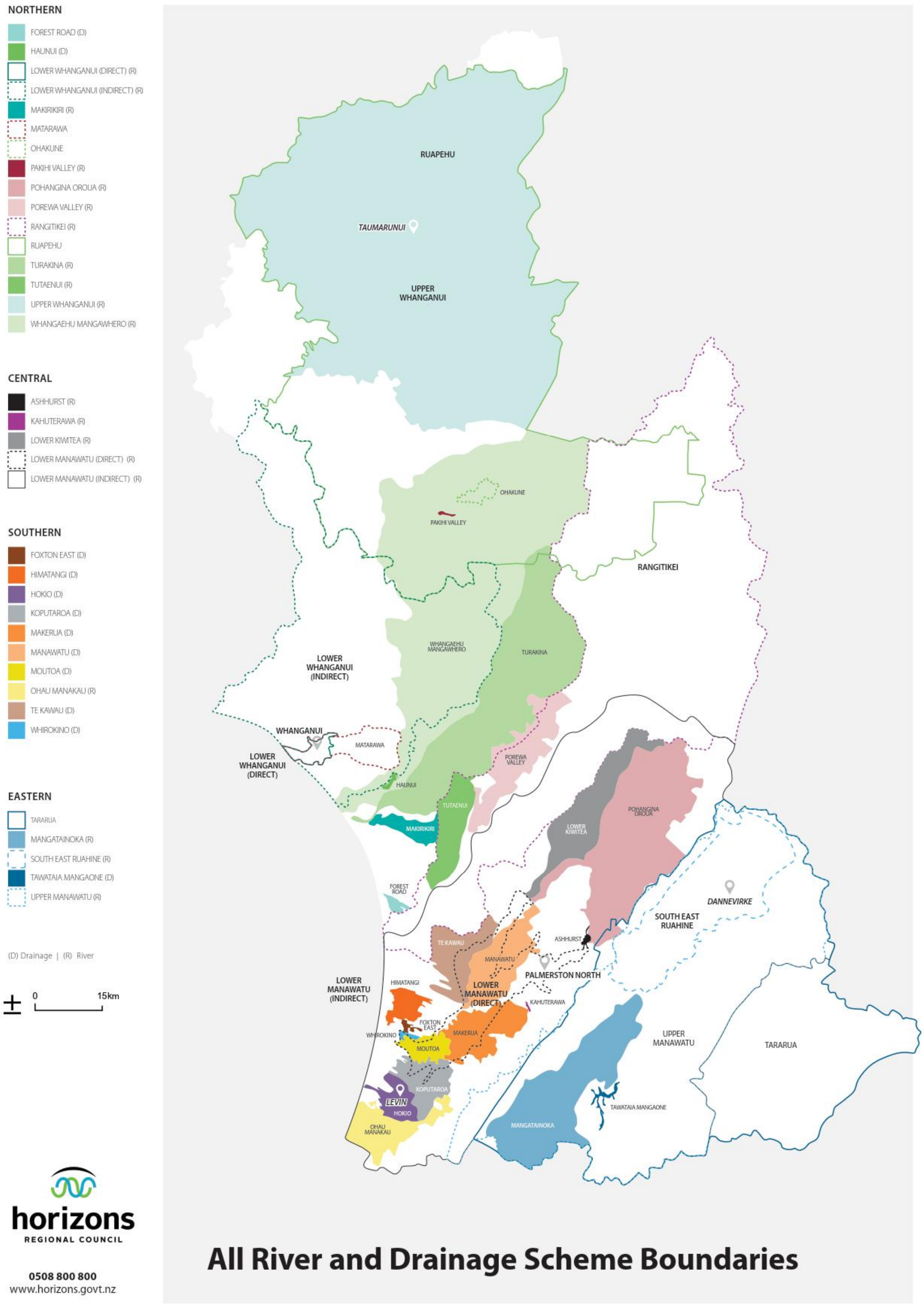


Figure 8.10: River and drainage schemes in the Manawatū- Whanganui region (Horizons Regional Council, 2021e).

8.4.2 Risk summary

The key risks to flood management schemes are from more extreme weather events and inland flooding (Table 8.5).

Table 8.5: Risk to flood management schemes by hazard

Hazard	Present	2050	2100	Commentary
Extreme weather events	Moderate	High	High	Assumed all assets are exposed due to their location on flood plains and along river channels. Sensitivities include scour, blockages and breaches which are dependant on the condition of the asset. Adaptive capacity generally low, however there is funding allocated to some schemes
Inland flooding	Moderate	High	High	Assumed all assets are exposed due to their location on flood plains and along river channels. Sensitivities include scour, blockages and breaches which are dependant on the condition of the asset. Adaptive capacity generally low, however there is funding allocated to some schemes

Note: we recognise that there is currently a lack of readily available documented information regarding wider information for flood management schemes and associated infrastructure for the region, which reduces the confidence in rating risk.

The current risk to flood management schemes from inland flooding and extreme weather events is rated moderate. This risk increases to high by mid-century and out to the end of century due to increased exposure from flooding events across the region, and the condition and age of the built infrastructure (dams, stopbanks etc.). It is assumed that all flood management infrastructure is exposed to inland flooding. This is due to their location in floodplains and along river channels, as their role is to protect urban areas from flooding.

Sensitivity of these assets can be influenced by their age, condition and design. Those assets that are older and in poorer condition have an increased risk from flooding as the likelihood of scour and damage increases (Environment Agency, 2006). Flooding events can also cause excessive sediment deposition, and blockages which can undermine the integrity of the assets, which can result in flooding of local communities (Environment Agency, 2006).

There are sections of the Lower Manawatū scheme that are in poor condition, increasing their risk of failure during inland flooding events (Horizons Regional Council, 2015, 2021a). Other schemes within the region that have an increased risk include Foxton, Rangitīkei and Whanganui. There are currently stopbanks in Foxton and sections along the Rangitīkei River that are in a degraded condition due to previous flooding events (2015 floods in Foxton, 2018 floods in Rangitīkei). This can lead to potential flooding impacts in communities if they fail (Horizons Regional Council, 2021a). The Te Pūwaha (the Port Revitalisation Project) has also highlighted that the river infrastructure protecting the township of Whanganui is not in good condition (Horizons Regional Council, 2018b).

The Lower Manawatū Scheme is in most part designed for the 1% AEP event. The exception of this is the city of Palmerston North which is protected from a 0.2% AEP flood, due to the high density population and associated infrastructure based in the city (Horizons Regional Council, 2015). Flood events that exceed this annual exceedance could lead to breaches in the stopbanks as they exceed the design standards. If this is to occur the Makerua Basin, Taonui Basin and south west of the Moutoa sluice gates are likely to be inundated in flood waters, therefore increasing the likelihood of damage within those communities (refer to Figure 8.11 which indicates the flood extent with no stopbank presence) (Horizons Regional Council, 2015). These breaches are likely to occur more frequently as the climate changes due design parameters being exceeded.

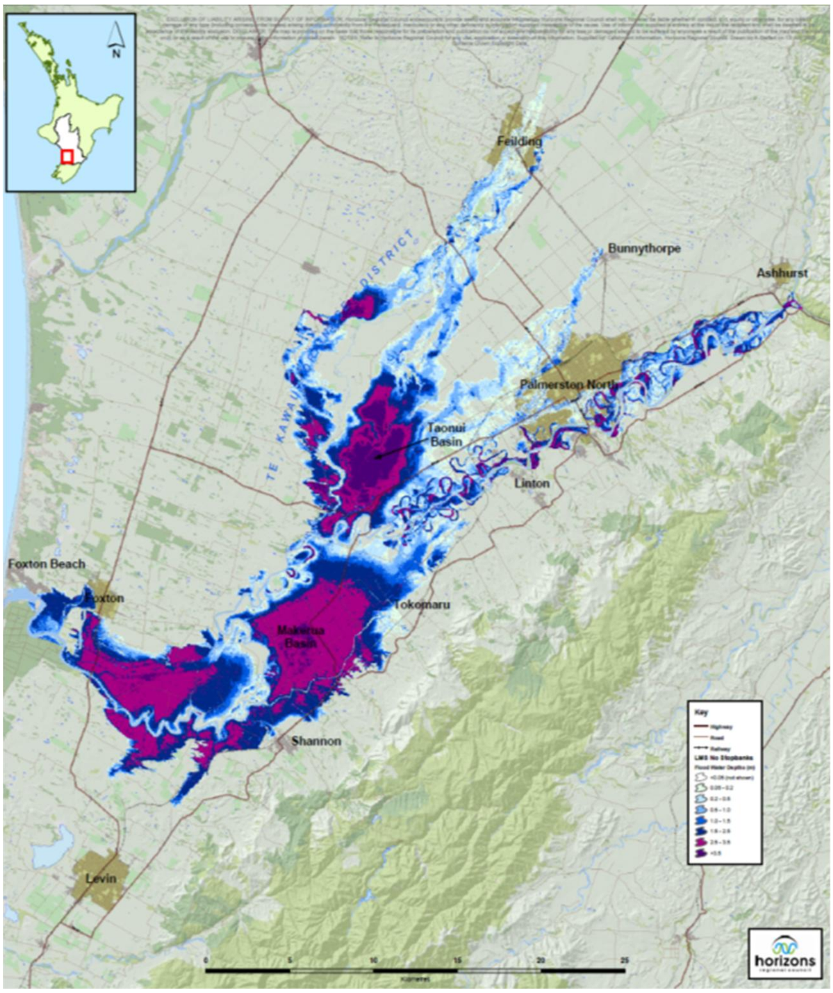


Figure 8.11: The 1% AEP flood event extent when no flood management is in place for Lower Manawatū scheme (Horizons Regional Council, 2015).

Often, adaptative capacity is limited due to the lack of funding, particularly for those areas not within flood protection schemes (> 50% of the region). However, in August 2020 the regional council received $26.9 million for climate resilience infrastructure projects from central government as part of the COVID-19 response. A proportion of the projects include flood mitigation and further investments into flood protection infrastructure for Foxton, Palmerston North and Rangitīkei (MWRI, 2020).

8.5 Energy

Risk to electricity generation and transmission, and distribution of electricity and gas - due to changes in rainfall, inland flooding, extreme weather events and drought.

8.5.1 Introduction

Energy is an essential part of the economic and social fabric of a community, with electricity and gas supplies being a key driver of economic activity, population, the structure of the economy and the climate and energy resources available (MBIE, 2018).

8.5.1.1 Generation

Energy generation in the region is split between both hydroelectricity and wind generation, with three wind farms and one hydroelectric dam operating in the region[5].

The Mangahao Power Station was the first of many large hydro-dams to be built in New Zealand. It was constructed in 1924 and differs from other hydroelectric dams, as it is not built on a river or supplied by a natural lake. The power station utilises small and remote rivers within the Tararua Ranges and has two reservoirs that are essential due to the variability in flows in the Mangahao River. The maximum capacity for the station is 39.8 megawatt (MW), and the annual output is 131 gigawatt hours (Ghw) (Trustpower, 2021). The first 110 kV lines in the Southern Hemisphere were built due to the Mangahao power station, and supply energy to Palmerston North, Manawatū and Wellington (Engineering NZ, 2021).

There are three operational wind farms within the region, represented in green in Figure 8.12; Te Āpiti, Tararua and Te Rere Hau. Six more farms are consented within the region (represented in orange), with one under construction; Turitea. Currently the Tararua wind farm is the largest in the country in terms of output, but once operational, the Turitea farm will surpass this (New Zealand Wind Energy Association, 2021). Those operational wind farms in the region feed into the national grid through various transmission lines and collectively can power more than 100,000 average homes annually.

New Zealand is generally recognised as having one of the best wind resources globally due to its location in the “Roaring Forties”. The Manawatū-Whanganui region is in an ideal position for harnessing high wind speeds due to both its coastal areas as well as hill tops and ridgelines (Tararua and Ruahine Ranges).

[5] Piriaka is also a smaller power station located in Piriaka.

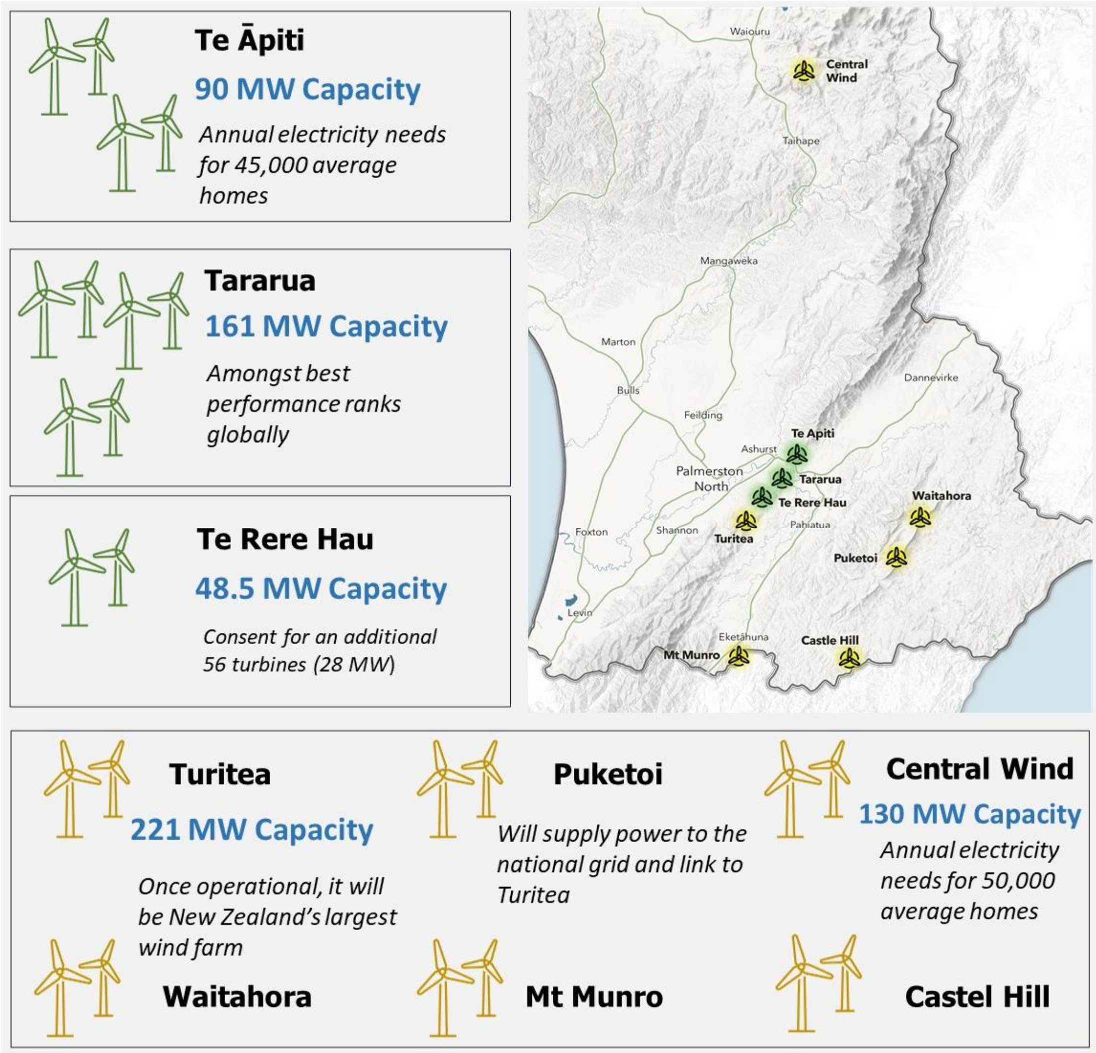


Figure 8.12: Location and information on wind farms in the region (New Zealand Wind Energy Association, 2021).

8.5.1.2 Transmission and Distribution

The transmission network for the Central North Island comprises of 220 kV and 110 kV transmission lines with interconnecting transformers at Bunnythorpe (Figure 8.13). Bunnythorpe is a nationally significant asset as it is a major switching point into the North Island Grid from the South Island Grid (Manawatū-Wanganui Emergency Management Group, 2016). The Manawatū- Whanganui region is a main corridor for the 220 kV transmission lines which form part of the grid backbone (Transpower, 2020). The 220 kV lines that come from Bunnythorpe are regionally significant, with the 110 kV transmission system mainly consisting of low capacity circuits of local significance (Manawatū-Wanganui Emergency Management Group, 2016).

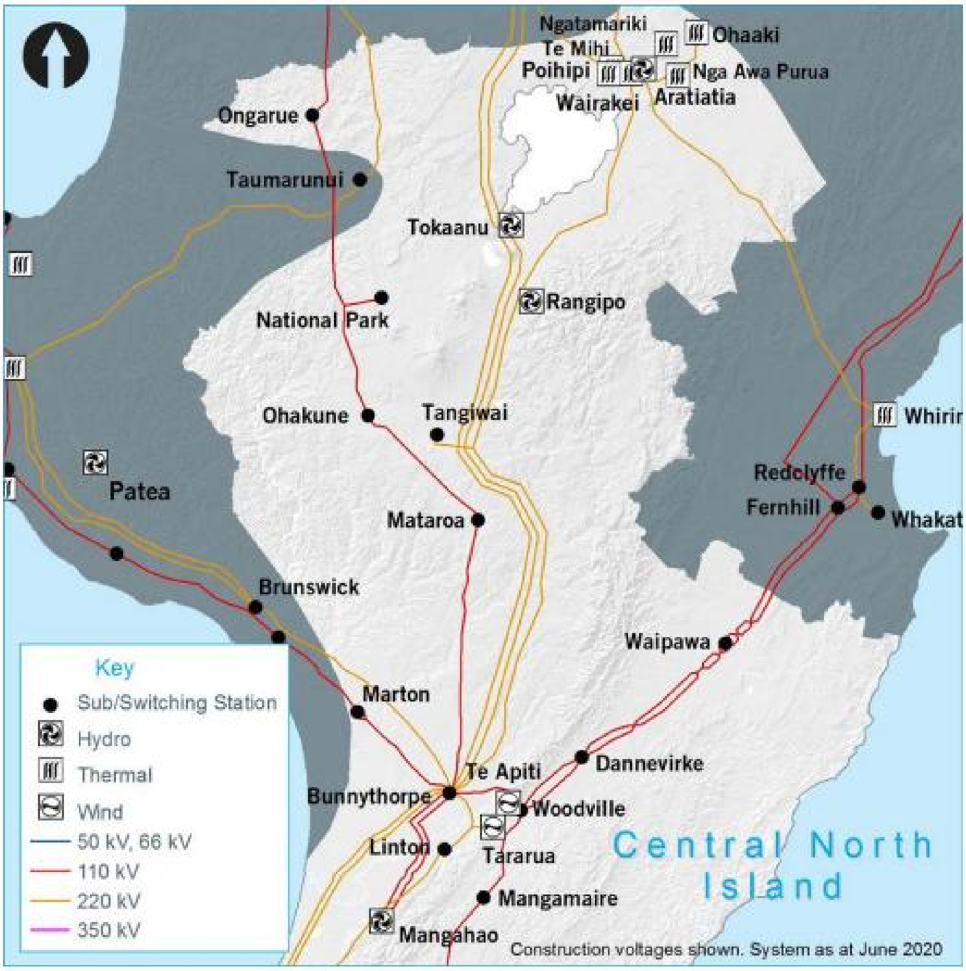


Figure 8.13: Central North Island transmission network (Transpower, 2020).

Transpower operate and manage the national grid within the region, supplying electricity to four distribution companies including:

- Powerco
- The Lines Company
- Scanpower
- Electra

In terms of gas, high pressure gas lines are also located in the region, particularly in the Whanganui, Palmerston North and Tararua Districts (MBIE, 2018) (Figure 8.14). The region's gas supply is piped via transmission lines that run south from the Taranaki gas fields, and is distributed by Powerco Gas to networks in Palmerston North, Levin and Foxton and by Gasnet to networks in Whanganui, Marton, Bulls, Flockhouse and Waitotara. The transmission line from Taranaki is a nationally significant line, as it not only supports the region but Wellington as well. Gas in the region is mainly utilised by customers within central business districts, with little usage in the industrial sector (Manawatū-Wanganui Emergency Management Group, 2016).

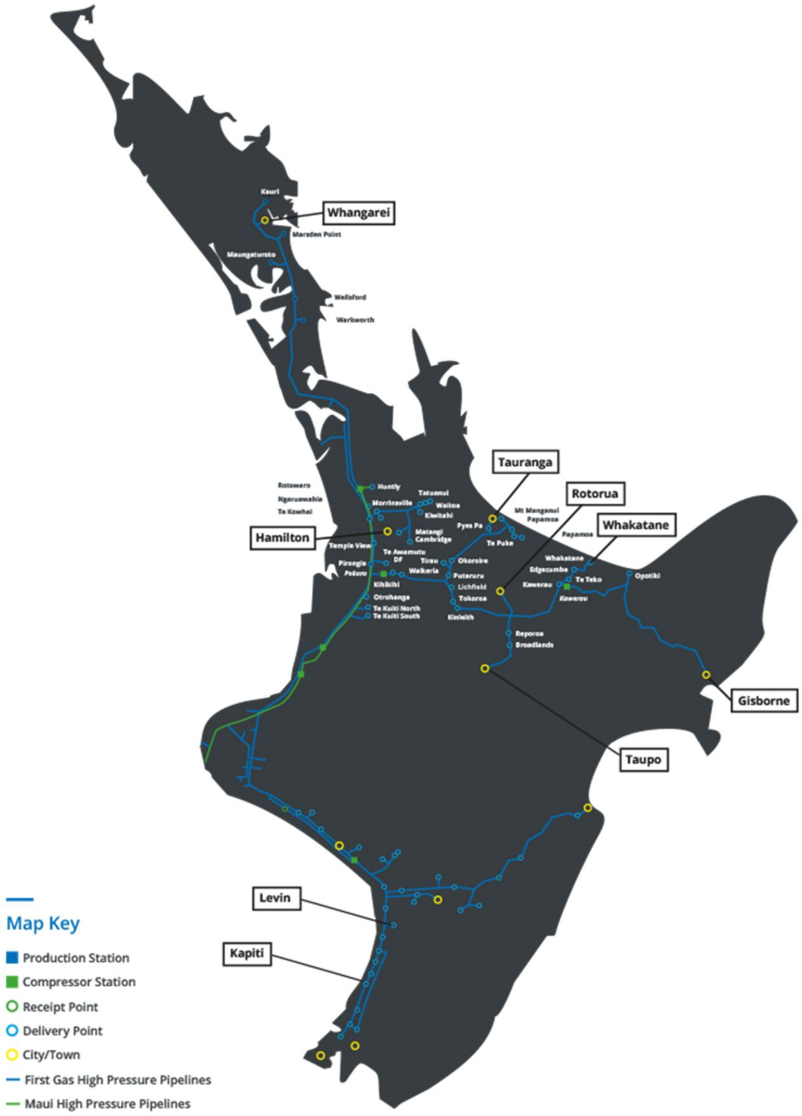


Figure 8.14: First Gas Network Map (First Gas, 2021).

8.5.2 Risk summary

8.5.2.1 Generation

The key risks to electricity generation are from changes in rainfall, drought, more extreme weather events, and inland flooding (Table 8.6).

Table 8.6: Risk to energy generation from differing hazards

Hazard	Present	2050	2100	Commentary
Extreme weather events	Low	Moderate	High	Westerly winds can increase generation capacity Turbines can be damaged at wind speeds above 90 kph Changes in design standards could allow turbines to operate above 90 kph
Drought	Low	Moderate	High	Reduced rainfall and increase in number of hot days projected around Mangahao power station Hydro-electricity generation relies on precipitation, therefore is sensitive to reduced rainfall
Change in rainfall	Low	Moderate	High	Increased rainfall projected for winter months, while reduced rainfall projected in summer months. Reduced rainfall can lead to low flows, which can lead to operational changes
Inland flooding	Low	Moderate	High	Flooding exposure projected to increase Flooding can cause damage to supporting infrastructure

Note: there is the potential for changes in rainfall discussed below to lead to a further increase in risk overtime, however further information is required in order to evaluate this.

The current risk to electricity generation from changes in rainfall, extreme weather events, drought and inland flooding is rated as low, increasing to moderate by mid-century, and high by the end of century. This is due to the changes in exposure overtime.

Currently, the area surrounding the Mangahao Power Station receives on average between 1200-1800 mm per year of rainfall. This is projected to *increase* in the winter months by 0-5% by both the mid and end of century (NIWA, 2016). In summer months, however, *reduced rainfall and an increase in the number of hot day*s are projected (NIWA, 2016).

Inland flooding can cause damage to supporting infrastructure, as was seen in the 1936 flood, which caused damage to the No. 1 Dam (Figure 8.15). This can lead to disruptions and operational changes which can have economic impacts (Allen-Dumas et al., 2019).

Figure 8.15: Damage to No.1 Dam in the 1936 floods (Kete Horowhenua, 2021).

The wind farms in the region predominantly harness westerly winds, with the Te Āpiti wind farm receiving 66% of its wind generation from westerly quarter winds, and only 34% from the other three quarters (Renwick et al., 2010). Exposure to changes in wind speed/direction is less clear for the region, as climate projections are more variable and uncertain. However, it is projected that westerly winds will become more prominent in the spring and winter months due to decreases in mean sea level pressure trends (NIWA, 2016).

Increased frequency in westerly winds can increase generation capacity, however high wind speeds can cause turbines to be shut down or damaged. The wind speeds that produce the maximum generation power are 36- 54 kph. When wind speeds reach 90 kph the turbine is stopped to reduce failure modes, which can include loss of blades, and buckling of the support tower (Allen-Dumas et al., 2019). Changes to design standards could occur, so that new infrastructure could withstand wind speeds of greater than 90 kph, like those being tested in Japan as a result of continuous damage from typhoon events (Liang, 2020).

There is generally a moderate level of adaptive capacity for electricity generation, due to the diverse distributed sources connected to the national grid. If hydroelectricity generation becomes non-viable within the region, further utilisation of wind energy could occur.

8.5.2.2 Transmission and Distribution

The key risks to energy transmission and distribution are from increased temperatures, extreme weather events, and inland flooding (Table 8.7).

Table 8.7: Risk to energy transmission and distribution from differing hazards

Hazard	Present	2050	2100	Commentary
Extreme weather events	Moderate	High	Extreme	Exposure will increase as the intensity and frequency of storms increases. Sensitivity is increased for overhead cables due to sagging, deformation and third party debris. Service disruptions can lead to impacts on other service operations and in the community
Inland flooding	Moderate	High	Extreme	390 km of transmission lines located on land exposed to flooding. 185 km are located in the Manawatū. Sensitivities increase for ground level assets where flood waters can damage electrical equipment and undermine pylon foundations. Adaptive capacity low, and constrained due to populations.
Higher temperatures	Low	Moderate	High	Low exposure currently with temperatures ranging between 6-15°C. Risk increases with every increase in temperature as power outputs are influenced by temperature. Adaptive capacity is generally low, however some improvements can be made with technological advancements

The risk to transmission and distribution infrastructure from inland flooding is currently rated as moderate, increasing to high by mid-century, and extreme by the end of the century. This is a particular risk for those assets that are located on the Plains, where flood exposure is higher.

There are approximately 390 km of Transpower transmission lines located on land that is exposed to inland flooding within the region. Of those exposed, the Manawatū district has the most exposed with approximately 185 km. This is equivalent to 47% of all assets exposed and relates to the 220 and 110 kV lines that run through the district (Figure 8.16). There are currently, 1,006 pylons and 4 substations exposed within the region of which the Tararua district has the most pylons exposed (336) and the Rangitīkei district has the highest number of substations exposed (2) (Paulik, Craig, et al., 2019).

Those assets that are located at ground level, such as substations, pylon foundations and underground cables all have an increased sensitivity to flooding, as they are more likely to be damaged by flood waters compared to those overhead assets (Allen-Dumas et al., 2019). Electrical equipment within substations can be damaged due to flood waters which can lead to disruptions within the network.

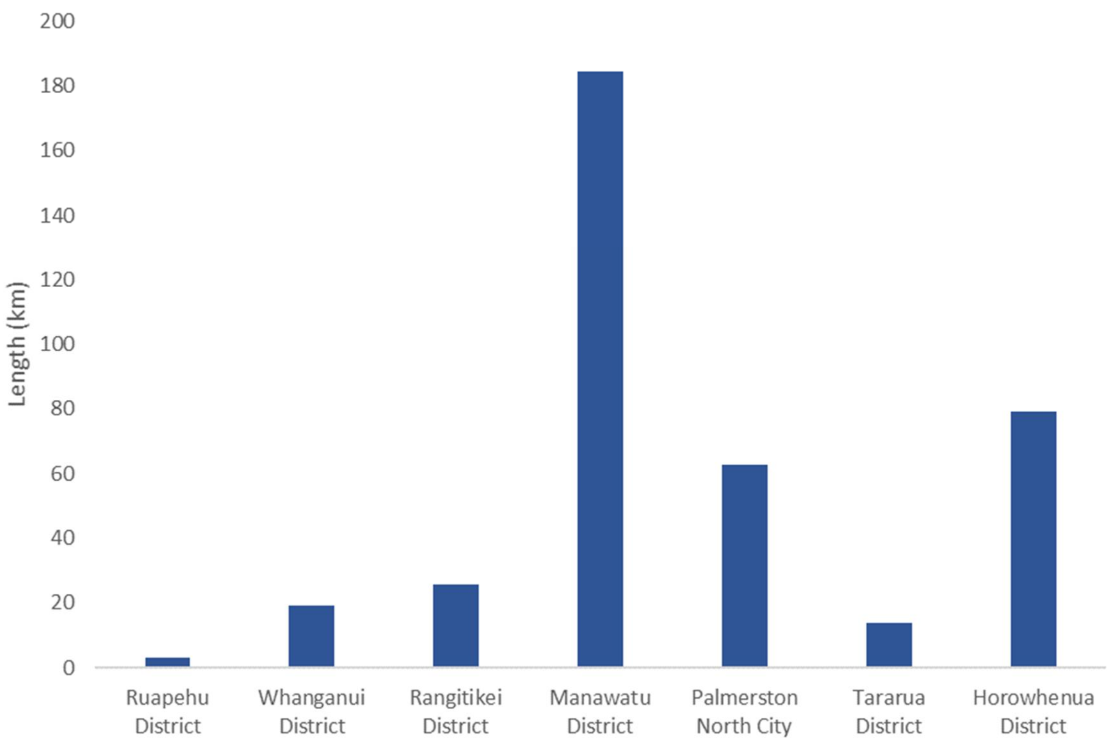


Figure 8.16: Length of transmission lines exposed to flooding, per district within the region (Paulik, Craig, et al., 2019).

The current risk to transmission and distribution infrastructure from extreme weather events is rated moderate, increasing to high by mid-century and extreme by the end of the century. This is due to the projected increases in frequency and intensity of storms in the region and the sensitivity of these assets to be damaged from these events. Overhead cables have an increased sensitivity to extreme weather events as they can sag to the point of deformation, or be damaged due to third party debris (Burillo, 2018). Pylons or poles can also snap and fall down in high winds which can cause widespread outages. Transpower's transmission towers, poles and lines are typically designed around 900-1200 Pa or 160 km/hr, therefore become increasingly vulnerable at wind speeds above this (Emergency Management Otago, 2018). Changes to design standards could occur to help improve the resilience of these assets from these extreme events as well as upgrades to existing infrastructure to withstand future climate conditions.

Currently temperatures in the region range from 6-15°C, therefore the current risk to transmission and distribution infrastructure is rated low. This risk is projected to increase to moderate by mid-century and high by the end of the century due to the projected increases in temperature across the region. Increased temperatures can lead to deratings, shorter life spans and abrupt failure of components, where the average power output decreases 0.7- 1.1% with every degree of warming (Allen-Dumas et al., 2019). The risk from increased temperatures therefore increases when looking at the mid-century and end of century timeframes, with 1.1°C and up to 3°C of warming, respectively (NIWA, 2016). Adaptive capacity for these assets is generally limited however, technological developments in the future could increase the resilience of these assets (Transpower, 2020).

8.6 Telecommunication

Risk to telecommunication due to higher temperatures, inland flooding, and more extreme weather events.

8.6.1 Introduction

Telecommunication is a critical lifeline utility and one that is most complex due to the rapid changes that occur in technology. There are three north-south trunk fibre cables located within the region that are considered to be nationally significant and provide redundancy for one another, should one fail. Spark have also identified two significant sites within the region; the Levin and Palmerston North exchange sites. The Levin exchange is nationally significant as it is the connection point between the North Island and South Island, while the Palmerston North Exchange provides switching services to a number of sites within the region. These assets contribute to providing 67% of households within the region with internet, which is a 22% increase since 2011 (Manawatū-Wanganui Emergency Management Group, 2016).

The Wharite and Palmerston North railway sites are critical broadcasting sites for Kordia within the region (radio communications). Wharite provides multi-directional services through Palmerston North and onto Whanganui and Taranaki whilst the Palmerston North site is where Kordia interconnects with customers in the region (Figure 8.17).

Figure 8.17: Kordia services in the Lower North Island. Red line: microwave linking, Light blue: Fibre, Blue triangles/ squares: High sites, Red dots: Inner-city interconnect sites (Manawatū-Wanganui Emergency Management Group, 2016).

The main telecommunication companies working within the region include:

- Vodafone
- Spark
- 2Degrees
- Inspire

Inspire is a local telecommunication company that works within the region, while the others are all national providers.

8.6.2 Risk summary

The key risks to telecommunication are from higher temperatures, more extreme weather events, and inland flooding.

Table 8.8: Risk to telecommunication from differing hazards

Hazard	Present	2050	2100	Commentary
Extreme weather events	Moderate	Moderate	High	Increased exposure for overhead cables, antennas and masts due to high wind speeds in the region causing loss of power and damage. Adaptive capacity higher than other utilities as assets have shorter life spans due to technological advancements.
Inland flooding	Moderate	Moderate	High	Increased exposure for assets located on the Plains and in modelled flood extents. Sensitivity is increased for ground assets such as transfer stations and cabinets due to damage and disruption caused by flood waters.
Higher temperatures	Insignificant	Low	Moderate	Exposure increases with every degree of temperature rise, particularly in Tararua, Whanganui and Taumarunui. Increased temperatures can reduce the life span of assets and stress telecommunication equipment. Resilience can be built due to shorter life spans and technological advancements.

Similarly to transmission and distribution infrastructure, telecommunication networks in the region are currently rated at moderate risk from inland flooding and extreme weather events. This risk is predicted to remain moderate to mid-century and increase to high by the end of the century due to the projected increases in the frequency of extreme weather and flooding events in the region (Table 8.8). Those assets that are located at ground elevation such as exchanges, underground cables, cabinets etc. have an increased sensitivity to flood waters compared to those above ground assets. This is due to the damage that flooding can cause to these assets, including degradation and exposure of underground infrastructure. Flooding also has the potential to cause failure of foundations, therefore disrupting overhead assets (Horrocks et al., 2010).

There is potential for increases in storm frequency and/or intensity to damage above-ground transmission infrastructure (masts, antennae, switch boxes, aerials, overhead wires, and cables), as well as access connection to homes and businesses. This would negatively impact telecommunications service delivery (Manawatu- Wanganui Emergency Management Group, 2016).

The risk to telecommunication infrastructure from increased temperatures is currently rated as insignificant, due to the cooler annual temperatures experienced in the region, in comparison to other parts of the country. However, this risk is predicted to increase to low by mid-century and moderate by end of century due to the projected increases in temperature throughout the region (NIWA, 2016). Increases in temperature can stress telecommunications equipment and infrastructure, reducing the life span. It can also create an additional burden on keeping equipment cool in exchanges and base stations, resulting in increased failure rates (Adams et al., 2014). These failure rates are likely to occur more frequently in summer months when temperatures are at their warmest. However, with the combination of technological advancements and the shorter life span of these assets, resilience can be built into these systems to allow for increased temperatures (Horrocks et al., 2010).

Adaptive capacity in the telecommunication sector is rated higher than other utilities as it is generally more inherently resilient and adaptable due to the short lifespans of components which can be updated and refined to meet changing needs (Horrocks et al., 2010).

8.7 Solid waste management

Risk to solid waste management due to more extreme weather events, and coastal and inland flooding.

8.7.1 Introduction

Solid waste management is a critical service within a community, both from a public health and sanitation perspective as well as to prevent contamination within waterways and soils – which can lead to harmful environments for disease-causing bacteria to form, harmful and unpleasant odour issues and adverse effects on land and water which are culturally important to Māori(Community & Public Health, 2021).

Solid waste management for the purpose of this assessment includes formal assets such as landfills and transfer stations, along with informal or unknown landfills, often referred to as legacy landfills. There is limited readily available knowledge of these legacy landfills for the region. There are two main operating landfills within the region (Levin and Bonny Glen) and additional refuse centres and transfer stations that take household waste (Figure 8.18). There are also closed landfills within the region such as the Awapuni, Ashhurst, Putorino Road and the closed portion of the Levin landfill.

The Levin landfill started initially as a dump in the mid 1970's and received large volumes of waste, which at the time was concerning for Tangata whenua, due to the potential implications of the dump on the Hōkio Stream and Wāhi Tapu. The site was due to reach capacity in the early 1990's, so plans for a new landfill on the same site began in 1994, and were consented in 2002. The new landfill is lined and monitored for environmental effects, while the old site is now capped and closed (Parliamentary Commissioner for the Environment, 2011).

The Bonny Glen landfill opened in 1995 and replaced a number of old 'tips' which served the towns in the southern portion of the Rangitīkei district. It was originally consented to serve the whole Rangitīkei district, however recently applications have been granted to receive waste from other districts (Douglas & Baines, 2000). Due to the landfill being constructed after the Resource Management Act (RMA), 1991, the landfill has improved characteristics to ensure reduced impact on the environment, including a clay liner, leachate collection pond, and leachate drains (Douglas & Baines, 2000).

The closed Awapuni landfill is one of two BioGas facilities that generate energy from landfill gas (the other is Horotiu landfill in Hamilton) in New Zealand. Methane gas is captured from the retired landfill and generates electricity for the Resource Recovery Centre and the nearby wastewater treatment plant. It has been claimed that over 75% of Palmerston North City Council's electricity could be generated from waste products this way (BioEnergy Facilities Directory, 2021).

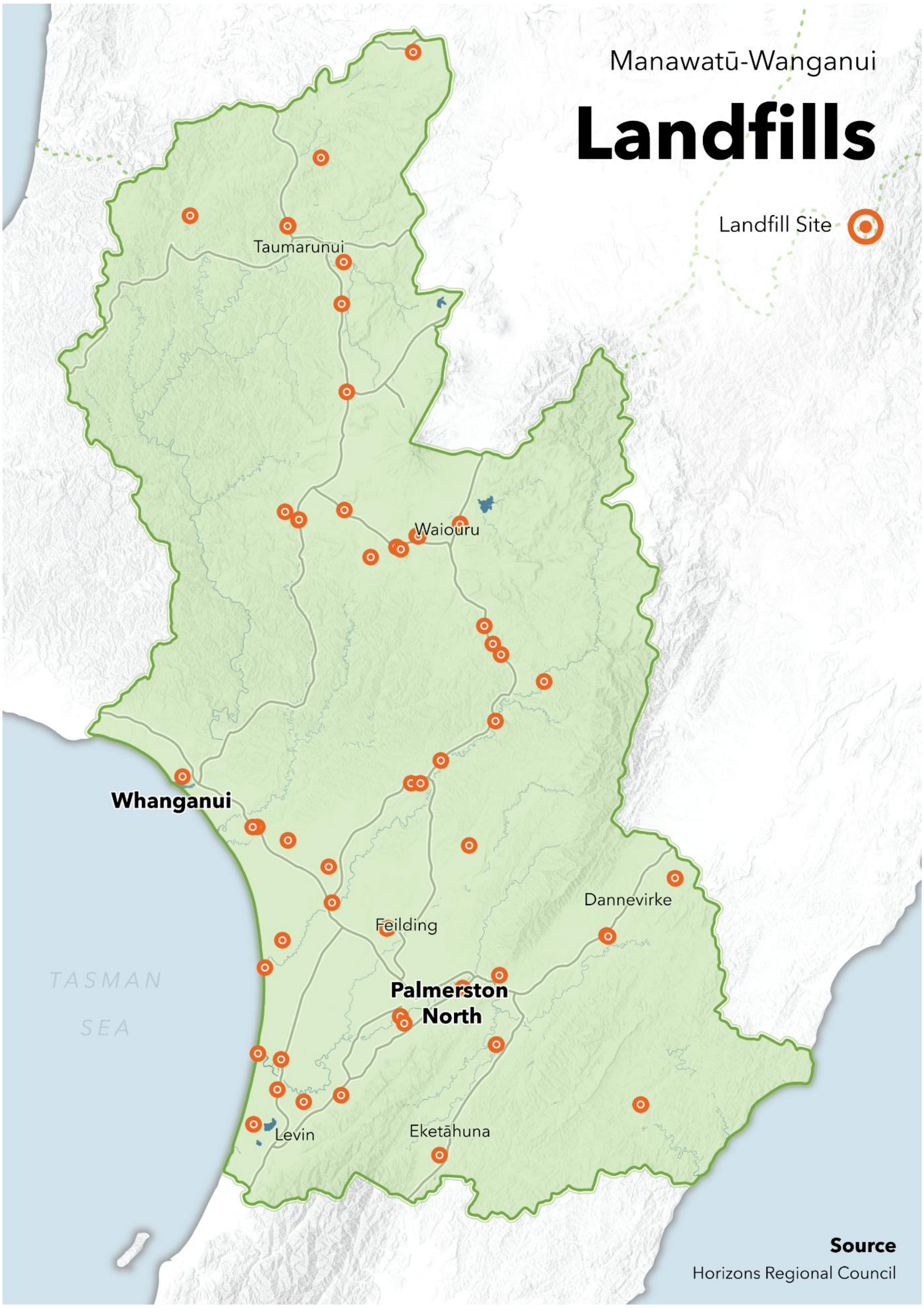


Figure 8.18: Formalised landfill locations throughout the region.

8.7.2 Risk summary

The key risks to solid waste management are from more extreme weather events, and coastal and inland flooding (Table 8.9).

Table 8.9: Risk to solid waste management from differing hazards

Hazard	Present	2050	2100	Commentary
Extreme weather events	Moderate	High	Extreme	Increased exposure for those landfills located on Plains and adjacent to rivers. Mobilisation of contaminants, undermined structural integrity and potential exposure of waste.
Coastal flooding	Moderate	High	Extreme	Increased exposure for coastal landfills (operating/closed), which will increase as sea levels rise. Sensitivities include mobilisation of contaminants, leachate, and potential impacts to receiving environment. Adaptive capacity low, due to permanent nature and lack of ability to relocate.
Inland flooding	Moderate	High	Extreme	Landfills located close to streams and rivers in the region. Sensitivities include mobilisation of contaminants, riverbank erosion exposing waste and impacts on receiving environment.

The risk to solid waste management from coastal and inland flooding and extreme weather events is currently rated moderate, which increases to high by mid-century and extreme by the end of the century. This is due to the projected increases in intensity and frequency of these events into the future.

Landfills and transfer stations located in Levin and Whanganui have an increased exposure to coastal flooding due to their location in coastal areas, while the Bonny Glen and Putorino Road landfills have an increased exposure to inland flooding due to their location adjacent to streams/rivers.

A landfill's design characteristics, maintenance and location all influence its sensitivity to flooding and extreme weather events (United States Environmental Protection Agency, 2014). The old Levin landfill has a higher sensitivity to flooding due to the absence of a liner. This can lead to flood waters mobilising contaminants and causing leachate to escape, impacting the surrounding environment (Beaven et al., 2020; Brand et al., 2018). This in comparison to Bonny Glen and the new Levin landfill which both have liners, which can reduce the likelihood of mobilisation and leachate.

Landfills that already have known issues are likely to have a higher risk to flooding and extreme events due to the reduced integrity and increased susceptibility of failure. The likelihood of landfill failure can be increased with more frequent and intense flooding events, as the infiltration of high-water volumes can adversely affect the structural integrity of the landfill (Brand et al., 2018). This has occurred at the closed Putorino Road landfill, where debris has become exposed on the banks of the Rangitīkei River (Figure 8.19). The landfill at the time of closure was 300 m from the river's edge, however due to riverbank retreat and erosion from high intensity flooding events the landfill is now exposed. This type of riverbank erosion is likely to occur more frequently, particularly during high energy flooding events.

Both the Levin and Bonny Glen landfills are likely to contain waste from the 1970's onwards, therefore, there is likely to be more plastic waste as well as asbestos which if leached could be detrimental to the receiving environment. The old Levin landfill was constructed pre the Resource Management Act (RMA) (1991), therefore there would be lower levels of environmental protection considered within the design (Te Ara, 2021). However, the Bonny Glen and new Levin landfill sites were constructed post RMA therefore have more controls to prevent leachate into the environment and have a reduced risk to climate hazards compared to the old Levin landfill.

Adaptive capacity for landfills is generally low due to the permanent nature and reduced capacity for relocation of these assets. The potential for unknown, historic landfill locations in the region also reduces the adaptive capacity of landfills, given the inability to assess or plan for future adaptations. Restoration and naturalisation of closed landfills in the region can help provide both ecological benefits and buffers against flooding, such as the site of the old Balgownie landfill in Whanganui (which is presently a reserve and is being further developed by the Whanganui District Council into the Kokohuia wetland and a public space).

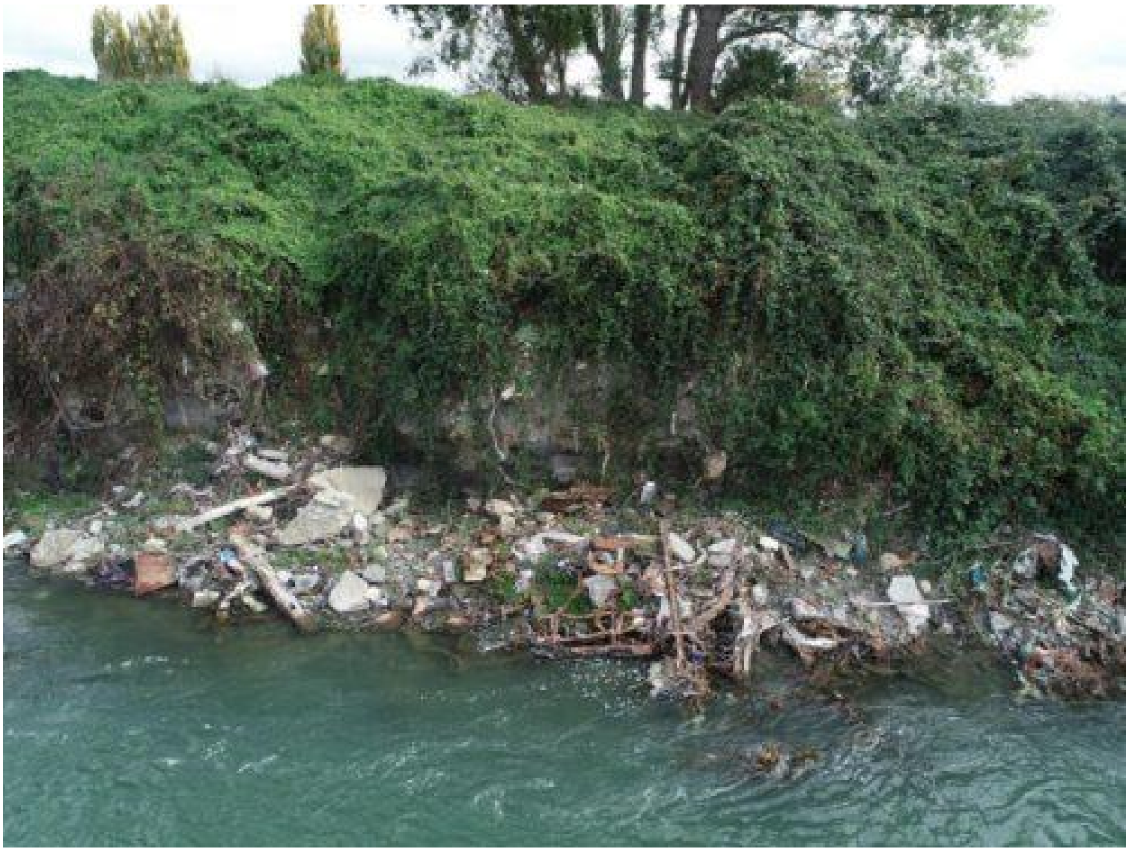


Figure 8.19: Exposed debris of Putorino Road landfill on the river bank of the Rangitīkei river (2018) (Rangitīkei District Council, 2020).

8.8 Rail network

Risk to rail network due to higher temperatures, more extreme weather events, inland flooding and increasing landslides and soil erosion.

8.8.1 Introduction

There are approximately 780 km of rail lines located within the region which are broken up into various different lines, including the North Island Main Truck Line, Marton-New Plymouth Line and the Palmerston-Gisborne Line (Figure 8.20).

The rail network within the region is used to transport freight to critical distribution centres within the region and provides a critical link between Auckland and Wellington. A new inter-modal freight hub is proposed to be located in Palmerston North, due to the strategic location of the city and the critical freight hub distribution point that it is (KiwiRail, 2021). This hub is proposed to contribute to the transportation of goods in the region and from the upper North Island and Hawke's Bay to Wellington. Along with connecting supplies from the region being distributed across New Zealand.

There is also passenger train service operating in the region - the Capital Connection train which is a commuter service between Palmerston North and Wellington. Over 2011-2020, the average number of journeys per year were approximately 129,000 per annum. In the future, the region could see the operation of additional passenger trains, with funding secured for a detailed business case to be undertaken (Horizons Regional Council, 2020b).

Figure 8.20: Linear transport links within the Manawatū-Whanganui region and high risk areas identified by Waka Kotahi in their 2020 National Resilience Programme Business Case.

8.8.2 Risk Summary

The key risks to the rail network are from increased landslides and soil erosion, inland flooding, more extreme weather events, and higher temperatures (Table 8.10).

Table 8.10: Risk to the rail network from differing hazards

Hazard	Present	2050	2100	Commentary
Increasing landslides and soil erosion	High	High	Extreme	Palmerston North-Gisborne Line has increased exposure through the Manawatū Gorge. Five additional locations at risk. Sensitivies include degradation, undercutting, blockages and service disruptions. Adaptive capacity can be costly, but tunnelling through steep sections has proven helpful.
Inland flooding	High	High	Extreme	30% (234 km) of network exposed throughout the region, with more than 5 flooding events causing closure between July 2004-2008. Sensitivities include ballast washout, inability for track drainage and possible embankment collapse. Designing drainage systems for future climate conditions can help reduce impact.
Coastal flooding	High	High	Extreme	
Extreme weather events	Low	Moderate	High	Increased exposure in National Park and Lower Retaruke from high winds and third party debris. 2.9 km exposed to 1% AEP storm event in Manawatū district. Sensitivities include, third party debris damage, reduced operating speeds and corrosion. Tree-free zones can help reduce third party debris.
Higher temperatures	Low	Moderate	High	Exposure low across region due to annual average temperatures. Track derailment due to buckling has occurred in Ruapehu in the past. Track maintenance important for reducing impacts.

The risk to the rail network due to landslides is currently rated as high, which increases to extreme by the end of the century, due to the projected increases in rainfall throughout the region and the highly erodible nature of the soils (Dymond & Shepherd, 2006). The Palmerston North- Gisborne Line has a higher exposure due to the steep terrain through the Manawatū Gorge. Increased rainfall partnered with the susceptibility of soil erosion, can lead to more frequent landslides in this area. The use of tunnels has allowed steeper sections of the gorge to be bypassed, reducing the likelihood of damage and disruption from landslides (MWH, 2012).

Five additional locations have been identified as being at risk from landslides by Waka Kotahi during their 2020 National Resilience Programme Business Case (Figure 8.20). The tracks in these areas are likely to experience increased degradation and potential undercutting, leading to damage and blockages, causing service disruption (Gardiner & NZ Transport Agency, 2009).

Adaptive capacity is generally limited due to the erodibility of the soils within the region and the permanent nature of these assets. However, as mentioned, tunnels can be used to bypass these sections, but the costs associated with these are often the limiting factor.

The current risk to the rail network from inland flooding is rated high, with 30% of the rail network (234 km) exposed to flooding (Paulik, Craig, et al., 2019). Between July 2004-2008 there was more than five flooding events that caused disruptions on the Wairarapa, Palmerston North-Gisborne and North Island Main trunk lines, demonstrating the current risk to the rail network (Gardiner & NZ Transport Agency, 2009). These events are likely to increase in frequency with the projected increases in high intensity rainfall events (NIWA, 2016).

The risk to the network from inland flooding is projected to increase to extreme by the end of the century due to the increase in exposure, particularly in the Rangitīkei, Tararua and Ruapehu districts (Figure 8.21). Flooding can lead to ballast washout, which can compromise the track's ability to drain flood waters from the network. This can lead to damage, including embankment collapse, disruption in services and reduced operating speeds (Gardiner & NZ Transport Agency, 2009). Vulnerability to flooding can be reduced by increasing the capacity of drainage systems (e.g. culverts) and designing them for future climate conditions, and with increased maintenance checks to ensure the track operates within health and safety regulations (Lindgren et al., 2009).

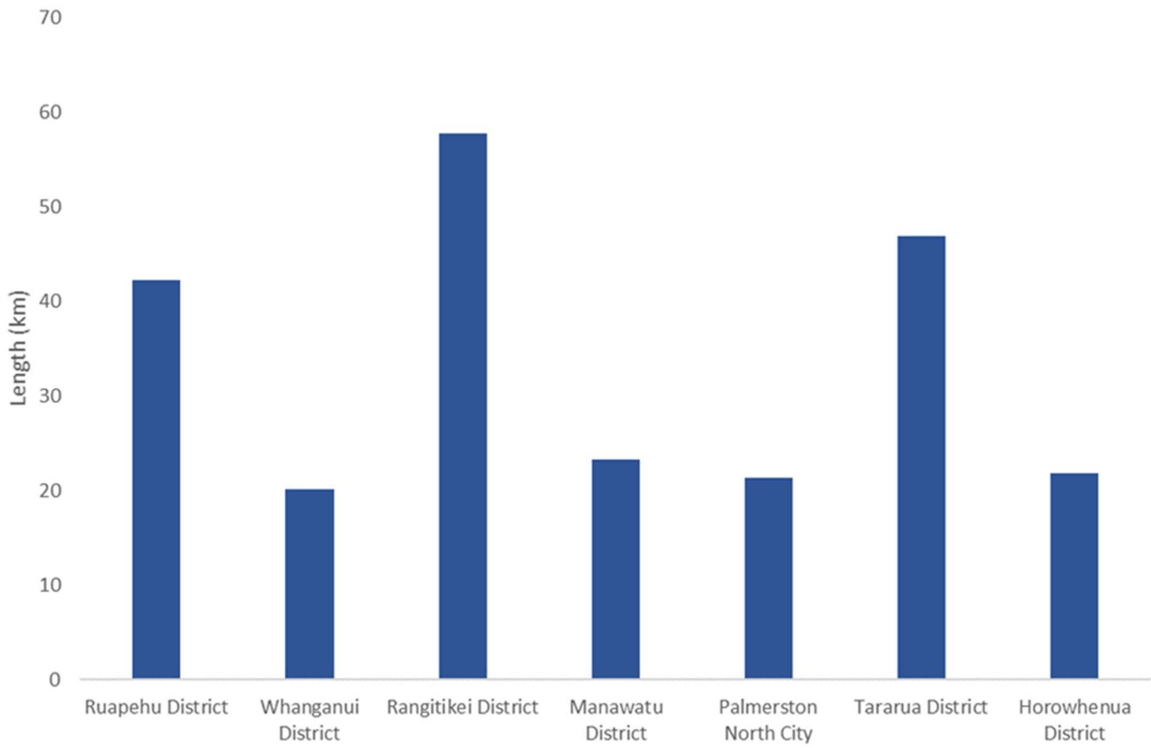


Figure 8.21: Length of rail exposed to inland flooding per district, within the Manawatū-Whanganui region (Paulik, Craig, et al., 2019).

Extreme weather events currently pose a low risk to the rail network, which is projected to increase to moderate by mid-century and high by the end of the century. Areas such as National Park and the

Lower Retaruke area experience more frequent storms therefore have an increased exposure to these events (Chappell, 2015b). Rail in these areas can be prone to damage due to third party debris and high winds, leading to reduced operating speeds (Gardiner & NZ Transport Agency, 2009).

Resilience can be improved with increased maintenance checks, however third party debris can be unpredictable, therefore hard to plan for and adapt to (Gardiner & NZ Transport Agency, 2009). Establishing tree-free zones in the railway corridor for critical sections of the network is a way to reduce the amount of third party debris that could occur as a result of extreme weather events (Lindgren et al., 2009).

Large low pressure systems that coincide with high tides and/or high intensity rainfall can lead to increased coastal flooding, particularly in the Whanganui and Manawatū districts. Currently, there is 2.9 km of rail exposed to the 1% AEP storm event, of which 97% is located within the Manawatū district (Paulik, Stephens, et al., 2019). This exposure would be expected to increase during extreme weather events, which can lead to track movement and corrosion (salt water intrusion), along with material deterioration and scour (Gardiner & NZ Transport Agency, 2009).

The current risk to the rail network from increased temperatures is rated low, increasing to moderate by mid-century and high by the end of the century. Currently, annual average temperatures range from 6-15°C (NIWA, 2016). By mid-century, these temperatures are projected to rise by 1°C, increasing the exposure across the region.

Increased temperatures can cause rail lines to buckle, and disrupt services throughout the region. An example of this occurred in 2016 when a train was derailed due to the track buckling on the North Island Main Trunk Line in National Park (Stuff, 2016a). Rail lines are generally designed to tight tolerances, and when temperature thresholds (40°C) are exceeded, the track can begin to buckle and deform. Those rail lines that are older have a higher sensitivity to buckling due to their natural deterioration (Gardiner & NZ Transport Agency, 2009; Stuff, 2016a).

8.9 Road network

Risk to road network due to higher temperatures, sea level rise and coastal erosion, more extreme weather events, inland flooding, and landslides and soil erosion.

8.9.1 Introduction

The road network throughout the region is used for both social and economic purposes, such as commuting, shifting freight and visiting friends and family. These networks also provide critical links within the region and inter-regionally during emergencies (Byett et al., 2019).

There are approximately 7,950 km of local roads, and 963 km of State Highways in the region (Figure 8.20). Along with connecting the region State Highway 1, 3 and 4 provide critical links between Wellington and the rest of the North Island for freight, and link up several major distribution centres operating within the region (Figure NZ, 2021; Waka Kotahi, 2020).

The road network within the region is approximately 70% sealed, and 30% unsealed, which is representative across most districts (Figure 8.22). The Ruapehu district has the longest length of roads, and unsealed roads in the region (Ruapehu District Council, 2021a), closely followed by Tararua, conversely, Palmerston North City has the shortest length of road in the region, with notably no unsealed roads. This can be related to the size of the district, and the urban nature, compared to that of Ruapehu.

A significant amount of each of the district council's budgets goes towards the maintenance and upgrading of roads. Tararua alongside other district councils such as Horowhenua, rely primarily on funding from Waka Kotahi to enable maintenance. Tararua's road network is the fourth largest of any local authority in New Zealand, with one of the fewest number of ratepayers per kilometre of road. This impacts the availability of council funding to be distributed to road maintenance and management, further reinforcing their reliance on Waka Kotahi (Tararua District Council, 2021a).

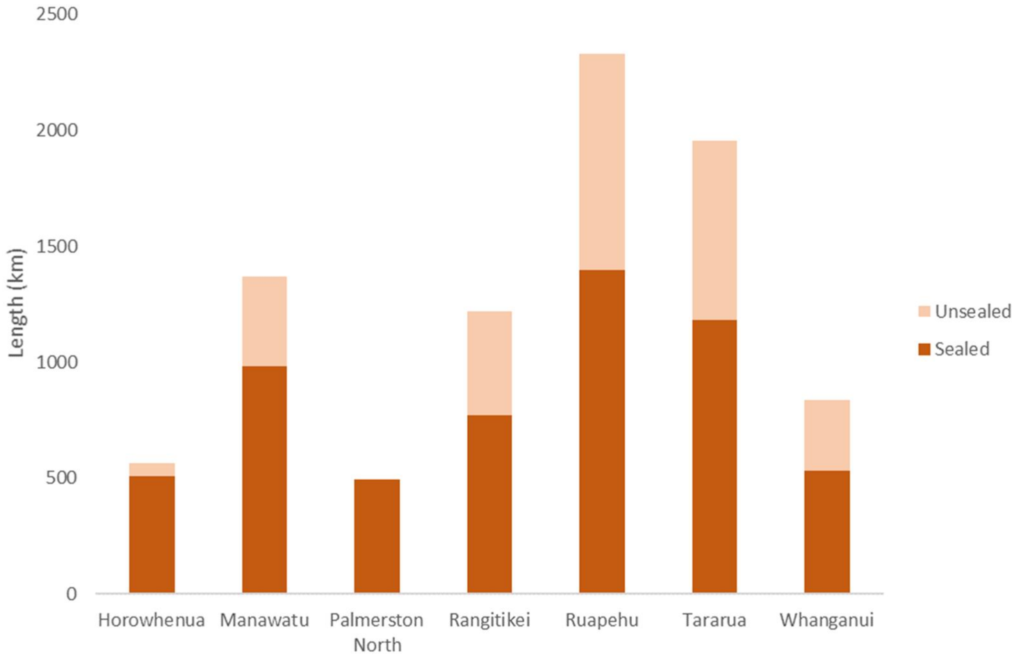


Figure 8.22: Length of sealed and unsealed roads per district within the Manawatū-Whanganui region (Source: council websites).

8.9.2 Risk Summary

The key risks to the road network are from increased landslides and soil erosion, inland flooding, sea level rise and coastal erosion, more extreme weather events, and higher temperatures (Table 8.11).

Table 8.11: Risk to the road network from differing hazards

Hazard	Present	2050	2100	Commentary
Increasing landslides and soil erosion	High	High	Extreme	Nine key locations identified by Waka Kotahi across the region. SH3 through Manawatū Gorge. Sensitivities include road surface damage, undercutting and collapse. Re-routing possible, like section of SH3 through the Gorge.
Inland flooding	High	High	Extreme	13% of entire network (including SH) exposed to inland flooding. Road wash out, sub-base degradation and reduced surface friction can occur. Unsealed roads have increased sensitivity due to condition. Maintenance checks and repairs are important.
Sea level rise and coastal erosion	Moderate	High	Extreme	More than 30 km of road exposed to the 1% AEP storm event. Horowhenua has highest exposure. Scour and corrosion can occur leading to damage and disruption.
Coastal flooding	Moderate	High	Extreme	
Extreme weather events	Low	Moderate	High	Increased exposure in coastal areas, from storm surge and on the Plains from flooding. Road degradation and disruption can occur.
Higher temperatures	Low	Moderate	High	Low exposure due to annual average temperatures. Increased exposure for roads in Tararua, Whanganui and Ruapehu. Roads can melt causing disruption. Resurfacing on a frequent basis can help reduce impact.

Landslides currently pose a high risk to roads, with nine key locations identified within the region by Waka Kotahi during their 2020 National Resilience Programme Business Case (shown in Figure 8.20). These areas are located in steep, hilly terrain where landslide susceptibility is higher. One such area is the Manawatū Gorge, where SH3 links Palmerston North to the eastern coast of the region. This section of road is known to have closures due to landslides, with damage costs estimated up to $2 million in damage after the 2011 landslide event (Rosser et al., 2017). The underlying road support can be undermined by landslides and cause the road to collapse, whilst debris can cause damage to the surface of the road, leading to disruptions and closures (Henderson & Land Transport NZ, 2006). The risk from landslides is projected to increase to extreme by the end of the century due to the projected increases in rainfall, particularly on the western side of the Tararua and Ruahine ranges (NIWA, 2016).

Adaptive capacity is generally low, due to the permanent nature of these networks and the high cost involved in replacement or relocation. Moreover, adaptive capacity may be reduced in the future given a limited availability of central government funding and the increasing climate risk profile.

However, a new road has been proposed to replace the section of SH3 that goes through the Manawatū Gorge, and is expected to cost $620 million (Waka Kotahi, 2021).

Inland flooding currently poses a high risk to roads, which increases to extreme by the end of the century as currently over 1,200 km of road is exposed throughout the region. This is equivalent to 13% of the entire roading network, including state highways. Specific hotspots on the state highway include SH1 (Levin), SH56 (Opiki), SH3 (Whangaehu), and SH43 (Taumarunui to Whangamōmona).

Every district has exposed roads where the road can be washed out, and sub-base degradation can occur. Reduced surface friction can occur as a result of excessive flood water, leading to loss of control and accidents for road users (Gardiner & NZ Transport Agency, 2009). Unsealed roads have a reduced surface drainage capacity compared to sealed roads and are more likely to have construction layers penetrated or submerged, which can lead to potential damage and failure of road materials. This is of particular concern in the Tararua District, with 39% of unsealed roads and 23% of roads exposed (Figure 8.23). Sensitivity of roads to flooding can be reduced with increased maintenance checks and repairs to roads that are in poor condition.

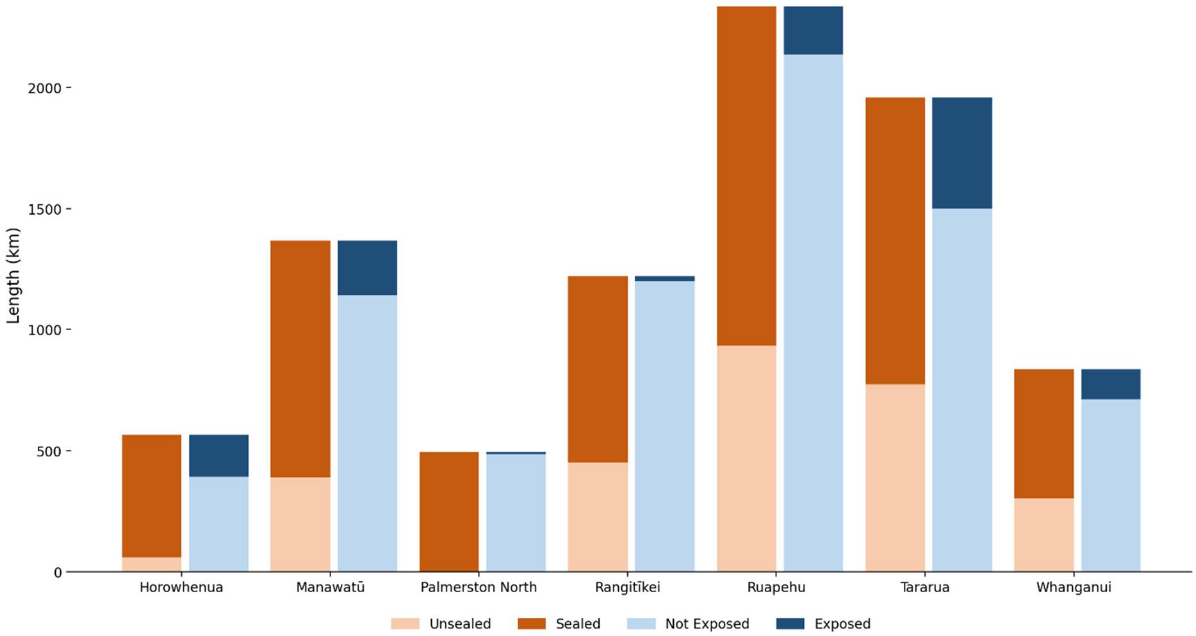


Figure 8.23: The length of sealed and unsealed road within each district and the length of road exposed and not exposed to flooding per district within the region (note that exposure is unknown if on sealed or unsealed road).

Roads located close to the coast are currently at moderate risk from sea level rise, coastal erosion and coastal flooding. Those roads located in the Horowhenua, Whanganui and Manawatū districts have an increased exposure to sea level rise and coastal flooding with more than 30 km of road exposed collectively across the districts (1% AEP storm event) (Paulik, Stephens, et al., 2019). This exposure is likely to increase by mid-century, increasing the risk to high.

When considering roads exposed to the current day 1% AEP storm event (0 m sea level rise), the Horowhenua district has the highest length of road exposed (Figure 8.24). This is still the case when looking at the mid and long term outlook (using increments of sea level rise 0.3 m and 0.6 m respectively). The Horowhenua district has more than twice the exposure of Whanganui, which has the second highest length of road exposed in the region.

These roads are sensitive to coastal hazards due to the potential for scour and damage by salt water corrosion (Gardiner & NZ Transport Agency, 2009). Those roads located in the Manawatū and

Whanganui districts are likely to have an increased sensitivity to sea level rise, and coastal flooding due to the percentage of unsealed roads, which are likely to be in poorer condition (Figure 8.23). Adaptive capacity measures can include resurfacing of roads which can contribute to reducing the impact from coastal flooding. Decommissioning may be feasible, but is often costly (AGIC, 2011).

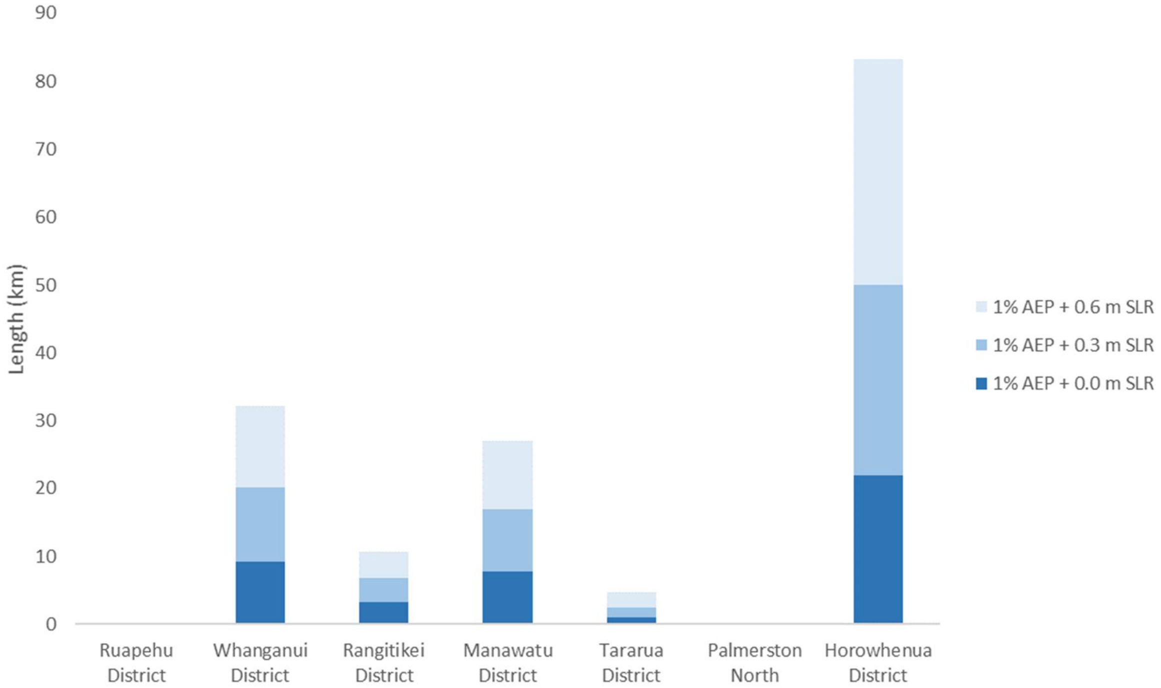


Figure 8.24: Length of road exposed to coastal flooding and sea level rise per district within the Manawatū-Whanganui region (Paulik, Stephens, et al., 2019).

Increasing temperatures currently present a low risk to the road network within the region as annual average temperatures range from 6-15°C (Chappell, 2015b). As temperatures and the number of hot days increases, the risk increases to moderate by mid-century and high by the end of the century.

Temperatures greater than 30°C can cause road deformation and asphalt to melt, particularly for roads in poorer conditions (Gardiner & NZ Transport Agency, 2009). Roads in the Tararua, Whanganui and Ruapehu districts are likely to experience these conditions due to the increase in hot days projected (where the temperature exceeds 25°C) (NIWA, 2016). Asphalt melting has already been seen in the region, particularly in the Whanganui district where in 2018, roads were showing signs of “bleeding seal” or melting due to the hot temperatures (Whanganui Chronicle, 2018). Adaptive capacity of roads is generally higher as they can be resurfaced and upgraded on a more frequent basis throughout their life cycle (AGIC, 2011).

8.10 Transportation by air and seaports

Risk to air transport and sea ports due to higher temperatures, extreme weather events, and inland and coastal flooding.

8.10.1 Introduction

There are two main domestic airports (Whanganui and Palmerston North) within the region that both receive freight and connect communities to other major cities. There are no international airports in the region, however there are two air bases located at Ohakea and Waiouru (Figure 8.25).

The Palmerston North airport is one of New Zealand's fastest growing regional airports which now manages the Ruapehu Business Park – the central North Island's peak business location for freight and logistics, aviation training, retail and light industrial business. It is the only business park within New Zealand that is easily connected to air, road and rail access, making it a strategically important asset within the region (Palmerston North Airport, 2021).

There is currently one seaport within the region, located at the mouth of the Whanganui River. It was built in the 1900's and enables goods to be transported by sea and provides berthing facilities for coastal freight vessels and commercial boats (Whanganui District Council, 2021). The Number 1 wharf was rebuilt in 2016 and is the primary commercial wharf capable of taking heavy vehicles. The Number 2 and 3 wharves are currently not suitable for commercial activities, and require remedial works. There is currently a Port Revitalisation project (Te Pūwaha) being undertaken that will enable better utilisation of the traditional port area and create jobs, training and opportunities for the local community (Whanganui District Council, 2021).

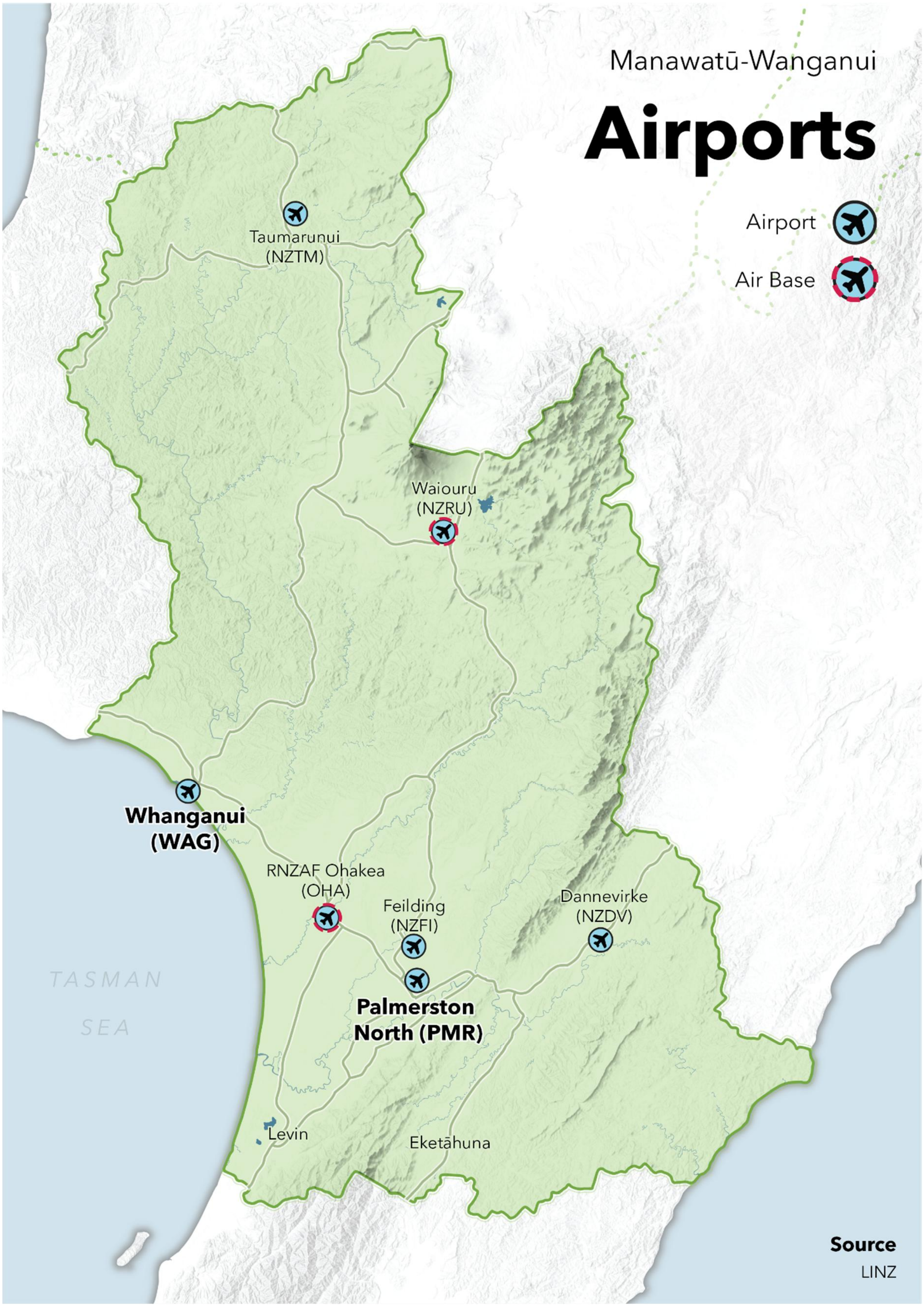


Figure 8.25: Location of airports, and air bases in the region.

8.10.2 Risk Summary

8.10.2.1 Airports

The key risks to airports are from higher temperatures, inland and coastal flooding, and more extreme weather events (Table 8.12).

Table 8.12: Risk to airports from differing hazards

Hazard	Present	2050	2100	Commentary
Extreme weather events	Moderate	High	Extreme	Both domestic airports are exposed to extreme weather events. High winds and lightning can cause aircraft damage and voltage spikes.
Inland flooding	Moderate	High	Extreme	Both domestic airports are currently exposed to inland flooding. Sensitivities include damage, drainage issues and service disruption. Adaptive capacity generally low, however protection measures can be put in place.
Coastal flooding	Moderate	High	Extreme	Whanganui airport exposed to sea level rise, coastal flooding and coastal erosion. Sensitivities include tarmac degradation from salt water corrosion and potential loss of capacity.
Higher temperatures	Low	Moderate	High	All airports exposed to increases in temperature, which currently has low exposure. Sensitivities include tarmac melting and disruption of services.

Airports in the region are currently rated at moderate risk from inland flooding, as the two main airports; Palmerston North and Whanganui, are both currently located within modelled flood extents (Horizons Regional Council, 2021b).

Airports are vulnerable to flooding as underground infrastructure and airport buildings can be damaged by flood waters, along with the apron and runway becoming waterlogged and unusable. Electrical infrastructure can also be compromised if inundated by flood waters and drainage capacity may also be insufficient (Burbidge, 2016). The risk to airports is projected to increase to high by mid-century and extreme by the end of the century, with projected increases in flood events within the region. Adaptive capacity is generally low due to the permanent nature of the assets, however flood protection measures could be put in place to lower the overall risk.

The risk to airports from sea level rise, coastal erosion and coastal flooding is currently rated moderate. This risk increases to high by mid-century and extreme by the end of the century due to the projected increases in sea level rise and the frequency and intensity of storm events that cause coastal flooding. The Whanganui airport has increased exposure to these hazards due to its location near the coast, where temporary reduction in capacity, and tarmac condition degradation could occur due to salt water intrusion (Burbidge, 2016). The potential permanent loss of capacity at the Whanganui airport could have implications for the region as ambulance services, and the commercial pilots academy use the Whanganui airport (Whanganui Chronicle, 2017).

All airports are exposed to extreme weather events – which result in flooding, lightning, and high winds. Lightning strikes have the potential to damage aircraft and escalate the potential for voltage spikes, leading to interruptions in power supply, and disruptions to control and communication systems (Baglin et al., 2012). This can cause delays in operations and damage to infrastructure. Strong winds can impact runway operations due to reduced landing capacity and the increased likelihood of third party debris (Baglin et al., 2012).

Risk to airports from increased temperature is currently rated low within the region, increasing to moderate by mid-century and high by the end of century, due to the increases in temperature projected for the region. All airports are exposed to increased temperatures, with those airports in the Tararua and Manawatū districts projected to experience more frequent hot days – +10-15 (RCP 8.5 – 2040) and +30-50 (RCP 8.5 – 2090) (NIWA, 2016). Airports are vulnerable to increased temperatures as it can cause heat damage to asphalt/ tarmac surfaces, and aprons and runways may experience damage from surface melting (Burbidge, 2016). There is no evidence to suggest airports within the region have been closed or disrupted due to surface melting however, they could be in the future with projected increases in temperature.

8.10.2.2 Sea ports

The key risks to seaports are from higher temperatures, inland and coastal flooding, and more extreme weather events (Table 8.13).

Table 8.13: Risk to seaports from differing hazards

Hazard	Present	2050	2100	Commentary
Coastal flooding	Moderate	Moderate	High	Assumed exposed due to constrained location. Wharf revitalisation project aims to improve condition of wharf, reducing impact from damage.
Extreme weather events	Low	Moderate	High	Wharf is exposed to extreme weather events, particularly those bring high wind speeds and flooding. Localised flooding can cause damage and high winds speeds can disrupt operations.
Sea level rise and coastal erosion	Low	Moderate	Moderate	Assumed exposed due to constrained location. Wharf revitalisation project aims to improve condition of wharf, reducing impact from damage.

Due to the constrained location of sea ports, it is assumed that the Whanganui Port is exposed to sea level rise, coastal erosion and coastal flooding. Ports are generally designed to withstand these events, however the Whanganui Port was built in the 1900's and is in poor condition, therefore is likely to be sensitive to these hazards (Gardiner & NZ Transport Agency, 2009). Te Pūwaha is likely to reduce the Port's sensitivity to these hazards as it aims to upgrade 424m of wharves to enable commercial marine activities to safely operate (Whanganui District Council, 2021). It is assumed that the design will consider future climate conditions, therefore reducing the Port's risk to these hazards. Generally, the adaptive capacity of seaports is limited due to their permanent nature and long life cycles, however over $50 million is being invested into the Whanganui Port to revitalise it, both for the community and for the economy (Whanganui District Council, 2021).

Risk to the Whanganui Port from extreme weather events is currently rated low, which increases to moderate by the mid and end of century. Strong winds and localised flooding that occur during extreme weather events can cause damage to port buildings. Crane infrastructure at the port could be damaged by strong winds (Gardiner & NZ Transport Agency, 2009). Adaptive capacity is generally low for these assets as relocation, and redesign can be costly, and require extensive planning constraints (Burbidge, 2016).

9 Cultural

The cultural domain encompasses risks to both Māori and non-Māori heritage and cultural practices. The assessment of cultural values in this section recognise the region's unique histories and is aligned with the principle of tiaki taonga (the preservation of iwi taongā and heritage). Each township, landscape and location within the region has a history which contributes to its unique cultural identity (Figure 9.1). Beyond this, cultural practices extend out to outdoor pursuits and recreational activities, including access through parks, huts and tracks and freshwater recreation.

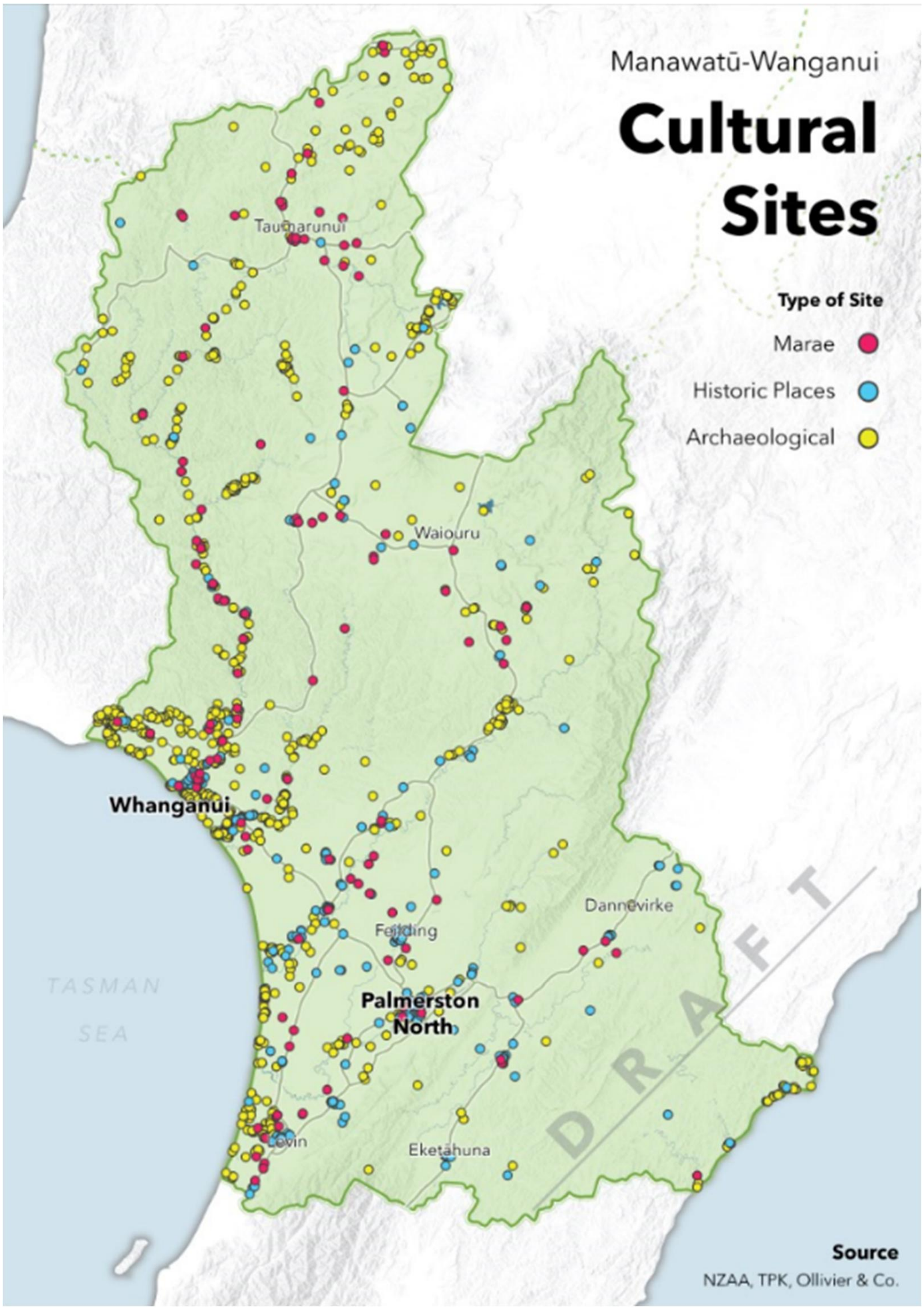


Figure 9.1: Cultural sites Manawatū-Whanganui.

The region has a rich cultural history, connected to Māori and European settlement across the various districts. Ngāti Tūwharetoa whakapapa (genealogy) to Tongariro maunga (mountain) and Taupō moana, with the first Tūwharetoa Māori Trust Board established in 1926 (pursuant to the Māori Land Amendment Act 1924 and Māori Land Claims Adjustment Act 1926). The Tongariro National Park was established as the first national park in New Zealand and legal ownership of the three peaks and a 25,000 ha land block was vested solely in the Crown (D.O.C, 2021b).

The Whanganui River and its tributaries (Te Awa Tupua) are central to the existence of Whanganui Iwi, providing both physical and spiritual sustenance to iwi and hapū. Te Awa Tupua is an indivisible and living being consisting of physical and metaphysical elements.

Whanganui township was established in 1840 and was the fifth largest township in New Zealand up until 1936. Whanganui in Te Reo Māori means 'big bay or big harbour', and is recognized as a key hub for servicing the large agricultural catchment upstream.

Palmerston North, now the region's largest city, was once a clearing called Papaioea up until 1864 when the land was sold to the Crown and a township created in 1866. In 1886, the west coast railway from Wellington was built and land began being cleared for pastoral farming. The original clearing had contained old Papaioea pā site created by Rangitāne iwi, and in 1878 Rangitāne and Ngāti Raukawa requested the town be named Te Marae o Hine but were declined (McKinnon, 2021).

Table 9.1: Summary of risks to Cultural elements from differing climate change hazards

Cultural	Higher temperatures			Inland flooding			Extreme weather events			Drought			Coastal flooding			Increased fire weather			Increasing landslides and soil erosion			Sea level rise and coastal erosion			Change in rainfall			River erosion			Reduced snow and ice			Sea level rise and salinity stress			Marine heatwaves			Ocean acidification		
	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100	Pres	2050	2100
Cultural landscapes				L	M	H										M	H	E	M	H	E	L	M	H																		
Parks, huts and tracks				L	M	H	L	L	H				I	I	M	I	L	L	L	H	E	I	I	M																		
Physical heritage	L	M	H																																							
Taonga	M	H	E																																							
Freshwater recreation				M	H	E				L	M	H																I	L	M												

9.1 Cultural landscapes

Risk to cultural landscapes from increased fire weather, increased landslides and soil erosion, inland flooding, sea level rise and coastal erosion.

9.1.1 Introduction

The identity of communities is influenced by and centred on cultural landscapes, and changes in these landscapes can affect community wellbeing. Cultural landscapes are defined as combined works of nature and humankind, and are an expression of the relationship between humans and their surrounding environment. The protection and maintenance of cultural landscapes should be prioritised, as these contribute to the collective identity of communities (I.C.O.M.O.S., 2013).

Cultural landscapes are at risk when landscape features change in appearance, including the impacts of climate hazards and potential maladaptation impacts from climate responses. The region is well-known for its productive rural land, with many landscapes of the region farmed and modified by agricultural practices overtime. With destruction and modification of rural landscapes due to climate change impacts and management responses will impact upon community identities (Stakeholder Engagement, 2021a).

Areas such as Tongariro National Park are also considered to be significant cultural landscapes, listed on the UNESCO World Heritage List, the mountains are identified to have both cultural and religious significance to Māori and symbolize the spiritual link of communities to the environment. Cultural landscapes and associated intangible cultural resources help to form distinctive and sustaining community identities (UNESCO, 2021).

9.1.2 Risk summary

Table 9.2: Risks to cultural landscapes from differing hazards

Hazard	Present	2050	2100	Commentary
Increased fire weather	Moderate	High	Extreme	Rural productive land at higher exposure centralised around the plains, where fire could damage or destroy large areas considered to be cultural landscapes. Exposure increases with increasing temperatures and decreased summer rainfall.
Increasing landslides and soil erosion	Moderate	High	Extreme	Large areas of rural productive land is located in hill country areas high susceptible to increased erosion and landslides. As landslides and erosion increases, the landscapes will continue to change visually, may become less usable and measures to prevent erosion will change the way they look. Exposure increases as already eroded areas continue to erode overtime, with increased storm events and flooding.
Inland flooding	Low	Moderate	High	Exposure is moderate increasing overtime where intensity and severity of flood events will increase and may visually impact upon the way landscapes look, and how landscapes are used. Largest catchments such as Manawatu and Whanganui likely higher exposure.
Sea level rise and coastal erosion	Low	Moderate	High	Exposure moderate, increasing as coastal areas become inundated and coastal erosion increases overtime as sea level rises. The appearance and use of well-known coastal areas such as Castlecliff at Whanganui more exposed.

Risk to cultural landscapes from increased fire weather is currently rated moderate, increasing to high and then extreme by the end of the century. The largest number of wildfires experienced in the region is within rural pasture land centred around the Manawatū Plains (Scion Research, 2021).

Fire has the potential to damage or completely destroy the appearance of cultural landscapes through loss of vegetation cover. Fire damage can decrease the usability of areas, resulting in further negative impacts. Rural landscapes are particularly vulnerable the presence of vegetation and high exposure to strong winds. The vulnerability of landscapes to fire weather is likely to increase, given that farmers are afforesting land in response to the increasing price of carbon. Fire can also result in impacts on wellbeing, including the alienation of people from places and a loss of connection to cultural landscapes (Welch, 2012).

The risk resulting from increasing landslides and soil erosion is currently rated as moderate. The region contains a high proportion of hill country and erodible land, and cultural landscapes located in hill country areas are likely to face increasing erosion into the future (Dymond & Shepherd, 2006). Therefore, the risk to cultural landscapes is assessed as increasing to extreme in the long term due to projected changes in rainfall and increases in extreme weather events. As landslides and erosion increase, rural productive landscapes will change visually and the usability of land for production purposes may also decrease. There are a range of adaptive capacity measures that could be employed, including the retirement of farm blocks and afforestation, the implementation of erosion control measures, and the stabilisation of slopes. These measures may change the visual appearance of rural landscapes, resulting in cultural impacts to communities (Stakeholder Engagement, 2021a).

Inland flooding currently poses a low risk to cultural landscapes, increasing to high by the end of the century due to projected changes in rainfall and increased frequency of flood events (NIWA, 2019). Flooding can change the visual appearance of landscapes, through deposition of debris and damage or complete destruction of landscape features. The usability of low-lying areas will also likely decrease as flood events become more frequent, changing the way communities interact with their surrounding environment. The historic and cultural value of floodplains will therefore also likely change overtime (Stakeholder Engagement, 2021a).

Risk to cultural landscapes from sea level rise and coastal erosion is currently rated as low. Risk increases to high over the long term associated with the inundation of low-lying coastal areas and projected increases in coastal erosion (NIWA, 2019). Exposure will increase over time due to sea level rise, which will result in a decreasing coastal margin and impacts on the appearance and use of coastal landscapes. Low-lying coastal landscapes, such as the Manawatū Estuary, are highly exposed and are likely to change significantly in the future. Increasing exposure to rising sea levels is projected to dramatically reduce estuarine intertidal areas, resulting in estuarine zones being more susceptible to erosion and inundation (Swales et al., 2020).

Adaptive capacity for cultural landscapes is generally rated as low, given that climate change will result in changes to the status quo. As the interaction of individuals and communities with cultural landscapes evolve overtime, the values and identity ascribed to these landscapes may also alter.

9.2 Taonga

Risk to taonga from increased fire weather, extreme weather events, inland flooding, increased landslides and soil erosion, river erosion, coastal flooding, sea level rise and coastal erosion.

9.2.1 Introduction

Taonga covers marae, urupa, and sites of significance such as pā sites, wāhi tapu, wāhi tupuna and papakāinga. There over 21 iwi within the region, with some of the rohe of iwi transboundary such as Maniapoto. The taonga of the region are the ancestral treasures of iwi, and this includes places, sites and items that are both physical and tangible to the natural environment and intangible cultural practices and heritage.

There are approximately 11 identified urupa, 97 marae and an extensive number of pā sites throughout the region, a large portion of which are not officially identified or mapped. Along the Whanganui River alone, there are 80 known pā sites (Whanganui River Māori Trust Board, 2021; BillionGraves Holdings, 2021). A large number of taonga sites are located in areas increasingly at risk from climate hazards, particularly pā sites and marae located near to water sources. Climate hazards can have impacts upon both the tangible and intangible values of taonga sites and associated tikanga practices.

9.2.2 Risk summary

Table 9.3: Risks to taonga from differing hazard

Hazard	Present	2050	2100	Commentary
Inland flooding	Moderate	High	Extreme	Many marae and pa sites located along rivers in low lying areas and are highly exposed, increasing overtime as flood frequency and severity increase due to changes in rainfall,
Coastal flooding	Low	High	Extreme	Low exposure due to location of taonga, increasing overtime at spot locations are coastal flooding events become more frequent and coastal inundation occurs.
Sea level rise and coastal erosion	Low	High	Extreme	Large number of marae are located inland and not directly within the coastal environment, however site such as Kaiwharawhara pā, Taurahere marae, Putiki pā and marae and Papauma marae will become more exposed as sea level rise and coastal inundation increases.
Extreme weather events	Low	Moderate	High	Moderate exposure increasing over time as extreme events become more frequent and severity increases. Road closures and damage to network infra will also indirectly affect marae and papakainga located in remote locations, Higher exposure of remote taonga.
Increasing landslides and soil erosion	Low	Moderate	High	Moderate exposure increasing overtime with highest exposure of sites within mountainous and hilly regions including the Central Plateau, Tararua and Ruahine ranges and hill country. Exposure increases as eroded areas continue to erode and landslides become more frequent along with extreme events.
River erosion	Low	Moderate	High	Many marae and pa sites located along rivers in low lying areas and are highly exposed, increasing overtime as flood frequency and changes in rainfall exacerbate eroded areas, River margin is reduced and sites in low-lying areas are more exposed.
Increased fire weather	Insignificant	Moderate	High	Low exposure increasing overtime as summer rainfall decreases and wind increases, particularly for sites in the east. Sites located within rural, wooded areas are more exposed.

Inland flooding currently poses a moderate risk to taonga due to projected increases in the frequency and severity of flood events. The risk is projected to increase to extreme over the long term. A large number of marae and pā sites are situated along rivers in low-lying areas and are therefore highly exposed to flooding. There are a number of marae in the region with a history of flooding: Te Rangimarie marae in Rangiotū was inundated in 2015, Kauangaroa marae and Whangaehu marae both flooded in 2004, and Poupatate marae in Tokorangi was flooded in 2004, 1907 and 1870 (Hudson & Hughes, 2007; Stuff, 2016b).

In general, sites along the Whanganui and Manawatū rivers have higher exposure due to the scale of their catchments and floodplain extents (Paulik, Craig, et al., 2019). Risk from river erosion is rated as low for present day. Risk is projected to increase due to associated increases in the frequency and severity of flood events, which will exacerbate existing erosion conditions. Marae and pā sites located in close proximity to rivers are considered as more sensitive, as erosion of the river margin may cause damage to sites or complete loss of land (Whanganui River Māori Trust Board, 2021).

Extreme weather events currently pose a low risk to taonga. Risk is assessed as increasing to high by the end of the century due to projected increases in heavy rainfall, high winds and storminess (NIWA, 2019). Extreme weather events can damage taonga sites through the deposition of debris, wind damage and water damage. Marae and papakāinga sites that are located remotely such as Kaitupeka and Parewaka marae are more vulnerable, as road closures and damage to network infrastructure will indirectly impact accessibility to and from these sites (Stakeholder Engagement, 2021a). Risk from increased landslides and soil erosion to taonga is also currently rated as low. Risk increases from moderate to high in the mid to long term. Sites located in hill country terrain are more vulnerable where continued erosion can create unstable batter for buildings and structures. Landslides can damage or completely destroy sites, and significant sites embedded in the land may be eroded away (Historic England, 2021).

Sea level rise, coastal erosion and coastal flooding currently pose a low risk to taonga. Risk increases to extreme by the end of the century at coastal locations as a result of sea level rise and increasing frequency of storm tide events and associated coastal inundation (Paulik, Stephens, et al., 2019). Exposure is rated low where a large proportion of taonga sites are located inland and not directly within the coastal environment. Sites along the west coast, such as Kaiwharawhara pā, Taurahere marae, and Putiki marae , have higher exposure in comparison to the east coast where there are no known sites located in the coastal environment. Although exposure is low, sites located within low-lying coastal areas have high sensitivity to sea level rise, coastal erosion and coastal flooding – and these climate hazards may lead to the total loss of taonga sites. Adaptive capacity for these sites is rated low, and is limited to retreat and relocation of these sites. Given the intangible and intrinsic values of taonga sites, and strong cultural connection to land and location, retreat and relocation will likely affect the wellbeing of Māori (Welch, 2012).

Risk to taonga from increased fire weather is currently rated as insignificant, increasing to high by the end of the century. Fire risk increases with projected decreases in summer rainfall and increases in wind, and there is particularly high exposure for sites located in the east and in rural or wooded areas where fuel sources are higher (Scion Research, 2021).

Overall adaptive capacity for taonga is rated medium, given that relocation and maintenance of sites are feasible interventions. Historically, marae have been relocated in response to flood events. For example, Poupatate marae was relocated following floods in 1870 and 1907 (Hudson & Hughes, 2007).

Human intervention and the implementation of protective measures to ensure sites are protected against climate hazards includes the instalment of firebreaks, flood mitigation works, erosion and sediment controls, and regular maintenance of sites to reduce deterioration (Historic England, 2021).

9.3 Physical heritage

Risk to physical heritage from increased fire weather, extreme weather events, inland flooding, increasing landslides and soil erosion, coastal flooding, sea level rise and coastal erosion.

9.3.1 Introduction

Physical heritage covers archaeological sites, heritage buildings, bridges, churches and cemeteries. Heritage is of value as it contributes to the cultural fabric of communities and helps to gain an understanding of the past and how this shapes and defines the region's distinctive identity.

There are 377 sites within the region listed on the Historic Place Trust New Zealand Heritage List (Rārangi Kōrero). Historic bridges of significance include Hapuawhenua Viaduct, the Mangapurua Bridge to Nowhere and Springvale Suspension Bridge (D.O.C, 2021d). There are also 88 cemeteries in the region, located in close proximity to the region's settlement areas (Figure 9.1). Physical heritage is at risk from climate change hazards, which may cause damage or destruction to significant sites, buildings and structures.

9.3.2 Risk summary

Table 9.4: Risks to physical heritage by hazard

Hazard	Present	2050	2100	Commentary
Increased fire weather	Low	Moderate	High	Exposure low increasing with increased temperatures and wind, particularly in the east. Risk to rural sites, outdoor areas, wooden structures - damaged or total loss of physical heritage items dependent on material of sites, fire controls within area and location of fire services.
Higher temperatures	Low	Moderate	High	Exposure increases as frequency and intensity of severe weather events (storminess, wind, flooding) increases overtime. Damage to sites and building from higher winds, flooding and storm events -
Inland flooding	Low	Moderate	High	Higher exposure of low lying areas along major river catchment such as Whanganui and Manawatu Rivers where populations are also higher. Exposure increases with predicted increase rainfall and severe flood events. Associated with damage to buildings and sites from flooding effects.
Coastal flooding	Insignificant	Moderate	High	Exposure for the region is low, with high exposure for a number of spot locations along the coast such as Scotts Ferry and Old Waitarere Fire Station. Exposure increases as flooding events become more frequent and coastal inundation occurs.
Sea level rise and coastal erosion	Insignificant	Moderate	High	Low number of physical heritage structures located within the coastal inundation zone, however as sea level rises and larger areas of the coast become inundated, exposure increases.
Increasing landslides and soil erosion	Insignificant	Low	Moderate	Historic buildings and archaeological sites at risk where landslides could damage buildings, ground deformation could damage structural components and erosion of archaeological areas. Low exposure increasing overtime as landslides and erosion increases with frequency of extreme events.

Increased fire weather poses a low risk to physical heritage at present, and this is projected to increase to high by the end of the century. Rural sites, outdoor archaeological sites and wooden structures have the highest exposure to increased fire weather, with risk of damage or total loss of the physical heritage items dependent on site material, fire controls within the area and proximity of fire services (Stakeholder Engagement, 2021a). For example, heritage sites such as Horopito School and Karioi Native School are assessed as having higher exposure than Mangapurua Bridge to nowhere or Hapuawhenua Viaduct in the Ruapehu District (Ruapehu District Council, 2014).

Risk to physical heritage from inland flooding is currently rated low. Risk increases from moderate to high over the mid to long term. Sites located in low-lying areas along the Whanganui and Manawatū rivers are highly more exposed. Entrained objects such as historic bridges are highly exposed during flood events such as White Elephant Bridge near Erua, Wyley's Bridge Whanganui and Opiki Suspension Bridge (Ruapehu District Council, 2014; Whanganui District Council, 2020; Horowhenua District Council, 2015a). Extreme weather events are also assessed as posing a low risk to physical heritage at present, increasing to high by the end of the century. Storm events can damage or completely destroy heritage sites and also lead to long-term damage due to rot and other impacts (Meier et al., 2007).

Increased landslides and soil erosion are currently pose an insignificant risk, and this is assessed as increasing to moderate by the end of the century due to projected changes in rainfall. Exposure increases overtime as erosion effects may create an unstable batter for historic buildings, cause structural deformation due to ground movements and exposed archaeological sites are eroded away (Historic England, 2021).

Risk due to sea level rise, coastal erosion and coastal flooding to physical heritage is also currently rated as insignificant as most identified heritage and archaeological sites are presently not exposed to coastal hazards. Risk increases to high over the long term associated with ongoing sea level rise and coastal inundation (Paulik, Stephens, et al., 2019). The west coast, in particular, has a higher number of sites located within the coastal inundation zone than the east. Sites most vulnerable to coastal climate hazards include Scotts Ferry, Old Waitarere Fire Station, and other spot locations along the west coast.

Overall adaptive capacity for physical heritage is rated medium, given the feasibility of undertaking relocation and retreat. Other adaptive measures that can reduce exposure and vulnerability include fire prevention and fire control measures such as the instalment of fire breaks and fire bans, the instalment of flood control measures such as stopbanks, and regular maintenance of physical heritage sites to prevent long-term deterioration (Meier et al., 2007).

9.4 Parks, huts and tracks

Risk to parks, huts and tracks from increased fire weather, extreme weather events, inland flooding, increased landslides and soil erosion, sea level rise, coastal erosion and coastal flooding.

9.4.1 Introduction

Parks, huts and tracks are used for recreational purposes, and these sites are also a key part of the regional cultural identity. The networks of huts and tracks allows people to access the unique landscapes of the national and forest parks throughout the region. Huts and tracks allow people to feel more connected to nature and facilitate access to the region's unique ecosystems and untouched wilderness (New Zealand Tourism, 2021).

As shown in Figure 9.2 below, the region contains two national parks (Tongariro and Whanganui), five forest parks (Pureora, Tararua, Kaimanawa, Kaweka and Ruahine) and Tōtara Reserve Regional Park (Te Ara, 2007; Horizons Regional Council, 2021). The region also contains two of New Zealand's 'Great Rides'; the Mountains to Sea Cycle Trail located in the Ruapehu and Whanganui districts, and the Timber Trail located in Pureora Forest Park. The Tongariro Northern Circuit is a New Zealand 'Great Walk' and is one of only three in the North Island (Horizons Regional Council, 2018c), with the Whanganui Journey providing an exploration of the Whanganui River.

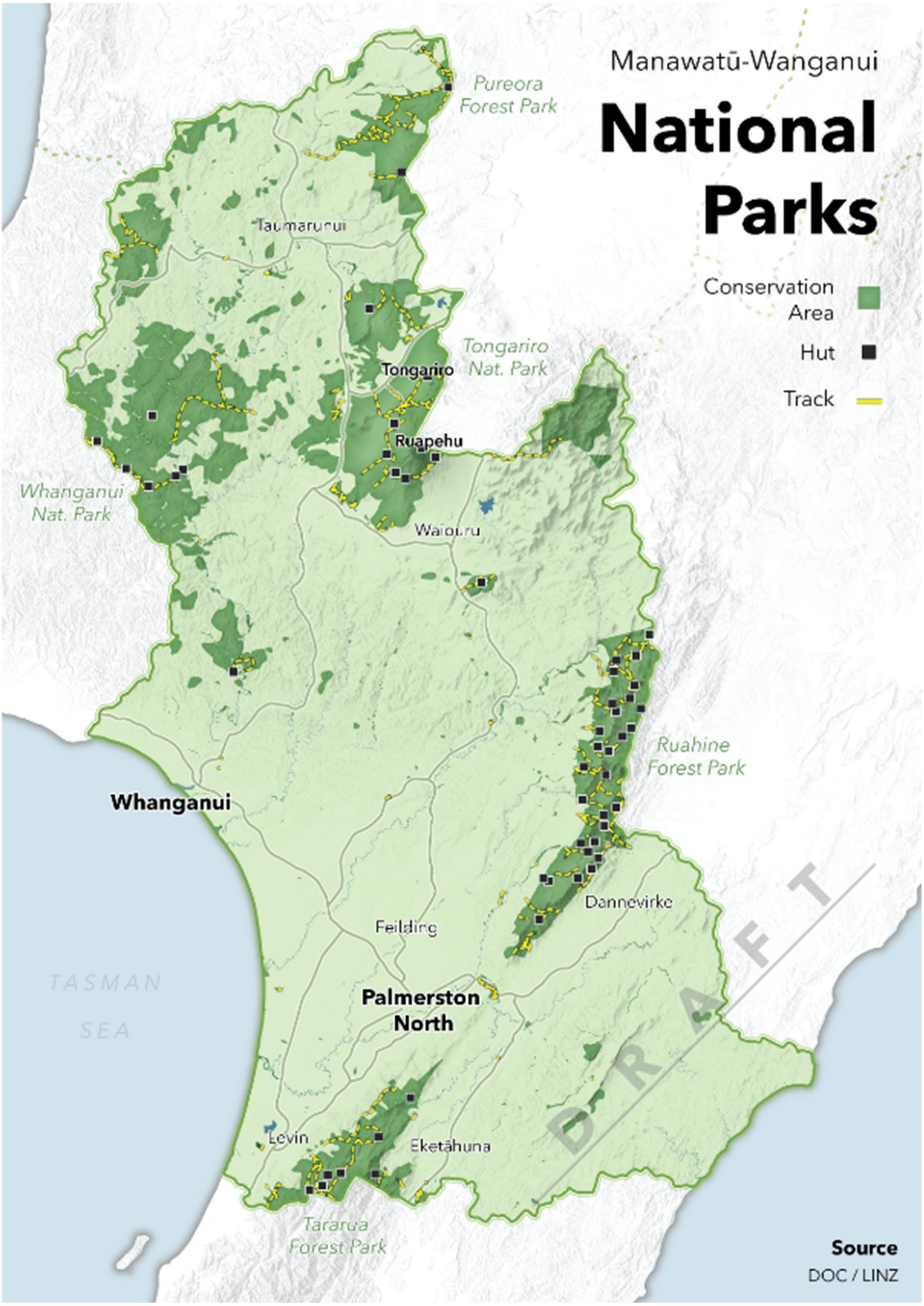


Figure 9.2: Parks, huts, tracks in the Manawatū Whanganui Region.

9.4.2 Risk summary

Table 9.5: Risks to parks, huts and tracks from differing hazards

Hazard	Present	2050	2100	Commentary
Increasing landslides and soil erosion	Low	High	Extreme	Large portion of the region is hill country with landslide exposure moderate, increasing overtime with increased intensity of rainfall. Sensitivity is moderate, also increasing overtime as rainfall events increase unstable areas. Adaptive capacity is moderate dependent on human intervention e.g. engineered solutions.
Inland flooding	Low	Moderate	High	Exposure increases with flood projections. Sensitivity remains constant where flood response would remain the same, and impact due to nature of activities. Moderate adaptive capacity dependent on human intervention.
Extreme weather events	Low	Low	High	Topographically varies due to Central Plateau mountains and Ruahine Ranges dividing the east/west. Strong gusts and gale force winds more common in high country. Increase with expected increased extreme rainfall and number of extreme events. Sensitivity likely to increase overtime.
Coastal flooding	Insignificant	Insignificant	Moderate	Exposure will increase overtime as frequency increases and morphological changes are experienced. Sensitivity is moderate increasing overtime to high, where impacts may prevent or extremely damage walkways and other recreational infrastructure along the coast.
Sea level rise and coastal erosion	Insignificant	Insignificant	Moderate	Inundation of low-lying coastal areas changing the way and ability for recreation within the coastal environment. Exposure increases as sea level rises and already eroded areas continue to erode. Sensitivity will also increase as coastal morphology changes.
Increased fire weather	Insignificant	Low	Low	Rural fires are most common throughout the region so lower risk to recreation. Higher fire risk around central region (Manawatu/Tararua districts). Exposure increasing overtime due to increased temperatures and wind. Low adaptive capacity due to nature of activities undertaken.

Landslides currently pose a moderate risk to parks, huts and tracks. Risk increases to extreme by the end of the century where a high proportion of the region's huts and tracks are located in mountainous and steep terrain prone to erosion and land movement. Exposure increases with projected increases in the frequency of extreme rainfall events, and exposure is likely to be exacerbated in areas with existing instabilities (Dymond & Shepherd, 2006). For example, Mangapurua Track on the Mountains to Sea Cycle Trail in Ruapehu District has a history of landslides, which has caused a number of track closures. Whanganui National Park is also prone to slips, due to much of land being formed of Papa Rock which is highly erodible during heavy rainfall and extreme events (D.O.C, 2011). Landslides and increased erosion can undermine, damage or completely destroy huts and tracks. Over the long term, erosion can cause ruts, deformation, and reduce accessibility to huts and parks for recreation. Regular maintenance and development of huts and tracks outside of erosion prone or extremely steep areas will result in improved adaptive capacity, and thereby reduce the vulnerability of huts and tracks to increasing landslides and soil erosion (D.O.C, 2008).

Risk from inland flooding to parks, huts and tracks is currently rated low, increasing to high by the end of the century due to projected changes in rainfall (NIWA, 2019). Tracks and huts located within rivers and within low-lying areas have higher exposure, such as Downes Hut along the Whanganui River, with large flood events causing closure of tracks and huts in the Whanganui National Park previously (D.O.C, 2015). A large number of the regions huts and tracks are located at higher elevations in the Central Plateau, Tararua and Ruahine Ranges (Figure 9.2) – these huts, tracks and other recreational infrastructure located in hill-country and mountainous areas generally have a lower exposure. Whilst exposure across the region is generally low, assets located in flood plains or close to the region's largest rivers such as the Whanganui are highly sensitive to flooding – this can result in assets being damaged or washed away completely. The placement of structures away from rivers where there is a high chance of flooding reduces risk (D.O.C, 2012).

Risk to parks, huts, and tracks from increased fire weather is currently rated insignificant, increasing low over the mid to long term. Rural pasture and forestry fires are currently occurring throughout the region, and these have been located away from a large proportion of huts, tracks and other recreational assets in the national and regional parks (Figure 9.2) (Scion Research, 2021). Parks, huts and tracks in the western region may be more highly exposed due to projected increased hot days and winds in the west compared to the east (NIWA, 2016). Sensitivity varies dependent on the composition of assets. For example, compacted dirt or gravel tracks have lower exposure than boardwalks or wooden structures. The management of fires in parks through prevention measures such as fire bans improves resilience (D.O.C, 2021c).

Risk to parks, huts and tracks from sea level rise, coastal erosion and coastal flooding is currently rated insignificant, increasing to moderate by the end of the century. There are a limited number of tracks located along the western or eastern coastlines of the region (see Figure 9.2) and exposure to coastal hazards is therefore low. Exposure to coastally located huts and tracks will increase overtime due to ongoing sea level rise and associated coastal inundation. As the frequency and severity of coastal flooding increases, changes to the morphology of coastal areas will occur (NIWA, 2019). Low-lying coastal tracks such as Sunset Walkway in Foxton and Castlecliff Domain in Whanganui are at particular risk due to coastal hazards.

Adaptive capacity for parks, huts and tracks is rated as medium overall, as in many cases it will be possible to reduce exposure by relocating assets and decrease vulnerability through increasing maintenance and climate-proofing at-risk structures. Although the cost of regular maintenance and asset relocation could be prohibitive due to the increasing risk profile and remote location of the regions tracks and huts.

9.5 Freshwater recreation

Risk to freshwater recreation due to drought, inland flooding and river erosion.

9.5.1 Introduction

Freshwater recreation covers all recreational activities undertaken on freshwater bodies including lakes and rivers. This includes swimming, kayaking, canoeing, rafting and fishing undertaken for leisure. There are 81 identified swimming sites in the region, monitored and rated for safe swimming (Figure 9.3). Additionally, the region contains over 17 identified kayaking runs including the Mangahao River slalom site, Rangitīkei River rafting and Whanganui canoeing which run year round, and sites such as Mangahao Gorge and the Whakapapa River which rely on dam releases (Whitewater NZ, 2021). There are a number of rivers renowned within the region for trout fishing including the Manawatū, Hautapu, Whanganui and Whakapapa rivers. Lakes such as Lake Whiritoa, Lake Namunamu and Lake Koitiata are known fishing locations (Fish and Game, 2021).

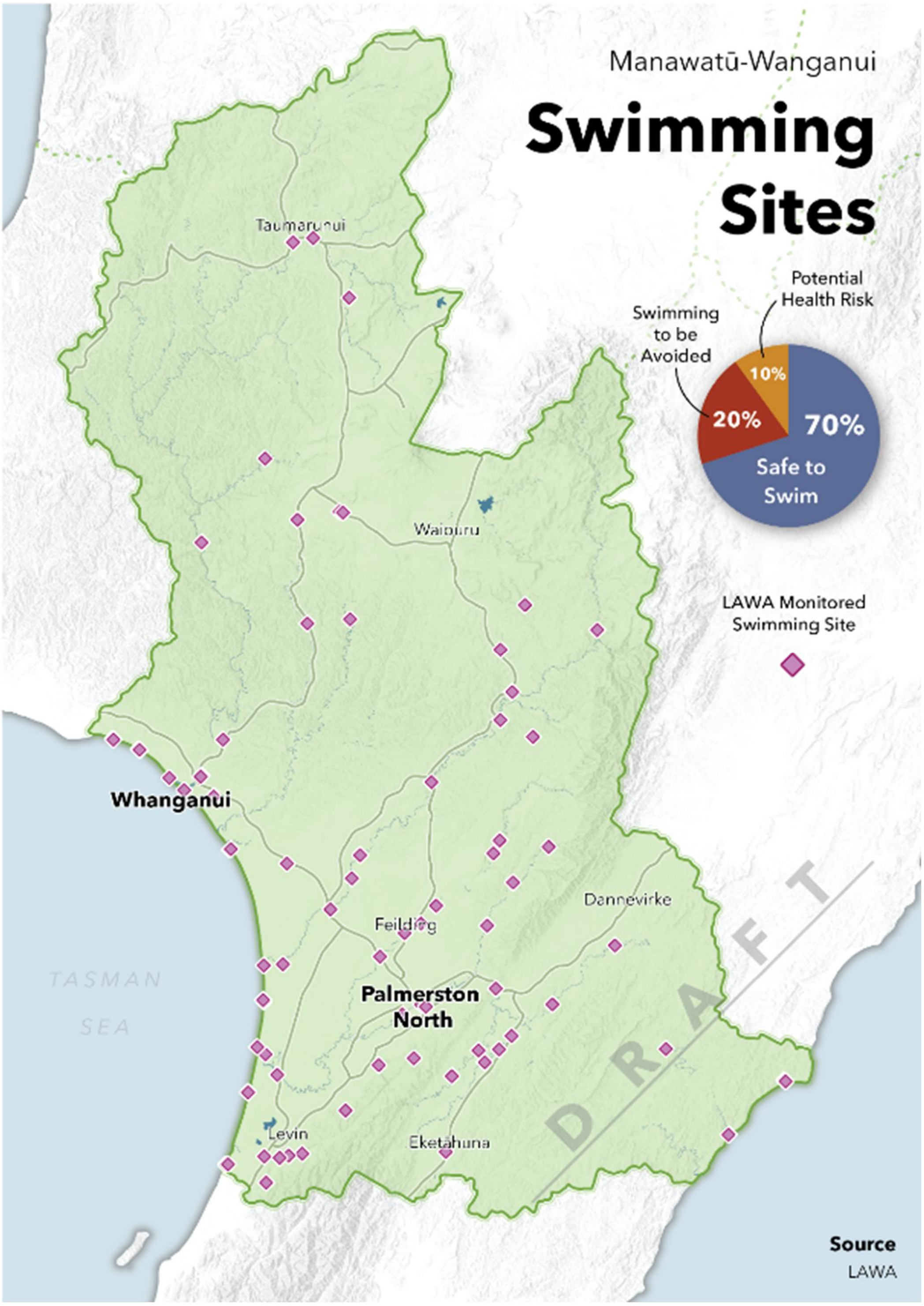


Figure 9.3: Monitored swimming spots in the Manawatū-Whanganui Region.

9.5.2 Risk summary

Table 9.6: Risks to freshwater recreation from differing hazards

Hazard	Present	2050	2100	Commentary
Inland flooding	Moderate	High	Extreme	Exposure related to rivers used as swimming spots, which when flooded render them dangerous/not useable. Flood events likely to increase with changes in rainfall and extreme events. Due to extent of river across the region exposure increases as flood risk increases. Sensitivity remains constant where effects of flood/response to for swimming remains the same. Low adaptive capacity.
Drought	Low	Moderate	High	Region is not typically drought prone so exposure currently low, this will increase overtime due to increased temperatures and changes in rainfall.
River erosion	Insignificant	Low	Moderate	Subset to inland flooding - exposure to erosion lesser than flooding but will increase over time as already eroded areas continue to erode and swimming areas potentially close. Sensitivity is low increasing to moderate overtime where erosion increases due to flood events and increased rainfall. Moderate adaptive capacity dependent on human intervention.

Risk to freshwater recreation from inland flooding is currently rated *moderate*, increasing from *high* to *extreme* in the mid to long term as flood events become more frequent and severe (NIWA, 2019). Rivers when flooded can become dangerous and unusable for swimming, fishing and other recreational activities. Swimming areas can become contaminated by farm and urban run-off after prolonged periods of rain and flood events, and swimming after flood events is not recommended for 2 – 3 days. Therefore, a reduction in the number of swimmable days per year is projected as a result of an increase in frequency of flood and storm events (LAWA, 2020). For activities such as white water kayaking and rafting, flooded rivers can improve the quality of the sport where certain rivers require higher flows for access. The Whangaehu, Manganui o te Ao and Rangitīkei rivers have low sensitivity to increased inland flooding as these rivers are identified as preferable for kayaking during flood flows (Whitewater NZ, 2021).

Risk from drought to freshwater recreation is currently rated *low*. Risk increases to *moderate* by mid-century and *extreme* by the end of the century associated with increasing temperatures and decreased rainfall, particularly over summer periods. Waterways in the eastern region used for recreation, such as the Rangitīkei and Oroua Rivers, have higher exposure where potential evapotranspiration deficit increases are expected east of Taihape (NIWA, 2019). Drought can increase the duration of low flows/water levels which may increase the risk of potentially toxic algal bloom occurrences. Algal blooms render these areas unsafe for swimming, alter species distribution with associated fishing limitations, and prevent sports such as kayaking and rafting being undertaken on rivers with low flows.

Adaptive capacity to flooding and drought is limited, associated with monitoring and minor maintenance works to improve and maintain accessibility for freshwater recreation. For example, monitoring of known recreational sites and the provision of hazard warnings to prevent recreation during dangerous flood events or at low flows when there is a risk to human health. Additional adaptive measures could include increased maintenance of access to sites which may be damaged and clearing of debris from flood events.

The risk from river erosion to freshwater recreation is currently rated *insignificant*, increasing to moderate by the end of the century associated with projected increase in the average number of high flow events. Larger increases in rainfall are expected for the western region during winter, with particularly high exposure on the Whanganui River (NIWA, 2019). The Whanganui River is well known for freshwater recreation activities including canoeing, fishing and swimming at various locations along its entire extent. High flow events will exacerbate river erosion in already eroded areas, increase sedimentation and cause changes to river morphology. Rivers used for recreation such as the Whanganui have high sensitivity to river erosion as access to swimming and fishing spots may be damaged or destroyed, changes in the morphology may change or reduce river navigability and increased sediment/nutrient loads may also render waters dangerous to human health. Adaptive capacity is rated medium, dependent upon engineered solutions and technological advances such as new boat designs that can access rivers made inaccessible and erosion control works (New Zealand Conservation Authority, 2011).

10 Governance

Governance is understood as the relationships between, coordination mechanisms for, and processes undertaken by the state, market and civil society to address collective issues (Driessen et al., 2012; Lange et al., 2013).

The governance value definition used in this risk assessment is aligned with the definition used in the NCCRA. Governance is defined as the governing architecture and processes of interaction and decision-making that exist in and between local and central government, and economic and social institutions. Governance permeates all aspects of New Zealand, from the Treaty partnership between Māori and the Government (the Crown) to the relationship between local government and communities, from the economy to the built environment to natural ecosystems.

The governance risks have not been rated in this section, as ranking or prioritising was not considered useful given the complexity of governance systems and paucity of data. A summary of the governance risks within the NCCRA is provided in Table 10.1.

Table 10.1: Risks to governance identified during the NCCRA

Risk statement	
Potential maladaptive outcomes	Maladaptation due to failure to account for uncertainty and change over long timeframes.
Institutional arrangements	Impacts exacerbated through unsuitable institutional arrangements (including legislative and decision-making frameworks, coordination within and across levels of government, and funding mechanisms).
Litigation risks	Litigation, due to inadequate or mistimed climate change adaptation.
Treaty of Waitangi	Breach of Treaty obligations through a failure to engage adequately or protect Māori from climate change impacts.
Limited research in adaptation	Delays due to underinvestment in adaptation research and capacity building.
Emergency events	Ability to respond to more frequent, more severe, and compounding emergency events.
Political support	Failure to secure political support to implement and sustain adaptation policy.
Democratic institutions	Ability of democratic institutions to cope with compounding and cascading climate change impacts.

These national level governance risks are discussed within this section, looking at their relationship to the communities within the region, and the potential impacts they may have at a local level.

10.1 Potential maladaptive outcomes

With climate change and other global macro risks, the Manawatū-Wanganui Region faces a highly uncertain future (World Economic Forum, 2021). Future projections of climate change are uncertain, as the global emissions trajectory and sensitivity of the New Zealand climatic system to greenhouse gas emissions cannot be predicted with accuracy. This uncertainty is due to limitations in the understanding of climate processes, natural climate variability, and future social and economic changes (Ministry for the Environment, 2020).

This deep uncertainty results in institutional challenges, particularly over long timeframes. New Zealand's present regulatory and policy frameworks are ill-equipped to manage uncertainty, which can lead to maladaptive outcomes as shown in Figure 10.1 (Lawrence et al., 2021). For example, planning frameworks used in the region rely on static assumptions of risk (such as a 1-in-200-year flood event), which can result in path dependency, a false sense of security for households, and rigid and inflexible interventions that are inflexible to changing levels of risk (Lawrence et al., 2013).

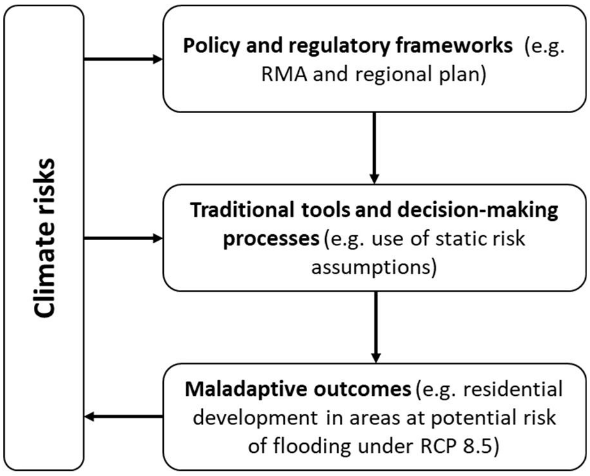


Figure 10.1: Summary of climate risks affecting existing policy and regulatory frameworks

Decisions need to be made, but the use of current approaches and frameworks that do not account for uncertainty and changing risk profiles can result in maladaptive outcomes. Maladaptation arises not only from poorly planned and designed adaptation actions, but also from deliberate decisions where greater emphasis is placed on short-term outcomes ahead of longer-term threats, or the full range of interactions arising from planned actions are not adequately considered (Noble et al., 2014).

10.1.1 Risk summary

As institutions are based on well-established disciplines, including law, engineering and economics, the frameworks used for decision making have a bias towards the status quo. This results in challenges to addressing climate risks, as property rights and the present location of infrastructure and communities are likely to create challenges for the implementation of adaptation strategies, particularly actions to reduce exposure to ongoing sea level rise and inland flood risk (Boston & Lawrence, 2018).

In addition, the high cost of adaptation action, particularly if this is perceived as being unfairly borne by households, could result in opposition and delays and the retaining of inappropriate traditional responses that maintain the status quo (Boston & Lawrence, 2018). Existing institutional and democratic processes may not sufficiently allow for the urgent action that is required, as these systems are slow-moving and can be captured by actors that delay adaptation proposals (Simon et al., 2020).

Decision-makers in the region, therefore, require new processes and tools that can better manage uncertainty, expedite urgent adaptation actions, and result in equitable and fair outcomes (Ministry for the Environment, 2020). Dynamic adaptive pathways, are one such approach, that have provided some help to decision makers nationally, including through the application of the national Coastal Hazards and Climate Change Guidance to greenfield developments and major new infrastructure (Lawrence et al., 2018).

The development of new frameworks and processes, including the National Adaptation Plan (NAP) and the Climate Change Adaptation Act (CCA), will also help to avoid maladaptive actions through improving coordination, providing guidance on the design of interventions, addressing complex issues associated with managed retreat, and providing clarity on sources of financing (Beehive, 2021; Mead, 2021). The Horizons Regional Council One Plan, which is the Consolidated Regional Policy Statement, Regional Plan and Regional Coastal Plan for the Manawatū-Wanganui Region, will need to be aligned to these processes.

The continued application of processes and tools that do not account for uncertainty and increasing risk profiles could result in increased exposure of communities in the region to climate change hazards. This risk will disproportionately impact the region's most vulnerable people and communities and future generations. Maladaptive actions may also result in cascading risks to other systems and sectors, and increase the overall cost of adapting to climate change for the region (Ministry for the Environment, 2020).

10.2 Institutional arrangements

Undertaking effective adaptation requires well-designed institutional and governance arrangements to ensure legislative and policy alignment, strong coordination across levels of government and with different sectors, and the availability of sufficient funding to support adaptation (Ministry for the Environment, 2020).

At summarised in Figure 10.2, the existing institutional frameworks at both the national and local level in New Zealand are unsuitable, resulting in barriers to implementing adaptive measures (Boston & Lawrence, 2018). There is inadequate coordination between local and national level government agencies, with a lack of legal clarity and overlapping responsibilities – this results in delayed decision-making processes and can hamper proactive action (Climate Change Adaptation Technical Working Group, 2018).

Existing policy and planning frameworks can also result in poor coordination of adaptation actions between national government, local government and the community level groups (Boston & Lawrence, 2018). This does not allow for a genuine and effective partnership across layers of government and with communities and iwi and hapū.

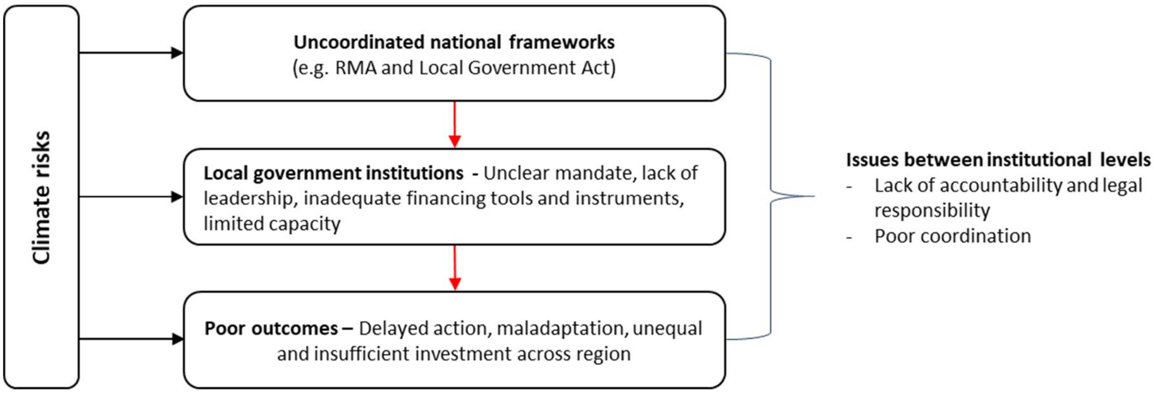


Figure 10.2: Issues with existing policy and planning frameworks

Local government agencies have been allocated major legal responsibilities across a number of statutes that are either directly related to undertaking climate action or are impacted by climate risks. Regional and territorial authorities have unclear roles in implementing these statutory responsibilities and managing climate-related implications, which can lead to fragmented planning and decision-making and a lack of clarity on the legal liability of public agencies in the region (Climate Change Adaptation Technical Working Group, 2018; Manning et al., 2015).

The failure to adequately invest in adaptation initiatives is another potential barrier, and delaying action will likely result in higher adaptation costs (Boston and Lawrence, 2018). The current financing frameworks are not fit for purpose, and regional and territorial authorities are constrained by a reliance on rates, debt limits, and central government grants and subsidies (New Zealand Productivity Commission, 2018). In the absence of clear financing frameworks and responsibilities from central government, there may be an expectation for compensation from local government for private losses resulting from climate change.

10.2.1 Risk summary

The current institutional arrangements can result in delayed action, low accountability and a lack of leadership, and regional and territorial authorities have limited tools for implementing adaptive measures. These arrangements could potentially exacerbate climate change risks and result in maladaptive outcomes (Boston & Lawrence, 2018), which could include: (a) coastal developments that are highly exposed to coastal hazards; (b) urban sprawl and associated infrastructure risks; and, (c) flood protection schemes resulting in moral hazards.

In summary, the key risks resulting from currently institutional arrangements are:

- The risk of delayed action due to the unclear mandate of regional and territorial authorities; inadequate and poorly aligned statutory and policy frameworks; and competing national interests and political uncertainty (Climate Change Adaptation Technical Working Group, 2018).
- Action can also be delayed as result of low accountability and a lack of leadership, as private interests demand public authorities to manage their climate risks and local authorities look to central government for guidance. This fragmented effort increases the risk of litigation, which may also result in delayed action (Lawrence et al., 2013).
- Inadequate financing tools and instruments prevent action, as regional and territorial authorities do not have the mandate or fiscal capacity to invest in climate-resilient infrastructure, support the private sector with addressing risks, and protect the livelihoods of communities. The present capacity of councils across the Manawatū-Wanganui Region is also varied, which may result in an unequal delivery of outcomes.

Central government is conducting a number of significant reforms and policy design at present, which should help to build the adaptive capacity of local authorities (Beehive, 2021). The repeal and replacement of the Resource Management Act 1991 (RMA) with the three new Acts, including the CCA, will help over the medium term to address some of these institutional issues raised in this section. Central government is also changing the policy and regulatory landscape with the development of the NAP and other climate change planning and reporting frameworks. These processes will help to provide further clarity on how regional and territorial authorities can finance climate action, including the compensating communities for planned relocation (Mead, 2021).

Councils across the region realise the importance of acting on adaptation, and would like to act with urgency. While central government action is likely to improve the situation over the medium-term, these changing frameworks will likely result in a number of governance challenges for regional and territorial authorities over the short-term.

10.3 Litigation risk

Public authorities are facing increasing litigation that has the aim of either advancing or delaying effective action on climate change. This is a global trend, and the number of strategic cases that aim to bring about some broader societal shift are dramatically on the rise (Setzer & Higham, 2021).

While climate change litigation remains in its relative infancy in New Zealand, there have been a few significant cases in recent years that have focused on mitigation action (Russell McVeagh, 2021). It is unclear if there have been any cases in the Manawatū-Wanganui Region.

In line with global trends, climate litigation is expected to increase in New Zealand in the future. Hodder (2019) states that “current local government litigation risk mostly relates to decisions to limit development (short-term judicial review)”. While in the future, “it seems likely to extend to the consequences of allowing development and failing to implement adaptation measures (e.g. from homeowners suffering the physical and economic consequences of climate change in the longer term)”.

10.3.1 Risk summary

Potential litigation on climate action in the region may result in a low tolerance of risk, which could limit public sector action. Public authorities may be at risk of litigation if action is not undertaken, and also at risk if the action undertaken that is deemed to be inadequate or in conflict with the views of private individuals or communities (Iorns, 2021). This may, in turn, polarise communities, particularly in relation to contentious decisions such as managed relocation of households. Increased litigation risk could also result in additional expenses for public authorities, which could impact the resourcing of other activities such as achieving climate action. The region requires clear guidance from national government, and the passing of the Climate Change Adaptation Act should help to provide more legislative clarity to local authorities (Mead, 2021).

10.4 Treaty of Waitangi

There are several iwi and hapū group who are mana whenua or have interests within the region, and a series of Treaty settlements have been negotiated over the past two decades[6]. These settlements are frameworks which outline obligations and responsibilities between the Crown and mana whenua in specific situations.

These situations may be altered by climate change, particularly the impact of sea level rise, which will result in impacts on economic, environmental, social and cultural values, practices and relationships. The impacts of climate change on Treaty settlements in the region will require careful consideration to ensure that Treaty obligations are maintained, and strong governance processes are in place.

10.4.1 Risk summary

The form and extent of Māori involvement in local decision making is changing, which includes Māori representation on the Horizons Regional Council from 2022. There is, however, limited capacity for both iwi and hapū groups to engage with local authorities in the region, and climate change may exacerbate engagement issues.

Climate change may result in particular impacts to partnership, participation and protection, which are the principles that underpin the relationship between the Government and Māori under the Treaty of Waitangi.

The failure to engage Māori and mana whenua adequately in climate-related decision making and protect future generations from climate change impacts may result in a breach of Treaty obligations (Iorns, 2019; Ministry for the Environment, 2020). Issues with engagement may also result in delays in climate action, which could also lead to harm to Māori and Māori cultural sites and practices.

At present, there are Treaty claims relating to climate change with the Waitangi Tribunal, which has determined that climate change is a Treaty issue because of the need to prevent harm to Māori coastal property (Iorns, 2019; Ministry for the Environment, 2020).

10.5 Limited research in adaptation

While there has been wide ranging research on climate hazard projections and the vulnerabilities of elements and assets, there remain significant research gaps. Much of the research undertaken has focused on the national and global level, with limited research on the specific vulnerabilities faced by Manawatū-Wanganui region.

Moreover, the Climate Change Adaptation Technical Working Group (2018) stated there is a critical under-investment in research in key sectors and thematic areas, including biophysical and ecological changes, biosecurity, changes in the hydrological cycle influencing fluvial and pluvial flooding, and the implications of climate change for human systems such as the economy, health and health services.

[6] There are also ongoing Treaty settlements in region.

10.5.1 Risk summary

There is overwhelming agreement and evidence that climate change will exacerbate existing risks and result in new risks for the region (Ministry for the Environment, 2020). The effective management of future risk requires an evidence-based approach to identify risks and design and implement effective adaptation actions.

Additional investment in research on community-level and regional risks is required to strengthen understanding of local hazard projections (e.g. fire weather and inland flooding), the exposure of particular assets and systems to climate hazards (e.g. undocumented landfills and the tourism sector), and specific local vulnerabilities (e.g. the impact of climate change on vulnerable groups in the region). Climate change will also result in non-linear risks and complex cascading risks, and additional research is needed to understand how these risks may impact the region.

Limited investment in adaptation, due to a lack of resources and the scale of the climate change challenge, will also have governance implications. The development of capacity in local authorities to address and manage climate change impacts requires an understanding of the future needs of the region, and this will, in part, be shaped by the impact of climate change on communities, the natural environment, economy and built environment.

10.6 Emergency events

With climate change resulting in increased incidences of extreme weather, along with changing mean conditions, there will be an increase in emergency events that require response to, and recovery from. These events could be increases in the number and severity of events already experienced within the region, such as flooding, along with occurrences of events that are, as yet, not experienced extensively in the region, such as heatwaves.

Significant events will likely result in the need to draw on resources from surrounding regions not just those impacted by the event, therefore requiring clear coordination at national and regional levels for consistency in emergency response and recovery. Ensuring community participation in preparedness and response planning will be essential for the successful response and recovery from the potential increase in emergency events due to climate change (van Krieken et al., 2017; Curtis et al., 2017; Ghazali et al., 2018; van Vonderen, 2018).

10.6.1 Risk summary

Changing hazards will interact with changes in exposure (including maladaptation risks highlighted above), as well as changes in insurability (including emergency relief reserves) and, potentially, in social cohesion / volunteerism. Climate change affects the emergency management sector's capacity to support preparedness, response and recovery efforts. This means that occurrences of similar hazards in the future may have more adverse impacts for communities, given the lack of capacity in the system to respond. In particular, rural populations, common across the region and which include a high representation of Māori communities, are usually dispersed across less accessible landscapes, which can leave them more exposed to the impacts of hazards.

This increase in demand on the emergency management system may impact on other public services as the funding for Civil Defence Emergency Management (CDEM) functions may be drawn from elsewhere. Furthermore, the increased financial recovery costs from events (associated with damage) may not be able to be met from public funding, reducing not only the ability to recover, but to undertake recovery in a more climate resilient way.

10.7 Political support

There is a risk that political support to implement and sustain adaptation policy will not be secured. The scale, nature and ambition of the responses will be affected by both national and local politics. Climate action in New Zealand has largely had bipartisan support in recent years, as shown by the unanimous support for the Zero Carbon Bill (Newsroom, 2019). Bipartisanship supports policy design and allows for consistent government guidance, ongoing funding commitments, and the long-term certainty needed for effectively responding to climate change (Ministry for the Environment, 2020). As climate change impacts escalate, and the costs of implementing adaptation action increases, there is a risk that political support will reduce due to the level of disruption experienced.

10.7.1 Risk summary

A weak political mandate may favour popular interventions over transformative ones. Given New Zealand's short electoral cycles, elected representatives and governments are often influenced by short-term priorities and are biased towards maintaining the status quo. To achieve effective adaptation responses, elected representatives at the local, regional and national level will need to make difficult decisions that balance the long-term benefits of climate action with short-term costs.

Local government is likely to be responsible for many contentious decisions – for example, managed retreat – which will involve significant consultation and may invoke community resistance. Influential parts of the community may lobby local authorities to develop maladaptive adaptation measures, such as sea walls, instead of retreating, which could exacerbate long-term costs. In addition, costs may fall disproportionately on less influential parts of the community, especially if political uncertainty results in a need for unmanaged retreat (Hanna et al., 2021).

There is a risk that political bipartisanship may lead to unclear long-term signals at the national level and a loss of public support, which would make it difficult to plan and implement effective local responses. Political disagreements could also result in less coordinated and timely action, exacerbated adaptation costs, increased risk of maladaptation and litigation-related risks (Ministry for the Environment, 2020). A failure to secure political support to sustain climate action may also result in disorderly adaptation approaches that lead to inequitable outcomes.

10.8 Democratic institutions

Democracies are dependent on transparent and accountable decision-making, and New Zealand's democracy is regarded as fair, functional and effective (Freedom House, 2020). Climate change may result in risks to democratic processes as a result of compounding and cascading impacts and extreme events.

While there is limited research on the impact of climate change on democratic functioning, it is foreseeable that climate change could create situations that bypass standard consultative processes and curtail public involvement in decision-making processes (Ministry for the Environment, 2020).

10.8.1 Risk summary

At the local level, democratic institutions may not facilitate timely and effective decision-making due to resource constraints and the inertia of statutory processes. This may exacerbate climate impacts, leading to reduced public confidence in democratic decision-making processes. The Local Government Review will help to improve understanding of the magnitude of this risk.

The increasing frequency and severity of extreme events may also result in risks to democratic processes in central government. Both Covid-19 and the Christchurch earthquakes are examples of how extreme events can require unprecedented political responses, and extreme climate events may also result in the temporary disruption of democratic rights and constitutional procedures (Ministry for the Environment, 2020; Williamson, 2020).

11 Knowledge gaps and future research

We recognise that there are knowledge gaps across the risks identified. This is the result of a lack of readily available information, where some information will be available from further engagement with wider stakeholders, and other information requiring future research. Key knowledge gaps are captured below by community value.

Table 11.1: Key knowledge gaps captured under community values

Research area	Key knowledge gaps
Exposure	· Landfills: limited knowledge and understanding of the quantum of informal, legacy landfills within the region, and their associated location in relation to known hazards. · Sites of cultural significance: spatial mapping of sites of cultural significance is incomplete for the region, limiting the confidence in exposure assessment. · Freshwater recreation: Key sites are known for the region, however many locally significant sites are not documented, limiting the assessment of scale of areas to generic location assumptions. · Public spaces: limited understanding of exposure of key public spaces and buildings, e.g. hospitals and fire stations, and the services these provide. · Climate events: The exposure of all value areas to extreme weather events is highly uncertain (e.g. extreme event experienced in Halcombe in 2018). With the frequency and severity of extreme weather events projected to increase, further research is needed to improve predictive capacity and understand exposure.
Vulnerability / impacts	· Flood management schemes: we recognise that there is currently a lack of readily available documented information regarding wider information for flood management schemes and associated infrastructure for the region, which reduces the confidence in rating risk. · Energy: risk ratings are provided, however the impacts of specific climatic changes, such as rainfall, on generation systems requires further information to provide confidence to the risk ratings. · Health: limited understanding of climatic impacts on health of vulnerable populations, including groups and communities with pre-existing conditions and high levels of social deprivation. Differences in vulnerabilities between urban, rural and socially deprived communities is also poorly understood. · Social capital: the understanding of underlying population demographics and vulnerabilities are based on pre-COVID datasets and information, which are unlikely to be representative of present communities. Differences in

	vulnerabilities between urban, rural and socially deprived communities is also poorly understood. · Land-use (agriculture and horticulture): Limited understanding of how climate risks will result in broader social and economic impacts to rural communities. · Institutional arrangements: · Tourism: similarly to social capital, much of the information presented is pre-COVID, with only anecdotal information available around current tourism activities and the level of adaptation given the impacts of COVID on the sector. Limited information on impacts of tourism-related climate risks on the regional economy, including employment, GDP and wider sectoral impacts. · Marine ecosystems: further acknowledgement and recognition of the impacts of climate change on marine ecosystems for the region by stakeholder groups is required to provide more reflective risk ratings.
Adaptation	· Understanding of underlying adaptation actions underway is required to provide an ability to effectively evaluate urgency of each risk. · Understanding of how existing adaptation actions could result in maladaptive outcomes and increased/additional climate risks. · Understanding of how changing national frameworks (e.g. RMA reform) will impact on adaptation processes in regional and territorial authorities.

12 Closing remarks

This document provides a broad understanding of climate change risks within the Manawatū-Whanganui Region presently, and how these may change over time, based on current understanding of climate science and climate projections. This document forms part of an ongoing journey to understand and respond to climate change and is designed to help inform steps toward adaptation. Through undertaking this regional CCRA in collaboration with Treaty Partners, Regional Council, Territorial Authorities and wider stakeholders, it is hoped that each stakeholder group feels a level of ownership and continues this important journey toward climate adaptation.

This regional CCRA sits within a wider cycle of climate risk assessment and associated adaptation at a local, regional and national level. Figure 12.1depicts the existing process for climate change risk assessments and adaptation planning. The desire is that local risk assessments and adaptation plans inform those at a regional level, and subsequently these assessments inform the National Adaptation Plan (NAP) and associated National CCRA. The first NAP is due for publication in 2022, with timeframes for review likely every five years, aligned to that of the National CCRA.

This provides a natural cycle for local and regional risk assessments and associated adaptation planning, following a similar timeframe to that at a national level, ensuring publication of regional assessments and plans in advance of the NAP review. It is recognised that Long Term Planning (LTP) processes occur on a three year cycle, resulting in a potential mismatch in planning for climate adaptation, and associated implications on funding. Consideration on the cycle of adaptation planning is required to best inform the NAP while aligning to financial requirements of LTP.

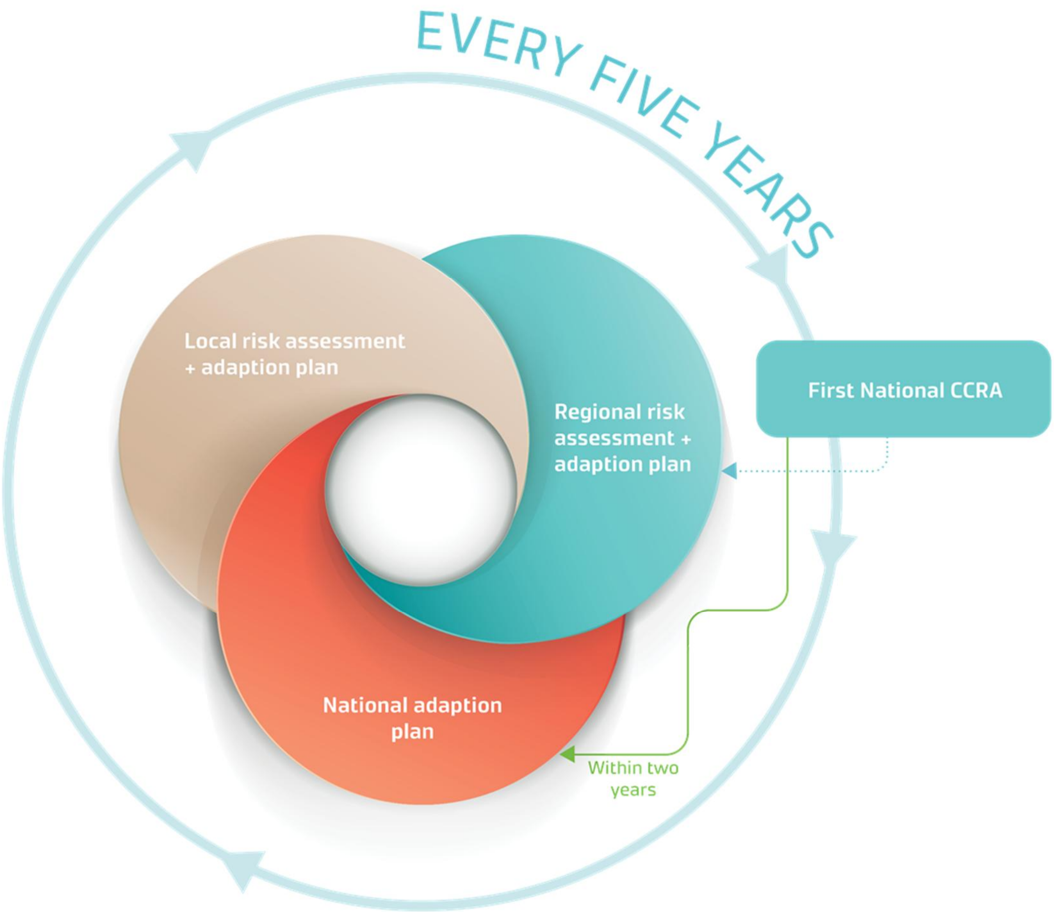


Figure 12.1: Cycle of local, regional and national climate risk assessment and adaptation planning.

12.1 Next steps

To support the progression toward adaptation, the next step is to consider the risks highlighted within this document, and agree which should be prioritised for adaptation planning. This should continue through a collaborative approach, identifying risk owners, and the role of Horizons Regional Council for each of the risks. Horizons Regional Council's role relating to action for each risk could include direct ownership, along with the need to advocate for and inform other risk owners and decision makers. Ensuring buy-in across risk owners, stakeholders and the wider public is fundamental for effective action now and into the future.

This process of prioritising risks for adaptation planning could be undertaken in a number of ways, but will likely include:

- Review of the *risk ratings* and associated *strength of evidence* (including knowledge gaps);
- Consideration of *urgency* through establishing action already underway; and
- Wider consideration of *consequences*.

Urgency is defined as 'a measure of the degree to which further action [including adaptation] is needed in the next five years to reduce a risk or realise an opportunity from climate change' (Committee on Climate Change, 2017). Urgency provides a further prioritisation of risks based on the breakdown of the risk against key urgency criteria, shown in Table 12.1 below.

Table 12.1: Urgency criteria

Urgency Criteria	Explanation
Watching brief	No action foreseen over next five years. Likely a low risk over short to mid-term. Low level of interaction with other risks.
Sustain current action	Current actions considered sufficient over the next five years.
Research priority	More knowledge (research) is needed now to inform action in next 5-10 years. Likely a high risk, but not well understood.
More action needed	Action (either as acceleration of current action, or new action) is needed for adaptation in next five years. Likely a high risk, and well understood. Presents potential for lock-in.

Rating urgency is strongly dependent on the institutional knowledge within Council and Territorial Authorities, along with wider Treaty Partner and stakeholder groups. Through establishing a stocktake of current climate change action underway for the region, effective urgency ratings can be established, providing a natural next step for the adaptation journey.

Beyond the technical nature of each risk, including exposure and vulnerability, consideration of the consequences (or consequential impacts) may aid prioritisation.

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14 Applicability

This report has been prepared for the exclusive use of our client Horizons Regional Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

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Appendix A: Risk database

DRAFT Manawatū-Whanganui CCRA Risk Workbook

Community Value	Element at Risk	Climate hazard	Risk statement	Exposure			Vulnerability				Risk			Commentary	NCCRA Domain
							Sensitivity			Adaptive capacity					
				Present	2050	2100	Present	2050	2100		Present	2050	2100		
Te Ao Tūroa | Natural world	Biodiversity and ecology	Marine heatwaves	Risk to biodiversity and ecology from marine heatwaves	Moderate	High	High	Moderate	High	High	Low	Moderate	Extreme	Extreme	Marine heatwaves projected to increase as sub-tropical front migrates further south over time. East/West coast ocean currents will have an effect on local changes, heatwaves may be mitigated somewhat close to large rivers.	Natural
Te Ao Tūroa | Natural world	Biodiversity and ecology	Ocean acidification	Risk to biodiversity and ecology from ocean acidification	Moderate	High	High	High	High	Extreme	Medium	Moderate	High	Extreme	Ocean acidification projected to increase by 2100. Sensitivity is high, adaptability is moderate for existing ecosystems.	Natural
Te Ao Tūroa | Natural world	Biodiversity and ecology	Higher temperatures	Risk to biodiversity and ecology from higher temeprature	Moderate	Moderate	High	Moderate	High	High	Low	Moderate	High	Extreme	Increasing risk where native/taonga species have lower heat tolerance, changing abundance and distribution of species. Species distribution expected to move southward and increase in altitude. Low adaptive capacity.	Natural
Te Ao Tūroa | Natural world	Biodiversity and ecology	Change in rainfall	Risk to biodiversity and ecology from change in rainfall	Moderate	Moderate	High	Moderate	Moderate	High	Low	Moderate	Moderate	Extreme	Rainfall distribution changes leading to increased rainfall events expected to become more common on the western side of the Plateau.	Natural
Te Ao Tūroa | Natural world	Biodiversity and ecology	Drought	Risk to biodiversity and ecology from drought	Low	Moderate	High	Moderate	Moderate	High	Low	Low	Moderate	Extreme	Potential evapotranspiration index likely to increase over time, so droughts expected to become more frequent/extreme, with exposure increasing with frequency. Large areas of native, particularly in the north are not drought prone. Low adaptive capacity.	Natural
Te Ao Tūroa | Natural world	Biodiversity and ecology	Increased fire weather	Risk to biodiversity and ecology from increased fire weather	Low	Moderate	High	Moderate	Moderate	High	Low	Low	Moderate	Extreme	Increased summer fire weather on western side of region (hot days and lower summer rainfall).	Natural
Te Ao Tūroa | Natural world	Biodiversity and ecology	Coastal flooding	Risk to biodiversity and ecology from coastal flooding	Moderate	High	Extreme	Moderate	Moderate	High	Medium	Low	Moderate	Extreme	Increased frequency/severity of storms leading to increased coastal erosion and habitat destruction/sedimentation of near-shore environment.	Natural
Te Ao Tūroa | Natural world	Biodiversity and ecology	Sea level rise and coastal erosion	Risk to biodiversity and ecology from sea level rise and coastal eroion	Moderate	High	Extreme	Moderate	Moderate	High	Medium	Low	Moderate	Extreme	Sea level rise may lead to a squeeze of the coastal margin, reducing habitat area for coastal ecosystems.	Natural
Te Ao Tūroa | Natural world	Biodiversity and ecology	Sea level rise and salinity stress	Risk to biodiversity and ecology from sea level rise and salinity stress	Low	Moderate	Moderate	Low	Moderate	Moderate	Low	Insignificant	Moderate	Moderate	Increased salinity in coastal areas due to sea level rise affecting species distribution and assemblage, particularly diadromous fish.	Natural
Te Ao Tūroa | Natural world	Biosecurity	Extreme weather events	Risk of increased invasive species and disease due to extreme weather events	Moderate	Moderate	High	Moderate	High	Extreme	Low	Moderate	High	Extreme	Invasive pests are better colonisers and will outcompete natives to re-establish in an area. Infectious disease outbreaks often follow extreme weather events where environmental conditions are disrupted. Low exposure increasing overtime as frequency and severity of events increases. Moderate sensitivity and moderate adaptive capacity dependent on human intervention and medical advancements.	Natural
Te Ao Tūroa | Natural world	Biosecurity	Higher temperatures	Risk of increased invasive species and disease due to higher temperatures	Low	Moderate	High	Moderate	High	Extreme	Low	Low	High	Extreme	Increased risk to human health where increased temperatures bring in new diseases and create more favourable breeding environments. Low exposure increasing overtime where rate of disease or infection may increase. Moderate adaptive capacity dependent on human intervention e.g. biosecurity and medical advancements	Natural
Te Ao Tūroa | Natural world	Biosecurity	Drought	Risk to natural habitats and native species due to drought	Low	Low	Moderate	Moderate	Moderate	High	Low	Low	Low	High	Invasive plant species are better suited to drought conditions, and will grow at a quicker rate than/ out compete native species during drought.	Natural
Te Ao Tūroa | Natural world	Biosecurity	Drought	Risk of increased invasive species and disease due to drought	Low	Moderate	Moderate	Moderate	Moderate	High	Medium	Insignificant	Low	Moderate	Increased risk to human health due to water shortages and low flows, increasing level of pollutants of waterborne diseases within water. Medium adaptive capacity through water filtration and cleansing measures.	Human
Te Ao Tūroa | Natural world	Freshwater ecosystems	Higher temperatures	Risk to freshwater ecosystems due to higher temperatures	Moderate	Moderate	High	Moderate	High	High	Low	Moderate	High	Extreme	Most freshwater species sensitive/intolerant of increases in temperature, with water temperature expected to increase with air temperature.	Natural
Te Ao Tūroa | Natural world	Freshwater ecosystems	Change in rainfall	Risk to freshwater ecosystems due to change in rainfall	Low	Moderate	Moderate	Moderate	High	High	Low	Low	High	High	Changes in rainfall expected to alter river/ lake water balances - putting stress on freshwater ecosystems.	Natural
Te Ao Tūroa | Natural world	Freshwater ecosystems	Drought	Risk to freshwater ecosystems due to drought	Low	Moderate	Moderate	Moderate	High	High	Low	Low	High	High	Changes in rainfall expected to alter river/ lake water balances - putting stress on freshwater ecosystems.	Natural

Community Value	Element at Risk	Climate hazard	Risk statement	Exposure			Vulnerability				Risk			Commentary	NCCRA Domain
				Present	2050	2100	Sensitivity Present	Sensitivity 2050	Sensitivity 2100	Adaptive capacity	Present	2050	2100		
Te Ao Tūroa | Natural world	Freshwater ecosystems	Inland flooding	Risk to freshwater ecosystems due to inland flooding	Moderate	High	High	Moderate	High	High	Medium	Low	High	High	Freshwater ecosystems flooding more frequently - with associated increase in sedimentation rates from catchment erosion - sedimentation likely to affect success/populations of freshwater species.	Natural
Te Ao Tūroa | Natural world	Freshwater ecosystems	River erosion	Risk to freshwater ecosystems due to river erosion	Moderate	High	High	Moderate	High	High	Medium	Low	High	High	Freshwater ecosystems at risk from increased erosion of rivers during floods/storms - changes in morphology/bed substrate, loss of bank-side habitat.	Natural
Te Ao Tūroa | Natural world	Freshwater ecosystems	Sea level rise and salinity stress	Risk to freshwater ecosystems due to sea level rise and salinity stress	Low	Low	Moderate	Moderate	High	High	Low	Low	Moderate	High	Salinity increases of groundwater and in wetlands close to the coast likely to change species distribution/assemblage. Changes to salinity at river mouths and further upstream, reducing extent of freshwater habitat within rivers.	Natural
Te Ao Tūroa | Natural world	Natural landscapes	Reduced snow and ice	Risk to natural landscapes and community identity due to reduced snow and ice	Low	Moderate	High	Moderate	High	High	Low	Low	High	Extreme	Affects alpine environment - reduced snow and ice in Central Plateau and Ruahine/Tararua ranges (fewer cold nights, more hot days, some increased rainfall - rather than snow). Minor changes to 2050, then increasing exposure. Sensitivity likely to increase over time, low adaptative capacity.	Natural
Te Ao Tūroa | Natural world	Natural landscapes	Increasing landslides and soil erosion	Risk to natural landscapes and community identity due to increasing landslides and soil erosion	Moderate	High	Extreme	Moderate	High	High	Medium	Low	High	Extreme	Sensitivity likely to increase over time as affected areas become more eroded. Adaptative capacity - moderate - depends on multiple factors and human intervention.	Natural
Te Ao Tūroa | Natural world	Natural landscapes	Sea level rise and coastal erosion	Risk to natural landscapes and community identity due to sea level rise and coastal erosion	Moderate	High	Extreme	Moderate	High	High	Medium	Low	High	Extreme	Sea level rise leads to inundation of low-lying coastal areas, and increased erosion of coastal cliffs. Increasing exposure as sea level increases, increased sensitivity as coastal margin changes.	Natural
Te Ao Tūroa | Natural world	Natural landscapes	Increased fire weather	Risk to natural landscapes and community identity due to increased fire weather	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Primarily affects vegetation/fauna and surface soils, changing the way the landscape looks. Infer that fire weather will increase with increasing temperature, and decreasing summer rainfall. Sensitivity both to fire event and recovery from it.	Natural
Te Ao Tūroa | Natural world	Natural landscapes	Coastal flooding	Risk to natural landscapes and community identity due to coastal flooding	Moderate	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	High	Morphology changes to coastal areas. Exposure to increase over time	Natural
Te Ao Tūroa | Natural world	Natural landscapes	Inland flooding	Risk to natural landscapes and community identity due to inland flooding	Moderate	High	High	Moderate	Moderate	Moderate	Medium	Low	Moderate	Moderate	Exposure is related to major catchments, particularly where rivers carry significant water volumes (Manawatu/Whanganui Rivers). Intensity and prevelance of flood and storm events likely to increase. Sensitivity to floods likely to remain constant - the response isn't likely to change.	Natural
Hauora | Wellbeing	Health	Extreme weather events	Risk to health due to extreme weather events	Moderate	High	Extreme	Moderate	High	High	Medium	Low	High	Extreme	Both direct health effects as the result of increased extreme events such as flooding and increased storminess which may increase transmission of diseases, and mental health effects as a result of increased stresses. Exposure increases as severity and intensity increases. Rural communities more sensitive given more limited services and infrastructure.	Human
Hauora | Wellbeing	Health	Higher temperatures	Risk to health due to higher temperatures	Low	Moderate	High	Low	High	Extreme	Medium	Insignificant	Moderate	Extreme	Health risk associated with heatwaves. Elderly, infants and those with activity limitations or severe illness are more vulnerable to the effects of increased temperatures and heat.	Human
Hauora | Wellbeing	Health	Drought	Risk to health due to drought	Low	Moderate	High	Moderate	Moderate	Moderate	Low	Low	Moderate	High	Drought puts stress on communities both mentally and physically in relation to water supply - drought reduces water availability and water quality for drinking - dehydration, increased toxins in water, water is unsafe to drink. Exposure increases with increased hot days and reduced summer rainfall. Communities most vulnerable are those that rely on surface water takes/ little to no groundwater available.	Human
Hauora | Wellbeing	Housing	Inland flooding	Risk to housing due to inland flooding	High	Extreme	Extreme	High	High	High	Medium	High	Extreme	Extreme	Exposure highest in the Plains. High sensitivity as timber and masonry buildings can swell, damage can occur to plasterboard wall linings. Older buildings generally have a higher sensitivity. Generally medium adaptive capacity for existing buildings with alterations possible.	Human
Hauora | Wellbeing	Housing	Coastal flooding	Risk to housing due to coastal flooding	Moderate	High	Extreme	High	High	High	Medium	Moderate	High	Extreme	Moderate exposure to coastal flooding within the region, particularly in the Whanganui, Foxton and Levin areas. High sensitivity as materials can corrode, and swelling and damage can occur to wall linings.	Human
Hauora | Wellbeing	Housing	Sea level rise and coastal erosion	Risk to housing due to sea level rise and coastal erosion	Moderate	High	Extreme	High	High	High	Medium	Moderate	High	Extreme		Human
Hauora | Wellbeing	Housing	Extreme weather events	Risk to housing due to extreme weather events	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Currently low exposure to extreme weather events increasing to high by the end of the century. High sensitivity as homes can be damaged by flood waters, high winds and heavy snow fall. Low adaptive capacity due to permanent nature however changes to design standards could improve resilience.	Human
Hauora | Wellbeing	Housing	Increased fire weather	Risk to housing due to increased fire weather	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Currently low exposure to increased fire weather, but increasing to high by the end of the century due to increased drought conditions and higher temperatures. High sensitivity particularly for those houses made from timber (compared to brick).	Human

Community Value	Element at Risk	Climate hazard	Risk statement	Exposure			Vulnerability				Risk			Commentary	NCCRA Domain
							Sensitivity			Adaptive capacity					
				Present	2050	2100	Present	2050	2100		Present	2050	2100		
Hauora | Wellbeing	Housing	Increasing landslides and soil erosion	Risk to housing due to increasing landslides and soil erosion	Moderate	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	High	Moderate exposure increasing to extreme by the end of the century due to the erodibility of soils within the region. Moderate sensitivity as building foundations can be designed with soil erosion in mind. Landslides however can completely destroy homes.	Human
Hauora | Wellbeing	Housing	River erosion	Risk to housing due to river erosion	Moderate	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	High	Moderate exposure to river erosion. Large sediment loads likely to be exacerbated due to more intense flooding events, which can lead to more river scour. This can reduce the amount of land available for housing and damage/ destroy buildings.	Human
Hauora | Wellbeing	Public spaces	Inland flooding	Risk to public spaces due to inland flooding	High	High	Extreme	Moderate	High	High	Medium	Moderate	High	Extreme	Higher exposure of community spaces in settlements around larger river catchments. Exposure increasing overtime as flood frequency and severity increases.	Human
Hauora | Wellbeing	Public spaces	Coastal flooding	Risk to public spaces due to coastal flooding	Low	Moderate	High	Moderate	High	Extreme	Medium	Insignificant	Moderate	Extreme	Low number of settlements directly located within low lying coastal zone. Higher sensitivity at these locations where materials can corrode, swell and damage.	Human
Hauora | Wellbeing	Public spaces	Sea level rise and coastal erosion	Risk to public spaces due to sea level rise and coastal erosion	Low	Moderate	High	Moderate	High	Extreme	Medium	Insignificant	Moderate	Extreme	Exposure increases as coastal area continues to be inundated, public spaces and erosion effects may damage buildings. Medium adaptive capacity connected with retreat, relocation and engineered human interventions.	Human
Hauora | Wellbeing	Public spaces	Extreme weather events	Risk to public spaces due to extreme weather events	Low	Moderate	High	Moderate	High	High	Medium	Insignificant	Moderate	High	Low exposure increasing overtime. Effects on community spaces due to extreme weather events associated with power outages, transport links and physical damage to buildings from flood water, high winds and heavy snowfall.	Human
Hauora | Wellbeing	Social capital	Inland flooding	Risk to Social capital due to Inland flooding	Moderate	High	Extreme	Moderate	High	Extreme	Medium	Low	High	Extreme	Exposure to climate hazards that result in high damages or a need for relocation, including low-lying coastal communities and communities on floodplains. As the frequency of these disruption increases, so does the likelihood that those who have the resources to relocate will move.	Human
Hauora | Wellbeing	Social capital	Extreme weather events	Risk to Social capital due to Extreme weather events	Low	Moderate	High	Low	Moderate	High	Medium	Insignificant	Low	High	High levels of social capital help with preparing, responding to, and recovering from extreme weather events and natural disasters. The impacts of climate change can result in reductions of social capital, and thereby increased risk due to extreme weather events.	Human
Hauora | Wellbeing	Social capital	Increasing landslides and soil erosion	Risk to Social capital due to Increasing landslides and soil erosion	Low	Moderate	High	Low	Moderate	Moderate	Medium	Insignificant	Low	Moderate	Rural communities and communities with high levels of tourism are sensitive due to a high reliance on the natural environment for their livelihoods, geographic isolation, and infrastructure risks. Landslides and soil erosion are likely to affect communities in hill country locations.	Human
Hauora | Wellbeing	Social capital	Sea level rise and coastal erosion	Risk to Social capital due to Sea level rise and coastal erosion	Low	Moderate	Moderate	Low	Moderate	High	Medium	Insignificant	Low	Moderate	Exposure to climate hazards that result in high damages or a need for relocation, including low-lying coastal communities and communities on floodplains. As the frequency of these disruption increases, so does the likelihood that those who have the resources to relocate will move.	Human
Hauora | Wellbeing	Social capital	Higher temperatures	Risk to Social capital due to Higher temperatures	Low	Moderate	Moderate	Low	Moderate	Moderate	Medium	Insignificant	Low	Low	Urban areas are less exposed to flooding, landslides and soil erosion, but are more highly exposed to heatwaves.	Human
Business	Agriculture - livestock animal welfare	Extreme weather events	Risk to animal welfare due to extreme weather events	High	Extreme	Extreme	High	High	High	Medium	High	Extreme	Extreme		Economy
Business	Agriculture - livestock animal welfare	Inland flooding	Risk to animal welfare due to inland flooding	High	Extreme	Extreme	High	High	High	Medium	High	Extreme	Extreme	High sensitivity as animals can drown if not evacuated or shifted and flood waters are high enough, crops can be destroyed limiting feed for stock, influencing the amount of yield produced. Medium adaptive capacity as improved farming practises can be put in place/ retreat of farming in particular locations if it is not viable. Or practices can change i.e. dairy changing sheep and beef etc.	Economy
Business	Agriculture - livestock animal welfare	Drought	Risk to animal welfare due to drought	Moderate	Moderate	High	High	High	Extreme	Medium	Moderate	Moderate	Extreme	Potential evaporation deficit percentages increasing and the number of hot days increasing through time, dictating exposure. Conditions below optimal for animal comfort plus their production (wool, milk or meat). Lack of feed can also occur during drought conditions. Medium adaptive capacity as improved farming practises can be put in place/ retreat of farming in particular locations if it is not viable.	Economy
Business	Agriculture - livestock animal welfare	Coastal flooding	Risk to animal welfare due to coastal flooding	Low	Moderate	High	High	High	Extreme	Medium	Low	Moderate	Extreme	Lower exposure of animals within coastal flood prone areas comparative to inland flood areas	Economy
Business	Agriculture - livestock animal welfare	Higher temperatures	Risk to animal welfare due to higher temperatures	Low	Moderate	High	High	High	Extreme	Medium	Low	Moderate	Extreme	Low exposure to increased temperatures, increasing over time. High sensitivity due to heat-stress for livestock.	Economy
Business	Agriculture - livestock animal welfare	Increasing landslides and soil erosion	Risk to animal welfare due to increasing landslides and soil erosion	Moderate	High	High	High	High	High	Medium	Moderate	High	High	Exposure concentrated on foothills, with increasing incidences of landslides into the future, and likely increasing use of higher sloping hills in time.	Economy

Community Value	Element at Risk	Climate hazard	Risk statement	Exposure			Vulnerability				Risk			Commentary	NCCRA Domain
							Sensitivity			Adaptive capacity					
				Present	2050	2100	Present	2050	2100		Present	2050	2100		
Business	Agriculture - productivity of land	Inland flooding	Risk to productivity of land due to inland flooding	High	Extreme	Extreme	High	High	High	Medium	High	Extreme	Extreme	Exposure of farmland located in the plains, set to increase through time. Sensitivities include destruction of crop/ feed, damage the integrity of the farm, animal welfare and reduction of overall yield.	Economy
Business	Agriculture - productivity of land	Increased fire weather	Risk to productivity of land due to increased fire weather	Low	Moderate	High	Extreme	Extreme	Extreme	Medium	Moderate	High	Extreme	Fire weather exposure increasing through time with potential evaporation deficit percentages and number of hot days increasing. Fire can destroy crops and stock which can have a substantial economic impact. Medium adaptive capacity as measures can be undertaken to reduce fire weather starters.	Economy
Business	Agriculture - productivity of land	Change in rainfall	Risk to productivity of land due to change in rainfall	Moderate	High	Extreme	High	High	High	Medium	Moderate	High	Extreme	Increases in rainfall are projected for winter months. Crops generally rely on a sufficient amount of rainfall to provide for stock, not enough and that can impact the amount of yield, and too much can waterlog crops also reducing yield. Medium adaptive capacity as strategies can be undertaken to reduce waterlogging of soils.	Economy
Business	Agriculture - productivity of land	Increasing landslides and soil erosion	Risk to productivity of land due to increasing landslides and soil erosion	Moderate	High	High	High	High	High	Medium	Moderate	High	High	Exposure particularly on the hill country farms. Soil erosion already issue for farmers based on livestock movements, so will be exacerbated by climate change. High sensitivity as it can damage/ destroy farmland resulting in economic loss. Medium adaptive capacity as relocation possible.	Economy
Business	Agriculture - productivity of land	Drought	Risk to productivity of land due to drought	Moderate	Moderate	High	High	High	High	Medium	Moderate	Moderate	High	Moderate exposure to drought in the present day but increases to high by the end of the century. High sensitivity to drought as it can reduce the amount of feed or viable land available for stock which can then impact animal welfare, milk quality and quality of crop. Medium adaptive capacity as there are alternative crops that can be used for feed.	Economy
Business	Agriculture - productivity of land	Extreme weather events	Risk to productivity of land due to extreme weather events	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Currently low exposure to extreme weather events, increasing to high by the end of the century with projected increases in the frequency and intensity of storms. High sensitivity due to waterlogged soils from flooding.	Economy
Business	Commerce	Inland flooding	Risk to commercial buildings and manufacturing due to inland flooding	High	High	Extreme	Moderate	Moderate	Moderate	Medium	Moderate	Moderate	High	Increasing intensity of flood events increasing exposure through time. Moderate sensitivity which can be influenced by material and condition of the building. Most commercial buildings are made from concrete. Medium adaptive capacity due to ability for alterations/ resilience measures.	Economy
Business	Commerce	Extreme weather events	Risk to commercial buildings and manufacturing due to extreme weather events	Low	Moderate	High	Moderate	Moderate	Moderate	Medium	Insignificant	Low	Moderate	Projected increases in storm events increasing exposure through time. Most commercial buildings are made from concrete so are less likely to suffer damage like the residential stock would.	Economy
Business	Goods and services	Inland flooding	Risk to FMCGs due to inland flooding	High	Extreme	Extreme	High	High	High	Medium	High	Extreme	Extreme	High sensitivity as accessibility into Palmerston can be inhibited which can result in impacts to the entire region. Medium adaptive capacity as progressive changes can be made to ensure goods last for more than three days. Limited redundancy currently.	Economy
Business	Goods and services	Extreme weather events	Risk to FMCGs due to extreme weather events	Moderate	Moderate	High	High	High	High	Medium	Moderate	Moderate	High	High winds can also cause trucks to topple over or reduce speeds which can have an impact on delivery.	Economy
Business	Goods and services	Higher temperatures	Risk to FMCGs due to higher temperatures	Low	Moderate	High	Moderate	Moderate	Moderate	Medium	Insignificant	Low	Moderate	If temperatures reach above design standards for road and rail structures then disruption to the service of FMCG can occur. Increased vulnerability due to there being only one hub for distribution within the region.	Economy
Business	Tourism	Reduced snow and ice	Risk to tourism due to reduced snow and ice	Moderate	High	Extreme	High	Extreme	Extreme	Low	High	Extreme	Extreme	Ski seasons are changing with snow becoming more frequent later in the year. High to extreme sensitivity as ski fields cannot operate if there is not enough snow. Generally low adaptive capacity. Snow machines like that on Whakapapa can be used, but not for the entire ski field.	Economy
Business	Tourism	Extreme weather events	Risk to tourism due to extreme weather events	Moderate	High	Extreme	High	High	High	Low	High	Extreme	Extreme	Attractions such as skiing and walking can be affected due to high winds and snow storms. Low adaptive capacity as these attractions get closed for public safety reasons.	Economy
Business	Tourism	Inland flooding	Risk to tourism due to inland flooding	Moderate	High	Extreme	Moderate	Moderate	Moderate	Low	Moderate	High	Extreme	Accessibility to tourist attractions can be cut off due to flood waters, and some attractions can be closed due to flooding or associated hazards such as landslides or scour. Low adaptive capacity as accessibility is generally out of tourist operators control.	Economy
Business	Tourism	Change in rainfall	Risk to tourism due to change in rainfall	Moderate	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	High	Current exposure to changes in rainfall are moderate, but increase with projected increases in rainfall particularly around the ranges. Moderate sensitivity as increases in rainfall can lead to track closure and therefore less foot traffic, as well as flooding that can block accessibility to tourist attractions. Medium adaptive capacity as tracks can be maintained to ensure they are not damaged by increased rainfall.	Economy
Business	Tourism	Drought	Risk to tourism due to drought	Low	Moderate	High	Moderate	Moderate	Moderate	Medium	Insignificant	Low	Moderate	Currently low exposure to drought conditions, but is projected to increase to high by the end of the century. Drought conditions are not generally seen in the mountainous areas of the region, but more on the plains.	Economy
Infrastructure	Airports and seaports	Extreme weather events	Risk to air transport due to extreme weather events	Low	Moderate	High	High	High	High	Low	Moderate	High	Extreme	Both domestic airports are exposed to extreme weather events. High winds and lightning can cause aircraft damage and voltage spikes.	Built

Community Value	Element at Risk	Climate hazard	Risk statement	Exposure			Vulnerability				Risk			Commentary	NCCRA Domain
							Sensitivity			Adaptive capacity					
				Present	2050	2100	Present	2050	2100		Present	2050	2100		
Infrastructure	Airports and seaports	Inland flooding	Risk to air transport due to inland flooding	Low	Moderate	High	High	High	High	Low	Moderate	High	Extreme	Both domestic airports are currently exposed to inland flooding. Sensitivities include damage, drainage issues and service disruption. Adaptive capacity generally low, however protection measures can be put in place.	Built
Infrastructure	Airports and seaports	Coastal flooding	Risk to air transport due to coastal flooding	Low	Moderate	High	High	High	High	Low	Moderate	High	Extreme	Whanganui airport exposed to sea level rise, coastal flooding and coastal erosion. Sensitivities include tarmac degradation from salt water corrosion and potential loss of capacity.	Built
Infrastructure	Airports and seaports	Coastal flooding	Risk to sea ports due to coastal flooding	High	High	Extreme	Moderate	Moderate	Moderate	Medium	Moderate	Moderate	High	Assumed exposed due to constrained location. Wharf revitalisation project aims to improve condition of wharf, reducing impact from damage.	Built
Infrastructure	Airports and seaports	Higher temperatures	Risk to air transport due to higher temperatures	Low	Moderate	High	Moderate	Moderate	Moderate	Low	Low	Moderate	High	All airports exposed to increases in temperature, which currently has low exposure. Sensitivities include tarmac melting and disruption of services.	Built
Infrastructure	Airports and seaports	Extreme weather events	Risk to sea ports due to extreme weather events	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Wharf is exposed to extreme weather events, particularly those bring high wind speeds and flooding. Localised flooding can cause damage and high winds speeds can disrupt operations.	Built
Infrastructure	Airports and seaports	Sea level rise and coastal erosion	Risk to sea ports due to sea level rise and coastal erosion	Moderate	High	High	Moderate	Moderate	Moderate	Medium	Low	Moderate	Moderate	Assumed exposed due to constrained location. Wharf revitalisation project aims to improve condition of wharf, reducing impact from damage.	Built
Infrastructure	Energy - distribution	Extreme weather events	Risk to energy distribution due to extreme weather events	Low	Moderate	High	High	High	High	Low	Moderate	High	Extreme	Exposure will increase as the intensity and frequency of storms increases. Sensitivity is increased for overhead cables due to sagging, deformation and third party debris. Service disruptions can lead to impacts on other service operations and in the community	Built
Infrastructure	Energy - distribution	Inland flooding	Risk to energy distribution due to inland flooding	Moderate	High	Extreme	Moderate	Moderate	Moderate	Low	Moderate	High	Extreme	390 km of transmission lines located on land exposed to flooding. 185 km are located in the Manawatū. Sensitivities increase for ground level assets where flood waters can damage electrical equipment and undermine pylon foundations. Adaptive capacity low, and constrained due to populations.	Built
Infrastructure	Energy - distribution	Higher temperatures	Risk to energy distribution due to higher temperatures	Low	Moderate	High	Moderate	Moderate	Moderate	Low	Low	Moderate	High	Low exposure currently with temperatures ranging between 6-15°C. Risk increases with every increase in temperature as power outputs are influenced by temperature. Adaptive capacity is generally low, however some improvements can be made with technological advancements	Built
Infrastructure	Energy - generation	Extreme weather events	Risk to energy generation due to extreme weather events	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Westerly winds can increase generation capacity Turbines can be damaged at wind speeds above 90 kph Changes in design standards could allow turbines to operate above 90 kph	Built
Infrastructure	Energy - generation	Drought	Risk to energy generation due to drought	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Reduced rainfall and increase in number of hot days projected around Mangahao power station Hydro-electricity generation relies on precipitation, therefore is sensitive to reduced rainfall	Built
Infrastructure	Energy - generation	Change in rainfall	Risk to energy generation due to change in rainfall	Moderate	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	High	Increased rainfall projected for winter months, while reduced rainfall projected in summer months. Reduced rainfall can lead to low flows, which can lead to operational changes	Built
Infrastructure	Energy - generation	Inland flooding	Risk to energy generation due to inland flooding	Moderate	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	High	Flooding exposure projected to increase Flooding can cause damage to supporting infrastructure	Built
Infrastructure	Flood management	Extreme weather events	Risk to flood management schemes due to extreme weather events	High	Extreme	Extreme	High	High	High	Medium	High	Extreme	Extreme	Assumed all assets are exposed due to their location on flood plains and along river channels. Sensitivities include scour, blockages and breaches which are dependant on the condition of the asset. Adaptive capacity generally low, however there is funding allocated to some schemes	Built
Infrastructure	Flood management	Inland flooding	Risk to flood management schemes due to inland flooding	High	Extreme	Extreme	High	High	High	Medium	High	Extreme	Extreme	Assumed all assets are exposed due to their location on flood plains and along river channels. Sensitivities include scour, blockages and breaches which are dependant on the condition of the asset. Adaptive capacity generally low, however there is funding allocated to some schemes	Built

Community Value	Element at Risk	Climate hazard	Risk statement	Exposure			Vulnerability				Risk			Commentary	NCCRA Domain
							Sensitivity			Adaptive capacity					
				Present	2050	2100	Present	2050	2100		Present	2050	2100		
Infrastructure	Rail networks	Increasing landslides and soil erosion	Risk to rail transport due to increasing landslides and soil erosion	High	High	Extreme	High	High	High	Medium	High	High	Extreme	Palmerston North-Gisborne Line has increased exposure through the Manawatū Gorge. Five additional locations at risk. Sensitivities include degradation, undercutting, blockages and service disruptions. Adaptive capacity can be costly, but tunnelling through steep sections has proven helpful.	Built
Infrastructure	Rail networks	Inland flooding	Risk to rail transport due to inland flooding	High	High	Extreme	High	High	High	Medium	High	High	Extreme	30% (234 km) of network exposed throughout the region, with more than 5 flooding events causing closure between July 2004-2008. Sensitivities include ballast washout, inability for track drainage and possible embankment collapse. Designing drainage systems for future climate conditions can help reduce impact.	Built
Infrastructure	Rail networks	Coastal flooding	Risk to rail transport due to coastal flooding	Moderate	High	Extreme	High	High	High	Medium	Moderate	High	Extreme	2.9 km exposed to the 1% AEP storm event in Manawatū district. This exposure is likely to increase over time. Sensitivities include salt water corrosion and accelerated material deterioration, and scour leading to line closures and more frequent repairs.	Built
Infrastructure	Rail networks	Extreme weather events	Risk to rail transport due to extreme weather events	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Increased exposure in National Park and Lower Retaruke from high winds and third party debris. Sensitivities include, third party debris damage, and reduced operating speeds Tree-free zones can help reduce third party debris.	Built
Infrastructure	Rail networks	Higher temperatures	Risk to rail transport due to Higher temperatures	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Exposure low across region due to annual average temperatures. Track derailment due to buckling has occurred in Ruapehu in the past. Track maintenance important for reducing impacts.	Built
Infrastructure	Road networks	Increasing landslides and soil erosion	Risk to the road network due to increasing landslides and soil erosion	High	High	Extreme	High	High	High	Medium	High	High	Extreme	Nine key locations identified by Waka Kotahi across the region. SH3 through Manawatū Gorge. Sensitivities include road surface damage, undercutting and collapse. Re-routing possible, like section of SH3 through the Gorge.	Built
Infrastructure	Road networks	Inland flooding	Risk to the road network due to inland flooding	High	High	Extreme	High	High	High	Medium	High	High	Extreme	13% of entire network (including SH) exposed to inland flooding. Road wash out, sub-base degradation and reduced surface friction can occur. Unsealed roads have increased sensitivity due to condition. Maintenance checks and repairs are important.	Built
Infrastructure	Road networks	Sea level rise and coastal erosion	Risk to road network due to sea level rise and coastal erosion	Low	Moderate	High	High	High	High	Low	Moderate	High	Extreme	Sea levels are projected to rise by approximately 0.3 m by mid century, increasing the exposure of roads in the Horowhenua, Manawatū and Whanganui districts. Sea level rise and coastal erosion can damage and undermine road structures, leading to disruption.	Built
Infrastructure	Road networks	Coastal flooding	Risk to road network due to coastal flooding	Moderate	High	Extreme	High	High	High	Medium	Moderate	High	Extreme	More than 30 km of road currently exposed to the 1% AEP storm event across the region. Horowhenua has highest exposure. Scour and corrosion can occur leading to damage and disruption.	Built
Infrastructure	Road networks	Extreme weather events	Risk to the road network due to extreme weather events	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Increased exposure in coastal areas, from storm surge and on the Plains from flooding. Road degradation and disruption can occur.	Built
Infrastructure	Road networks	Higher temperatures	Risk to the road network due to higher temperatures	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Low exposure due to annual average temperatures. Increased exposure for roads in Tararua, Whanganui and Ruapehu. Roads can melt causing disruption. Resurfacing on a frequent basis can help reduce impact.	Built
Infrastructure	Solid waste management	Extreme weather events	Risk to household waste due to extreme weather events	Low	Moderate	High	High	High	High	Low	Moderate	High	Extreme	Increased exposure for those landfills located on Plains and adjacent to rivers. Mobilisation of contaminants, undermined structural integrity and potential exposure of waste.	Built
Infrastructure	Solid waste management	Inland flooding	Risk to household waste due to inland flooding	Moderate	High	Extreme	Moderate	Moderate	Moderate	Low	Moderate	High	Extreme	Landfills located close to streams and rivers in the region. Sensitivities include mobilisation of contaminants, riverbank erosion exposing waste and impacts on receiving environment.	Built
Infrastructure	Solid waste management	Coastal flooding	Risk to household waste due to coastal flooding	Low	Moderate	High	High	High	High	Low	Moderate	High	Extreme	Increased exposure for coastal landfills (operating/closed), which will increase as sea levels rise. Sensitivities include mobilisation of contaminants, leachate, and potential impacts to receiving environment. Adaptive capacity low, due to permanent nature and lack of ability to relocate.	Built

Community Value	Element at Risk	Climate hazard	Risk statement	Exposure Present	Exposure 2050	Exposure 2100	Vulnerability Sensitivity Present	Vulnerability Sensitivity 2050	Vulnerability Sensitivity 2100	Vulnerability Adaptive capacity	Risk Present	Risk 2050	Risk 2100	Commentary	NCCRA Domain
Infrastructure	Telecommunications and network infrastructure	Extreme weather events	Risk to telecommunications and network infrastructure due to extreme weather events	Moderate	Moderate	High	High	High	High	Medium	Moderate	Moderate	High	Increased exposure for overhead cables, antennas and masts due to high wind speeds in the region causing loss of power and damage. Adaptive capacity higher than other utilities as assets have shorter life spans due to technological advancements.	Built
Infrastructure	Telecommunications and network infrastructure	Inland flooding	Risk to telecommunications and network infrastructure due to inland flooding	High	High	Extreme	Moderate	Moderate	Moderate	Medium	Moderate	Moderate	High	Increased exposure for assets located on the Plains and in modelled flood extents. Sensitivity is increased for ground assets such as transfer stations and cabinets due to damage and disruption caused by flood waters.	Built
Infrastructure	Telecommunications and network infrastructure	Higher temperatures	Risk to telecommunications and network infrastructure due to higher temperatures	Low	Moderate	High	Moderate	Moderate	Moderate	Medium	Insignificant	Low	Moderate	Exposure increases with every degree of temperature rise, particularly in Tararua, Whanganui and Taumarunui. Increased temperatures can reduce the life span of assets and stress telecommunication equipment. Resilience can be built due to shorter life spans and technological advancements.	Built
Infrastructure	Three waters - drinking water	Drought	Risk to drinking water due to drought	Moderate	Moderate	High	Extreme	Extreme	Extreme	Medium	High	High	Extreme	Increased exposure of water supply sources with time, with Tararua district liekly to be the most affected. Sensitivities include reduced flows, over allocation, and reduced water availability and quality. Water restrictions and metering can help reduce the impacts of drought.	Built
Infrastructure	Three waters - drinking water	Higher temperatures	Risk to drinking water due to higher temperatures	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Increased exposure of water supply sources with time, with Tararua district liekly to be the most affected. Sensitivities include reduced flows, over allocation, and reduced water availability and quality. Water restrictions and metering can help reduce the impacts of drought.	Built
Infrastructure	Three waters - drinking water	Inland flooding	Risk to drinking water due to inland flooding	Moderate	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	High	Increased exposure on the Manawatū Plains (including Manawatū, Rangitīkei and Whanganui). Flood waters can overwhelm groundwater wells and cause rivers to swell, leading to contamination. Legislation is in place to improve water quality within the region through One Plan and Water Matters.	Built
Infrastructure	Three waters - stormwater infrastructure	Extreme weather events	Risk to stormwater infrastructure due to extreme weather events	Low	Moderate	High	High	High	High	Low	Moderate	High	Extreme	225 km of pipe exposed to inland flooding, which is set to increase with projected increase in high intensity rainfall events Sensitivities include damage to infrastructure (scour and erosion), overwhelmed systems and increased contaminants. Low adaptive capacity due to vast network and funding issues.	Built
Infrastructure	Three waters - stormwater infrastructure	Drought	Risk to stormwater infrastructure due to change in rainfall and drought	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate	All stormwater infrastructure is exposed to drought, particularly in Tararua, Whanganui and Taumaranui Sensitivities include increased contamination, scour, and capacity breaches due to reduced base flows, and ground settlement. Low adaptive capacity due to vast network and costly.	Built
Infrastructure	Three waters - wastewater infrastructure	Extreme weather events	Risk to wastewater due to extreme weather events	Low	Moderate	High	High	High	High	Low	Moderate	High	Extreme	150 km of pipes exposed to inland flooding, of which 40% is in Palmerston North. Sensitivities include, blockages within pipes, overflows leading to health impacts within communities and disruption to services. Generally low adaptive capacity, however upgrades/improvements can be made to adapt to current and future flows.	Built
Infrastructure	Three waters - wastewater infrastructure	Drought	Risk to wastewater due to change in rainfall and drought	Low	Moderate	High	Moderate	Moderate	Moderate	Low	Low	Moderate	High	Increased exposure in Taihape and Dannevirke and lower elevations. Sensitivities include, blockages, siltation, increased contaminants and odour Adaptive capacity is low due to vast network and permanent nature.	Built
Cultural	Cultural landscapes	Increased fire weather	Risk to cultural landscapes due to increased fire weather	Moderate	High	High	High	High	Extreme	Medium	Moderate	High	Extreme	Rural productive land at higher exposure centralised around the plains, where fire could damage or destroy large areas considered to be cultural landscapes. Exposure increases with increasing temperatures and decreased summer rainfall.	Human
Cultural	Cultural landscapes	Increasing landslides and soil erosion	Risk to cultural landscapes due to increased landslides and soil erosion	Moderate	High	Extreme	High	High	High	Medium	Moderate	High	Extreme	Large areas of rural productive land is located in hill country areas high susceptible to increased erosion and landslides. As landslides and erosion increases, the landscapes will continue to change visually, may become less usable and measures to prevent erosion will change the way they look. Exposure increases as already eroded areas continue to erode overtime, with increased storm events and flooding.	Human

Community Value	Element at Risk	Climate hazard	Risk statement	Exposure Present	Exposure 2050	Exposure 2100	Vulnerability Sensitivity Present	Vulnerability Sensitivity 2050	Vulnerability Sensitivity 2100	Vulnerability Adaptive capacity	Risk Present	Risk 2050	Risk 2100	Commentary	NCCRA Domain
Cultural	Cultural landscapes	Inland flooding	Risk to cultural landscapes due to inland flooding	Moderate	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	High	Exposure is moderate increasing overtime where intensity and severity of flood events will increase and may visually impact upon the way landscapes look, and how landscapes are used. Largest catchments such as Manawatu and Whanganui likely higher exposure.	Human
Cultural	Cultural landscapes	Sea level rise and coastal erosion	Risk to cultural landscapes due to sea level rise and coastal erosion	Moderate	Moderate	High	Moderate	High	High	Medium	Low	Moderate	High	Exposure moderate, increasing as coastal areas become inundated and coastal erosion increases overtime as sea level rises. The appearance and use of well-known coastal areas such as Castlecliff at Whanganui more exposed.	Human
Cultural	Freshwater recreation	Inland flooding	Risk to freshwater recreation from inland flooding	Moderate	High	Extreme	Moderate	Moderate	Moderate	Low	Moderate	High	Extreme	Exposure related to rivers used as swimming spots, which when flooded render them dangerous/not useable. Flood events likely to increase with changes in rainfall and extreme events. Due to extent of river across the region exposure increases as flood risk increases. Sensitivity remains constant where effects of flood/response to for swimming remains the same. Low adaptive capacity.	Human
Cultural	Freshwater recreation	Drought	Risk to freshwater recreation from drought	Low	Moderate	High	Moderate	Moderate	Moderate	Low	Low	Moderate	High	Region is not typically drought prone so exposure currently low, this will increase overtime due to increased temperatures and changes in rainfall.	Human
Cultural	Freshwater recreation	River erosion	Risk to freshwater recreation from river erosion	Moderate	Moderate	High	Low	Moderate	Moderate	Medium	Insignificant	Low	Moderate	Subset to inland flooding - exposure to erosion lesser than flooding but will increase over time as already eroded areas continue to erode and swimming areas potentially close. Sensitivity is low increasing to moderate overtime where erosion increases due to flood events and increased rainfall. Moderate adaptive capacity dependent on human intervention.	Human
Cultural	Parks, huts and tracks	Increasing landslides and soil erosion	Risk to parks, huts and tracks due to increasing landslides and soil erosion	Moderate	High	Extreme	Moderate	High	Extreme	Medium	Low	High	Extreme	Large portion of the region is hill country and recreational activities undertaken in parks risk of landslide onto tracks so exposure is moderate, increasing overtime with increased intensity of rainfall. Sensitivity is moderate, also increasing overtime as rainfall events increase unstable areas. Adaptive capacity is moderate dependent on human intervention e.g. engineered solutions.	Human
Cultural	Parks, huts and tracks	Inland flooding	Risk to parks, huts and tracks due to inland flooding	Moderate	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	High	Large number of catchments and waterways over the region, exposure increases with incidences of flooding. Sensitivity remains constant where flood response would remain the same, and impact due to nature of activities. Moderate adaptive capacity dependent on human intervention.	Human
Cultural	Parks, huts and tracks	Extreme weather events	Risk to parks, huts and tracks due to extreme weather events	Moderate	Moderate	High	Moderate	Moderate	High	Medium	Low	Low	High	Topographically varies due to Central Plateau mountains and Ruahine Ranges dividing the east/west. Strong gusts and gale force winds are more common in the high country. Increase with expected increased extreme rainfall and number of extreme events. Sensitivity likely to increase overtime, moderate adaptive capacity dependent on location of parks/huts/tracks.	Human
Cultural	Parks, huts and tracks	Coastal flooding	Risk to parks, huts and tracks due to coastal flooding	Low	Low	Moderate	Moderate	Moderate	High	Medium	Insignificant	Insignificant	Moderate	Coastal flooding impact how coastal areas are used for recreation and exposure will increase overtime as frequency increases and morphological changes are experienced. Sensitivity is moderate increasing overtime to high, where impacts may prevent or extremely damage walkways and other recreational infrastructure along the coast. Adaptive capacity is moderate dependent on human intervention and retreat.	Human
Cultural	Parks, huts and tracks	Sea level rise and coastal erosion	Risk to parks, huts and tracksdue to sea level rise and coastal erosion	Low	Low	Moderate	Moderate	Moderate	High	Medium	Insignificant	Insignificant	Moderate	Inundation of low-lying coastal areas changing the way and ability for recreation within the coastal environment. Exposure increases as sea level rises and already eroded areas continue to erode. Sensitivity will also increase as coastal morphology changes. Moderate adaptive capacity dependent on human intervention and retreat.	Human
Cultural	Parks, huts and tracks	Increased fire weather	Risk to parks, huts and tracks due to increased fire weather	Low	Moderate	Moderate	Low	Moderate	Moderate	Medium	Insignificant	Low	Low	Rural fires are most common throughout the region so lower risk to recreation. Higher fire risk around central region (Manawatu/Tararua districts). Exposure increasing overtime due to increased temperatures and wind. Low adaptive capacity due to nature of activities undertaken.	Human
Cultural	Physical heritage	Increased fire weather	Risk to physical heritage due to increased fire weather	Low	Moderate	High	High	High	High	Medium	Low	Moderate	High	Exposure low increasing with increased temperatures and wind, particularly in the east. Risk to rural sites, outdoor areas, wooden structures - damaged or total loss of physical heritage items dependent on material of sites, fire controls within area and location of fire services.	Human
Cultural	Physical heritage	Higher temperatures	Risk to physical heritage due to extreme weather events	Moderate	Moderate	High	Moderate	High	High	Medium	Low	Moderate	High	Exposure increases as frequency and intensity of severe weather events (storminess, wind, flooding) increases overtime. Damage to sites and building from higher winds, flooding and storm events -	Human
Cultural	Physical heritage	Inland flooding	Risk to physical heritage due to inland flooding	Moderate	High	High	Moderate	Moderate	High	Medium	Low	Moderate	High	Higher exposure of low lying areas along major river catchment such as Whanganui and Manawatu Rivers where populations are also higher. Exposure increases with predicted increase rainfall and severe flood events. Associated with damage to buildings and sites from flooding effects.	Human
Cultural	Physical heritage	Coastal flooding	Risk to physical heritage due to coastal flooding	Low	Moderate	High	Moderate	High	High	Medium	Insignificant	Moderate	High	Exposure for the region is low, with high exposure for a number of spot locations along the coast such as Scotts Ferry and Old Waitarere Fire Station. Exposure increases as flooding events become more frequent and coastal inundation occurs.	Human

Community Value	Element at Risk	Climate hazard	Risk statement	Exposure Present	Exposure 2050	Exposure 2100	Vulnerability Sensitivity Present	Vulnerability Sensitivity 2050	Vulnerability Sensitivity 2100	Vulnerability Adaptive capacity	Risk Present	Risk 2050	Risk 2100	Commentary	NCCRA Domain
Cultural	Physical heritage	Sea level rise and coastal erosion	Risk to physical heritage due to sea level rise and coastal erosion	Low	Moderate	High	Moderate	High	High	Medium	Insignificant	Moderate	High	Low number of physical heritage structures located within the coastal inundation zone, however as sea level rises and larger areas of the coast become inundated, exposure increases.	Human
Cultural	Physical heritage	Increasing landslides and soil erosion	Risk to physical heritage due to increasing landslides and soil erosion	Low	Moderate	High	Moderate	Moderate	Moderate	Medium	Insignificant	Low	Moderate	Historic buildings and archaeological sites at risk where landslides could damage buildings, ground deformation could damage structural components and erosion of archaeological areas. Low exposure increasing overtime as landslides and erosion increases with frequency of extreme events.	Human
Cultural	Taonga	Inland flooding	Risk to taonga due to inland flooding	High	High	Extreme	Moderate	High	High	Medium	Moderate	High	Extreme	Many marae and pa sites located along rivers in low lying areas and are highly exposed, increasing overtime as flood frequency and severity increase due to changes in rainfall,	Human
Cultural	Taonga	Coastal flooding	Risk to taonga due to coastal flooding	Low	Moderate	High	Moderate	High	Extreme	Low	Low	High	Extreme	Low exposure due to location of taonga, increasing overtime at spot locations are coastal flooding events become more frequent and coastal inundation occurs.	Human
Cultural	Taonga	Sea level rise and coastal erosion	Risk to taonga due to sea level rise and coastal erosion	Low	Moderate	High	Moderate	High	Extreme	Low	Low	High	Extreme	Large number of marae are located inland and not directly within the coastal environment, however site such as Kaiwharawhara pā, Taurahere marae, Putiki pā and marae and Papauma marae will become more exposed as sea level rise and coastal inundation increases.	Human
Cultural	Taonga	Extreme weather events	Risk to taonga due to extreme weather events	Moderate	Moderate	High	Moderate	High	High	Medium	Low	Moderate	High	Moderate exposure increasing over time as extreme events become more frequent and severity increases. Road closures and damage to network infra will also indirectly affect marae and papakainga located in remote locations, Higher exposure of remote taonga.	Human
Cultural	Taonga	Increasing landslides and soil erosion	Risk to taonga due to increasing landslides and soil erosion	Moderate	Moderate	High	Moderate	High	High	Medium	Low	Moderate	High	Moderate exposure increasing overtime with highest exposure of sites within mountainous and hilly regions including the Central Plateau, Tararua and Ruahine ranges and hill country. Exposure increases as eroded areas continue to erode and landslides become more frequent along with extreme events.	Human
Cultural	Taonga	River erosion	Risk to taonga due to river erosion	Moderate	High	High	Moderate	Moderate	High	Medium	Low	Moderate	High	Many marae and pa sites located along rivers in low lying areas and are highly exposed, increasing overtime as flood frequency and changes in rainfall exacerbate eroded areas, River margin is reduced and sites in low-lying areas are more exposed.	Human
Cultural	Taonga	Increased fire weather	Risk to taonga due to increased fire weather	Low	Moderate	High	Moderate	High	High	Medium	Insignificant	Moderate	High	Low exposure increasing overtime as summer rainfall decreases and wind increases, particularly for sites in the east. Sites located within rural, wooded areas are more exposed.	Human

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